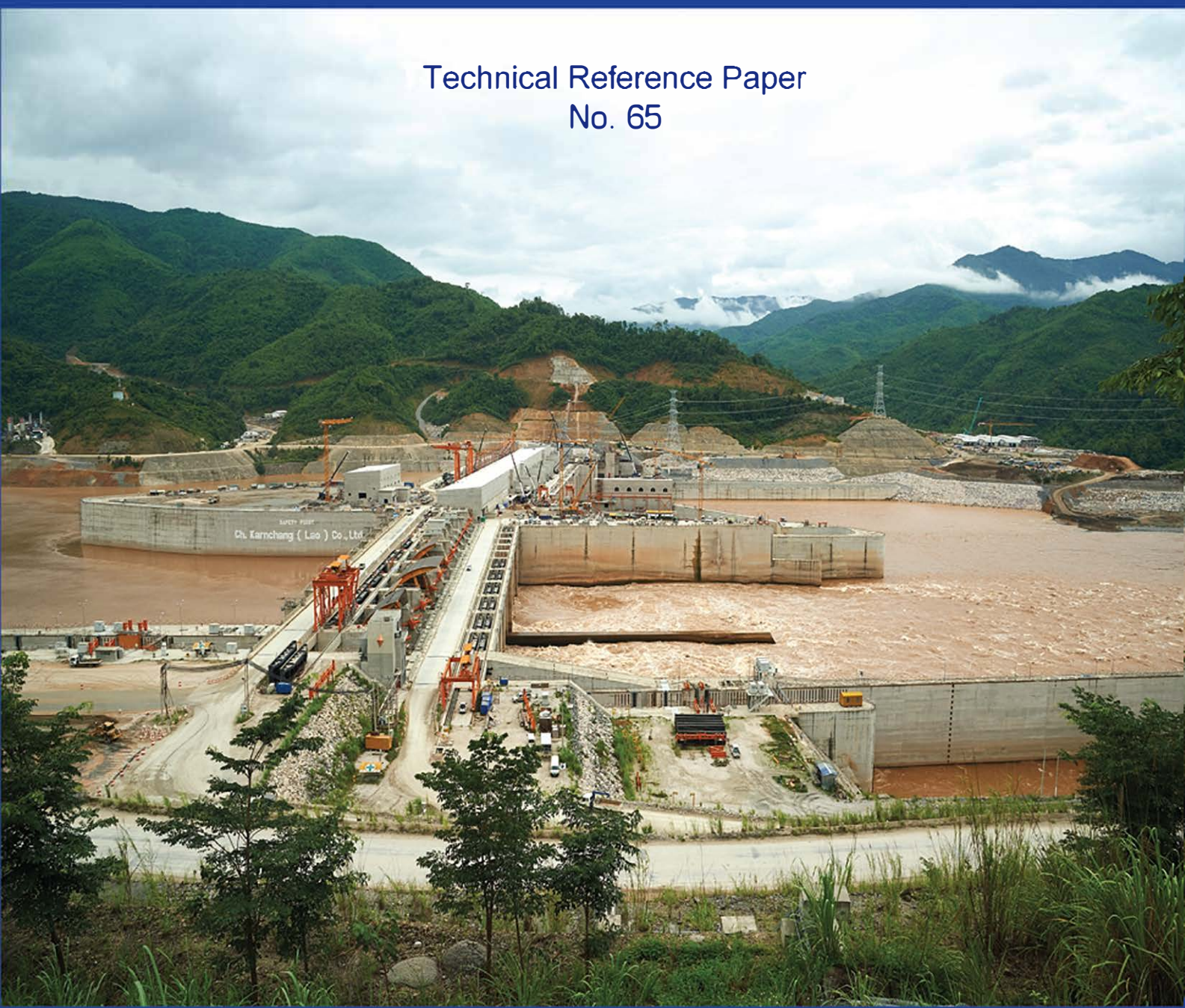
Review of the Design Changes Made for Xayaburi Hydropower Project

Technical Reference Paper
No. 65



January 2019

The MRC is funded by contribution from its member countries and development partners including Australia, Belgium, European Union, Finland, France, Germany, Japan, Luxembourg, the Netherlands, Sweden, Switzerland, the United States and the World Bank.

First published (2019)

Title: Review of the design change made for Xayaburi hydropower project: A technical reference paper
Published date: 2019
ISSN: 1683-1489
Technical Reference Paper: No. 65
Keywords: Water-power; Xayaburi; river navigation

Cover photo: Sayan Chuenudomsavad

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Acknowledgements

The proactive actions taken by the Government of Lao PDR to address the findings of the Xayaburi Technical Review Report (XTRR) after the conclusion of the prior consultation process is sincerely appreciated, and the considerable additional investments made are acknowledged.

In particular, we thank the Lao National Mekong Committee and its Secretariat for their ongoing and transparent cooperation, and the arrangements for the site visits throughout the construction period and for facilitating meetings with the developer. This review could not have been completed without their active cooperation.

1 Summary

The prior consultation process on the Xayaburi Hydropower Project (Xayaburi HPP) was formally initiated on 22 October 2010, once the documentation submitted by the Lao National Mekong Committee (LNMC) was reviewed for completeness and submitted to the Member Countries.

The Joint Committee – the MRC's management body – requested the MRC Secretariat (MRCS) to prepare a technical review of the submitted documents (the Xayaburi Technical Review Report, Xayaburi TRR). The initial six-month period provided for prior consultation in the Procedures for Notification, Prior Consultation and Agreement (PNPCA) came to an end on 22 April 2011. However, a special session of the Joint Committee on 19 April 2011 could not come to a decision on the conclusion of the prior consultation process under Article 5.4.3 of the PNPCA and elevated the issue to the Council for a decision. On 8 December 2011, the Council resolved to initiate the "Council Study" formally titled the "Study on Sustainable Management and Development of the Mekong River including Impacts of Mainstream Hydropower Projects" to provide a better basis for future processes but did not make any further decision on the Xayaburi HPP.

Following a review of the Xayaburi TRR and project documents by consultants Pöyry Pty. Ltd., the developer (Xayaburi Power Company Ltd. (XPCL)) and Government of Lao PDR (GOL) undertook the re-design of certain aspects of the project to address the concerns raised during the prior consultation process. Documentation including reports, PowerPoint presentations and designs were made available from time to time during the re-design and construction process.

Because the prior consultation process was not formally concluded, the requirements for monitoring as the record of the proposed use once commenced have not been formalized. The Secretariat has now reviewed the revised design[1] based on all the documentation made available. This review has not replicated the detailed assessment made in the Xayaburi TRR, but focusses on whether the documentation provided answers the following questions:

a) Is **sufficient detailed information** provided to describe how the recommendations of the Xayaburi TRR have been considered in the revised design of the project?
b) Does the documentation provide **sufficient evidence that the revised design addresses the recommendations of the Xayaburi TRR,** and allay the concerns raised during the prior consultation process?
c) Is sufficient information provided **to establish the record of the proposed use, and the record of the proposed use once commenced** (PNPCA Article 5.4.3)?

The possible effectiveness of the mitigation measures in the revised design is assessed both against the recommendations in the Xayaburi TRR, as well as where studies or research have subsequently been undertaken to provide more evidence of the benefits of mitigation measures.

[1] Design in this context refers to both the changes in the infrastructure (some of which is already in place), as well as the changes in the operating rules.

The major findings of this review are as follows:

- The review reinforced the importance of the 1995 Mekong Agreement, the prior consultation process, the Preliminary Design Guidance (PDG), and the mutual benefits of ongoing dialogue and actions towards resolving concerns regarding the impacts of the Xayaburi HPP;
- The information provided by the developer and GOL, along with field trips to the facilities, and ongoing discussions on the technical details have been important to reduce uncertainty and misunderstanding between stakeholders;
- Many recommendations included in the Xayaburi TRR have been considered by the developer in the redesign of the Xayaburi HPP;
- The XPCL has made substantial investments in monitoring, research and re-engineering to further minimize potential impacts based on the Xayaburi TRR and subsequent discussions.
- However, in some cases the detailed baseline information (e.g. on fisheries, water quality, aquatic ecology and sediment data and related operating rules) has not been provided in sufficient detail to allow an in-depth assessment of the likely efficacy of the revised design.
- Due to the unique nature of this major infrastructure, it is not possible to fully assess the effectiveness of the design of fish passage and sediment flushing operations without access to the data and knowledge of the rationale used in the design and operations.
- The analyses undertaken in the MRC's Mitigation Guidelines[2] on the mainstream cascade indicate that major impacts can only be partially mitigated, and that the efficacy of the measures and any residual impacts may only be fully felt in two or three decades.
- Concerns regarding sediment transmission through the dam have been partially addressed by the inclusion of four large low-level gates to facilitate sediment flushing. The gates have the potential to improve sediment transmission, but as no operating rules have been provided the efficacy of these measures cannot be evaluated.
- No assessment of the sediment flushing regime on downstream fish and fisheries, water quality and aquatic ecology has been provided.
- The MRC Mitigation Guidelines suggest that the silt may be readily flushed through the reservoir, but gravels and coarse sands will not be effectively flushed until the sediment deposits reach the toe of the dam, which will require years to decades. During this period coarse sands and gravels will be trapped, accounting for trapping of up to ~80% of incoming sediment load.
- The MRC Mitigation Guidelines study has demonstrated that an erosional 'wave' will progress downstream of hydropower projects over the next few decades and the impact on sediment transport further downstream can only be assessed by looking at the entire mainstream cascade.

[2] Development of Guidelines for Hydropower Environmental Impact Mitigation and Risk Management in the Lower Mekong Mainstream and Tributaries, Volume 4 – Draft Final Case Study Report, Final Mainstream Dams Assessment Including Alternative Scheme Layouts (Version 2.0)

- Substantial work has been undertaken by the XPCL to understand the fisheries baseline characteristics and the implications for the revised upstream and downstream fish pass design. However, detailed documentation has not been supplied and the scientific rigour of the monitoring and evaluation processes cannot be evaluated.
- The complex array of both upstream and downstream fishpass facilities has been modified extensively to improve *attraction* and *passage* of a wide variety of fish species and high biomass. However, these have not addressed all the recommendations of the Xayaburi TRR, and monitoring will be needed to: i) assess the efficacy of the fish passage facilities *vis-à-vis* the guidance provided in the PDG, ii) optimise fish pass operation, and iii) assess whether modifications may be required.
- Target species for monitoring should be based on size (e.g. small, medium, large), life stage (e.g. larvae, juvenile, adult) and behavioural guilds (surface, mid-water, benthic and migratory characteristics).
- The rationale behind the re-design of the fish passage is only partially described in the submitted documentation and it is not possible to assess the likely efficacy of these facilities given the unique nature of the project, and the difficulty in describing the nature of the fishery accurately.
- Whilst considerable effort has been put into the assessment of the fish population dynamics, little information on the ecological characteristics of the species, biodiversity and conservation status or assessment of the transboundary impacts has been provided.
- The Joint Environmental Monitoring (JEM) programme will be vital to enhance the technical understanding of the upstream and downstream impacts, and assess the effectiveness of the mitigation measures, and build confidence that the impacts of development can be addressed.
- Adaptive management will be necessary to modify operations and manage impacts once this detailed information is available.
- The cumulative impacts of infrastructure development in the Mekong, analysed by the MRC's Council Study, indicate major adverse effects on Mekong River system, and riparian communities if all proposed developments in the basin proceeds. This reinforces the need for joint monitoring, analysis and dialogue on regional strategies in the water, food and energy sectors to meet all the Member Countries development needs.
- Approaches, both up and downstream for boats and vessels have to be improved allowing the crew of berthed waiting boats and vessels to go on shore for procuring essential provisions. Some of them have to be supplied at the berthing areas, which now only consist of a number of heavy vertical poles with no catwalk or access to the shore. These are among others potable water, waste disposal (liquid and solid), power supply for households and lighting, etc.;
- Maintenance devices for substantial repairs like replacing joints from valves, miter doors, hydraulics, damage from ship impacts, etc. are not foreseen;
- The accessibility for heavy duty cranes to allow lifting of door components, valves, hydraulics, etc. has to be improved;
- Essential spare parts should be provided, e.g. gate pintle assembly and gudgeon pin assembly, hydraulic spare parts, electronic sensors, etc. to reduce downtimes.

In conclusion, the developer has made significant efforts and investments towards addressing the concerns raised in the Xayaburi TRR. However, insufficient information has been provided to fully assess the likely efficacy of these measures. As the revised operating rules have not been provided, there is insufficient information to establish the record of the proposed use once commenced for the purposes of the Procedures for Water Use Monitoring.

Ongoing interaction throughout the re-design process are likely to have led to a more effective design and would have built further confidence in the outcomes in all the Member Countries. Monitoring through the JEM and adaptive management will be required to further optimise the design as far as is provided for in the Power Purchase and Concession Agreements.

In the longer term, earlier engagement of potential mitigation measures in the project development cycle and in the Business Case for future HPP will be required to ensure the economic viability of any mitigation measures. Moreover, regional strategies across the water-food-energy nexus will be required to comprehensively address sustainable development of the Mekong River Basin.

2 Background

The Lao National Mekong Committee (LNMC) submitted documentation on the Xayaburi Hydropower Project (Xayaburi HPP) to the MRC Secretariat, for the purpose of prior consultation, on **20 September 2010**. The prior consultation process was initiated on **22 October 2010** once the documentation was reviewed for completeness and submitted to the Member Countries. This was the first project to undergo the prior consultation process in the MRC, and there was much to be learnt from the process.

The prior consultation process is detailed in the MRC Procedures for Notification, Prior Consultation and Agreement (PNPCA), and takes place over an initial six-month period, which may be extended indefinitely by the Joint Committee. The prior consultation process concludes as provided for in Article 5.4.3 of the PNPCA as follows:

> *The MRC JC shall aim to arriving at an agreement on the proposed use and issue a decision that contains the agreed upon conditions. That decision shall become part of the record of the proposed use and of the record of the use of the waters when commenced.*

The *'record of the proposed use'* is important, as it establishes the proposed use and an existing use, and any further developments must consider the cumulative impacts of their proposed use after accounting for all the existing uses. The '*record of the proposed use once commenced*' is important, as ongoing monitoring will be required to ensure that any measures identified during the prior consultation are implemented. These records form part of the Procedures for Water Use Monitoring (PWUM).

After the initial six-month prior consultation period on the Xayaburi HPP, a special session of the Joint Committee on **19 April 2011** in Vientiane could not agree on whether the process

was complete. At this meeting Lao PDR argued that the six-month prior consultation process was complete, while the notified countries raised concerns around the gaps in the understanding of the potential impacts of hydropower development on the mainstream and requested more time for studies, as was provided for by the PNPCA. While Lao PDR agreed to take the other countries' concerns into account in the further development of the Xayaburi HPP, it argued that it may take many years before there was sufficient understanding and noted that they could not hold up all hydropower development until the answers were found. Ultimately, the JC agreed to elevate the discussion to the Council.

