Mekong River Commission
Cambodia • Lao PDR • Thailand • Viet Nam
For sustainable development

Procedures for Notification, Prior Consultation and Agreement (PNPCA)

TECHNICAL REVIEW REPORT

Prior Consultation for the Proposed Pak Beng Hydropower Project

Prepared by the **Mekong River Commission Secretariat**
June 2017

PREFACE

This final draft of the Technical Review Report (TRR) has been prepared by the MRCS in support of the prior consultation process for the Pak Beng Hydropower project (PBHPP). It includes comments received from the Member Countries (MCs), as well as from the JCWG at its third meeting in Vientiane, on 5 June 2017, and the Special Session of the Joint Committee on 19 June 2017. Feedback on the stakeholder consultations has also been provided.

This TRR includes the assessments of the possible impacts of the PBHPP. It aims to provide a basis for discussions through a robust and scientifically sound evaluation of all ***available*** information and data, as far as the initial timeframe for prior consultation has allowed.

The Special Session of the Joint Committee also noted that this review could be considered as a living document, and may be adjusted as the post- prior consultation process unfolds.

The report draws on the following documents and information:

- The Expert Groups' evaluations of the documents submitted by the Lao National Mekong Committee (LNMC);
- The agreed Integrated-Water-Resource-Management-(IWRM)-based Basin Development Strategy (BDS) and its scenarios; and
- The MRC Preliminary Design Guidance (PDG) for Proposed Mainstream Dams.

The following Annexes support this draft Technical Review Report, and form part of the Report. Annexes C-I presents independent review from our international experts.

- Annex A1: Prior Consultation Road Map
- Annex A2: List of International, National and MRCS Expert contributors
- Annex A3: List of documents used to support the transboundary impact assessment
- Annex A4: Comment matrices from the regional and national consultation processes
- Annex B: Alignment with the MRC PDG
- Annex C: Hydrology and Hydraulics Report
- Annex D: Sediment and Geomorphology Report
- Annex E: Water Quality and Aquatic Ecology Report
- Annex F: Fish Passage and Fish Ecology Report
- Annex G: Socio-Economic Report
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1. BACKGROUND

1.1 Introduction

Lao PDR submitted documentation outlining the proposed PBHPP the 4th of November 2016, thus initiating the MRC third PC process under the MRC's Procedures for Notification, Prior Consultation and Agreement (PNPCA). This Technical Review Report presents the outcomes of the review of the documentation provided by the Secretariat.

From the outset, there was a clear expectation from the MRC Member Countries, Development Partners and stakeholders that the PC process for the PBHPP should demonstrate a continual improvement from the previous two PC processes. Two key elements to ensuring a better process were identified; firstly, to provide a clear endpoint and decision to the process, and secondly to improve the way external stakeholders understand and perceive the process. Both aspects are dealt with in this TRR. The former by including a section on "What happens after prior consultation" – Section 6.5, and the latter by increasing the engagements with stakeholders at the regional and national levels, and including a summary of the 1995 Mekong Agreement and the PNPCA specifically with respect to the way the prior consultation process must be conducted (Section 1.2). In addition, the MRC has provided summaries of the submitted documents and this report for non-technical readers (see Section 1.3). These have been made available on the MRC Website at:

http://www.mrcmekong.org/assets/Consultations/PakBengBengHydropowerProject/2nd-RSF-ppt-presentations/Summary-of-2nd-Draft-TRR-290417.pdf.

1.2 The 1995 Mekong Agreement

An improved appreciation of the legal framework and rights and obligations that stem from this is central to building an understanding of the PC process for external stakeholders.

The PC process for the proposed PBHPP is governed by the Agreement on Cooperation for the Sustainable Development of the Mekong River Basin (the 1995 Mekong Agreement or 'the Agreement'[1]), the PNPCA. The other four Procedures (namely Procedures for Data and Information Exchange & Sharing, Procedures for Water Use Monitoring, Procedure for Maintenance of Flow on the Mainstream, and Procedure for Water Quality), as well as the objectives and principles of international water law[2] are also relevant to the process. Importantly, the MRC can only work within this framework, and is not mandated to regulate or direct the Member countries' use of the Mekong River system.

This first part of the TRR, therefore, summarises the sections of the 1995 Mekong Agreement that pertain to the Prior Consultation process, as well as the provisions of the PNPCA itself. It draws on the

[1] The 1995 Mekong Agreement is available at:
http://www.mrcmekong.org/assets/Publications/agreements/95-agreement.pdf

[2] The preamble to the 1995 Mekong Agreement includes the following statement;
"***PROCLAIMING*** *further the following specific objectives, principles, institutional framework and ancillary provisions in conformity with the objectives and principles of the Charter of the United Nations and international law*."

objectives and principles of international water law, and is intended to provide some legal context for stakeholders outside of the MRC.

1.2.1 Objectives and Principles of the Agreement

On 5 April 1995, the Governments of Cambodia, Lao PDR, Thailand, and Viet Nam signed the Mekong Agreement. This re-affirmed the Member Countries' desire to develop, *inter alia*, hydro-power in the Mekong River Basin (MRB) in a sustainable and cooperative manner. The Agreement therefore, recognises that utilisation of the waters of the Mekong River System (MRS) for socio-economic development would occur, and promotes cooperation for the sustainable development of the Basin in a constructive and mutually beneficial manner in that context. However, recognising that development could result in adverse impacts, Chapter III of the Agreement establishes a framework of principles and objectives to guide the MC's use of the Mekong River System. In Chapter III the Member Countries (MCs) (the Parties) agree to, *inter alia*;

- Protect the ecological balance of the MRB;
- The reasonable and equitable use of the waters of the MRS, pursuant to all relevant factors and circumstances, and the Rules of Water Utilisation and Inter-Basin Diversion[3];
- Discuss and aim to agree (in the JC) on *significant* water uses on the mainstream in the dry season (PC);
- Maintain flows in the Mekong mainstream;
- *Make every effort* to avoid, minimise and mitigate harmful effects on the river system;
- Take responsibility where harmful effects result in *substantial* damage to the other MCs;
- Maintain the freedom of navigation on the mainstream; and
- Warn other MCs of water quality and quantity emergencies.

The Agreement provides for the achievement of these objectives and principles through the unique spirit of cooperation and mutual assistance that inspired cooperation between the Countries since 1957, and which has been reaffirmed on many subsequent occasions, including at the outset of this current PC process.

1.2.2 Institutional arrangements, powers and functions

Chapter IV of the Agreement establishes the MRC and its standing bodies. These are the Council, the Joint Committee (JC), and the Secretariat. Through the Agreement the MCs conferred certain powers and functions to these bodies.

The Council is empowered to establish policy and the 'Rules for Water Utilization and Inter-Basin Diversions' under Article 26. The PNPCA were agreed by the Council through this delegated power, on 30 November 2003. The Council is also empowered to address and resolve any *differences and disputes* referred to it. The PNPCA, in turn, empowers the JC to undertake the PC process, and to agree on the proposed use which may include conditions which become part of the record of the proposed use [PNPCA Art 5.4.3]. The JC must make every effort to resolve *differences* referred to it. Importantly, the Agreement does not permit the MRC to direct the actions of any of the MCs.

For the purposes of the PC process; a '*difference*' is interpreted as "*diverging interpretations of a technical nature*", and a '*dispute*' is interpreted as a "*different interpretation of policy or the Agreement*". As such, the JC receives the TRR, and discusses its findings, or may request further

[3] Now the 5 Procedures.

clarification should there be a *difference* in any technical interpretation, so that they can arrive at a unanimous decision. The Council may be requested to address any *dispute* on whether the proposed use reflects a reasonable and equitable use, or whether the notifying country has made all reasonable efforts to avoid minimise and mitigate any potential harmful effects.

The JC agreed on the Technical Guidelines to support the implementation of the PNPCA on 31 August 2005. These Technical Guidelines spell out the functions of the MRCS as the technical and administrative support arm of the MRC, highlighting that the Secretariat should be proactive in its approach. The MRCS has prepared this draft TRR under supervision from the JCWG for the PBHPP.

National experts in the MCs have also provided comments on the TRR, which have been included in this final draft.

Importantly, the Member Countries are not limited to consultations through the Agreement and MRC, and may on a bilateral or multilateral basis, engage in Country-to-Country discussions at any point.

1.2.3 The PNPCA and PC Process

The PNPCA derive from Article 5 of the 1995 Mekong Agreement where the Parties agree to the reasonable and equitable use of the Mekong River system. The PNPCA specify three distinct forms inter-State communication: i) notification, ii) Prior Consultation and iii) Specific Agreement. Notification is applicable to water use on the tributaries of the Mekong mainstream, and for 'wet season' use on the mainstream. PC is required for water use on the mainstream in the 'dry season', and for inter-basin diversions in the 'wet season'. Specific agreement is required for inter-basin diversions in the dry season. These increasing levels of interaction reflect a balance between the likelihood of adverse transboundary impacts, and the principle of sovereignty. The PBHPP represents a year-round use of the Mekong mainstream, and is therefore subject to PC.

PC is aimed at evaluating whether the proposed development is consistent with the principles and objectives of cooperation agreed in Chapter III of the Agreement, and its alignment with the Preliminary Design Guidance for Proposed Mainstream Dams in the LMB. This TRR supports this process specifically with respect to PC on the PBHPP.

PC is defined in the Agreement as:

> *"Timely notification plus additional data and information to the Joint Committee, as provided in the Rules for Water Utilisation and Inter-Basin Diversion under Article 26, that would allow the other member riparians to discuss and evaluate the impact of the proposed use on their uses of water and any other affects, which is the basis of arriving at an agreement. Prior consultation is neither a right to veto the use, nor a unilateral right to use water by any riparian without taking into consideration other riparians' rights."*

This underpins that PC *need not* end with approval of the project by the JC. This is because the JC's Rules of Procedure require decisions to be made by consensus (which is common in international bodies like the MRC). It is therefore possible that the JC will be unable to agree on whether a proposed use can proceed. However, in these cases the JC may be able to agree on what measures (or conditions) should be applied to the project to further limit any potential transboundary impacts it may have. The JC may also agree on a post prior consultation process which may aim at resolving technical differences or at further refining the design and operations of the proposed use. The MRC's Brochure on the PNPCA[4], therefore, emphasises that the intention of PC is not a 'yes' or 'no' answer on the proposed use, but rather to discuss a set of measures that should be considered to avoid, minimise or mitigate transboundary impacts.

1.2 Principles Governing the PC Process

As PC is neither a unilateral right to proceed, nor a veto right; its success relies heavily on good faith cooperation, recognising the rights of all the Parties. The PNPCA's Article 3 specifies that consultations shall be governed by the following principles;

a. Sovereign equality and territorial integrity;
b. Equitable and reasonable utilisation;
c. Respect for rights and legitimate interests; and
d. Good faith and transparency.