On **8 December 2011**, the 18th Meeting of the MRC Council in Siem Reap agreed to conduct a Study on Sustainable Management and Development of the Mekong River including Impacts of Mainstream Hydropower Projects (known as the **Council Study**). The "Council Study" was completed in December 2017 and has provided invaluable material to support future prior consultation processes. However, the Council did not pronounce on the Xayaburi prior consultation *per se* at its December 2011 meeting. To date the Xayaburi prior consultation process has not led to any agreed measures to avoid, minimize, or mitigate the potential impacts, or established any record of the proposed use once commenced.

Following the meeting of 19 April 2011, the Government of Lao PDR commissioned Pöyry Engineering, an international consulting and engineering firm, to prepare a Compliance Report to respond to the MRC Technical Review Report on the Xayaburi HPP. The MRC received this report in October 2011. The Compliance Report noted that the Xayaburi TRR provided valuable insights and guidance to the re-design process. Construction of the Xayaburi HPP commenced in 2012, but work on the re-design has been ongoing throughout the construction period.

Between April and October 2011, the Government of Lao PDR and the Xayaburi Power Company Ltd (XPCL) engaged Compagnie Nationale du Rhône (CNR) from France and Pöyry Engineering from Switzerland to carry out studies and to propose re-design solutions to address the concerns raised during the prior consultation process. According to the Government of Lao PDR, these re-design proposals included:

- Additional fish passage facilities and modifications to the design of the originally proposed upstream and downstream passages;
- Additional navigation facilities;
- Adding sediment transport facilities, including low level gates to facilitate the flushing of sediments; and
- Investigations of Seismic Risk.

The MRC and the notified Member Countries requested that the documents outlining the revised design are shared through the appropriate channels.

3 The objectives of this Review

The objectives of this review are to:

1. Assess the extent to which the developer has made every effort in addressing the concerns and recommendations raised in the Xayaburi TRR;
2. Use the outcomes of the Council Study, the MRC Hydropower Mitigation Guidelines (ISH0306), and other studies to advise the MRC Member Countries on whether there is sufficient evidence that the revised designs will allay their concerns regarding any transboundary impacts of the Xayaburi HPP; and
3. Make recommendations to the Joint Committee for the development of a *record of the proposed use, and a record of the proposed use once commenced* as outlined in Article 5.4.3 of the PNPCA.

However, as the Xayaburi HPP was the first time the prior consultation process had been implemented it is recognised that there is much to learn from how the developer perceived and responded to the Xayaburi TRR. Moreover, the Statement agreed by the Joint Committee at the end of the prior consultation for the Pak Beng HPP noted that the review of the design of the fish passage facilities at Pak Beng should learn from the process at Xayaburi. This review therefore also provides a basis for the ongoing improvement of the prior consultation process.

The review considers all reports, drawings, presentations, and correspondences provided by the Government of Lao PDR and the developer as well as their advisors and any pertinent information that is available in the public domain. A list of the documentation provided by the Government of Lao PDR is shown in Section 4, while the subsequent work undertaken by the MRC and used to assess the likely efficacy of the revised design is shown in Section 5. It is recognised that this work has only recently been completed and has not therefore been available to support the re-design process.

Because the efficacy of the many of the measures proposed in the revised design will only become evident through the Joint Environmental Monitoring for the Mekong Hydropower Projects (JEM) programme, and this may take decades to provide objective results, and because the JEM will assess the sum of all the impacts on the system, not only those related to the Hydropower development, objective 2 above is weighed against the simulated outcomes of mitigation measures and expert opinion.

Ultimately, this review will be made available to stakeholders to understand how the Xayaburi TRR, and more broadly the MRC and prior consultation process have contributed to a better Xayaburi HPP with minimised and mitigated impacts. Reference is also made to the Council Study, the update of the Preliminary Design Guidance (PDG2018), the JEM, the Guidelines for Transboundary Environment Impact Assessment (TbEIA), and the Review and Update of the Sustainable Hydropower Development Strategy for the Mekong (SHDS2019), as part of a suite of tools available to help minimise the transboundary impacts of hydropower development.

4 Revised design information received by the MRC

4.1 MRCS Request for information on revised design

In May 2013, the MRC Secretariat sent a request for information on the re-design proposals to the Government of Lao PDR, detailing the kind of information that would be necessary to undertake this review. The list of information requested is attached in Appendix 1. However, to date only the information outlined in the following sections has been provided.

4.2 Revised design reports received February 2014

- Improvement of Lock Design (125 pages);
- Physical Hydraulic Model Study of Xayaburi HPP (197 pages);
- Plant Safety Concept (7 pages); and
- Seismic Hazard Study (101 pages).

4.3 Presentations received July 2015

The Government of Lao PDR held a stakeholder consultation meeting in July 2015 called "Open Forum on Xayaburi" and several presentations covering aspects of the redesign of Xayaburi were provided. These contained some information on the redesign of the fish passage, the sediment flushing facilities and other design details. The following is a list of these presentations:

- "Lao PDR Power Policy and Development Plan" – Dr Daovong, DG Dept Energy Planning, Ministry of Energy and Mines, LAO PDR
- "Requisites for Concession Agreement: *Requirements of MRC-1995 Agreement",* Xaypaseuth Phomsoupha, DG Dept of Energy Business, Ministry of Energy and Mines
- "Development and Status of Xayaburi HPP", Knut Sierotski, Pöyry Engineering
- "Xayaburi HPP: Fish Migration Facilities", Pöyry and Fishtek (V1)
- "Xayaburi HPP: Fish Migration Facilities", Pöyry and Fishtek (V2)
- "Follow-up of recommendations made by CNR during the peer review regarding navigation and sediments issues", Benjamin Graff, CNR

4.4 Drawings received August 2016

In August 2016, the MRC Secretariat received further details of the revised designs. The drawings are A3 scanned copies of sections of the construction drawings, marked up with comments and text. The complete drawing set was not received, although several requests have been made for these to be provided.

No reports of the detailed analyses behind the re-design of the fish passage and the sediment transmission have been provided. These would be valuable to make a more thorough assessment of the likely efficacy of the proposed mitigation options in the revised design. Importantly, the proposed operating rules for the infrastructure have not been provided.

Further to a request from MRC Secretariat in April 2017, the Government of Lao PDR shared a report on design adaptation of the Xayaburi HPP in November 2017[3]. The draft report provides information on the design changes related to four main aspects, including (1) navigation lock, (2) fish passage, (3) sediment transport and morphology, and (4) dam safety, but no drawings are provided. Information on water quality and aquatic ecology is not available in the report.

The construction of the project is now more than 82% complete (as of November 2017), and opportunities to make any alterations to the design are very limited at this stage. However, changes in the operating rules are still feasible, to the extent allowed by the Power Purchase and Concession Agreements (PPA &CA).

5 Follow-up work by the MRCS

As part of the MRC Strategic Plan (SP) 2011-2015 and SP 2016-2020, investigations of global best practices for sustainable hydropower, and specifically for mitigating the risks and impacts of HPP, have been undertaken. This work has included several studies important for the Xayaburi case. These include:

- Review of Existing Knowledge on the Effectiveness and Economics of Fish-Friendly Turbines; Niels M. Nielsen, Richard S. Brown, Z. Daniel Deng[2], July 2014.
- Review of Existing Research on Fish Passage through Large Dams and its Applicability to Mekong Mainstream Dams; S Schmutz, Boku University, Austria, June 2014.
- Development of Guidelines for Hydropower Environmental Impact Mitigation and Risk Management in the Lower Mekong Mainstream and Tributaries; MRC 2017. (MRC Mitigation Guidelines).
- A detailed case study on the mitigation recommendations contained in the above studies applied to the mainstream Mekong cascade upstream of Vientiane, including the Xayaburi project. MRC December 2017, (Volume 4 of the MRC Mitigation Guidelines).
- Study on the Sustainable Management and Development of the Mekong River, including Impacts of Mainstream Hydropower Projects (MRC Council Study); MRC, December 2017.
- MRC Joint Environment Monitoring for Mekong Hydropower Projects (In Progress).
- MRC Guidelines for Transboundary Environment Impact Assessment, including the EMP implementation and monitoring (In Progress).
- Discharge and Sediment Monitoring Programme Review, Discharge Sediment Monitoring Project (DSMP) 2009-2013 Summary & Analysis of Results (Koehnken, 2014).
- The MRC fisheries programme has conducted studies on larvae drift in the reaches near the Xayaburi project.

[3]Design adaptations implemented in the Xayaburi Hydropower Scheme based on the Preliminary Design Guidelines; Progress on Xayaburi Hydroelectric Power Project Construction; Pöyry, 2017.

These investigations provide further information on the likely efficacy of various mitigation options. Therefore, they extend and support the analyses undertaken in for the Xayaburi TRR and the CNR/Pöyry analyses.

6 Approach to the review of the revised design

This review has been undertaken by MRC Secretariat technical experts supported by international experts. The review has not replicated the detailed assessment made at the time of the Xayaburi TRR. Instead the review focusses on whether the evidence of design changes provided by the Government of Lao PDR can answer the following questions:

a) Is **sufficient detailed information** provided to describe how the recommendations of the Xayaburi TRR have been considered in the revised design of the project?
b) Does the documentation provide **sufficient evidence that the revised design addresses the recommendations of the Xayaburi TRR,** and allay the concerns raised during the prior consultation process?
c) Is sufficient information provided **to establish the record of the proposed use, and the record of the proposed use once commenced** (PNPCA Article 5.4.3)?

Ultimately, the merits of the revised design measures can only be assessed through monitoring their implementation. However, where the documentation provided does not provide sufficient detail, the efficacy of the mitigation measures in the revised design are assessed in light of the outcomes of the Council Study and MRC Mitigation Guidelines.

Furthermore, the recommendations of the Xayaburi TRR were based on the knowledge available to the reviewers at that time. The developer has in the interim gathered additional data and information on the fisheries, sediment, and water quality aspects of the river at that location. However, the majority of the additional data has not been shared with the MRC and has not been evaluated or used in this review. The data would be of immense value to the ongoing efforts to minimise the cumulative impacts of hydropower development in the Mekong River Basin, and the Government of Lao PDR is urged to make these data available.

The review team is aware that the engineering aspects of the project (e.g. dam safety) have been investigated in much more detail and foundation conditions have been confirmed during construction, but as this information has not been provided, it is not included in this review.

Therefore, the review considers the broad technical intent of the Xayaburi TRR recommendations and how these have been further developed in the redesign process. The review also notes where there is insufficient detail provided for redesign choices.

7 Review of the Xayaburi Design Changes

This review covers six aspects related to the revised design including navigation, fisheries, hydrology, sediment, water quality and aquatic ecology, and dam safety. Information on the social aspects and cumulative impacts was not made available, but a brief reflection is provided here. The review provides a summary of recommendations made in the 2011

Xayaburi TRR, then describes the design changes as was evident from the submitted documents. It finally provides a reflection on the design change by the MRC Secretariat expert teams.

7.1 Navigation

7.1.1 Recommendations in the Xayaburi TRR

The Xayaburi TRR remarked that provisions for navigation in the MRC Preliminary Design Guidance were mostly addressed. However, the following issues need to be addressed:

- The Design should confirm the dimensions of the lock chambers and filling and emptying arrangements need to be improved;
- Vessels 2x 500T (109mx10.8mx2m) need to be accommodated;
- The effects of backwater effects on lock operation and the maximum and minimum navigable discharge need to be determined to allow for safe navigation;
- Navigation during construction needs to be accommodated;
- The approach and exit design need to allow for 2x vessel length and in accordance with PIANC[4] regulations. Access to land for berthing ships awaiting to enter the lock chamber should be provided. Facilities like water supply, garbage collection, waste water disposal, etc. should be provided;
- The provision for adding a second series of navigation locks should be fully addressed;
- The institutional and operational arrangements should be confirmed, including management of lock operations 12h/day, with less than 2h duration outages for maintenance, and weather-related outages for <2% of operating time;
- Road and crane access during emergencies needs to be confirmed; and
- The potential to use navigation lock as fish pass should be explored.

7.1.2 Measures taken up by the XPCL

The revised design of the navigation lock and details of the hydraulic design analysis are described in the submitted documentation. The following design modifications are described:

- A revised lock filling and emptying regime is proposed through a detailed analysis and modelling;
- Passage for vessels (2x 500T) has been confirmed;
- The maximum navigable discharge has been confirmed at 25,000 m^3/s, with a minimum of 1,000 m^3/s;
- The backwater effect of the possible Pak Lay HPP has been considered;
- The approach and exit conditions have been modelled physically and the conditions during flood operation of the gates detailed;
- The upstream and downstream approaches are wide enough to allow large barges crossing with barges going in either direction;
- The revised design makes provision for a possible second parallel navigation lock along the right abutment in the future; and
- The navigation lock has been modified to support fish passage.

[4] World Association for Waterborne Transport Infrastructure.

***Figure 1**: Aerial photo of Xayaburi construction site showing navigation lock (Source: Poyry presentation, July 2015)*

7.1.3 Comment on the revised design

Adequacy of Information Provided

The reports on "Improvement of the Lock Design" (mainly on the filling and emptying system) and on "Design Adaptation", indicate that most of the concerns raised in the Xayaburi TRR have been dealt with by the XPCL.

A modelling report has been provided covering some of the approach and exit conditions during spillway gate operation. The operations have been described in some detail, as has the hydraulic design.

Limited information has been provided on the design characteristics of using the fish lock for passage other than a boat with a 'crowder' screen over the full width of the lock that is used to drive fish through the lock structure. The system will also only be operational during the rainy season, which may not be sufficient as the peak fish migration period is at the onset of the increased flows (i.e. in May, see Figure 2).

The highest and lowest Operating levels have been reported as providing for a 20m head difference (HOL=275 masl, LOL=236 masl). This does not appear to be feasible.

Evidence the revised will address the intent of the Xayaburi TRR

It appears that the PDG performance standards have been adequately included in the revised design and operations. However, some details have not yet been provided, but could still be addressed. These include:

- The design could be adjusted to include a suitable work platform for accommodating unusual heavy-duty maintenance equipment in the immediate neighbourhood of the ship locks (e.g. damage to hydraulics and doors from ship impact, replacement of valves or seals and hydraulics from culvert valves, etc.);
- Provision can be made for an overhead rolling bridge (maximum capacity 5t) over the entire ship lock chamber(s) to lift objects/obstacles from the lock chambers (e.g. barrels getting stuck behind the pintle doors, sinking or damaged small boats, etc.);
- An RIS system (VTS radio) with up and downstream stations could be developed to facilitate efficient locking for approaching shipping, and inform pilots of the up- and down-stream water levels;
- A control cabin overlooking operations in both of the tandem locks can be included; and
- Provisions could be included for night mooring facilities with access to the shore provided (e.g. floating pontoons or catwalk connected to the shore).

General

The XPCL has addressed the concerns raised in the Xayaburi TRR. However, the subsequent prior consultation process for the Pak Beng HPP has highlighted some additional measures that could still be considered.

7.2 Fisheries

7.2.1 Recommendations in the Xayaburi TRR

Fish ecology data:

It was recommended that gaps in knowledge – about the ecology of the fishes, status of the fisheries, livelihoods analysis in relation to operational design of the dam and upstream and downstream fishways – are addressed and made available to the MRC. This should include evidence to justify the assumptions made in the design of the fishways.

Modifications to upstream fish passage design:

The Xayaburi TRR concluded that the proposed design of the fish ladder for upstream migration and the provision for downstream migration of adult fish as well as larvae and fry would be ineffective. The following recommendations were made:

- A full review of upstream/downstream passage options should be considered, including a full cost-benefit analysis;
- The vertical–slot design proposed was considered unsuitable for the high biomass and the diverse size range, swimming abilities and behaviour of Mekong fishes expected near Xayaburi;
- The facilities for fish passage should be reconsidered based on a more exhaustive scientific analysis and understanding of the capacities of different species to utilize successfully the facilities;

- The left-bank fish pass needed to be revised to pass 10% of low flows with sufficient space for high biomass and low-water velocities for the passage of smaller species;
- Alternative designs and operation regimes including a longer and more natural bypass channel with higher flow rates working, with a ***separate*** fish lift in the central pier[5] and modifications to use the navigation channel for upstream migration should be considered;
- Physical modelling of the fish pass entrances was recommended to optimise abutment shapes and spillway design to ensure they work in harmony with the fish-passage facilities; and
- The likelihood that species longer than 150 cm can successfully bypass the dam upstream was considered to be low, implying that there was a strong possibility of the naturally-migrating Mekong giant catfish becoming extirpated from the upper LMB.

Downstream fish pass

The following recommendations for downstream fish passage were made:

- A more detailed technical analysis of downstream fish-passage facilities including a fish-collector system appropriate to all species, life history stages and sizes including benthic species should be undertaken;
- Downstream passage at the spillway can be provided by one or more overshot gates and an improved stilling basin design, which can both be developed using the physical model; and
- A full appraisal of the impacts of dam development on fish and fisheries during and after the construction phase, including appraisal of loss of ecosystem services should be undertaken.

Fisheries Management and Monitoring:

The following recommendations were made:

- A detailed baseline study on the socio-economic impacts both in the immediate Xayaburi reach, including the most upstream area likely to be impounded, and any transboundary areas likely to be impacted by the development is required;
- A full social and economic impact analysis of livelihoods of those dependent on the fisheries is also required with an alternative livelihoods analysis to identify options to compensate the fishing communities;
- A detailed monitoring programme is recommended to address knowledge gaps in fish biology that can improve dam and fish pass design and operation as well as the impact of the dam on fish and fisheries, together with a response strategy for adverse impacts; and
- Measures to prevent fishing near the dam wall including in and near the fishways should be outlined.

The Xayaburi TRR noted that with a revised design, the impact of the Xayaburi dam on upstream passage can potentially be reduced to a significant extent.

[5] The revised design makes provision for a fish lift in series with the fishpass, rather than in parallel which may multiply the dis-benefits, rather than amplify the benefits of both systems.

A workshop was recommended with the MRC Secretariat, international experts (Fisheries Expert Group) and the XPCL design team to further evaluate the design and risks, and to develop solutions together.

7.2.2 Measures taken up by the XPCL

Fish Ecology:

The XPCL has undertaken, and is still undertaking, extensive monitoring of the fish biomass and migration patterns about 1 km below the powerplant site. These are detailed in the *Fish Biomass & Migration Study* covering the period March 2012 and March 2013. It consisted of systematic surveys carried out with a hydro-acoustic camera. Currently, while additional biomass surveys are being carried out allowing a longer observation period, XPCL is continuing these studies with 3 -4 campaigns every year.

The *Fish Sampling Study* summarizes the investigations done during ten different fish catching periods between March 2012 and March 2013 and supplements the Fish Biomass & Migration Study. XPCL is conducting regular fish sampling 1 – 2 times a month in the upper chamber of the Navigation Lock.

The *Baseline Study on Mekong Fish & Fisheries* was carried out between 2012 and 2014. This study aimed at establishing a list of the relevant species to consider for the design of the fish passage facilities, depending on different criteria as their representativeness or whether the species are threatened.

Swimming speeds of Mekong fish species were assessed to gain knowledge of the swimming abilities of the fish for which the pass was designed, as a low swimming ability can prevent particular species from using the pass. Specifically, this work was designed to determine the (i) burst swimming speed of a sub-set of species which are representative of the wider fish fauna within the Mekong at the project area and (ii) the volitional swimming response of as many species as possible to different water velocities within an open channel. Additional information and results of these studies are provided in Annex 3.

Modifications to fish passage design:

Upstream

The fishpass has been significantly modified and combined in a system with two fish locks, transferring the fish from the upstream end of the fishpass to a channel connected to the reservoir. An auxiliary powerhouse (8 MW) has been implemented to reduce power losses caused by the flow allocated to the fishpass. The fishpass has been made wider (18 m instead of 10 m), with four slots of different sizes instead of one, its slope reduced to 1.2 % and its flow significantly increased. In addition, provisions for the installation of a fish lift have been foreseen, should it be necessary in the future to enhance the efficacy of the system, and pass a greater biomass. A second fish pass facility on the right bank incorporated in the navigation lock is also provided. These facilities provide entrances for upstream migrating fish on either side of the powerhouse, above the draft tubes, at the end of the left-hand abutment, and at the downstream end of the navigation lock.

Downstream

Downstream fish passage facilities were improved as follows:

- The downstream terminal chute will operate the whole year instead of only during the wet season.
- A new pumping station (pumping station 2) was implemented to reduce the flow and power losses caused by the operation of this facility.
- The design of the chute itself has been changed from a straight outlet to a "Shaped" outlet to achieve smoother hydraulic conditions along the chute more favourable for the fish.
- Minimum gap, Kaplan turbines are proposed.

Figure 2: *Vertical slot component of upstream fish pass (Source: Coe 2015 Xayabury HPP: Fish Migration Facilities, Pöyry and Fishtek [V1])*

The revised multi-slot channel with a rock-lined floor is intended to be more efficient across a wide range of fish species. The heterogeneity of flows and velocities within the pass as a result of the different-sized slots will, to an extent, recreate the conditions found in a natural bypass channel. However, all fish that pass through the multi-slot pass need to also pass through a fish lock to pass the dam.

The majority of the migrating fish at the site are smaller than 300 mm, implying low swimming abilities. The smaller slots create passage conditions with reduced velocities and turbulences for the smaller fish. Mekong giant catfish might attain length of three m. The larger slot will allow the passage of such large-bodied fish.

Concerns have been raised during the design process about possible predation issues with a single slot design. The multiple passage routes should help to reduce possible predation issues.

Appendix 2 provides a detailed assessment of the extent that recommendations of the Xayaburi TRR have been addressed in the revised design.

Fisheries Monitoring and Management:
XPC and Fishtek have carried out monitoring of fish species and biomass. In addition, fish swimming tests have been undertaken and incorporated into the design.

7.2.3 Comment on the revised design

Adequacy of the Information Provided
The Report on Design Changes (November 2017) provides a summary of the work done to study baseline conditions and re-design the fish passage and demonstrates that the developer has clearly applied considerable effort and resources to the re-design of the fish pass facilities, and to address the knowledge gaps identified in the Xayaburi TRR.

There were additional studies on (1) Fish Biomass & Migration, (2) fish sampling, and (3) Mekong fish species and fisheries, including swimming speed/ability. However, there is little detailed information and data on fish abundance (including fish biomass) and diversity, and migration and swimming ability provided, and most information is only in PowerPoint presentations. Additional documents and presentations submitted by Pöyry are consequently not detailed enough to allow for a review of the rigour of the scientific methodologies. Details of the experiments, monitoring and assessments of the ecological characteristics should be included in reports for evaluation. There are also concerns over the frequency of the surveys, which are still undertaken only 3-4 times per year, which could miss key migration periods, and whether the overall programme has provided an adequate baseline on which to base the redesign of the mitigation measures. In addition, there appear to be no surveys explicitly examining the biodiversity and conservation species endemic to the Mekong and the Xayaburi region.

It is hoped that the XPCL will still provide a detailed and robust fish monitoring programme. This is required to assess the status of fish and fisheries at the project site (downstream and upstream, including in the reservoir), and the effectiveness of fish passages (for both up and downstream fish migration). Currently, the monitoring is largely based on DIDSON imagery, which has considerable limitations in large river systems, notably because benthic species are not accounted for and the numerical assessment of large shoals of fish is problematic.

Comment on the revised upstream/downstream fish passage design
Many of the recommendations and key design criteria from the Xayaburi TRR have been adopted, but there are also key omissions and design aspects that have not been adequately addressed. These may entail a high-risk to effective fish passage, and these have been highlighted as high-priority areas for monitoring during operations.

For downstream migration, larval behavior and thresholds to maintain drift in the reservoir remain unknown. The trash screens at the turbine intakes have been modified with narrower gaps but the screen angle remains steep and there are only surface entrances, so there is a major risk of impingement of large fish. Much work has been done on the turbine design but without specific data for Mekong fish species, only blade strike can be assessed and not the impacts of shear or barotrauma (pressure impacts). Turbine passage remains an important unknown to assess in monitoring.

For upstream passage, assessment of fishway entrance location and design at varying spillway flows has been overlooked; only very high flows were assessed (12,000 and 15,000 m^3/s) and only on one spillway abutment. The design philosophy of Pöyry, suggested by PowerPoint drawings, indicates they do not expect fish to migrate onto the stilling basin at any spillway flow.

The Xayaburi TRR recommendation to use the navigation lock for fish passage was adopted. The redesign of the navigation lock has been outlined, however, further details such as attraction flow and cycle times would aid evaluation, as would information on the crowding mechanism in relation to the capacity to move fish in the system. The frequency and timing of the use of the lock for passage requires in-depth evaluation, as does the mechanism for use of the tandem lock system.

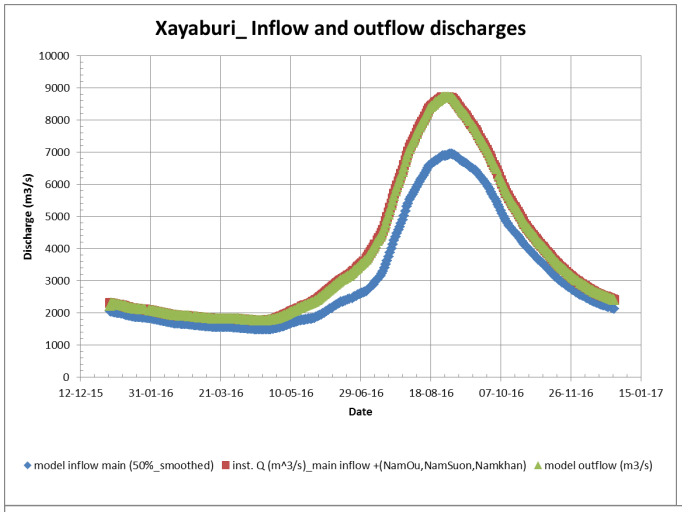
Extensive work and re-design have been done on the fish collection gallery above the draft tubes but the recommendation for benthic entrances was not adopted. An assessment of benthic fish migration will determine if these should be installed for future projects.

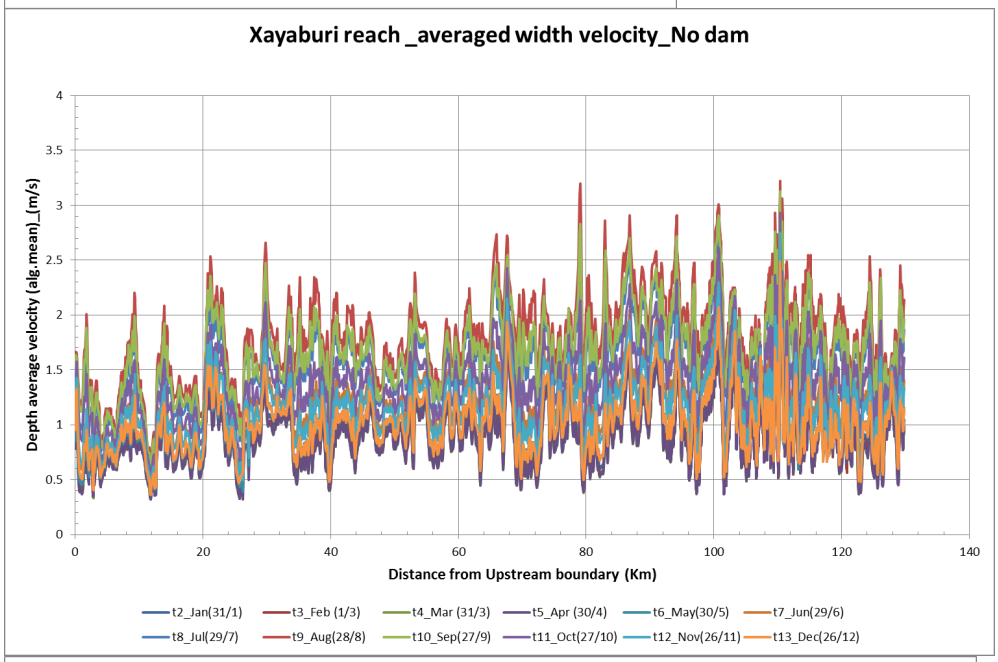
The main pool-type pass is a new variation of a vertical-slot design. It utilises criteria from the Xayaburi TRR which are conservative and provide a low risk. However, the baffle design is untested and, significantly, all fish that reach the top of the vertical-slot fishpass need to use one of two fish locks. The fish locks have small chambers and may be a bottleneck during periods of high migratory biomass; this will require assessment to optimise cycle times and assess whether the additional fish lift is required.

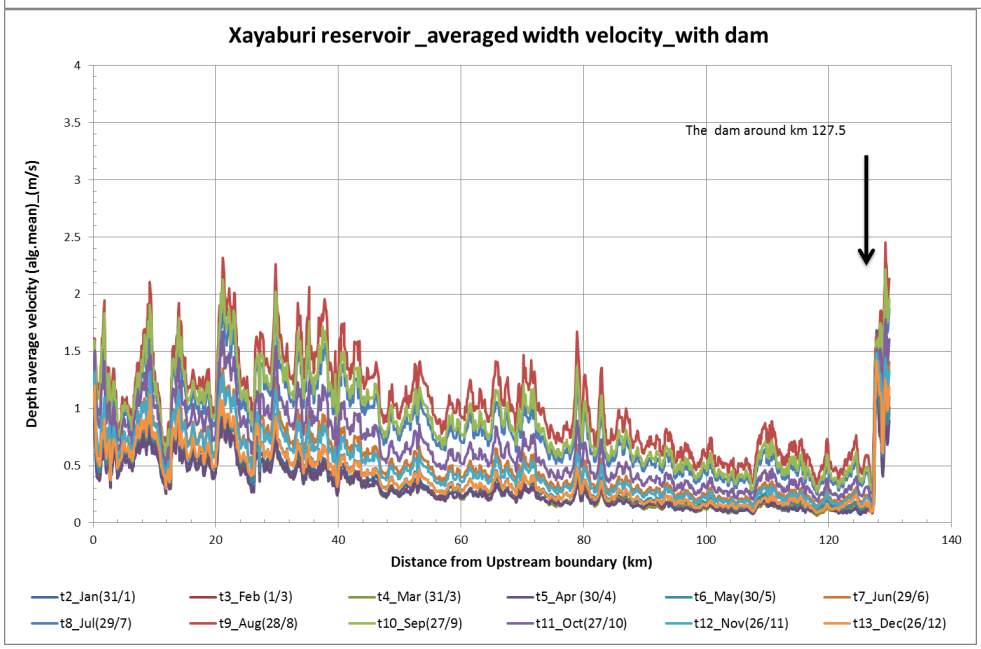
It is not possible in this provisional overview to assess the effectiveness of the design and ultimately only a quantitative assessment of fish passage during operation provides that evaluation (note some important details are not available to this review. See Appendix 2). The Xayaburi TRR also recommended that a workshop involving the MRC experts and the Design Team should be convened to make best use of all the available experts. However, the design has not been shared with MRC for comment before construction, which may have provided opportunities for improvements.