Any proposed use that *may* fall within the requirements for PC is submitted to the MRC Secretariat (MRCS) by the notifying Country, who as expeditiously as possible, must transmit the documentation to the other MCs, the notified Countries. The formal process of PC starts from the date that the last Member Country acknowledges receipt, or as decided by the JC.

In the case of the PBHPP, the MRCS received submission of the proposed use from the LNMC for PC on **4 November 2016**. The MRCS prepared a Scoping Level Review of the documentation, and submitted this together with documents to the Member Countries on 6 December 2016, and per the JC agreement on 12 January 2017, the PC process formally began on **20 December 2016**. Article 5.5 specifies a 6-month timeframe for the process, with a possible extension by a decision from the JC. The 6-month period for PC on the PBHPP ended on **19 June 2017** (see Appendix A1).

The PC process may end in agreement by the JC on the proposed use, or if elevated to the Council, agreement by that body. Article 5.4.3 of the PNPCA indicates that the JC shall *aim* to arrive at an agreement on the proposed use that contains agreed upon conditions, which become part of the record of the proposed use. These 'conditions' are added to the record of the proposed use to ensure that the concerns of the notified Parties are accommodated, and their inclusion in the Procedures for Water Use Monitoring (PWUM) can ensure that implementation of the conditions is monitored and reported to the MRC. Noting that the term 'conditions' implies that the MRC is empowered to instruct the Member Countries, the intention in this process is to present a 'Statement' outlining measures that urge the notifying Country to request that the developer either improves the design and operation of certain aspects of the PBHPP, or to do further studies to resolve potential 'differences' in the technical interpretations. These 'measures' aim to avoid, minimise, and mitigate potential harmful effects, which the notifying country should take into consideration. They do not necessarily reflect tacit approval of the proposed water use, and the Member Countries may provide their opinions in their formal replies. In addition, the Statement establishes a post prior consultation process which will provide the opportunities for ongoing engagement between the MRC and developer's specialists.

The primary purpose of this TRR is to support discussion and consultation in the JC towards this end. It aims to provide the information that would be required for the JC to reach a decision under Articles 5.4.3 (agreement and conditions) or 5.5.2 (extension or postponement of the final meeting of the JC) of the PNPCA. The report aims to support a balanced basis for good faith consultations and

[4] This is available at: http://www.mrcmekong.org/assets/Publications/PNPCA-brochure-11th-design-final.pdf

cooperation, as well as providing some indication of the extent of any possible impacts, and the level of confidence in the findings.

Should the JC not be able to come to agreement on the proposed use or measures to guide the proposed water use, they may (after making every effort to resolve any difference under Article 24 F of the Agreement), raise the matter to the Council to resolve under Article 18 C. If the MRC is unable to resolve the difference or dispute in a timely manner, the issue shall be referred to the Governments to resolve by negotiation through the diplomatic channels as provided for in Article 35 of the Agreement.

In addition to this TRR and the discussions in the JC, the notified countries will submit formal replies to the prior consultation process.

1.3 Public participation

1.3.1 Background

While there is no specific requirement for public participation in the prior consultation process in the 1995 Mekong Agreement and the PNPCA, both the MRC and the Member Countries have committed themselves to an open and transparent process. Broader stakeholder engagement is also seen as one of the priorities in the MRC's Strategic Plan for 2016-2020. Importantly, the MRC and the Member Countries have specifically recognised the need to improve stakeholders' perceptions of the prior consultation process.

Two main groups of stakeholders are recognised;

- **Internal stakeholders:** This includes the structures of the MRC, the Council, the Joint Committee and the Secretariat, as well as other government agencies in the Member Countries;
- **External stakeholders:** This includes non-state actors and outside bodies such as development partners, dialogue partners (China and Myanmar), NGOs, implementing partners, civil society organizations, research institutions, academics, individuals and other interested groups. Stakeholder engagement also takes place at national and regional levels. National level engagements are conducted by the National Mekong Committees in each Member Country, and are used to inform that Member Country's position in the Joint Committee discussions. The regional consultations are managed by the MRC, and inform the development of this Technical Review Report (TRR). Stakeholders may also submit comments and feedback through the MRC website at: http://www.mrcmekong.org/stakeholder-consultations.

1.3.2 Stakeholder engagements for the PBHPP

Stakeholder engagement in the prior consultation process for the PBHPP builds on the extensive participation processes used to support the development of tools to support sustainable hydropower development, and the lessons learnt from the Xayaburi and Don Sahong cases. Key lessons from these previous processes were to engage at an earlier stage, and to be more proactive and transparent. The following issues were flagged for greater attention;

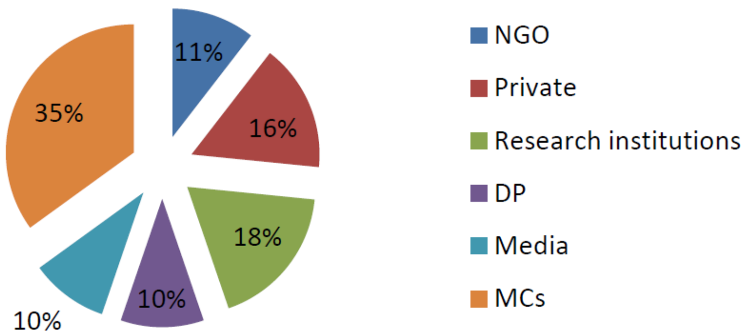
- To be clearer on the roles and mandates of the various MRC bodies; and
- To have a clearly defined post - prior consultation process, and end point.

As a first step, the MRC has prepared a Fact Sheet on the PBHPP, as well as a summary of the documentation provided by the Lao National Mekong Committee[5], and has established a web feedback portal. This TRR also responds to these needs by providing more background on the delegated powers and functions of the MRC bodies and outlining what happens after the 6-month prior consultation process.

The Roadmap for the Pak Beng PC process, presented in Appendix A1, includes two regional sharing and consultation meetings, and two or more occasions for national sharing and consultation meetings. The Don Sahong process only included a regional session, although Cambodia and Viet Nam held four sessions each, and Thailand held six.

The first regional session for the PBHPP was conducted on 22 and 23 February 2017 under the theme "***SHARE-LISTEN-ACT***". The meeting presented the proposed Pak Beng hydropower project and the Study on the Sustainable Development and Management of the Mekong River including impacts by mainstream hydropower projects (the Council Study) to stakeholders, and shared the results of the Scoping Review of the documentation, and the lessons learnt from the Xayaburi and Don Sahong PC processes.

The forum attracted more than 180 participants representing the MRC member countries, development partners, NGOs and civil society, as well as research institutions, academics, private developers and media, as outlined below.



The outcomes of this regional consultation are not discussed in depth here, as a full report is available at: http://www.mrcmekong.org/assets/Publications/Forum-report-for-website.pdf

The main concerns identified by stakeholders related to the PNPCA process itself, the Pak Beng Hydropower Project, as well as technical questions related to the Hydrology, Sedimentation, Environment and Water Quality, Fisheries, Socio-Economic, Dam Safety and Navigation concerns. The latter are comprehensively addressed later in this TRR, while the PNPCA process and the powers and functions of the MRC are clarified in the proceeding sections.

A second round of national consultation meetings was held on 5 May 2017, and a second round of regional meetings was held in May 2017, which were also well attended. The regional consultation

[5] These documents are available at: http://www.mrcmekong.org/assets/Consultations/PakBengBengHydropowerProject/Overview-of-Key-Features-of-Submitted-Documents-26-Jan-2016.pdf

process is driven by the MRC and outlines the progress of the prior consultation process, while the national meetings are driven by the Member Countries, and are aimed at sharing information on and discussing the PBHPP, and will help the Member Countries formulate their position in the JC.

Importantly, the developer is mandated to engage stakeholders within the Lao PDR, and to gather any relevant data to support the Environment and Social Impact Assessment. However, the developer is not mandated to engage stakeholders in the other Member Countries to gather similar data. Relevant socio-economic data and stakeholders' perceptions from notified Countries must, therefore, come from the national engagements and the MRC itself.

1.3.3 Feedback from the stakeholders

Annex A4 presents comment matrices from the regional and national consultations. Generally, apart from the technical queries the stakeholders' comments and the responses fall into the following four categories. The responses to these are outlined below;

A. The perceived status of the PDG as a regulatory instrument. The PDG is clearly defined as being preliminary and advisory in nature. The guidance is therefore aspirational rather than regulatory, and there is no legal obligation for the developer to follow them. Nonetheless, the PDG does bring together global best practice for the Mekong mainstream, and the developer should make every effort to apply the guidance, or at least to indicate why a deviation is warranted. Alignment with the PDG is therefore a key focus of the review process. The review team has found that the developer has not made much attempt to be guided by the PDG.

B. The need for compensation. Stakeholders who fear their livelihoods may be threatened, made calls for compensation. However, any compensation must be linked to the extent to which the PBHPP will cause *substantial damage,* and the provisions of Articles 7 and 8 of the Agreement in this regard. In these cases, the affected parties must demonstrate this damage with proper and valid evidence. In this case, attribution, (i.e. proving that the damage is caused by the PBHPP), or mainstream hydropower in general and not by other developments, will be difficult. Similarly, determining the quantum of the damage attributable to the developer will be challenging. This does not apply to circumstances where attribution is not an issue, for example villages inundated by the project or its operations.

C. The transboundary socio-economic impact study. The adequacy of the transboundary impact assessment is central to many of the comments. Transboundary EIA's are considered international customary law and, irrespective of any requirements under the Agreement, the developer should undertake a rigorous transboundary assessment. However, any such assessment will be hindered by;

- The perception that should such an assessment find any transboundary impacts, the developer or notifying country would automatically be liable for compensation;
- The extent to which the *'no [transboundary] harm'* principle is consistent with the Mekong Agreement and international law;
- The lack of a mandate to collect data in the notified States;
- The uncertainties surrounding the likely efficacy of the measures to minimise potential impacts; and
- The problem of attribution of any harm to specific developments.

Nonetheless, a comprehensive transboundary impact assessment is needed primarily to ensure that all the potential impacts have been identified, and measures to avoid, minimise and mitigate them are fully explored.

D. The need for the developer to monitor impacts in the notified States. The principle of territorial integrity runs throughout the Mekong Agreement. This means one Country (or its agents) cannot undertake monitoring in any of the other Countries. The notified Countries will therefore have to institute their own monitoring programmes, and share these data, or mandate the MRC to collect the data. This is also linked to 'B' and 'C' above - and the problem of attribution, as any monitoring done would measure the impacts of all the developments in the basin. This does not mean that the developer should not monitor, or that they should not establish a baseline status. The review team found that the developer had paid little attention to monitoring before, during and after construction.