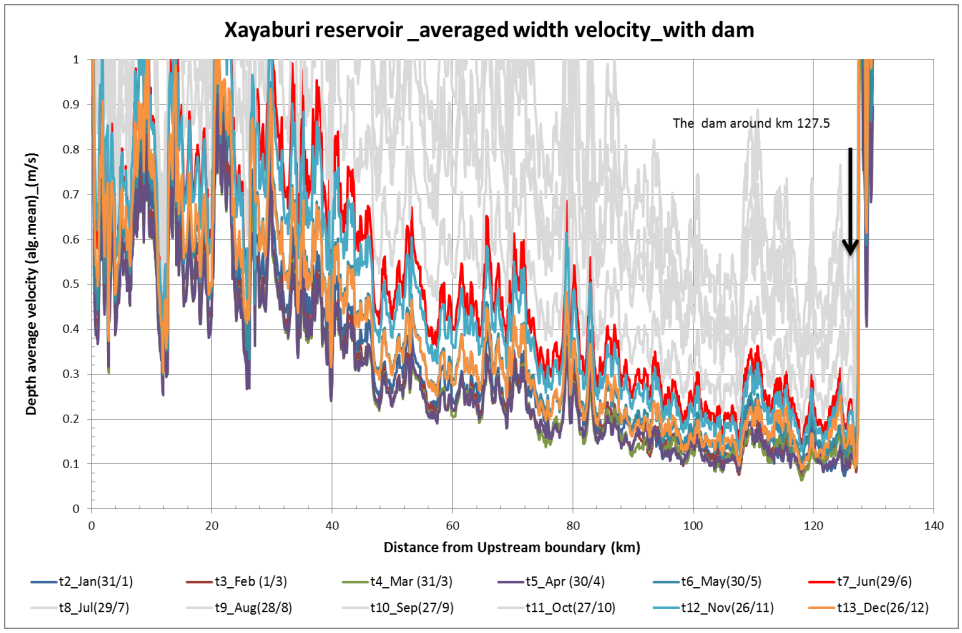
A detailed description on alternative downstream migration possibilities has been given. However, there are no details on the maximum amount of fish that the rest area can hold, and how “a significant number of fish” is defined.

The redesign of the navigation lock has been outlined, but the amount required for the attraction flow was not mentioned for upstream fish passage. Also, the lock requires a crowding boat to push fish through. No assessment on water velocities in the reservoir, and whether these can be maintained above critical thresholds, has been provided to assess the survival of fish eggs and larvae drifting downstream through the reservoir.


Xayaburi_ Inflow and outflow discharges
Discharge (m3/s)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
12-12-15
31-01-16
21-03-16
10-05-16
29-06-16
18-08-16
07-10-16
26-11-16
15-01-17
Date
model inflow main (50%_smoothed)
inst. Q (m^3/s)_main inflow +(NamOu,NamSuon,Namkhan)
model outflow (m3/s)


Xayaburi reach _averaged width velocity_No dam
Depth average velocity (alg.mean)_(m/s)
4
3.5
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
140
Distance from Upstream boundary (Km)
t2_Jan(31/1)
t3_Feb (1/3)
t4_Mar (31/3)
t5_Apr (30/4)
t6_May(30/5)
t7_Jun(29/6)
t8_Jul(29/7)
t9_Aug(28/8)
t10_Sep(27/9)
t11_Oct(27/10)
t12_Nov(26/11)
t13_Dec(26/12)


Xayaburi reservoir _averaged width velocity_with dam
The dam around km 127.5
Depth average velocity (alg.mean)_(m/s)
4
3.5
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
140
Distance from Upstream boundary (km)
t2_Jan(31/1)
t3_Feb (1/3)
t4_Mar (31/3)
t5_Apr (30/4)
t6_May(30/5)
t7_Jun(29/6)
t8_Jul(29/7)
t9_Aug(28/8)
t10_Sep(27/9)
t11_Oct(27/10)
t12_Nov(26/11)
t13_Dec(26/12)



The proposed larger pool of the fishpass would allow catfish reaching a size of up to 300 cm, but no additional data (monitoring or sampling) or information were provided to confirm this statement.

Comment on Fisheries Monitoring and Management

Although a presentation from Fishtek in 2015 has been provided, the complete results on monitoring and sampling were not shared in detail in the reports, hence, they cannot be evaluated.

Furthermore, a detailed and robust fish monitoring programme, including budget, to monitor the status of fish and fisheries at the project site (downstream and upstream, including the reservoir) and the effectiveness of fish passages (for both up and downstream fish migration) continuing in the future should have been provided. This would enable better integration into the Joint Environment Monitoring programme and strengthen the understanding of the impact of the development on fisheries and make adaptive changes to the mitigation measures as was suggested in the PNPCA documents provided by XPCL.

Evidence that the revised design will allay concerns

The XPCL has made commendable efforts to address the recommendations outlined in the Xayaburi TRR and has invested considerably in studies to support the redesign process, and in constructing the revised fishpass facilities. In many cases, the revised designs directly reflect the recommendations in the Xayaburi TRR, and the fish pass facilities at Xayaburi are now likely to be the largest fishpass facilities on a tropical river system anywhere in the world. However, without ongoing monitoring the efficacy of these facilities cannot be assessed, and some concerns remain regarding the potential impacts on fish migration.

There are several critical recommendations in the Xayaburi TRR that were not taken up. Most notably the suggestion in the Xayaburi TRR that a workshop be convened to bring the developer's and the MRC experts together was not taken up. This may have provided the

opportunity to optimise the facilities before construction, and to build confidence in the revised design in all the Member Countries.

7.3 Hydrology

7.3.1 Summary Recommendations in the Xayaburi TRR

The Xayaburi TRR noted the following:

- While no changes in downstream flow regimes *vis-à-vis* the PMFM are expected, the changed flow characteristics in the impounded reach are likely to have negative impacts.
- The operating rules such as daily operating periods, ramping rates for starting and stopping units, minimum flows for environmental or navigation periods, etc. should be provided. It was specifically recommended that the opening of the spillway gates to reach flood-warning level be carried out carefully to avoid increasing downstream flood flows at critical times.
- The monitoring of flow conditions in the river during construction was not addressed.
- The reservoir level should be lowered during floods to provide some flood protection for Luang Prabang.

7.3.2 Measures taken up by XPCL

An extensive monitoring programme has been set up by XPCL upstream and downstream of the reservoir. However, the documentation provided for this review does not include detailed information on this programme, and the data were not made available to the MRC, as requested in the Xayaburi TRR.

Additional low-level spillway gates and model tests (numeric and physical) have been conducted. However, while the report on the physical hydraulic model study (May 2013) has been provided, the numerical model study has not been provided.

The report provided in November 2017 report does not include hydrology, which has also constrained this review.

The documentation provided for this review still does not include sufficient details on the operating rules – outside of those outlined for downstream fish passage, and in particular on a possible limited peaking operation.

The river flow regime during construction in relation to fish migration and the expected rapidly-changing fluctuation of water levels downstream from the dam during peak hydropower operation have still not been elaborated.

7.3.3 Comment on the revised design

Adequacy of Information Provided

The lack of data and information in the documentation provided makes it difficult to assess the extent to which the revised design accommodates the recommendations in the Xayaburi TRR.

The operational rules for:

- Addressing backwater effects to Luang Prabang;
- The expected ramping operation, and consequently the magnitude of the additional discharge on top of the ongoing flood; and
- Limiting the impacts of drawdown on the downstream reach.

… have still not been provided. These are critical to this review

Evidence the revised design will allay the concerns

- Both the Council Study and the MRC Mitigation Case Study confirmed that the Xayaburi HPP will not affect the seasonal patterns downstream. These seasonal flows are mainly impacted by Lancang cascade and the tributary dams.
- However, flow velocities in the reservoir are significantly reduced. This will have considerable impact on fisheries and disrupt the downstream movement of migratory fishes. As no operating rules or analyses have been provided in the documentation it is not known whether the revised design accommodates this.
- However, the work by the MRC on Hydropower Mitigation Guidelines (ISH0306) suggests that for a large part of the year (for discharges less than about 4000 m^3/s) the velocities drop below 0.3m/s for the lower 30 to 40km of the reservoir.
- The MRC's subsequent work has also highlighted the need for coordinated operations along the full cascade to minimise the potential impacts on fish migration and sediment transport. The extent to which this adaptive management can be accommodated by the XPCL is not known.
- Environmental flows are not detailed in the documents. However, the inclusion of functional flows that serve a range of environmental and socio-economic purposes (not just restrictions to minimal flows, but also pulses needed for maintaining functions of the river), should be included in the operating rules.

7.4 Sediment

7.4.1 Recommendations in the Xayaburi TRR

Modifications to dam design:

- The dam design should be modified to enhance and optimize the capacity for sediment routing and flushing (low level gates). This should include modifications to the spillway and provision of low-level outlets of appropriate dimensions to allow operators to recreate river-like flow conditions required to execute flushing operations.
- Modifications were needed to ensure the sustainable generation hydropower, with appropriate maintenance, in the long term. The capability to manage sediment

adaptively is necessary because of the uncertainty in modelling future sediment loads and operating conditions.

Modifications to operations

- The operating procedures needed to be reconsidered to optimise sediment routing and flushing, based on exploiting the enhanced sediment-management capabilities possible with the recommended modified design.
- It was highly recommended that an environmental flow strategy is set up for the river downstream of the dam.
- Since the cumulative effects of multiple-dam developments on the mainstream and in tributaries would be significant, **an adaptive sediment-management regime** at Xayaburi is important to protect its long-term generating capacity while minimising bank erosion and scouring of the riverbed.
- **Amending the design and operation** would come at the cost of reducing power generation in the short term during sediment-routing operations while preserving long-term capacity of the reservoir.

7.4.2 Revised design implemented by XPCL

XPCL Report and CNR presentations:

The following changes have been made to the original design

- Three spillway gates have been removed and replaced with four low level outlets (LLO); The low-level gates include a flap gate to allow surface discharge as well as low level flow when the gate is open. These gates are intended to increase flexibility with respect to sediment management;
- Three sediment monitoring campaigns were completed, including the collection of washload and bedload samples;
- A provisional operating curve is provided showing draw down and sediment routing at flows of greater than 10,000 m^3/s; and
- The sand flushing outlet of the power house has been removed from the original design.

Additional details of the changes made are provided in Appendix 4.

7.4.3 Comment on the revised design

Sediment budget and sediment trapping

The details of the sediment monitoring methodologies and sediment trapping model are not provided. The results presented in the documentation also differ markedly from that held by the MRC both in terms of the total incoming sediment load and loss of sediment in the impounded reach. The documentation provided suggests input sediment loads of **82.5 Mt/yr, with 34% sand, and only 10% trapped**. Whereas the MRC's studies suggest an incoming load of **13.5 Mt/yr, with 72% sand, and some 80% trapped**. In both cases the modelling results show that the fine clay and silt, and hence the nutrient fraction, is passed through the impoundment.

Resolving these differences is critical to assessing the likely transboundary impacts of Xayaburi, and other mainstream dams, and hence to assessing the extent to which the concerns raised in the Xayaburi TRR have been addressed.

Low Level Outlets

The following comments are provided and supported by the outcomes of the Council Study and the MRC Mitigation Guidelines:

- The Low-Level Outlet (LLO) provides an increased capacity to flush sediments, but information is lacking as to how the system will be operated to maximise sediment passage and minimize transboundary impacts. A provisional operating curve is provided for flows greater than 10,000 m^3/s but no other operational information has been provided;
- The lower sill level (238 masl) reduces the height between the river bed and the sill by 14 m, which will allow the passage of bedload earlier than with the initial design. However, even with the revised design, substantial sediment deposition is required before bedload can be transmitted;
- Given the length of the impoundment and the reduced sediment input, it is likely to be years to decades before sufficient sediment accumulates near the dam wall for a new equilibrium to establish;
- No target suspended sediment concentrations have been identified for adoption during sediment flushing to minimise downstream impacts; and
- Sediment outlets in the power house have been omitted, but no reason or justification for this is provided.

Evidence the revised design will allay the concerns

- While the documentation suggests that the revised design will facilitate flushing with different grain sizes for both operating condition and flood release, no evidence supporting this claim was presented.
- No detail is provided as to how the sediment grain-size distribution for the sediment model was determined (e.g. number of samples, when the samples were collected, etc). The sediment load and grading adopted in the CNR analysis differ to that adopted in the MRC Mitigation Guidelines study which were based on MRC monitoring results and included the effect of the Lancang cascade on sediment yields. The most recent MRC Discharge and Sediment Monitoring Program (DSMP) data reflects a lower percentage of silt and more fine and coarse sand. If this sediment grain-size distribution is valid for Xayaburi then a higher percentage of sediment would be expected to be trapped than shown in the CNR presentation.
- The submitted documents conclude that 97% of the sediment will be transmitted through the impoundment and suggest that with this level of sediment passage the trapping of nutrients will not be an issue. The MRC Mitigation Guidelines study (ISH0306) found that finer sediments, which transport the majority of sediment-bound nutrients, are effectively passed through the run-of-river dams, but coarser sediments are trapped, and that it would take years to decades for a new sediment transport equilibrium to be established.

In conclusion, it is likely that the revised sediment transport measures included at Xayaburi will substantially improve the capacity to transport sediment. However, some residual impacts will be felt downstream due to the deposition of the coarser sediments in the impounded reach.

7.5 Water Quality and Aquatic Ecology

7.5.1 Recommendations in the Xayaburi TRR

Monitoring

- The design of monitoring programmes to assess impacts on water quality, aquatic ecosystems and the environmental flows during construction and operation was recommended.

Water Quality:

- WQ during construction and operation was to be managed (algal blooms, aquatic weeds, physico-chemical) proactively by continuous monitoring and action taken if problems were to arise. This would include all waste water management, excavation runoff and construction wastes.

Aquatic Ecology:

- Xayaburi TRR concluded that several pressures resulting from the proposed Xayaburi dam project will alter aquatic ecology. It was recommended that monitoring of the aquatic biodiversity was needed through both the construction and operational phases.