1.4 The scope of the Review and end points

Any large project undergoes several phases, as illustrated below;

Phasing in this way allows the developer to incrementally assess the viability of the proposed project before sinking additional resources into it, or allows them to identify specific design requirements before finalising the design. Each phase provides more information on the economic, technical, social and environmental viability of the project. The IWRM-based Basin Development Strategy for the Mekong Basin already identifies several potential hydropower projects at the Opportunities Analysis stage, but does not include the level of detail required to undertake the prior consultation process.

The Technical Guidelines for the PNPCA indicate that the submission of the documents for prior consultation must be at least 6-months before commencement of the project[6], preferably longer. The PNPCA notes that ***in addition to a feasibility study report***, implementation plan, schedule and all available data required should be provided to support prior consultation. In this context, PC requires the impact assessment documents, and *all available data required by the notified Countries and the JC to carry out their evaluations*.

In the case of the PBHPP, Lao PDR has notified at the end of the Feasibility stage, and as such these documents must be used as a basis for this Technical Review Report. There are both advantages and disadvantages to this;

- Advantages;
  - Prior consultation takes place before the final design, and can directly influence the final design and operational plan for the PBHPP;
  - The Lao PDR and the developer can make an earlier decision on the viability of the PBHPP based on the inputs from the MRC, before sinking additional resources into the project;
- Disadvantages;
  - There may be insufficient information available at the feasibility stage for the JC to formulate a final set of measures for the proposed use;

[6] Commencement is normally taken to assume the start of construction work.

- The developer may already plan to implement many of the recommendations emerging from the Technical Review Report, and an unnecessarily negative impression of the proposed project may arise; and
- The any measures established by the JC may pertain to the final design stage, and may need to be made subject to review after the final design[7].

The last of these bullets is relevant to the post - prior consultation process. In both the Xayaburi and Don Sahong cases, discussions and improvements to the design took place after the initial 6-month period. In both cases this is leading to a better project with potentially fewer impacts, and in the Xayaburi case Lao PDR and the developer have decided to invest an additional US$ 400 million to address the issues emerging from the PC process.

The MRC anticipates that discussions and interaction on the PBHPP may also continue after the initial 6-month period, particularly in the light of the Feasibility Stage of the PBHPP. In this case, it is necessary to ensure good faith, positive, and ongoing cooperation between the developer, Member Countries and the MRC as further details may emerge from the ongoing phases.

> Work on the final design of the PBHPP is ongoing, and the MRC has been made aware that certain design changes are already being considered, which may address, or change the nature of, some of the recommendations in this TRR. As these changes have not been included in the documentation provided for Prior Consultation, or have been provided verbally, the MRC is unable to fully reflect on these changes. Nonetheless, it is recognised that they reflect an ongoing commitment to further reduce any potential impacts on the Mekong River System. In these cases, therefore, the proposals being considered are highlighted in text boxes like this one. However, no further comment has been provided on these proposals.

1.5 Lessons learnt

As early as 2013, and following the PC process for Xayaburi, the MRC recognised the need to improve the implementation of all five MRC Procedures, and particularly the PNPCA. A Joint Platform was established to engage in this process, and has held several workshops and meetings to this end.

As part of this process, the Joint Platform arranged a dialogue workshop in Bangkok on 25 February 2016. The key recommendations emerging from this workshop were that;

a. Greater clarity regarding the commencement and conclusion of the Prior Consultation process is needed;
b. A process for the review and approval of the adequacy of documentation received for Prior Consultation should be included;
c. Greater clarity regarding the roles of all actors who have a responsibility for implementing the PNPCA is needed;
d. Appropriate project information disclosure practices for effective stakeholder participation should be developed;
e. Greater clarity regarding the role of a transboundary EIA is needed;

[7] The measures that the JC may wish to attach to the PBHPP may pertain to any of the upcoming phases.

f. A six-month timeframe was too short to undertake a comprehensive review, and were needed source additional data and studies to confirm the results; and
g. "Commentaries" on the PNPCA, to supplement the current Technical Guidelines for the PNPCA, should be developed. These commentaries must place key provisions of the PNPCA in the wider context of international best practice, but would not constitute an amendment to the Procedures.

A *Working Paper on Lessons Learnt from Implementation of the Procedures for Notification, Prior Consultation and Agreement (PNPCA)* has been developed by the MRCS and discussed with the member countries, and they agreed to treat it as a living document. This working paper has influenced the preparation of this Technical Review Report. The Council Study, initiated after the Xayaburi PC specifically aims to provide more information on the potential impacts of the Mekong mainstream dams, and the emerging results from this study have been used to support this TRR.

1.6 Key considerations

Stakeholders need to bear the following in mind when engaging the prior consultation process, and this report.

- The Member Countries have committed to the *reasonable and equitable* use of the Mekong River System.
- The determination of whether any proposed use is *reasonable and equitable* is nuanced, and is beyond the scope of a technical review process.
- The Member Countries have committed to making *every effort to avoid, minimise and mitigate possible harmful effects*, whether transboundary or not. This is the focus of recommendations for the developer.
- The Joint Committee's deliberations are primarily focused on potential transboundary impacts, and a set of measures to avoid, minimise or mitigate these impacts ***may*** emerge from the process.
- In the PBHPP case, documentation at a feasibility level has been put forward to support the prior consultation process. Any measures the JC may wish present to guide the ongoing development of the project can refer to either the Final Design, Construction or Operational phases should the project proceed.

The main purpose of the TRR and the PC process is, therefore, to highlight what additional reasonable efforts can be made to avoid, minimise and mitigate any harmful effects. It also evaluates the extent of any residual harmful effects, particularly those of a transboundary nature.

2 THE PAK BENG PRIOR CONSULTATION PROCESS

2.1 Background

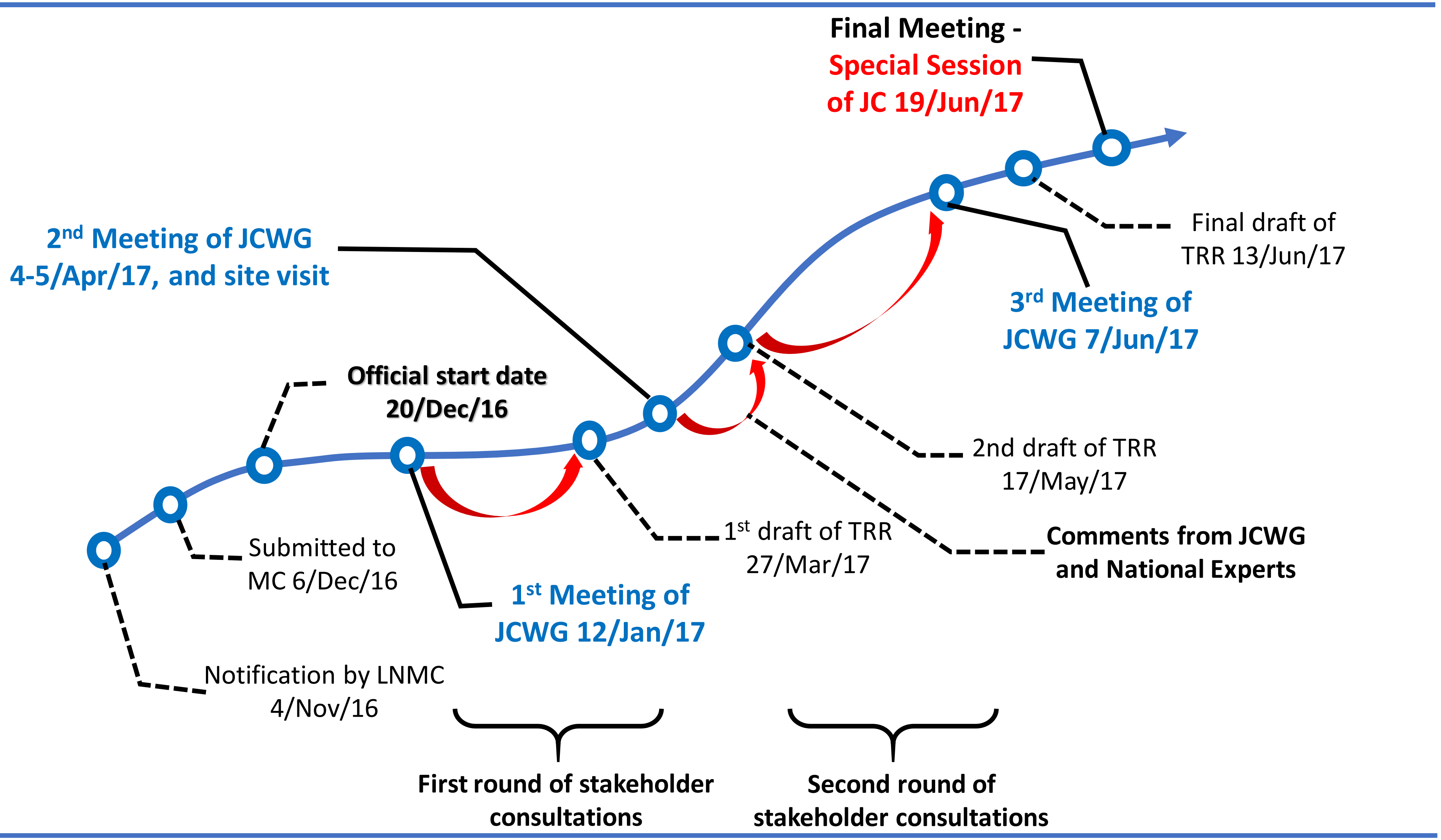
On 4 November 2016, the MRC Secretariat received notice of the Lao PDR's intention to submit the Pak Beng Hydropower Project (PBHPP) for prior consultation. The notice included a letter, the completed forms for prior consultation, and four sets of supporting documents. The PBHPP is the first in a cascade of five planned Mekong mainstream hydropower projects in the northern territory of Lao PDR, and lies in the Pak Beng district of Oudomxay Province of northern Lao PDR.

The MRC Secretariat forwarded the documents to the Member Countries on 6 December 2016, after preparing a scoping assessment report. The first meeting of the PNPCA JC-Working Group (JCWG), which was organized on 12 January 2017, subsequently established the official start date for the prior consultation process as 20 December 2016. The end of the initial 6-month period for prior consultation was consequently 19 June 2017, when a special session of the Joint Committee will consider the final Technical Review Report.

The JC under Article 5.3.3 [c] of the PNPCA established a Joint Committee Working Group (JCWG) to support the prior consultation process. Under guidance from the JCWG the MRC Secretariat appointed several expert groups, made up of Secretariat and international experts, to provide independent specialist evaluations of any potential impacts associated with the PBHPP. In addition, national experts have also been engaged to support the Member Countries in reviewing the submitted documents and the draft technical review report and to help facilitating national meetings. Participation by the Secretariat and international experts as well as national experts is outlined in Annex A2.

A preliminary review contained in the 1st draft of the TRR has been presented at the 2nd meeting of the JCWG in Oudomxay on 4 April 2017. National experts in the three notified countries have reviewed that first draft version, and the comments from the JCWG, and the national experts have been considered in a 2nd draft of the TRR which was presented to the final meeting of the JCWG. The third and final draft of the TRR was prepared based on the feedback from that meeting, as well as the feedback from the regional and national stakeholder forums. The final draft TRR was tabled for discussion at the Special Session of the JC on 19 June 2017. Recommendations from that meeting have been included in this final version of the TRR.

The diagram on the following page summarises this process, while Annex A1 outlines the process in more detail.


Final Meeting -
Special Session
of JC 19/Jun/17
2nd Meeting of JCWG
4-5/Apr/17, and site visit
Final draft of
TRR 13/Jun/17
3rd Meeting of
JCWG 7/Jun/17
Official start date
20/Dec/16
2nd draft of TRR
17/May/17
1st draft of TRR
27/Mar/17
Comments from JCWG
and National Experts
Submitted to
MC 6/Dec/16
1st Meeting of
JCWG 12/Jan/17
Notification by LNMC
4/Nov/16
First round of stakeholder
consultations
Second round of
stakeholder consultations

2.2 The drafting process for the Technical Review Report

This Technical Review Report (TRR) has been based on the similar template as used for the Xayaburi and Don Sahong prior consultations. However, recognising the MRC's desire to continually improve the process, and particularly address external stakeholders' perceptions, the content of the first section has been expanded to provide a better explanation of the prior consultation context and framework provided by the 1995 Mekong Agreement and Procedures. Much of Chapter 1 therefore responds to questions raised at the regional stakeholder forums. Similarly, the concluding section provides a clearer description of the potential end points and post prior consultation process.

Chapter 4 'Technical Review' the TRR was summarised by the expert teams for the main body of this report. The full reports from the expert teams have been included in an unabridged form as Appendices C to G. The other Chapters of the TRR were prepared by the Planning Division of the Secretariat, and include inputs from the expert teams.

All the drafts of both the TRR and the reports from the expert teams have been internally reviewed by the MRCS to check for consistency, and were signed off by the CEO before submission to the JC. This version is highlighted in **Bold.**

Report	Ver.	Date	Comment
Scoping Assessment Report for Prior Consultation for the PBHPP	V 0.2	07 Dec 2016	Submitted to the 1st meeting of the JCWG to define the scope of the assessments that would be undertaken, and confirm the composition of the expert groups
Drafts of the Technical Review Report	V 1.1 – 1.x	21 Mar 2017	This report MRCS internal draft submitted to MRCS Divisions and CEO
	V 2.0	27 Mar 2017	This report: Includes comments from MRCS and CEO – submitted to the JCWG. It does not include inputs from the national experts.
	V 2.1	15 Apr 2017	2nd draft submitted to CEO for signoff. Includes inputs received from national experts through the JCWG.
	V 2.2	17 Apr 2017	2nd draft submitted to the JCWG
Final Draft of the Technical Review Report	V 3.0	12 June 2017	Submitted to the CEO and Expert Groups for Final review – includes feedback from the regional and national consultations
	V 3.1	13 June 2017	Final draft version, Submitted to the JCSS
	V 4	**23 June 2017**	**Final version, Submitted to the JC**

2.3 Documents used for the Review[8]

The Technical Review Report is based on the 20 reports and relevant appendixes submitted by the Lao PDR, through the Lao National Mekong Committee (LNMC). These documents contain data, design concepts, methodology, and analysis results for: hydrology and hydraulics; sediment transport and river morphology; fish passage and fisheries ecology; water quality and aquatic ecology; navigation

[8] All the documentation relevant to the PBHPP is available from: http://www.mrcmekong.org/topics/pnpca-prior-consultation/pak-beng-hydropower-project/

and navigation lock; dam safety; and transboundary socio-economic impacts. These are outlined below, and a summary of their content is available from: http://www.mrcmekong.org/assets/Publications/Overview-of-Key-Features-of-Submitted-Documents-26-Jan-2016.pdf

Documents received from the project developers via the LNMC, and which were reviewed for the prior consultation process are [9]:

[1]. Engineering status report, September 2015
[1.1] - Appendix-Compliance-with-MRC-Preliminary-Design-Guidance.pdf
[2]. Engineering status report Drawings, September 2015.
[3]. Hydrological data and sediment sampling, September 2015.
[4]. Reservoir sedimentation and Backwater, September 2015.
[5]. Overall design report of an automatic system of hydrologic data collection and transmission.
[6]. Overall design report of sediment monitoring system, September 2015.
[7]. Sediment management, September 2015.
[8]. Two-dimensional sediment numerical simulation of Pak Beng HPP in Laos Mekong River, September 2015.
[9]. Numerical simulation of sediment movement in the ship channel of Pak Beng HPP Downstream, September 2015.
[10]. Hydraulic physical model investigation of Filling and emptying system, September 2015.
[11]. Hydrodynamic characteristics research on valve and culvert section for Pak Beng ship Lock, September 2015.
[12]. Overall hydraulic physical model investigation of Pak Beng HPP, September 2015
[13]. SIA-social impact assessment, September 2015.
[14]. SMMP-social management and monitoring plan, September 2015.
[15]. EGDP – ethnic group development plan, September 2015
[16]. RAP-resettlement action plan. September 2015.
[17]. Environmental management and monitoring plan, September 2015.
[18]. Environmental impact assessment, September 2015
[19]. Trans-boundary environmental and social impact assessment and cumulative impact assessment, September 2015.
[20]. Design Report of fish passage facilities, September 2015
[21]. Consulting-and-opening-workshop, presentation in pdf format, September 2015.
[22]. Feasibility-Study-on-Pak Beng-Hydropower-Project, presentation in pdf format. Date not clear.

During discussions with the Lao PDR and developer, it has become evident that considerable progress has already been made in some areas. Much of this has been written up in additional reports, and it appears that many of the measures raised in the TRR are already being addressed. These reports have, as yet, not been formally presented to support the prior consultation process, and have not therefore been formally considered here. Moreover, specialists from the MRCS have participated in a study tour of the physical model for the PBHPP, and have reported back to the Secretariat specialists. This TRR

[9] This does not include documents not formally provided by the LNMC.

notes where this ongoing work may change the findings in text boxes, but does not provide specific comment on this new work.

In addition, the review is set against a raft of MRC documents, including:

- Procedures for Water Quality (PWQ).
- Procedures for Maintenance of Flows on the Mainstream (PMFM).
- Procedures for Notification, Prior Consultation and Agreement (PNPCA).
- Diagnostic study of water quality in the Lower Mekong Basin, MRC Technical Paper no 15, 2007.
- Impacts of Climate change and developments on Mekong Flow regimes – First assessment 2009, MRC Technical paper no. 29, 2010.
- The Mekong River Report Card on Water Quality Volume 2, 2010 – Assessment of potential human impacts on Mekong river water quality.
- 2011 Water Quality Assessment Report, MRC Technical Paper No 40, 2013.
- MRC Water quality report card, Volume 3, 2013.
- Biomonitoring of the Lower Mekong River and selected Tributaries 2004 – 2007, MRC Technical Paper No. 20, 2008.
- Report on the 2011 biomonitoring survey of the Lower Mekong River and selected tributaries, MRC Technical Paper No 43, 2014.
- MRC Aquatic ecological health report card 2011, Volume 3, 2013
- MRC Aquatic ecological health report card 2013, Volume 4, 2014.
- Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong basin, 2009.
- BDP Scenario Assessment Report.
- MRC Basin Development Strategy.
  MRC, 2016, Rapid Basin-wide Sustainability Assessment Tool (RSAT), Part 2: RSAT topics and criteria (selected performance statements)
  MRC, 2016, *Development of Guidelines for Hydropower Environmental Impact Mitigation and Risk Management in the lower Mekong Mainstream and Tributaries- Volume 4-Case Study Report, v1-Modelling Scenarios and Impact Mitigation Assessment,* The ISH0306 Study.

2.4 Scope of the Technical Review Report

The primary purpose of TRR is to support discussion and the JC in its deliberations. It aims to provide key information that would be required by the JC to reach a decision on a set of measures under Article 5.4.3 of the PNPCA, or to support a possible postponement of the final meeting under Article 5.5.2 of the PNPCA. The TRR aims to provide a balanced basis for good faith consultations and cooperation, as well as providing some indication of the nature and extent of any possible impacts, and the level of confidence in the findings. It is primarily aimed at supporting the JC's discussions around conditions that may be attached to the further design, construction and operation of the PBHPP.

The Technical Review Report also makes recommendations with respect to opportunities to increase the level of confidence in the assessments of the possible impacts. This particularly because the PBHPP is still in the Feasibility Assessment Stage. Recommendations are made with respect to options to increase transboundary cooperation and mutual benefits should the PBHPP proceed. The Technical Review Report makes no comment on the acceptability or otherwise of the PBHPP.