Environmental flows

- Environmental flows and respective negative impacts were not considered, and a corresponding baseline was not proposed. Monitoring to ensure that there are no unacceptable changes during the construction and operation phases was recommended.
- Hydro-peaking effects that impact on the aquatic ecology have not been taken into account.
- The Xayaburi TRR concluded that the flows needed for the environment covering flow volume, temporal variability (including any diurnal variations), biological and chemical water quality are very likely to be impacted.

7.5.2 Revised design Implemented by XPCL

No additional details on Water Quality or Aquatic Ecology issues or monitoring have been shared by the XPCL/Government of Lao PDR.

7.5.3 Comment on the revised design

Adequacy of information provided

No information has been provided regarding water quality monitoring of the river, waste water streams, site run-off or mitigation actions, as recommended by the Xayaburi TRR. An inventory of pollution/water quality issues arising during the construction phase has not been provided as part of the monitoring recommended in the Xayaburi TRR.

Similarly, no information on aquatic biodiversity and conservation species has been provided.

Evidence the revised design will allay the concerns

As no new information has been provided, it is not possible to assess whether the concerns expressed in the Xayaburi TRR will be addressed. Nonetheless, these aspects have been investigated in the MRC Mitigation Guidelines, from which the following assessments are made:

Water quality risks associated with Xayaburi

Water quality risks of mainstream hydropower include:

- Increased water clarity due to the reduction in suspended sediment concentrations from sediment trapping in the Lancang cascade and tributary dams. This can increase the risk of algal blooms;
- Increased water temperature due to storage increases the risk of algal blooms;
- A reduction in river flow velocity will decrease mixing and promote algal growth, especially when associated with increased nutrient loading. (An algal bloom was observed in the backwater created by the Xayaburi project in March 2016.)
- Changes in water quality resulting from immediate land use change and population growth around the reservoir will potentially lead to nutrient enrichment.

Figure 3: *Algal bloom in the Xayaburi backwater during construction (Photo: Lois Koehnken)*

The Council Study addressed water quality issues by assuming a fixed percentage of nutrients are attached to nutrients and captured in the impoundments, so nutrient capture is directly proportional to sediment capture.

Applicability of LLO to water quality issues

The inclusion of additional low-level gates in the project increases operational flexibility with respect to water quality. Water can be released from variable depths within the impoundment if required to manage a water quality issue, such as an extreme algal bloom or oil spills. Although the downstream effects must also be taken into consideration.

7.6 Dam Safety

7.6.1 Recommendations from the Xayaburi TRR

The Xayaburi TRR made the following recommendations:

- Formation of an Independent Dam Safety Review Panel for the Xayaburi dam project and assignment of the task to review the Design Report in a timely manner.
- Provide clarity on the expected scope and timing for an overall Dam Safety Management System (DSMS).
- Provide clarity on the process for consultation and engagement of local stakeholders, especially for the Emergency Preparedness Plan (EPP).
- Provide clarity on the cost of dam safety measures and plans in project budgets.
- To align with the PDG, full use needs to be made of experience in Lao PDR including use of Lao guidelines.
- Other recommendations with potential transboundary implications:
    - Assess the effect of cascade operation and upstream developments, and climate change on the design floods;
    - A dam break analysis must be undertaken incorporating all proposed mainstream dams above the Xayaburi site in Lao PDR and considering the Chinese dams.
    - Transboundary mechanisms to involve other MRC countries, reporting and compliance activities related to dam safety in the design, construction and operation phases.

In addition, while after the submission of the documentation for prior consultation, the earthquake near Xayaburi in February and March 2011 raised the need for an independent review of the project according to international safety standards.

7.6.2 Revised design by XPCL

A Probabilistic Seismic Hazard Assessment report has been provided by the Asian Institute of Technology in Thailand. This noted that:

> *"The Xayaburi dam and reservoir are classified as a storage project (NB in regard with the reservoir volume and dam height, but not in regard with its operation) with large damage potential and all the dam and safety-relevant elements have to be designed for the worst earthquake ground motion to be expected at the dam site, the so-called Safety Evaluation Earthquake (SEE) ground motion. The SEE ground motion parameters were determined probabilistically considering a return period of 10,000 years based on all available earthquake catalogues and seismotectonic data (faults in greater project region).*
>
> *A Seismic Hazard Study assessment was elaborated at the Asian Institute of Technology in Thailand. Its analysis was carried out by state-of-the-art seismic hazard analysis concepts. The seismic ground motion parameters are determined for the Xayaburi dam site such as peak ground acceleration, acceleration response spectra for horizontal and vertical earthquake components on the rock surface. Additional seismotectonic investigations were undertaken to locate the Dien Bien Phu fault, which passes close to the Xayaburi site and which is capable of producing large earthquakes. The ground motions caused by an earthquake at the Dien Bien Phu fault were then considered in the probabilistic seismic hazard analysis.*

A Plant Safety Concept for the structural safety was implemented based on international standards to ensure an earthquake resistance design based on these ground motion parameters. All dam and safety-relevant elements have to be designed for the SEE, only if appropriate less critical structures shall be designed with reduced earthquake loads."

7.6.3 Comment on the revised design

Adequacy of Information Provided

The documents related to Dam Safety were requested by the MRC, but as yet not all the documents have been provided. The documents that were not received are the following:

- Flood risk and dam break analysis;
- Spillway gate operations and backup power arrangements;
- Dam safety management plans; and
- Flood warning and emergency response plans.

As such, this review is unable to fully evaluate the extent to which the concerns in the Xayaburi TRR have been addressed. Nonetheless, it is noted that the seismic hazards have been addressed in detail, and the Asian Institute of Technology study demonstrates a commitment to observing international standards for dam safety including consideration of a Maximum Credible Earthquake.

Evidence the revised design will allay the concerns

An Independent Dam Safety Review Panel for the Xayaburi dam project and assignment of the task to review the Design Report were not established. Instead Pöyry engineers have been engaged as "Owners Engineer" to review designs and dam safety matters.

The seismic design was reviewed by the MRC in 2015. This review recommended that due to uncertainties over the size of the Safety Evaluation Earthquake (SEE), the design of the dam should be checked for a higher peak ground acceleration. The review also recommended that there should be further investigations of the foundations during the construction period to identify any risk of fault rupture through the foundation. It is unclear if these recommendations were carried out.

A Plant Safety Concept for the structural safety was implemented based on international standards to ensure an earthquake resistance design based on the ground motion parameters. All dam and safety-relevant elements have been designed for the safety evaluation earthquake (a 10,000-year return period). Earthquake resistance design of Xayaburi HPP for each structure was summarised in the Plant Safety Concept document in Oct 2012. It is unclear if this Plant Safety Concept was reviewed and the calculations revised to take account of the recommendations to check the dam for a higher SEE.

The process for consultation and engagement of local stakeholders, especially for the Emergency Preparedness Plan (EPP), needs to be implemented during the construction as well as the operation phases. As noted above, documents related to flood risk, dam break, dam safety management plans, flood warning and emergency response plans have not been

received and these are required to confirm that dam safety issues have been sufficiently addressed.

7.7 Socio-Economics

7.7.1 Summary Recommendations in the Xayaburi TRR

The MRC Secretariat review of transboundary social issues related to the Xayaburi project focused mainly on the consequences of any possible environmental impacts. Social issues related to resettlement and other local impacts such as loss of livelihoods were outside of the scope of the Xayaburi TRR. Comments were made with regard to the potential disruption to livelihoods and food security from the dam development and the proposed measures to mitigate the impacts. In particular, concerns were raised regarding the replacement of lost fisheries by aquaculture, as these may only promote those with the capital and skills to successfully engage in fish farming.

7.7.2 Revised design Implemented by XPCL

These aspects were not dealt with in the documentation provided. It is recommended that mechanisms for achieving sustainable livelihoods and equitable distribution of benefits should be developed (if these have not already been developed), and shared.

7.7.3 Comment on the revised design

The MRC Member Countries have undertaken studies on national-to-Local benefit sharing, and their priorities have been documented. In addition, the MRC is considering regional benefit sharing projects. There are examples of international best practice being adopted in Lao PDR including the increasing trend towards project-based benefit- sharing mechanisms for affected communities.

These should be considered as a basis for mitigation measures at Xayaburi. For the cascade of six dams upstream from Vientiane excluding proposed tributary dams, incremental effects regarding fish losses due to reduced capture fisheries are estimated at about 66,000 tons per year. The livelihoods of about 450,000 people would be at risk to some extent. The distribution of the number of affected people among countries would need to be further analysed based on more extensive social information.

Social issues are not dealt with in the PDG and this has been considered in the updated PDG 2018.

7.8 Cumulative Impacts

This section deals with the broader efforts to avoid, minimise and mitigate the potential impacts of development, rather than the extent to which the XPCL has addressed the Xayaburi TRR.

7.8.1 Recommendations in the Xayaburi TRR

General

The Xayaburi TRR recommended that the preliminary assessments carried out by the MRC regarding the cumulative impacts of development in the LMB need to be further investigated. Similarly, the Concession Agreement and Power Purchase Agreement should include provisions that allow for the recommendations of the Xayaburi TRR to be taken up. The Xayaburi TRR also made suggestions for implementing the PNPCA, and the work plans of the MRC programmes.

Monitoring

Appropriate monitoring programmes would need to be in place to fill existing knowledge gaps that have been identified. Such programmes would be required to assess impacts, and to provide information to adapt mitigation measures to minimise negative effects.

7.8.2 Uptake of the recommendations by the MRC

The Council Study was initiated as a direct result of the Xayaburi prior consultation process and the recommendations made in the Xayaburi TRR. Other studies have also merged out of the need to provide guidance to efforts to mitigate the impacts of hydropower development, with the injection of resources to address this in large part because of the Xayaburi prior consultation process. Similarly, the outcomes of the process led to the establishment of the Joint Platform to improve the uptake of the MRC Procedures, and ultimately the development of Commentaries for the PNPCA. This process is ongoing and will help the MRC address the water diplomacy aspects of prior consultation.

The JEM has emerged at least in part to respond to the need to monitor the efficacy of the mitigation measures implemented by all the developments in the basin.

7.8.3 Comment on the contribution made by the Xayaburi TRR

The Council Study and other initiatives in the MRC since 2011, initiated in large part because of the Xayaburi prior consultation process, have made an invaluable contribution to the understanding the impacts of development on both the tributaries and mainstream. These studies have indicated that:

- While the overall flow regimes in the LMB will not be substantially affected by run-of-river hydropower projects in the mainstream, increased storage in the tributaries and the Lancang cascade will reduce the volume of the return flow into the Tonle Sap;
- Even run-of-river developments on the mainstream and developments on tributaries will result in substantial and irreversible impacts associated mostly with reduced fish migration and sediment transport;
- Measures to avoid, minimize or mitigate impacts at each of these projects (as provided for in Article 7 of the 1995 Mekong Agreement) can limit possible transboundary effects;
- Conjunctive operation of the hydropower projects can further reduce the possible impacts; and

- If the required infrastructural changes are in place, it may be possible to retrospectively adjust the operating rules at each project to accommodate the growing understanding of the Basin and the impacts of hydropower development, as well as monitoring through the JEM, provided that these can be accommodated by the concession and power purchase agreements.

However, key water diplomacy aspects of the prior consultation process still must be clarified through the PNPCA Commentaries. Whether the residual impacts of ***all*** developments in the Mekong River Basin constitute a reasonable and equitable use of the shared watercourse. This includes the potential impacts of developments outside of the energy sector, as well as population pressures, over fishing, sand mining, increased nutrient loads, and increased use of herbicides and pesticides and other pollutants.

8 Conclusions and Recommendations

This section provides concluding remarks and recommendations based on the discussions in section 7.

8.1 Navigation

Many of concerns raised in the Xayaburi TRR have been addressed. However, based on the lessons learnt from the Pak Beng prior consultation process, some additional recommendations can be made, which can still be addressed at this point in the construction process.

- The approaches to the locking facility and the mooring facilities up- and down-stream need modification to allow for access to the shore during night berthing, and the inclusion of refuelling, water supply, waste disposal, elementary food and drink and other supply facilities.
- An overhead portal crane that can lift some five tonnes to remove obstacles in the lock chambers that hinder or jeopardise safe operation can still be added.
- There is no information provided on the maintenance of the infrastructure. It would be important to provide evidence that the vital components of the pintle doors can be replaced after years of operation. Similarly, a list of the critical spare parts should be made available, in particular those that require long manufacturing times. Further evidence should be provided that the lock chambers can be accessed by heavy duty cranes.
- A RIS (River Information System) should be considered. This should be available for all skippers and captains (via VTS radio), giving information on water levels, oncoming vessels (size and speed), incidents and accident announcements, weather forecast or weather reports, etc.

8.2 Fisheries

The XPCL has undertaken an extensive redesign as a result of the recommendations in the Xayaburi TRR, and many of the recommendations and key design criteria have been adopted or addressed. The fish pass facilities are now likely to be the largest such facilities on a tropical

river system anywhere in the world. The additional investments in infrastructure and studies have been considerable, and the facilities now presented are a substantial improvement on the original design.

However, additional details on the revised designs and operating rules would aid an evaluation of the extent to which they may address the concerns raised in the Xayaburi TRR. For some items no information is provided, so the logic for the redesign is unclear, while for other items the methods of collecting data are described only briefly, so the scientific rigour of the methodologies is unknown.

Some supporting information has been provided by way of graphs in PowerPoint presentations on ecological studies, mostly swimming speed experiments and Didson monitoring of a 12-month cycle. However, the information provided is limited and this review has been unable to make a robust assessment of whether they would allay the concerns raised in the Xayaburi TRR, or whether the proposed mitigation measures will be effective.

The data collated through the redesign process should be shared, and the methodologies should be transparent, to determine their relevance to addressing issues raised and whether further adaptions are required with increasing evidence base. Similarly, these data will contribute to the MRC's understanding and would assist further studies and should therefore be shared as part of the general commitment to cooperate and the ***Mekong Spirit***. Unfortunately, the tools chosen are generic in terms of assessing the status of the fish populations and community and do not provide any indication of possible transboundary impacts.

While commendable efforts have been made to address the knowledge gaps, key gaps may still exist. These include:

- attraction and passage of benthic (bottom-dwelling) species upstream and downstream;
- behaviour of fish in the stilling basin and spillway;
- effectiveness of the innovative vertical-slot /fish lock combination;
- behaviour and health of fish at the modified trash racks and sluice;
- turbine passage (remains unknown for Mekong fishes); and
- larval behaviour and drift within the reservoir.

Any information on these aspects that may be currently available should be shared.

It is consequently unknown whether the revised design will address ***all*** of the concerns raised in the Xayaburi TRR. These knowledge gaps therefore highlight high-priority areas for monitoring and adaptive management.

Issues associated with the potential lost livelihoods of fishing communities, and their replacement have not been addressed.

8.3 Hydrology

The hydrological impacts from HPPs are restricted to daily flow fluctuations caused by dam operations. These fluctuations occur in the reservoir, and in the river reach downstream. They are occasional if related to sediment-routing and flushing, or flood control at Luang Prabang, but recurrent if related to power peaking.