3 THE PROPOSED PAK BENG HYDROPOWER PROJECT

3.1 General description and location

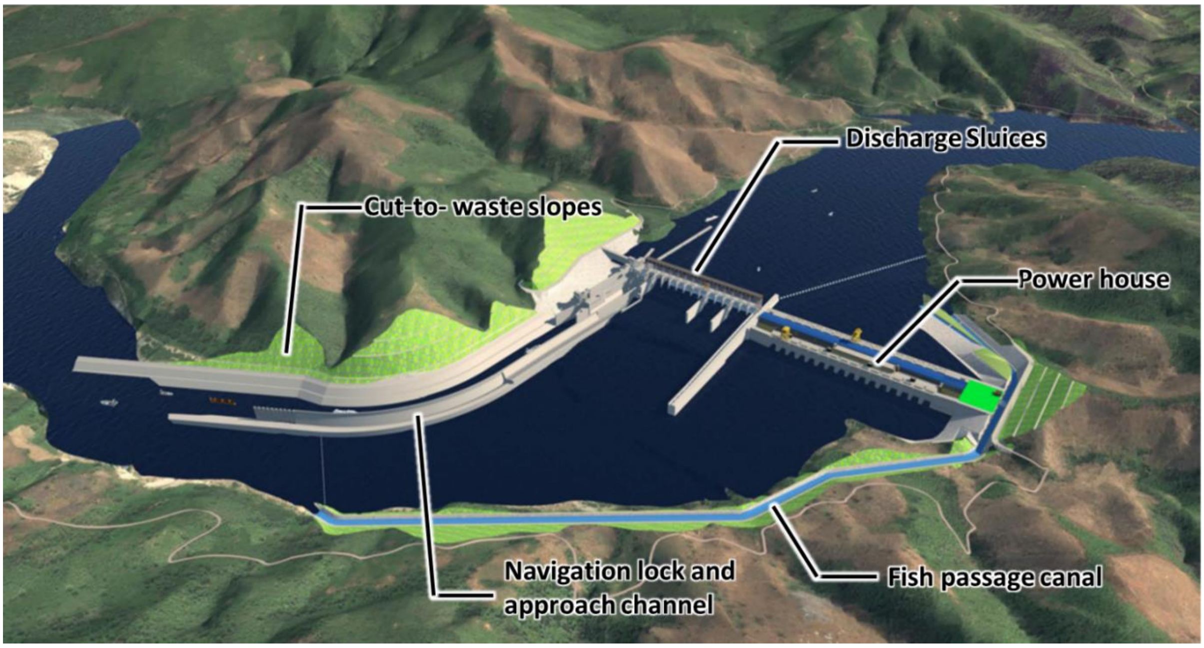
This section provides an overview of the planned PBHPP, derived primarily from the Fact Sheet available on the MRC website. It is intended to provide the context for the technical review in the following section.

The PBHPP dam site is in the Pak Beng District, Oudomxay Province, northern Lao PDR, about 530km downstream from Jinghong Hydropower dam, in China. It lies 180km downstream of Chiang Saen (the first hydrological station on the Lower Mekong River). Pak Beng, if completed, will be the upper most dam in a planned cascade of hydropower projects on the mainstream of the Lower Mekong River. It is being developed by the Datang (Lao) Pak Beng Hydropower Co., Ltd (henceforth “the developer”).

The PBHPP is located at 298m above the mean sea level (masl) and is 2,188 km from the sea, 174 km upstream of Luang Prabang and 258 km upstream of the Xayaburi Hydropower Project. The project site is situated in the northern part of the Lower Mekong Basin, where the landform is mostly hills and mountains covered by natural forests.

Power generated by the Project will primarily be for export to Thailand, with some 10% being used to support domestic demands in Lao PDR. The following sections reflect the developer’s description of the project.

THE PROPOSED PAK BENG HYDROPOWER PROJECT



3.2 A Run-of-River project

The developer notes that the PBHPP is being designed, and will be operated, as a run-of-river hydropower project. It has a total storage capacity of 559 million m^3 at a normal water level of 340 masl (mean average sea level). However, the water levels will be operated at 335 masl at lower flows to mimic the natural inundation at the Keng Pha Dai reef on the border with Thailand. The change in water level between these operating limits will be limited to less than 1m / day.

The PBHPP will not store water in the wet season to support dry season generation, the impacts on the inter-seasonal flow regime of the Mekong mainstream is therefore small. However, the developer will use the first floods of the wet season to raise the water levels from 335 m to 340 m, but the restriction to 1 m/day in levels may limit the impact on downstream flows.

3.3 Power generation capacity

The PBHPP consists of 16 bulb turbines of 57 megawatts (MW) each, totalling an installed capacity of 912 MW. This makes it one of the larger HPP planned on the Lower Mekong River. The annual average energy production is 4,765 gigawatt hours (GWh); 2,947 GWh in the wet season between June and November and 1,818 GWh in the dry season between December and May. Up to 10% of the power produced by the project will be made available to Électricité du Laos (EDL) and the rest will be supplied to Thailand.

3.4 Design characteristics

The PBHPP consists of water retaining structures, flood release structures, a powerhouse, a navigation ship lock and fish passage facilities. The key features of this infrastructure are presented below.

3.4.1 The dam and related structures

The water retaining structures include a gravity dam, a powerhouse, discharge sluices and a ship lock. The dam crest elevation is 346 masl, with a maximum height of about 64m, and a crest length of 896.70 masl. The powerhouse is located at the left side of main river channel (looking downstream), the discharge sluices are located on the right terrace, and the ship lock is arranged on the right bank.

The flood release structures consist of discharging sluices and sand outlets. The discharging sluices are located on the right side with 14 sluices of 15 m wide × 23 m high. A stilling basin with energy dissipation is designed just behind the sluices. The sand outlets are within the powerhouse section, with an opening of 2.5 m wide × 5 m high. They will be constructed between every two generating units, with a total of 8 sand outlets.

3.4.2 The powerhouse

The powerhouse consists of 16 bulb turbines, and is on the left side of the main river channel looking downstream. It has a design discharge of 5,771 m^3/s. The powerhouse section is 82.5 m long in the direction of the water flow, and 410 m along the dam axis across the river. The main powerhouse spans 21 m, and the spacing of generating units is 20.5 m. An erection bay will be constructed at both ends, and the auxiliary powerhouse is located on the downstream side of the main powerhouse, while the outgoing transmission line platform is situated on top of the auxiliary powerhouse.

3.4.4 Navigation locks

The navigation lock structure is a one-way, one-step ship lock capable of conveying 500-ton ships. Space has been reserved for a second ship lock parallel to the first, hence doubling the capacity for shipping and providing opportunities to minimise the impacts on navigation during maintenance.

The maximum working head of the navigation lock is 32.38 m, and as such during the dry season shipping may be lifted or dropped over 30m. The size of the lock chamber is 120 m long × 12 m wide

× 4 m deep. There are limited mooring points for shipping waiting to move upstream, and no specific mooring points for shipping waiting to move downstream.

3.4.5 Fish passage

The design of the fish passage channel in the documentation provided is on the left bank, and consists of a 1.6 km long trapezoidal channel, with a U shape in the upper reaches. It has bottom width of 10 m and a 17.2 m top width, and a longitudinal slope of about 1.85%.

Several pools will be set along the channel to serve as resting pools. The planned fish bypass channel entrance is some 1 km downstream of the dam wall. An observation room is set downstream of the service gate, and a counting, observing and trapping facility will be provided in this room.

3.4.5 Hydrology and hydraulics

The dam and water transfer structure are designed for a 500-year return period flood (i.e. 26,800 m^3/s, and to safely pass on a 2,000-year return period (i.e. 30,200 m^3/s) flood. Energy dissipation and protection structures are based on a 50-year return period.

3.4.6 Social impacts

The Social Impact Assessment has identified 26 villages in the three provinces of Oudomxay, Xayaburi, and Bokeo in northern Lao PDR who will be *directly* impacted by the project. This includes 923 households, and 4,726 people.

3.5 Operational considerations

The operational plans for the PBHPP focus on energy generation, navigation requirements, the impact on natural reef of Keng Pha Dai and the requirement for sediment management. As the project is situated on a navigable stretch of the Mekong mainstream, the proposed operation aims to avoid any significant impact on navigation through large daily fluctuations in hydropower production (and hence rapid changes in flows).

The reef of Keng Pha Dai, 97 km upstream of the dam, is recognised as a natural marker of the border between Thailand and Lao PDR, and operations will aim to minimise the impact on the visual perception of the border by maintaining water levels throughout the year close to what would have been the case without the Pak Beng Dam.

The sediment flushing facilities, and the operation of the PBHPP aim to pass significant quantities of sediment downstream. Comprehensive hydrological and sediment as well as fish monitoring, before and after construction and during operation, is planned and budgets have been provided.

3.6 Developer and economics

The project developer is the Datang (Lao) Pak Beng Hydropower Co., Ltd. The construction period is expected to be five years. The project is estimated to be worth around 2,372 million USD, of which 96% is for the dam infrastructure, and 4% is for power transmission. The developer suggests reserving a total budget of 1.3 million USD for the hydrological monitoring network, and 0.5 million USD for sediment monitoring and 0.6 million USD per year for the annual operation and maintenance of the monitoring networks.

4 TECHNICAL REVIEW

4.1 Introduction

Under direction from the JCWG, the MRC Secretariat has established six Expert Groups to support the expert review process;

- Fisheries and Environment Expert Group (FEEG);
- Hydrology Expert Group (HEG);
- Dam Safety Expert Group (DSEG)
- Navigation Expert Group (NEG)
- Sediment Expert Group (SEG); and
- Socio-economic Expert Group (SOEG)

These Expert Groups are comprised of internationally recognised experts working together with the experts from the relevant Divisions in the MRCS. The national experts contribute to the review of the draft technical review report at national level through the JCWG. The Planning Division of the MRC Secretariat, is coordinating the process, and has also established an expert team to draw this TRR together. Members of these Expert Groups are listed in Annex A2. In the interests of transparency, the reports prepared by these groups are appended in original form in Annex C-I, and must be considered as part of the Technical Review Report for the purposes of supporting the Joint Committee's deliberations.

The following summary draws out the key elements of the expert group's reports and conclusions that are considered directly relevant to discussions in the Joint Committee, and the formulation of a set of measures. The technical review, while considering all the Articles in Chapter III of the 1995 Mekong Agreement, focuses on Article 7. The summaries provided below therefore assess the extent to which the design and operation of the PBHPP will avoid, minimise and mitigate potential harmful effects, as well as the extent to which it aligns with the PDG. For the purposes of this TRR[10];

- *Avoid* means the measure, if implemented, would ensure that any harmful effects will be negligible;
- *Minimise* means the measure, if implemented, would reduce harmful effects, or the risk of harmful effects, considerably; and
- *Mitigate* means the measure, if implemented, would reduce the impact of any residual harmful effects on other users of the Mekong River System, including those in the other Member States. These may include Corporate Social Responsibility measures.

[10] Infrastructure development projects often refer to avoid, mitigate and compensate. Avoid, minimise and mitigate are used here to ensure alignment with the 1995 Mekong Agreement.

4.2 Structure of the review

The sub-sections in this Chapter reflect the results of the reviews undertaken by the various expert groups, and are formulated to common structure to facilitate cross referencing. Each sub-section, ***includes;***

- ***Background:*** Highlights why the issue is important to the prior consultation process, and to the notifying country's commitment to make every effort to limit harmful effects on the Mekong River System.
- ***Data used:*** This reflects on the data used by the developer as an input to the design and operating rules, or to evaluate the potential impacts of the PBHPP.
- ***Review of the documentation:*** This sub-section presents the review of the documentation provided by Lao PDR. It does not include a review of any documentation not initially provided for prior consultation. Text boxes are presented where the Review Team has been made aware of updated documentation.
- ***Monitoring proposed:*** This sub-section comments on the monitoring proposed by the developer to support the HPP operations, or its potential impacts.
- ***Alignment with the PDG:*** This sub-section summarises the extent to which the design and operation of the PBHPP, as outlined in the documentation provided, aligns with the PDG. The full analysis of alignment with PDG is outlined in Annex B.
- ***Other relevant issues:*** This outlines any other issues that may be relevant to the extent to which any harmful effects could be limited.

Chapter 5 focuses on those harmful effects that may be transboundary in nature from which the recommendations are drawn.

4.3 Hydrology and Hydraulics

4.3.1 Background

Getting the hydrology and hydraulics of the proposed PBHPP right is critical to the way the infrastructure is designed and operated for hydropower production, navigation, sediment flushing and to accommodate social and environmental considerations. Importantly, an improved understanding of the hydrology and hydraulics may provide some flexibility to accommodate the recommendations made in the following sections without affecting the economic viability of the PBHPP. It is therefore central to the whole review process, and is consequently addressed up front.

The documents submitted for the Prior Consultation process recognise the broad principles the MRC uses to characterise the hydrology of the Lower Mekong Basin. They have made a distinction between the wet and dry season, and refer to the hydrological zones.

At the outset, a distinction must be made between;

- Annual/Inter-annual changes to flow regimes; and
- Daily/Short-time period changes in flow regimes.

The former depends on the size of the storage, relative to the inflows, whereas the latter results from the operations of the water infrastructure. Both have potential impacts on the fish, ecology and human use of the Mekong River System, but the scales at which the hydrological and hydraulic impacts are felt different. The former has a basin wide impact, whereas the latter a localised impact. However, because of the interconnectedness of the ecosystem, the local hydrological and hydraulics impacts may be evident on the fisheries and human use of the system much further afield.

The main concerns addressed below are:

- The backwater of the headpond/in-channel storage can potentially extend upstream into the border reach with Thailand. Operation strategies are proposed to prevent submergence of the Keng Pha Dai reefs at the Thai border during the dry season. Concerns nonetheless remain around this backwater effect, particularly with respect to floods, tributaries and bridge infrastructure, and this requires more careful analyses.
- The Pak Beng HPP will be operated as a run-of-the-river scheme, and as such it will not affect the monthly average and seasonal variations of the downstream hydrology. Unfortunately, the TBESIA & CIA report presents the cumulative effects of all upstream dams (in China) and tributary dams, incorrectly referring to this as the impact of the PBHPP on its own.
- Hydropeaking will create rapid fluctuations in water levels in the headpond/in-channel storage and the downstream reaches. Rapid variations in the order of several meters are reported by the developer in some technical reports. However, they have also indicated that the PBHPP will be operated as a run of river project, with no hydropeaking. This remains unclear.

4.3.2 Data used by the developer

The developer has used MRC hydrological data (daily discharges) from Chiang Saen and Luang Prabang stations for the period 1960 – 2007. Based on a basin-scaling method, a discharge series was constructed for Pak Beng site from these data series. For 2008-2014 the developer used data from direct measurements at the dam site, based on six water-level stations and repeated discharge measurements. The quality of the constructed data series (rainfall not included), as well of the direct measured series (consistancy to the MRC series), are a point of concern to the reviewers. The inconsistencies in values of active volume and turbine design discharge in the different reports, and the consequences to the design, need to be addressed.

The historic data from the sources above, is used throughout the entire series of documents to design the structures and operation rules for the PBHPP. Despite the recognition that the upstream flow regime has changed due to the dams in China, the developer has based the design and operating rules largely on the historical flows from 1960-2015, which are not representative of the future flow regimes. In particular, the higher flows required for flushing sediment may occur less frequently, while base flows in the dry season may be higher, which may provide scope for adjusting the operating rules to accommodate the recommendations made in the following sections.

The water levels immediately downstream of the PBHPP were derived from the water level stations at the dam site (2008-2014). These downstream tailwater levels will affect the hydropower potential, as they determine the available head. These water levels are in turn largely dependent on whether the Luang Prabang HPP (LPHPP) will be developed[11]. LPHPP is expected to have an operation level

[11] The Government of Lao PDR have indicated their intention to develop the Luang Prabang HPP, and the

between 310 m and 315 m. Without LPHPP these levels are only reached at Pak Beng dam at flows greater than 2,000 m^3/s. There may consequently be periods when the LPHPP could affect the power output at the PBHPP. This has not been considered in the documentation submitted. The Luang Prabang operating levels may also affect the fishpass entrance, which is currently situated at 308m. The implications of this, and potential mitigation measures, are discussed in the Fish passage and fish ecology section.

The determination of the rating curve for the dam site used measured flows from 2008 – 2014. Water levels varied between 301 and 321m in this period, and discharges were below about 7,500 m^3/s. The extension of the rating curve to accommodate higher flows was based on a single methodology. There are no records to assess the accuracy of this approach. This also means that the availability of higher flows for flushing operations may also be wrongly estimated.

The flood peak determinations are based on the Pearson Type III method, applied to the daily discharge series for the dam (which were constructed from the data from Chiang Saen and Luang Prabang, and partially from direct measurements at the dam site). Given that the 1966 flood has a dominant effect on the flood frequency determination at Chaing Saen, it is common practice to apply several different methods to ensure due diligence in flood peak determinations. It is not clear whether this has been done for the PBHPP. Similarly, the scaling method between Chaing Saen and Luang Prabang would not fully accommodate floods in the Nam Ou tributary at Luang Prabang. These station dependencies and independencies have not yet been accounted for in the analyses. The influence of the Lancang cascade is only partly accommodated in the flood frequency analysis. While this may have limited impacts on the determination of extreme flood frequencies, determination of the smaller flood return periods will be affected. This is an appropriate assumption because it is not expected that the Lancang cascade will attenuate the extreme floods (e.g., headpond/in-channel storages may be full, floods will be spilled to prevent damage), while the cascade may significantly attenuate the more frequent floods (e.g., floods maybe used to fill the storage).

Based on the analysis, the developer has selected the following flow conditions for the design of the structure:

- The design flood discharge for the spillways and sluices is 26,800 m^3/s (p=0.2%, 500 year return period). The assumption to consider a 1 in 500 years flood as design flood (SPF_ Standard project flood) is standard as the hydraulic head ranges between 12 and 30 m.
- The check flood discharge for the entire structure is 30,200 m^3/s (p=0.05%, level is 343.74, 2000 year return period). For the check discharge the developer has not chosen to use the Probable Maximum Flood (PMF), as is applied for dam saftey of Xayaburi dam.

The two cofferdams have been designed to a return period of 20 or 50 years (18,900 m^3/s, or 21,400 m^3/s, respectively), which is standard procedures. Although, it is not clear why different design discharges are used. In addition, the developer could engage the operators of the dams in China to minimise the impacts of their operations on flood peaks at the PBHPP.

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proposed dam is included in the Basin Development Strategy. However, until it is formally notified, and the operating rules specified, the MRC is not in a position to assume that it will proceed.

The reported recurrence intervals for extreme floods are inconsistent with those found in different MRC reports. It is important for the developer to relate the recurrence intervals for extreme floods to the hazard created by the dam in the event of a theoretical dam break failure. These could also accommodate future hydrological conditions, including climate change and upstream development. During the review process the developer provided a simple dam break calculation to assess the downstream impacts. However, this needs to be carried out in more detail so as to provide assessment of the risk it migh have on the peoples who live along the river and likely damage to the environment.

4.3.3 Review of the proposals by the developer

Mitigation of water level fluctuations (impoundment and downstream)

The developer proposes that the PBHPP will be operated as a run-of-the-river scheme with only minor active storage. Most of the inflows will pass through the PBHPP with little storage and hence little modification. Nonetheless, there is the intention to store some of the early wet season floods to raise water levels, and to operate the PBHPP between 340 m and 335 m to mimic the natural exposure and inundation of the Keng Pha Dai reefs (at the border with Thailand), and to draw down water levels for sediment sluicing during flood conditions. These operations are expected to have temporary impacts on the hydrology of the river both immediately up- and downstream of the dam. To minimize the impacts, the developer proposes a ramping rate of 1 m/day for the headpond/in-channel storage[12] emptying and filling.

The following rough calculations illustrate the potential impacts of the proposed operation rule on the downstream hydrology:

- *Filling:* using a limitation on up-ramping of 1 m/day, the minimum time needed to raise water levels from 335 masl to 340 masl at the start of the wet season, is 5 days. Roughly 400 m^3/s must be used for filling during this 5-day period. Flows downstream will be reduced with this discharge for this period. However, because dry season flows are higher due to the dams in China (some 1,500 m^3/s), Pak Beng will have a limited *additional* impact on delayed flood season flows.
- *Draw down*: for flows above 10,000 m^3/s water levels will be gradually lowered by roughly 1 m per day. This can be achieved by releasing an extra 500 m^3/s to 1000 m^3/s (roughly) on top of the flood discharge. This may add an additional 0.5 m to 1 m (order of magnitude) to downstream water levels than without the dam.

The fluctuations mentioned above are occasional, and not comparable to the daily fluctuations which would occur during hydropeaking operations. Because of their regular occurrence, fluctuations due to hydropeaking are more damaging for ecology and river use (notably navigation) than the occasional

[12] In this document, the term '*headpond*' or '*in-channel storage*' is used specifically in relation to the impoundment of water immediately upstream of the proposed Pak Bang Hydropower dam site. The term '*reservoir*' is used in the context of all other storages other than the Pak Beng headpond. Note that in other submitted documents including the Annexes to this report, the term reservoir may apply to the Pak Beng water impoundment.

fluctuations. Although hydropeaking fluctuations can also be minimized by applying a ramping rate, the frequent character will demand a much stricter ramping than for the occasional fluctuations.

Nevertheless, the 1-2 m/day water level fluctuations downstream of the dam can still have impacts, even if they are occasional. It is assumed that these variations cannot be fully mitigated, if inundation at Keng Pha Dai is to mimic natural conditions. In this case, a public information network could be installed to advise river users of expected fluctuations in water levels, be they occasional or daily. However, it is contingent on the developer to make every effort to avoid, minimise or mitigate any potential impacts due to these changes, and to consider the requirements of PDG Para 170 with respect to ramping flows. Lower ramping rates will implicitly cause reduced ramping rates in the downstream reaches as well. However, this may temporarily affect water levels upstream at the border with Thailand.

Typical variations due to natural changes in this reach of the river are in the order of decimeters per day. Rates of change of water surface elevation are highest with the arrival of the flood pulse, and are typically up to about +/- 0.16 m/day at Luang Prabang (SEA, main report[13]). In order to minimise the potential impacts on ecological functions, these rates would guide the operating rules for raising and lowering water levels. This in turn will require compromises with the potential inundation upstream into Thailand.