However, as very little information has been provided on the operation rules, and the expected flow fluctuations in the reservoir and downstream river, it is not possible to assess whether the concerns raised in the Xayaburi TRR have been addressed. If hydropeaking is being contemplated, additional information and discussion are needed. In particular, information on the operating rules and ramping rates used to reduce the impacts of rapid changes in water level and discharge is required. The proposed restrictions to water-level fluctuations are also critical in this regard.

Additional information on the monitoring network and monitoring parameters is required as these details are indispensable to investigating hydrological changes and related impacts that occurred during construction or may be occurring during the operation. This network should cover stations upstream as well as downstream of the project, as far up as Luang Prabang, and as far downstream as Vientiane.

8.4 Sediment

The redesign of the project and inclusion of four low-level outlets provides the necessary infrastructure for increasing sediment transport through the impoundment as recommended in the Xayaburi TRR. However, the efficacy of these measures to reduce the potential transboundary impacts associated with sediment trapping cannot be assessed as no operating procedures have been provided. These should specify the frequency of flushing and the operating conditions during flushing as these will determine the magnitude and timing of sediment discharge downstream.

The sediment transport information provided by XPCL over estimates the sediment load in the river as compared to MRC's monitoring results or numerous modelling studies. This issue raises questions about the estimated sediment trapping and transmission rates, which must be resolved to understand the potential transboundary impact of sediment trapping by the dam. The XPCL estimates that only 3% of 80 Mt/yr of sediment will be trapped, whereas MRC's Hydropower Mitigation Guidelines suggest that ~80% of 13 Mt/yr will be lost. The discrepancies are due to the difference in estimated total sediment load and differences in sediment grain-size distribution.

Sediment transport through the dam will also be affected by changes to sediment input associated with the development and operation of upstream dams. The Xayaburi TRR recommended that an adaptive management strategy be developed to address these changing conditions, but no information has been provided outlining such a strategy. Similarly, no information is provided regarding the development or implementation of an environmental flow regime to minimise downstream geomorphic impacts, or details about

sediment or geomorphic monitoring programs to quantify downstream changes and impacts and guide adaptive management, as recommended in the Xayaburi TRR.

8.5 Water Quality and Aquatic Ecology

The Xayaburi TRR raised many concerns related to water quality and aquatic ecology. However, the documentation provided did not include information on water quality or aquatic ecology, and it is thus not possible to assess whether the concerns raised have been addressed.

In particular, attention should be paid to WQ incidents during the construction and the likely impacts of changed WQ in the reservoir on downstream environments when the dam becomes operational. Additional information of the aquatic ecology, including species that are exploited for food, is urgently required.

8.6 Dam Safety

The Plant Safety Concept for the structural safety, recommended in the Xayaburi TRR was implemented based on international standards to ensure an earthquake resistance design based on these ground motion parameters. However, it is unclear whether the recommendations regarding the checking of the safety of the dam under higher peak ground accelerations and confirming the risk of fault rupture through the dam foundation have been implemented.

An Independent Dam Safety Review Panel (DSRP) for the Xayaburi dam project and assignment of the task to review and Design Report was not established as suggested. Whilst the construction of the project is almost complete, there is still value in a DSRP carrying out a review of the geological and fault information collected during the construction period to confirm its impact on the design. The DSRP should also review the DSMS and EPP (these plans are still to be submitted) to confirm their completeness and adequacy.

The process for consultation and engagement of local stakeholders, especially for the Emergency Preparedness Plan (EPP), still needs to be implemented and emphasised during the construction and operation phases.

8.6 Conclusions

In Article 7 of the 1995 Mekong Agreement, the Member Countries agree to make every effort to avoid, minimise and mitigate any harmful effects of development and use of the Mekong River System.

In this regard:

- The XPCL has made commendable ***efforts*** to further reduce the potential harmful effects of the Xayaburi HPP, but it is not possible to assess whether ***every*** effort has been made without the inclusion of the operating rules.

- The documentation provided primarily outlines the infrastructural changes, but the efficacy of these changes will be realised through the operational rules which have mostly not been provided.
- The details of the monitoring, data and analyses that have led to the design changes have not yet been shared, which limits any assessment of the scientific rigour of the methodologies. Of concern are the differences between the XPCL and MRC sediment analyses.
- The potential constraints to design and operational changes have not been shared, to assess the extent to which the ***all reasonable measures*** have been considered.

It is, therefore, not possible to completely assess the extent to which the revised design addresses the concerns raised in the Xayaburi TRR, or the extent to which transboundary impacts may be reduced. However, given that some of the infrastructural measures have been constructed, the operational measures could be retrospectively included, provided that the CA and PPA allow. It is understood that the Lao PDR's Standard Environmental and Social Obligations have domesticated the provisions of the 1995 Mekong Agreement, but it is unknown how these have been taken up in the CA and PPA.

However, the efficacy of the revised fish passage infrastructure, irrespective of any operating rules is unknown at this stage. This highlights the importance of ongoing interaction between the developer and the MRC throughout the re-design process. The Joint Action Plan for the Pak Beng Statement should help address this need.

Nonetheless, the admission by the XPCL in its Compliance Report, highlights that the Xayaburi TRR and the prior consultation process have been instrumental in identifying additional measures to avoid, minimise and mitigate harmful effects. Similarly, the studies that have emerged because of the Xayaburi prior consultation process have been invaluable and can still contribute to optimising the operating rules to further minimise impacts.

However, there is insufficient information, in the documentation currently available, particularly as the revised operational rules have not been provided, to establish the record of the use once commenced as outlined in Article 5.4.3 of the PNPCA, and as required by the PWUM.

Appendix 1: List of information requested to be shared with MRCS (20 May 2013)

Topic	Related issues	Comment

Sediment	<u>General Technical Reports</u>
	- Report on modelling of sediment movements under the flushing regime (CNR).
	  o Any assessment of changes in sediment concentrations, particle size and visibility in the reservoir, during normal operation and during flushing;
	  o Any spatial variations of sediment concentrations and deposition within the reservoir.
	- Modelling report of physical model of gates by AIT/Pöyry.
	- Report on Operational Options and Tail water and Head water level.
	- Assessment of change in downstream bank stability as a result of changed sediment release procedure.
		Not provided

	<u>Hydrology and sediment data</u> - Sediment data used for above analysis. - Nutrient flux data collected upstream and downstream of the dam site. - Modelling parameters and methods. - Measured sediment concentration to date (including any sediment grading measurement and detail of method used for sampling). - Measured water quality parameters to date (DO, temperature, algae, organic material including any assessment of woody debris). - Water level/flow measurements at site and temporary gauges elsewhere and location of gauge used.	
	<u>Physical dimensions</u> - Gates proposed: low level spillway gate levels, revised high level spillway gates: dimensions (width, crest level, top of gate when closed). - Approach channel dimensions to low level spillway – at similar scale as the feasibility study. - Detailed river and valley topographic/bathymetric survey in area of the dam. - River Cross Section (Distance (m) Bed/Ground level (m Above specified Datum, Coordinates).	

	<u>Information on the proposed operating procedures</u>
	- Flushing regime:
	  o Timing of flushing and gate opening;
	  o How long the gate opening will take;	

Topic	Related issues	Comment
	o Power station operation, regular and during flushing; o How long will full opening of gate be sustained. o The expected month when this will be done and whether it will be every year etc. - Any nutrient, water quality or temperature modelling of these operations on reservoir pond and downstream. - Description of any provisions made to adapt operations to improve mitigation options, based on monitoring. - Effect of these operational measures on the economic viability of the project.	
Fisheries	<u>General Reports</u> - Recent reports on the results of fisheries monitoring activities upstream and downstream of Xayaburi dam site. - Recent reports on effectiveness of fish passage and other mitigation options to reduce impact of Xayaburi on fish biomass and species diversity.	
	<u>Fisheries data</u> - Detailed of methods and results of fisheries monitoring (biomass assumptions, species found, larvae drift etc.). - Assumptions on fish biomass and size distribution and species for fish passage design.	
	<u>Fish Passage Philosophy and Design</u> - Detailed design and drawings of the various fish passages (or fish ways). - Fish specific design and operational elements of navigation locks. - Enhancements to fishway galleries. - Other offset measures proposed by XPC (stocking, etc.). - Details of proposals to address the issues of downstream migration and larvae drift including the issues of fish larvae passing through turbines.	
Flow changes	<u>Operational Information</u> - Hydrological assumptions (including climate change issues). - The details of the operational arrangements of the dam (power station, gates, fish passage) as requested above under “Sediment” including: o Changes that may occur in flow, water level and water quality (daily, weekly, seasonally); o Rise and fall rates immediately downstream of dam and at locations further downstream. - Difference in releases anticipated if further mainstream dams are developed downstream.	

Topic	Related issues	Comment
Floods	<u>General Information</u> - The statistical risks (linked to different discharge frequencies such as for instance 1/100 years, 1/1000 years) of emergency release in terms of duration and magnitude of discharges in case of excessive rainfall upstream of the dam during flood season, and during dry season. - Maximum variation of the estimated hourly discharges over a period of one week due to normal dam operations during for instance 1/1year, 1/5 years, 1/10 years, 1/20 years for flood season conditions. - Proposed links with downstream warning and disaster prevention. - Operation during floods to reduce flood level at Luang Prabang.	
Navigation	<u>Data on Dimensions and Operations</u> - Diagram or longitudinal profile that shows how far the back water will reach upstream at minimum operating levels – to determine the extent of the free-flowing stretches that will influence the navigability. - Schedule that indicates when navigation will be interrupted during construction of the dam. - Outline design plans and reports for the reserve space for the second (parallel) ship locks (indicating the exact dimensions), and report how and when they will be materialized. - Diagrams or simulations that shows the surface flows (strengths and directions – mean velocities at cross sections) up to 2km upstream and downstream of the dam (to see how this will act on the maneuverability of the ships), after dam construction. - Maps and charts that show the access channel depths and alignment – up to 2 km upstream and downstream before and after dam construction. - Report on navigation simulation modelling if available. - Plans for dredging work for the navigation channel; navigational aids (daytime and night time); lead-in, fendering and mooring jetties. - Full set of as-built drawings from the ship locks with hydraulics, pintle doors and valves, and approach facilities up- and downstream in AutoCAD format. - List of essential spare parts to be provided, which otherwise would take too long to manufacture in case of replacement (gate pintle assets, gudgeon pin assets, hydraulics, etc.).	
	<u>Detailed Requirements for later discussion</u> - Details of drawings and standards to be used in the design and operations of the navigation locks including: cranage to bring the small boats across the dam; dam – lock – powerhouse arrangement; safety measures and devices; filling and emptying system selection (bottom, lateral); selection of edge protection, water sealing, valves, bollards,	

Topic	Related issues	Comment
	fenders; protection from ship impact; mooring devices inside the lock chamber; standards in place for prevention and contingency management of oil spills upstream of the dam; fire protection measures (hydrants); safety instructions for transport of dangerous goods; lock operations and communication systems; requirement outside the locks, such as control tower, supply machines, video control, two-way communication system with lock master, etc. - Coordination mechanisms of the operations of the locks in association with the operation of the dams; - Institutional structure for the actor(s) coordinating the locks/dams. Automated systems.	
Dam safety	<u>Dam Safety</u> - Dam Safety Management approach and governance arrangements - As required the MRC Preliminary Design Guidance and accepted international practice, are there plans for an Independent Panel of Expert on Dam Safety? What other safety governance arrangements are in place? - Proposals for monitoring and reporting.	Not provided Panel not instigated Not provided
	<u>Key Reports</u> - Seismic risk - Flood risk and dam break analysis - Spillway gate operations and backup power arrangements - Flood warning and emergency response plans.	Submitted Not provided Not provided

Appendix 2: Comparison of Xayaburi TRR recommendations and XPCL re-designs with respect to fish passage

Xayaburi TRR recommendation	XPCL re-design	Is there sufficient information on re-design and does it address Xayaburi TRR recommendations?
UPSTREAM PASSAGE		
Concept: three fishpasses, passing a high flow, were recommended, combined with optimised dam operation.	Concept: a single pool-type vertical-slot fishpass was adopted with small twin fish locks at the upstream end. All fish that ascend the vertical-slot fishpass must then pass through one of two small fish locks (dimension not specified but appear to have 5 m by 7 m lock chambers). Capacity for future fish lift provided if biomass higher than estimated. Navigation lock modified for fish passage (see below).	*Sufficient Information?* In general, yes, but some detail is lacking such as fish lock chamber size, and cycling regime. *Address Xayaburi TRR recommendations?* In general, yes, but there are significant unknowns. The intent of the Xayaburi TRR recommendations were to provide: multiple fishpasses for the anticipated high biomass; high flow for high *attraction* and *passage*; and multiple entrances for the multiple points of fish attraction downstream of the dam and powerhouse. Passage through the vertical-slot design is unknown, as it not a standard design. Conservative design criteria from Xayaburi TRR have been used, so it has a low-risk and a very high likelihood of effective passage. However, the baffle does not include a standard upstream return baffle which prevents carry-over of velocity into next pool. Passage within the fishpass will require assessment (e.g. PIT tags and trapping at various locations within the pass). Fish locks are a potential bottleneck in this system as they are a discontinuous system compared to a pool-type fishway, which constantly passes fish. Two fish

Xayaburi TRR recommendation	XPCL re-design	Is there sufficient information on re-design and does it address Xayaburi TRR recommendations?
		locks will enable one to always be in attraction mode. Fish locks of this size have not previously been successful in passing high biomass in other tropical rivers. Quantitative assessment will be required to evaluate the effectiveness of this combined pool-type/fish lock system. *For future designs in the Mekong it should be noted that fish passes that are installed in parallel combine the strengths of different designs, whereas fish passes installed in-line combine the weaknesses.* *For example, large pool-type passes can pass a high biomass but have a fixed water velocity, whereas fish locks historically pass a low biomass but can vary water velocity to adapt to new data on swimming ability.*
Revise left-bank fishway concept to pass 10% (100 m^3/s) of low flows and 1% (230 m^3/s) of high flows.	Major change in design and major increase in attraction flow and passage flow through the vertical slot pool-type pass, but not through the fish lock. Design now has 160 m^3/s attraction flow, but not passage flow which is highly reduced in the two fish locks.	*Sufficient Information?* Yes. *Address Xayaburi TRR recommendations?* In general, yes for *attraction flow* but no for *passage flow*, which is constrained by the fish locks. Monitoring will be needed to assess whether the intent of the Xayaburi TRR recommendation - passing 95% of each migratory species – is achieved.

Xayaburi TRR recommendation	XPCL re-design	Is there sufficient information on re-design and does it address Xayaburi TRR recommendations?
Revise left-bank fishway concept to have sufficient space for large-bodied fish and high biomass	Biomass estimated through studies by hydro acoustic camera. Pool size and openings (slot widths) of fishpass enlarged.	*Sufficient Information?* Yes, except for lock chamber size and behaviour of large fish in confined spaces. *Address Xayaburi TRR recommendations?* In general, yes. However, fish lock may not pass large fish and biomass; monitoring is required to assess the final design.
Revise left-bank fishway concept to have: i) maximum water velocities of 1.4 m/s (max. head differential between pools of 100 mm). ii) turbulence less than 30 W/m^3, for the passage of small-bodied fish. iii) maximum velocity in linking channels of 0.3 to 0.4 m/s	All three key design criteria have been adopted in the pool-type vertical-slot fishway. As a result the gradient has been reduced from 5% to 1.2%. Investigations of swimming ability done, but future projects need to assess swimming ability in prototype fish passes to assess passage through turbulence as well as water velocity.	*Sufficient Information?* In general, yes. However, more detail would provide further clarify. The CFD (Computational Fluid Dynamics) modelling of the vertical-slot fishpass, as presented, is only one horizontal slice. It is unclear whether this is a 2D model or one slice through a 3D model. The model has velocity but does not show turbulence. It reveals there may be potential conflicting flow patterns within the small slots but this is not addressed. *Address Xayaburi TRR recommendations?* In general, yes. But non-standard vertical baffles are used, and all fish in the pool-type pass then need to also use the fish locks. Assessment of fish passage is required to assess baffle design, and passage through the locks.

Xayaburi TRR recommendation	XPCL re-design	Is there sufficient information on re-design and does it address Xayaburi TRR recommendations?
Fishway depth should be equal to the thalweg depth at low flows, or 2/3 of this.	Fishway designed revised as above but depth relative to thalweg is unknown.	This requirement is for the passage of large benthic fish species. Passage of these fish may be sub-optimal if depth is insufficient, and will need to be specifically assessed.
Potential other options are a nature-like bypass on a low gradient (< 1:100) or two large fish locks.	Pool-type vertical-slot design adopted, as above	*Sufficient Information?* Yes. *Address Xayaburi TRR recommendations?* Yes. XPCL selected one design option. The twin fish lock option was intended as a separate option, not a combined option with the pool-type fishpass as has been applied. Monitoring will assess effectiveness.
Add solutions for mid-water, benthic and thalweg migrating fishes, including a benthic collection gallery. Provide benthic entrances underneath the draft tubes, or vertical slots between the draft tubes.	Not applied. Entrances above draft tubes retained but no midwater or benthic entrances added.	*Sufficient Information?* Yes *Address Xayaburi TRR recommendations?* No. Benthic (bottom-dwelling) species may have difficulty locating fishpass entrances above draft tubes, or the larger entrances at the sides of the powerhouse. Monitoring of these species, probably with radio and sonic tags, will be required to assess fish behaviour and fish passage effectiveness.
If possible, shape thalweg to fish pass entrances, for thalweg-oriented species.	Not applied.	*Sufficient Information?* Insufficient. As constructed plans not provided. In original design the thalweg led to the middle of the

Xayaburi TRR recommendation	XPCL re-design	Is there sufficient information on re-design and does it address Xayaburi TRR recommendations?
	Right-hand and left-hand side power-houses entrances have sill levels that are 2 to 3 m higher elevation than thalweg.	powerhouse and not to either side where the low level (sill level of 232-233 m ASL) fishpass entrances are located. *Address Xayaburi TRR recommendations?* Unknown. Specific assessment of thalweg-oriented species will be required in monitoring.
Include a high-capacity fishpass in the intermediate block; most likely a fish lift or possibly two large fish locks.	Not adopted in the short-term, but the space for a future fish lift has been included in the design.	*Sufficient Information?* Yes *Address Xayaburi TRR recommendations?* Yes. The intent of the recommendation was to pass the anticipated high biomass. XPCL has estimated biomass and they consider their design is adequate, which can only be evaluated in monitoring. To this extent they have addressed the recommendation.
May need multiple entrances and/or shaping of the left spillway abutment for low, medium and high flows; to be refined in physical modelling.	Multiple spillway entrances not adopted, or investigated. Single spillway entrance retained as proposed in original design. Design of single entrance improved in physical modelling. Recirculating flows at entrance reduced.	*Sufficient Information?* No. Physical modelling was only done at equivalent flows of 12,000 m^3/s (7,000 m^3/s spillway) and 15,000 m^3/s (10,000 m^3/s spillway). There were no model tests at low (e.g. 1000 m^3/s spillway) or moderate (e.g. 3,000 m^3/s) spillway flows; and the biological monitoring by XPCL suggests these lower flows are when fish are migrating, rather than higher flows of 12,000 to 15,000 m^3/s.

Xayaburi TRR recommendation	XPCL re-design	Is there sufficient information on re-design and does it address Xayaburi TRR recommendations?
		Address Xayaburi TRR recommendations? No. Fish attraction may be sub-optimal near the spillway but can only be assessed in operation. Note that migrating fish will swim to the upstream *limit of migration* and this point varies with different flows and gate openings. Behavior of fish when the spillway is being used is a major knowledge gap.
Modify the navigation lock to provide fish passage as well as navigation.	Adopted	*Sufficient Information?* In general, yes. However, more details would provide further clarification. *Address Xayaburi TRR recommendations?* Yes.
Navigation lock as a fishpass: add multiple entrances for low, medium and high flows.	Not adopted. No investigation in physical modelling.	*Sufficient Information?* No. Not addressed in any of the material. See above comments regarding limited flows tested in physical modelling. *Address Xayaburi TRR recommendations?* No. Note that migrating fish will swim to both sides of the spillway and low discharges. Lock entrance is

Xayaburi TRR recommendation	XPCL re-design	Is there sufficient information on re-design and does it address Xayaburi TRR recommendations?
		downstream of fish attraction, which will need assessment (e.g. radio tags, sonic tags, PIT tags, DIDSON). As for the left-hand abutment, behavior of fish when the spillway is being used remains a major knowledge gap.
Optimise dam operation (turbines, attraction flow, fishpass flow, spillway gates) for periods with high fish migration, based on physical model and 2d/3d CFD hydraulic model at different discharges and turbine operations.	Not adopted. It could be considered part of adaptive management but initial settings required and can be easily investigated in physical modelling, compared to on-site.	*Sufficient Information?* No. Not addressed in any of the material. Spillway gates could be used in a range of configurations to optimize fish attraction; see above comments regarding limited flows tested in physical modelling. *Address Xayaburi TRR recommendations?* No, but could be considered part of adaptive management.
DOWNSTREAM		
It should be recognized that downstream migration and drift is extremely complex and there are potentially no solutions to mitigate the impact, especially during low flow periods.	No re-design required.	Not applicable
During periods of abundant larvae drift and downstream migration in the wet season:	No re-design required. These are operational recommendations which need to be balanced with power generation.	Not applicable

Xayaburi TRR recommendation	XPCL re-design	Is there sufficient information on re-design and does it address Xayaburi TRR recommendations?
i) the primary mitigation is to use the sediment sluice gates, with no differential head, which provides passage of larvae through the impoundment mitigating the hydrodynamic barrier of the impoundment and providing passage bypassing the turbines and spillway. ii) the secondary mitigation is to maximize spill flow and minimize turbine passage by reducing power generation.		
Provide safe (95% survival) downstream passage of larval drifting in reservoir.	No re-design required.	*Sufficient Information?* Optimum water velocity for larval drift is unknown and can only quantitatively be assessed after construction. Investigation of this aspect was not within the scope of the construction period. *Address Xayaburi TRR recommendations?* No recommendations for re-design provided in Xayaburi TRR. The issue remains an <u>important knowledge gap for monitoring post-construction</u>.
During the dry period, consideration should be given to deflecting the downstream migrating fish through the	Nature-like bypass channel was not used, so this recommendation is not applicable	Not applicable

Xayaburi TRR recommendation	XPCL re-design	Is there sufficient information on re-design and does it address Xayaburi TRR recommendations?
fish bypass channel, hence the need to maintain adequate flows.		
At powerhouse and turbine intakes use fish screens for benthic and surface fish. Use physical and 2d/3d CFD model to optimise screens. Fish screens at turbine intakes needed to guide adult fish that are migrating downstream. These are recommended to have: i. less than 2 cm spacing ii. low approach velocities to prevent impingement, and iii. approach vectors that guide fish across the screen to a bypass.	These screens have not been adopted. Trash screens provided in original design retained, with surface entries (2m by 2m) for downstream passage of fish via a sluice. The spacing of the trash screens has been reduced to 12 cm to reduce the size of large fish passing through the screen and reduce mortality from the turbines. The screens are close to perpendicular to the flow, rather than angled.	*Sufficient Information?* In general, the drawings of the trash screens are sufficient to evaluate the screen angle and issues relating to fish. No physical or CFD modelling provided which would help determine vectors and paths of migrating fish, and approach velocities. *Address Xayaburi TRR recommendations?* No. Screens follow trash rack design and not fish screen design. These are at an abrupt angle to the flow, so that vectors do not guide fish to a bypass. It is likely that 2 cm spacing and angled screens was too complex and costly but no evaluation in supplied material. It should be noted that no high discharge (e.g. 5000 m^3/s) hydropower dam globally has a fish screen, although almost all would have trash racks to protect the turbines. Effectiveness of screens will need to be assessed, especially behavior and impingement of fish. <u>This represents one of the most significant unknowns of the fish passage facility</u>.

Xayaburi TRR recommendation	XPCL re-design	Is there sufficient information on re-design and does it address Xayaburi TRR recommendations?
		The XPCL design philosophy is to pass small fish, which pass through the trash screens, through the turbines.
Operate downstream facilities all year	Adopted	*Sufficient Information?* Yes. *Address Xayaburi TRR recommendations?* Yes.
Provide safe (95% survival) downstream passage.	Downstream sluice from collection gallery at trash screens modified: internal weir heights (and head losses) reduced to 3 m, with 11 weirs in total. Turbulence reduced in physical model study.	*Sufficient Information?* Sufficient hydraulic data but insufficient biological data. There are no biological tests on fish dropping 3 m over 11 drops. *Address Xayaburi TRR recommendations?* Unknown. Untested solution. May be sufficient for safe passage but need to assess health of fish passing through the downstream sluice in monitoring.
Provide safe (95% survival) downstream passage.	Design of "Fish friendly turbines" refined with: less shear, turbulence, less blades (5 instead of 6), tighter clearances and oil-free hubs.	*Sufficient information?* Although it is acknowledged that there have been improvements in the Xayaburi turbine design, no specific data is provided on the three major impacts on fish: shear, blade strike and barotrauma (pressure impacts). "Experimental data" mentioned in compliance report but not provided.

Xayaburi TRR recommendation	XPCL re-design	Is there sufficient information on re-design and does it address Xayaburi TRR recommendations?
		Address recommendations? Without specific data on Mekong fishes it is unknown whether the re-design will address the recommendations and provide safe passage for fish. Of the three major impacts on fish, blade strike can be quantified with theoretical models; this will be very dependent on the maximum size of fish that pass through the trash racks. In general, the effectiveness of the proposed turbines for passage of Mekong fish species (including larvae, juveniles and adults) remains unknown and will need to be assessed. Acknowledging the specific design to improve fish passage, the turbines still represent one of the most significant unknowns of the fish passage facility.

Appendix 3: Supplementary information on the fisheries monitoring

Fisheries monitoring

Fish Ecology:

The *Fish Biomass & Migration Study* was carried out between March 2012 and March 2013, ≈ 1 km downstream of the future power plant site (Figure A3.1). It consisted of systematic surveys carried out with a hydro-acoustic camera. An average peak biomass passage of 1,233 kg per hour was estimated in May 2012. During the same period, peak fish passage rates were recorded and estimated at 308 single fish and 41 fish schools per hour. Currently, additional biomass surveys are being carried out allowing a longer observation period, XPCL is continuing these studies with 3 -4 campaigns every year.

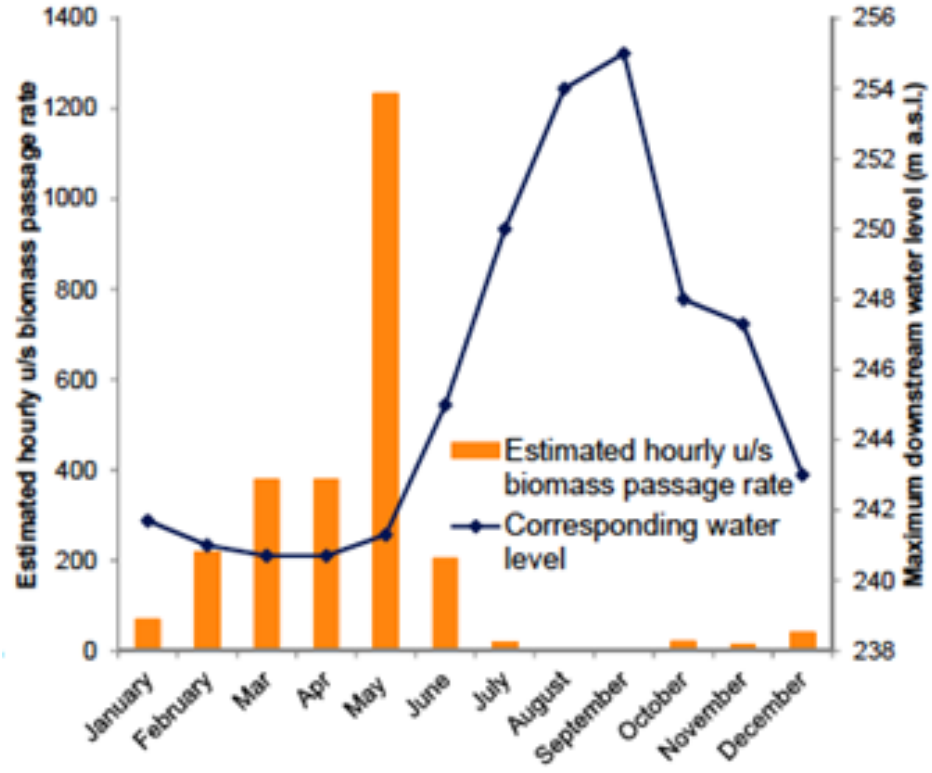


Figure A3.1: Fish biomass and migration. (Source: Coe 2015 Xayabury HPP: Fish Migration Facilities, Pöyry and Fishtek (V1))

The *Fish Sampling Study* summarizes the investigations done during ten different fish catching periods between March 2012 and March 2013 (Figure 2) and supplements the Fish Biomass & Migration Study. XPCL is conducting regular fish sampling 1 – 2 times a month in the upper chamber of the Navigation Lock. The *Baseline Study on Mekong Fish & Fisheries* was carried out between 2012 and 2014. This study aimed at establishing a list of the relevant species to consider for the design of the fish passage facilities, depending on different criteria as their representativeness or whether the species are threatened.