An additional limit was set for the operations of the Xayaburi HPP. The maximum limit for daily water level fluctuation at Xayaburi is 0.5 m/day, taking safety, navigation and environment considerations into account. In the dry season this limit is connected to the maximum daily active storage fluctuation, to be able to maintain the operation level with relatively low inflows.

> The Government of Lao PDR has subsequently confirmed verbally that water level changes in the headpond/in-channel storage would be kept to < 1m per day, and that the PBHPP will produce a constant power output over a 24-hour period.

Minimising backwater effects

Due to the impoundment, the water levels will rise over a reach of several tens of kilometres upstream of the maximum operating level (backwater effects). The Mekong River forms the Lao PDR / Thailand border upstream of the impounded reach, and these backwater effects consequently constitute a transboundary impact. This is discussed in the relevant section below.

Design of the hydraulic structure

The design for the PBHPP provides for a spillway with fourteen gates with a width of 15 m each, with sill elevation of 317 m, and a stilling basin of 60 m. A broad-crested weir is used as the overflow, and the elevation of the discharge sluices is 317m. The structure is designed, in combination with the navigation lock/sluice and sand sluices, to safely release a design discharge of 26,800 m^3/s. A physical scale model has been used to test and optimise the elements of the spillways and sluices for flow and

[13] MRC, 2010, Strategic Environmental Assessment of Hydropower on the Mekong Mainstream (SEA). Final report. Prepared by ICEM, October 2010

sediment. The scale factor used for downscaling is 70, which means that the structure is 70 times smaller than the prototype. This is considered an appropriate scale for representing the hydraulics of the prototype.

The stilling basin absorbs the energetic outflow from the flood sluices, and is planned at 60 m long (at Xayaburi it is 92m). However, the developer has not provided the rational for this design in the submitted documents. It is, consequently, not possible to assess its likely efficacy.

The developer has communicated verbally that the length of the flood sluices has been based on the worst-case scenario as the downstream water levels drown out the stilling basin during higher floods. The developer should review the stilling basin design during the detailed design stage to confirm that this is still the worst-case scenario, and that there is no risk of stilling basin failure that could undermine the main structures.

Powerhouse

To accommodate the structure in the chosen cross-section, the left bank has to be partially excavated. The left turbines are therefore situated in a small bay which creates unfavourable approach- and out-flow conditions. The documents do not provide information regarding the expected flow patterns at the powerhouse inlet and outlets. It is expected that this shape of the left side guide wall may create eddies, unstable water levels, and may affect the efficiency of the sediment sluicing and turbine performance. At flow less than 5,770 m^3/s, only the inner turbines will be operational, causing eddy development in front of the closed turbines, and consequently sediment deposition. At high flows when all turbines are operational, the flow toward the left series of turbines will cause secondary currents and turbulence affecting the efficiency of these turbines. In addition, the outflow from these turbines will cause raised water levels, and some loss of head. This may also be influenced by the recommendations made for the redesign of the fish pass.

The inlets of sand sluice gates are designed below the turbines intakes, under the piers between the turbines, and with roughly the same outlet levels as the turbines outlets. This design promotes the sustainability of power generation. However, the efficiency of the sluicing gates is not clearly illustrated with respect to their sizing, placement and capacity. It would be useful to use numerical or physical modelling to assess the efficacy of these systems.

Navigation approaches

The outputs of the 2D and 3D numerical modelling show a very strong transition from a rotating low velocity eddy in the approach channel, towards the main channel with high flow velocities of 2 to 3 m/s. As the main channel flow crosses the lock approach at an angle, it is expected that this may cause serious challenges and risks to the ships entering and leaving the locks. The navigation section has made recommendations for aligning the shipping approaches, and could also be considered here.

Operational rules

The developer indicates an intention to operate the PBHPP on the inflow discharge only. However, the operational rules are not clear on the:

- Influence of Chinese dams, and changes in discharges in both dry and wet seasons;

- Procedures to accommodate environmental flows;
- Limitations and procedures to prevent undesired water-level fluctuations (maximum variations, ramping rates (PDG Para 170);
- Downstream impacts of flood flows on the river users (fishermen, tourists, boats etc) and villages along the river bank
- The synchronization of operation of Pak Beng to the operation of the Chinese dams and the downstream dams in the cascade (joint operation).

This operational regime will have to be aligned with the expectation of an annual average energy output of 4,846 GW.hr. The impacts of this operating regime on the fisheries and fish passage is addressed in more detail in that section.

4.3.4 Monitoring proposed by the developer

Knowledge of impending higher flows will be important to optimising operations, particularly with respect to minimising potential environmental and social impacts. The developer intends to use an automatic hydrological forecasting system (ASHDCT) to do this. This will include stations in China to provide longer lead times, and will also support operations during construction. The system is designed to Chinese standards and regulations. Because existing stations will be used, most of the development costs relate to the telemetry and the set-up of a control station to process the data. The reported costs are quite large for only installation and operation, but the proposed operational investment of U$ 0.5 million requires more explanation and a breakdown of the costs. Similar systems exist in several places in the world (e.g. flood-early-warning systems). In these lead times are improved using radar and satellite based forecasting and hindcasting. The developer does not explore these options.

The ASHDCT system may become quite relevant for operating the mitigation measures. A response to floods can be anticipated more in advance, such that gate operations and releases can be introduced more smoothly in time.

4.3.5 Alignment with the PDG

The PDG provides guidance on minimizing rapid water level fluctuations in the upstream and downstteam reaches, and optimising low flow conditions, notably the environmental flows.

The PDG (paragraph 172-175) notes that environmental flows must be considered in dam design and operations, and that a comprehensive Environmental Flow Assessment (EFA) is necessary at the EIA stage. The ISH0306 study points out that minimum flow limits could be based on natural flow conditions in the river. For Pak Beng this is 830 m^3/s, which is unlikely to be a constraint due to the operation of the Lancang dams. The developer could also consider the constraints for minimal flow from the Procedures for the Maintenance of Flow on the Mainstream (PMFM), as they are more stringent than the condition mentioned above.

Additional storage in the whole Mekong River System creates opportunities to deal with the issue of drought (El Nino) responses. However, there is not enough storage in Pak Beng to provide drought relief. Any required downstream flows must be accommodated in the PMFM, and could be provided if needed by releases from tributary storage.

4.3.6 Other relevant issues

The documents submitted for Prior Consultation do not provide clear information on the conjunctive operation ot the Pak Beng HPP operations with the other hydropower projects in the region. It is expected that PBHPP will be able to adapt its operational rules to allow a more flexible response to releases from Lancang cascade and the potential hydropower schemes in the Nam Tha and Nam Pha. Furthermore, it must align with operations in Xayaburi dam. This becomes even more relevant if Luang Prabang HPP is developed, because its tailwater directly influences the performance of Pak Beng HPP and vice versa.

4.4 Sediment transport and river morphology

4.4.1 Background

Sediment transport and geomorphic processes create and maintain the physical environments in rivers, which in turn determine the distribution and quality of aquatic habitats, such as fish spawning and nursery areas and bird nesting habitat. Sediment transport is necessary for maintaining bank stability and associated infra-structure. The coarse sediment transported by rivers is extracted for construction and development activities, whilst the fine sediment is necessary for the transport of nutrients onto the flood plain and delta areas and the maintenance of estuarine and coastal ecosystems.

The geomorphic impacts associated with hydropower projects include the disruption of sediment continuity due to sediment capture in the dam. This in turn will alter the downstream sediment supply and grain-size characteristics. These impacts are largely linked to the size and siting of the project, with large, deep headpond/in-channel storages generally having a greater impact as compared to small volume run-of-river projects.

The Pak Beng hydropower project was identified in the 1990s with the site included in the 2009 optimization study (CNR, 2009). These initial investigations focussed on maximising energy output and did not consider potential impacts or mitigation measures with respect to sediment transport or river morphology. From this perspective, the Pak Beng project has 'inherited' many impacts due to the history of the project.

The developer has, included several options to minimise sediment deposition near the power house infrastructure. As proposed in the feasibility documentation, these measures are primarily aimed at minimising sediment deposition for the protection of the infrastructure rather than passing fine and coarse sediment through the impoundment for downstream environmental benefit. It is, however, recognised that the present description of the project is at a feasibility level and the design and operating strategy of the project will evolve during the detailed design phase.

4.4.2 Data used by the developer

Sediment transport

The proposed sediment management infrastructure and strategies at Pak Beng are based on modelling using the annual sediment budget, the seasonal patterns of sediment delivery and the sediment characteristics at the site. The approach is appropriate, but the data used for the modelling is considered limited. Constraints of the data include:

- *Sediment loads:* The initial sediment work for Pak Beng was completed prior to the commissioning of several large impoundments on the Lancang River, and the annual sediment loads are based on historic sediment loads in China, extrapolated to the Pak Beng site. These loads were then reduced based on the assumed trapping efficiency of the Lancang cascade. The final estimate sediment load of ~37 Mt yr^{-1} has not been verified through monitoring or compared with the recent sediment monitoring results collected through the MRC Discharge Sediment Monitoring Project (DSMP). Using these estimated sediment inputs for modelling raises concerns about all aspects of the sediment modelling completed for the project, including the sediment transport, sedimentation in the impounded reach and sediment flushing models, and the dam design based on the outcome of these models. It would assist if the developer would provide the data underlying the estimates used in the documents to the MRC for comparison with the MRC data sets;
- *Grain-size distribution:* The grain-size distributions adopted for the suspended sediment fraction are based on limited sampling in June 2008 and June 2015 or results obtained at Luang Prabang. Sediments collected in June are unlikely to have the same grain-size distribution as those collected under higher flow conditions occurring later in the flood season, and sediment collected at Luang Prabang may not be applicable to Pak Beng due to different hydraulic conditions and the inflow of the large Nam Ou tributary between the two sites. There are large differences between the grain-size distributions used in the developer's documents and the grain-size results recently measured by the MRC DSMP at Chiang Saen, with the measured distributions being coarser and comprised predominantly of sand rather than silt. Higher sand loads will increase deposition, reduce the amount of sediment passing to the downstream environment and potentially increase abrasion on the turbines;
- *Bedload:* Bedload sediment transport rates were estimated as a percentage of the estimated total sediment load, which is a reasonable approach due to the difficulty of measuring bedload. However, because of the availability of sand in the river channel downstream of the final dam in the Lancang Cascade, the reduction in bedload attributed to development of the Cascade may not be as large as the reduction in the fine- sediment trapped in the impoundment (at least until the material is removed from the channel). To accommodate this, a range of bedload quantities could be considered by the developer and additional measurements could be completed at Pak Beng to confirm the bedload and grain-size distribution;
- *Bedload grain-size distributions* used in the modelling and design of Pak Beng were based on samples collected at Luang Prabang, and are unlikely to reflect the conditions at Pak Beng due to the inflow of the Nam Ou. Bed material samples were collected within the impounded reach but it is unclear how these were used in modelling;
- *The sediment time-series* used in the sedimentation modelling were based on the 1984 – 1988 period, 'adjusted' to account for the presence of the Lancang Cascade. These years contain wet and dry flow years, but there is no comparison with recently measured sediment results during wet and dry periods. There is also no consideration of more extreme wet or dry periods, or the changes to flow and sediment variability due to the operation of the upstream cascade or tributary HP projects. The sediment time series have not been compared to the existing MRC DSMP data sets;