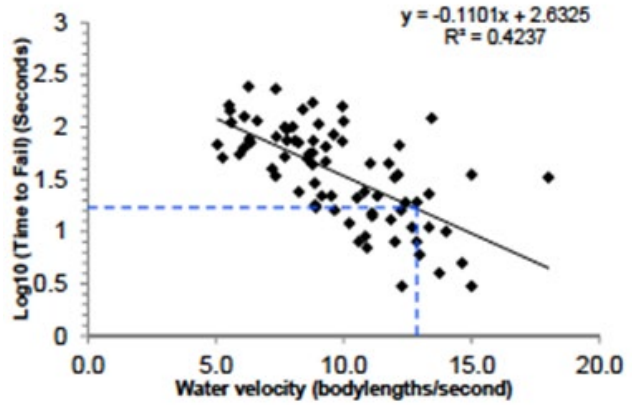


Figure A3.2: Fish swimming ability (Source: Coe 2015 Xayaburi HPP: Fish Migration Facilities", Pöyry and Fishtek (V1))

Swimming speeds (Figure A3.2) of Mekong fish species were carried out to gain knowledge of the swimming abilities of the fish for which the pass was designed, as a low swimming ability can prevent particular species from using the pass. Specifically, this work was designed to determine the (I) burst swimming speed of a sub-set of species which are representative of the wider fish fauna within the Mekong at the project area and (II) the volitional swimming response of as many species as possible to different water velocities within an open channel.

Modifications to fish passage design:

Upstream

The fishpass has been significantly modified and combined in a system with two fish locks, transferring the fish from the upstream end of the fishpass to a channel connected to the reservoir. An auxiliary powerhouse (8 MW) has been implemented to reduce power losses caused by the flow allocated to the fishpass. The fishpass has been made wider (18 m instead of 10 m), with four slots of different sizes instead of one, its slope reduced to 1.2 % and its flow significantly increased. In addition, provisions for the installation of a fish lift have been foreseen, should it be necessary in future to enhance the efficacy of the system. A second fish pass facility on the right bank incorporated in the navigation lock is also provided. These facilities provide entrances for upstream migrating fish: at either side of the powerhouse, above the draft tubes, at the end of the left-hand abutment, and at the downstream end of the navigation lock

Downstream

Downstream fish passage facilities were improved as follows: the downstream terminal chute will operate the whole year instead of only during the wet season. A new pumping station (pumping station 2) was implemented to reduce the flow and power losses caused by the operation of this facility. The design of the chute itself has been changed from a straight outlet to a "Shaped" outlet to achieve smoother hydraulic conditions along the chute more favourable for the fish.

Minimum gap, Kaplan turbines are proposed to be utilised.

The nature-like channel type is more efficient across a wide range of fish species. The heterogeneity of flows and velocities within the pass as a result of the different sized slots will to an extent recreate the conditions found in a natural bypass channel.

The majority of the migrating fish at the site are smaller than 300 mm, implying low swimming abilities. The smaller slots create passage conditions with reduced velocities and turbulences for the smaller fish. Mekong giant catfish might attain length of 3 m. The larger slot will allow the passage of such large-bodied fish.

Concerns have been raised during the design process about possible predation issues with a single slot design. The multiple passage routes should help to reduce possible predation issues.

Fisheries Monitoring and Management:

XPC and Fishtek have carried out monitoring of fish species and biomass. In addition, fish swimming tests have been undertaken and incorporated into the design.

Comment on the revised design

Adequacy of the Information Provided

The Report on Design Changes (November 2017) provides a summary of the work done to study baseline conditions and re-design the fish passage and demonstrates that the developer has clearly applied considerable effort and resources to the re-design of the fish pass facilities.

There were additional studies on (1) Fish Biomass & Migration, (2) fish sampling, and (3) Mekong fish species and fisheries, including swimming speed/ability. However, there is little detailed information and data on fish abundance (including fish biomass) and diversity, and migration and swimming ability provided, and most information is only in PowerPoint presentations. The, additional documents and presentations submitted by Pöyry are consequently not detailed enough to allow for a review of the rigour of the scientific methodologies. Details of the experiments, monitoring and assessments of the ecological characteristics should be included in reports for evaluation. There are also concerns over the frequency of the surveys, which are still undertaken only 3-4 times per year, which could miss key migration periods, and whether the overall programme has provided an adequate baseline on which to base the redesign of the mitigation measures. In addition, there appear to be no surveys explicitly examining the biodiversity and conservation species endemic to the Mekong and the Xayaburi region in particular.

The developer should still provide a detailed and robust fish monitoring programme, including a budget allocation. This is required to assess the status of fish and fisheries at the project site (downstream and upstream, including in the reservoir) and the effectiveness of fish passages (for both up and downstream fish migration). Currently the monitoring is largely based on DIDSON imagery, which has considerable limitations in large river systems, notably because benthic species are not accounted for and the numerical assessment of large shoals of fish is problematic.

Evidence on Modifications to upstream/downstream fish passage design:

The November 2017 Report provided a summary of the measures that have been undertaken at Xayaburi in response to the recommendations in the Xayaburi TRR. In addition, the facilities have been considered under the MRC's Mitigation Guidelines Case Study.

Details of the Xayaburi TRR recommendations, the XPCL modifications, and whether these address the recommendations are provided in Appendix 2. Appendix 2 also includes an evaluation of whether there is sufficient information to provide an assessment of each recommendation. Many of the recommendations and key design criteria from the Xayaburi TRR have been adopted, but there are also key omissions and design aspects that have not been adequately addressed. These may entail a high-risk to effective fish passage, and these have been highlighted as high-priority areas for monitoring.

For downstream migration, larval behavior and thresholds to maintain drift in the reservoir remain unknown and will need to be assessed. The trash screens at the turbine intakes have been modified with narrower gaps but the screen angle remains steep and there are only surface entrances, so there is a major risk of impingement of large fish; and this also needs to be assessed. Much work has been done on the turbine design but without specific data for Mekong fish species, only blade strike can be assessed and not the impacts of shear or barotrauma (pressure impacts). Turbine passage remains an important unknown to assess in monitoring.

For upstream passage, assessment of fishway entrance location and design at varying spillway flows has been overlooked; only very high flows were assessed (12,000 and 15,000 m^3/s) and only on one spillway abutment. The design philosophy of Pöyry, suggested by PowerPoint drawings, indicates they do not expect fish to migrate onto the stilling basin at any spillway flow.

The Xayaburi TRR recommendation to use the navigation lock for fish passage was adopted. The redesign of the navigation lock has been outlined, however, further details such as attraction flow and cycle times would aid evaluation, as would information on the crowding mechanism in relation to the capacity to move fish in the system. The frequency and timing of the use of the lock for passage requires in-depth evaluation, as does the mechanism for use of the tandem lock system.

Extensive work and re-design has been done on the fish collection gallery above the draft tubes but the recommendation for benthic entrances was not adopted. An assessment of benthic fish migration will determine if these should be installed for future projects.

The main pool-type pass is a new variation of a vertical-slot design. It utilises criteria from the Xayaburi TRR which are conservative and provide a low-risk. However, the baffle design is untested and significantly, all fish that reach the top of the vertical-slot fishpass then need to use one of two fish locks. The fish locks have small chambers and may be a bottleneck during periods of high migratory biomass; this will require assessment to optimise cycle times and assess whether the optional fish lift is required.

It is not possible in this provisional overview to assess the effectiveness of the design and ultimately only a quantitative assessment of fish passage during operation with provide that evaluation (note some important details are not available to this review. See Appendix 2). The Xayaburi TRR recommended that a workshop involving the MRC experts and the Design Team should be convened to make best use of all the available experts. However, the design

was not shared with MRC for comment before construction, which may have provided opportunities for improvements.

A detailed description on alternative downstream migration possibilities has been given. However, there are no details on the maximum amount of fish that the rest area can hold, and how "a significant number of fish" is defined.

The redesign of the navigation lock has been outlined, but the amount required for the attraction flow was not mentioned for upstream fish passage. Also, the lock requires a crowding boat to push fish through. No assessment on water velocities in the reservoir, and whether these can be maintained above critical thresholds, has been provided to assess the survival of fish eggs and larvae drifting downstream through the reservoir.

The proposed larger pool of the fishpass would allow catfish reaching a size of up to 300 cm, but no additional data (monitoring or sampling) or information were provided to confirm this statement.

Evidence on Fisheries Monitoring and Management

Although a presentation from Fishtek in 2015 has been provided, the complete results on monitoring and sampling were not shared in detail in the reports, hence, they cannot be evaluated.

Furthermore, a detailed and robust fish monitoring programme, including budget, to monitor the status of fish and fisheries at project site (downstream and upstream, including the reservoir) and the effectiveness of fish passages (for both up and downstream fish migration) continuing in the future should have been provided. This would enable better integration into the Joint Environment Monitoring programme and strengthen the understanding of the impact of the development on fisheries and make adaptive changes to the mitigation measures as was suggested in the PNPCA documents provided by XPCL.

General

The XPCL has made efforts to address the recommendations outlined in the Xayaburi TRR and has invested considerably in studies to support the redesign process, and in constructing the revised fish pass facilities. In many cases the revised designs directly reflect the recommendations in the Xayaburi TRR, and the fish pass facilities at Xayaburi are now likely to be the largest fishpass facilities on a tropical river system anywhere in the world. However, without ongoing monitoring the efficacy of these facilities cannot be assessed, and some concerns remain regarding the potential impacts on fish migration.

However, there are several critical recommendations in the Xayaburi TRR that were not taken up, and the documentation provided for this review did not provide sufficient information to make a through assessment of the extent to which the recommendations have been taken up. Most notably the suggestion in the Xayaburi TRR that a workshop be convened to bring the developer's and MRC experts together was not taken up. This may have provided the opportunity to optimise the facilities within the constraints of the economic viability of the XHPP.

Appendix 4: Additional information on the revised sediment flushing infrastructure

XPCL Report and CNR presentations:

- Three spillway gates have been removed and replaced with 4 low level outlets (LLO) each with the dimension of 12 m x 16 m with a sill level of 238 m (Figure 5 & 6). The low-level gates include a flap gate to allow surface discharge as well as low level flow when the gate is open. These gates are intended to increase flexibility with respect to sediment management.
- Three sediment monitoring campaigns were completed, including the collection of washload and bedload samples
- A provisional operating curve is provided (Graf, 2015) showing draw down and sediment routing at flows of greater than 10,000 m^3/s.
- Sand flushing outlet of the power house have been omitted
- Based on sediment modelling it is reported that 3% of the sediment load will be trapped within the dam based on a total sediment inflow of 82.5 Mt/yr.
- Based on the sediment results it is also suggested that nutrient transmission would not be greatly affected;

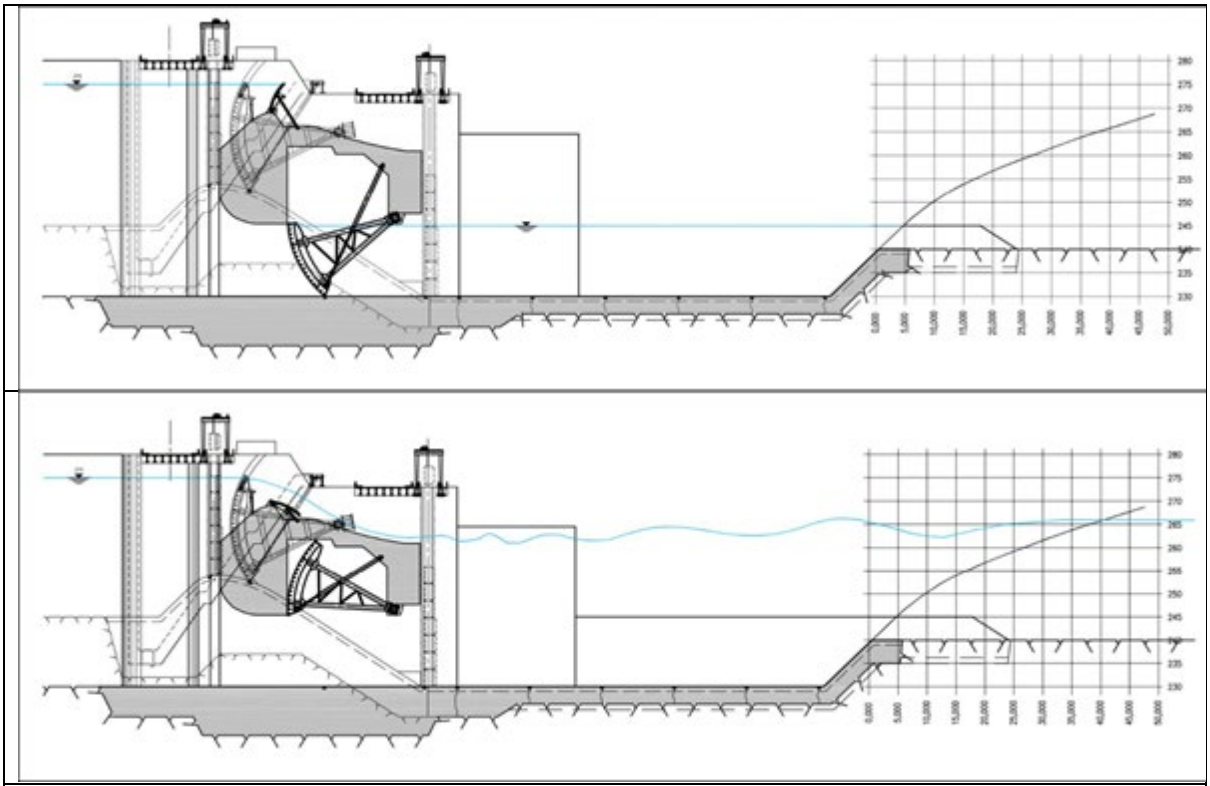


Figure A4.1. Drawing of Low level outlet (LLO) included in the re-design of the Xayaburi HPP. Top shows closed position, bottom shows LLO open, including operation of the flap gate. (GOL, 2011)

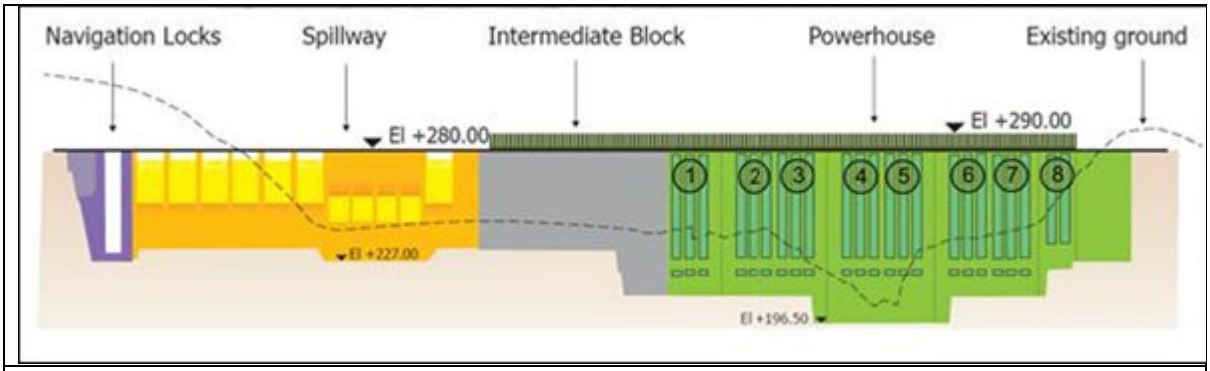


Figure A4.2. Layout of spillway gates and LLOs in the redesign of Xayaburi (Graf, 2015).

Figure A4.3: Low Level Spillway Gates under construction. Source: Poyry presentation July 2015

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