River morphology

The PNPCA documents do not provide a geomorphic baseline for the project area with respect to the distribution of bedrock or alluvial reaches, or deep pools in the impounded reach , or downstream of the project, except for the Keng Pha Dai reef at the border with Thailand. Information about the depth of alluvial fill in the area is limited to near the project infrastructure, but suggests channel fill in the range of 3 m to 16 m in common, but locally fill may be up to 40 m. There is a high risk of sediment removal due to scour downstream of the dam following commencement of operations, and these depths provide indicative values as to the maximum depth of scouring which could occur prior to the underlying bedrock channel becoming exposed. In the 2-dimensional sediment modelling results, scour holes of up to 3 m are recorded within the first few hundred meters downstream of the project site, but there is no detailed channel modelling beyond this distance, and these results are not discussed in the context of the distribution of alluvial fill. Additional detailed modelling of the downstream channel is required to more accurately assess the impact of dam development on the impounded reach or downstream river channel, including transboundary impacts.

4.4.3 Review of the developer's proposal

The sediment data is used in a range of models to quantify the potential impact of the project on sediment loads and to develop sediment management strategies. The uncertainty in the input data, as discussed above, therefore affects the developer's proposals to minimise the impacts of sediment trapping on the Mekong River System, and their proposals for flushing sediments from the impounded reach.

Sediment Modelling

A range of 1D and 2D numeric sediment models have been applied to Pak Beng, as well as a physical model of the dam site. The models appear to have been developed and run at different times, and it is unclear if the input parameters and time-series used were consistent between the models. An integrated summary of the numeric and physical modelling results would assist with understanding the overall findings.

Additional information related to the calibration of the model is required to fully assess the model results, and for the two-and three- dimensional models additional information about the development of the model is warranted, although it is stated that the models have been used in many other rivers. Parameters for the two-dimensional model are generally based on other river systems, and greater justification for their use in the Mekong is warranted.

Sediment deposition near the project infrastructure was investigated using two- and three-dimensional models and the physical model. The results suggest that 80% of the suspended sediment will pass through the turbines, with coarser material passed through the low-level sand gates in the power house section of the project, or directed by the sediment 'training wall' to deposit behind the sill of the flood section of the project. Areas of potential sediment deposition were also identified near the left bank of the power house section and behind the sluice gates. There is no description of the mineralogy of the suspended sediment to evaluate the potential for abrasion.

Modelling of sedimentation near the navigation system found there were areas in the approach channels where deposition had the potential to limit navigation over time, and suggested that flushing using low flow rates through the flood sluice gate and / or dredging could be used to manage the deposition.

Sediment flushing was modelled using the numerical and physical models. Due to the high sill level the flushing is limited to 'pressure' flushing with sediment removed from only 100 to 200 m from behind the sluice gate section of the project. This is because even if water levels are reduced to pre-dam levels, the hydraulic conditions of a free-flowing river are not restored due to the high sill level. No information is provided as to the grain-size distribution of the sediment used in the physical model.

Sedimentation in the impounded reach was investigated using a 1-dimensional model, with special attention paid to the Keng Pha Dai reef and tributary confluences. Seasonality was included through the rule-curve, and use of a 'representative' flow sequence that contained high, medium and low flow totals. The model results suggest that ~20% of the sediment will be captured over the first decade of operations, reducing to ~8% after 100 years of operations. An estimation of the sediment deposits at the head of the impounded reach is provided for the end of a 15-year period, with no change in bed level projected to occur beyond 95 km upstream (Keng Pha Dai is located at 96 km upstream). There is no discussion as to the impact of sediment flushing on impounded reach deposition, nor on management and mitigation options if sedimentation extend to the Keng Pha Dai rapids.

Erosion in the downstream channel was modelled for the first few hundred metres downstream of the project using the 2-D model with scour of up to 3 m projected to occur. Modelling of impacts farther downstream are not provided.

A SWAT model was used to examine downstream transboundary impacts, with the model results indicating the project will decrease suspended sediment in the downstream river by 22% at Luang Prabang, (consistent with the modelled trapping rate) with impacts decreasing with distance downstream. Based on the SWAT results the TBIA concludes that the dam would likely be responsible for transboundary sediment, morphology and nutrient impacts, leading to environmental impacts. Impacts could include not only the channel but also the floodplains, wetlands and seasonal lakes, the delta, the nearby coast of the sea, and the offshore sediment plume.

Modelling did not include geomorphic impacts associated with short-term (daily or sub-daily) water level fluctuations, and did not consider future climate change scenarios.

Project design

Dam site selection: It is recognised that the Pak Beng dam site was identified decades ago based on maximising energy production at a time when environmental concerns were not as well recognised. At a large scale, the potential locations for a dam in the area are constrained by the locations of the other proposed, or under construction, projects in northern Lao PDR and the upstream border with Thailand.

Given these constraints, it is not surprising that the Pak Beng proposal does not present alternative locations that would result in a shorter impounded reach, or provide options for sediment routing around the project. The developer discusses two dam sites within the same general location of the river, with the chosen site identified as being more advantageous for passing sediment due to the power house being aligned with the existing thalweg of the river to reduce sedimentation near the power house.

The Reservoir Sedimentation and Backwater Report (Doc 4) indicates little deposition in the Keng Pha Dai reef area, but no consideration is given to potential management actions if the modelling results are not accurate, and increased deposition near the reefs occurs.

There is no discussion as to the location of the proposed development with respect to sediment sources (upstream or downstream), the susceptibility of the channel to erosion, or the location of downstream tributaries that could contribute unregulated sediment inputs.

Dam design and infrastructure: The dam design includes 7 low-level sand flushing outlets situated in the powerhouse section of the dam, and 14 high level sluice gates in the flood control section of the dam. The two sections are separated by a sediment 'training wall' that will reduce the ingress of coarse sediments to the power house section. The low-level sand outlets are small (2.5 mx 6 m) and are intended to remove sediment that is not captured by the training wall and accumulates in front of the power house inlets only. They are intended to assist in the protection of infrastructure and are not designed with the aim of flushing large volumes of sediments to the downstream environment on a regular basis.

There is a discrepancy between the infrastructure used in the sediment modelling (Doc 8) and the Engineering Status Report (Doc 1) that has a direct effect on sediment management. The Engineering Status Report states that the sediment barrier has a crest height of 297.4 m whereas the sediment model uses a barrier height of 325.0 m. The modelling shows that after 5-years, the elevation of sediment behind the barrier is at 315 m, which is above the proposed height of the barrier as provided in the Engineering Status Report. This suggests that sediment flushing will be required on a more frequent basis than projected by the sediment modelling.

The design of the dam substantially limits the ability to flush sand and gravel from the dam on a seasonal or annual basis. The sill of the weir in the 'flood control' section is up to 40 m above the base of the dam, and sediment deposits will need to reach the top of the sill before coarse material can be passed efficiently downstream. Opening the sluice gates can lower the water surface level to near 'pre-dam' levels, but the hydraulic conditions will not be similar to 'pre-dam' conditions as water and sediment can only flow over the weir. This will allow 'pressure flushing' to be implemented, but will not permit sediment routing of sand and coarse sediment.

The physical model results show once sediment has accumulated to above the level of the sill, opening the gates will remove sediment from 100 m to 200 m upstream of the sluice gates but only to the depth of the sill of the weir. This is not consistent with the Preliminary Design Guidance which calls for large low-level sediment gates to enable annual or seasonal routing.

The developer considered the inclusion of a small (2.5 m x 6 m) low level sediment gate in the 'flood' section of the dam but rejected the design change due to high costs, increased risks associated with the under-flow, and no substantial improvement with respect to sediment flushing. This information was provided in a power point presentation but a detailed written report was not provided with the PC submission. The developer has not considered the inclusion of multiple large low-level gates in the flood control section of the project, which would enable sediment routing (return of pre-dam hydraulic conditions to the river) rather than limiting sediment management to pressure flushing.

Operations and sediment management

Sediment management of the Pak Beng Hydropower Project is facilitated by water retaining structure, sluice gate, bottom holes under the powerhouse, the navigation structure and fish pass with operations of different incoming flow patterns. Sediment management proposed for the Pak Beng Hydropower Project included the following.

- ***Sediment deposit in the*** impounded reach ***area***: The modelling results suggest that the effective storage capacity of the project will be reduced about 7% after 50-year operation and about 10% after 10-year operation.
- ***Sediment control at powerhouse intakes and sediment flushing***: Fine grained sediment that remains in suspension shall be continuously passed through the power house. Coarse suspended sediment and bed load will be prevented from entering the power house and diverted towards the flood sluice gates by the sediment barrier, and sediment flushing using the sluice gates will occur when inflows exceed 5,961 m^3/s. Sediment that is deposited in front of the powerhouse will be episodically discharged downstream via the low-level sand outlets located under the powerhouse. In areas where this proposed mechanism is found ineffective, artificial or mechanical dredging measures shall be taken.
- At the time of initial investigations for the project, which was pre-Lancang Cascade, average monthly flow at Pak Beng exceeded 5,961 m^3s^{-1} for at least three months of the year. Following establishment of the cascade average monthly flow only exceeds this value for one-month. Because this flow level now occurs less frequently, sediment flushing will occur less frequently than projected in the documentation, and may not occur at all during dry years. The developer does not discuss any sediment flushing strategies to maintain sediment delivery downstream on an annual basis.
- ***Sediment control at the navigation approach channel***: the sediment that enters the approach channel would be flushed by sand-sluicing gate, adjacent to navigation channel. If it is found not effective, artificial or mechanical dredging measures shall be taken.
- ***Eco-friendly sediment flushing***: Sediment flushing will not be conducted during the peak fish spawning period between March and June. Additionally, gates shall be gradually opened to allow well-mixed sediment concentration, and a maximum sediment concentration limit will be identified prior to operations
- ***River bank scouring****:* Water level fluctuations caused by hydropower operations can impact bank stability of the impounded reach and downstream channel. Counter-measures of bank stability were not presented; however, the monitoring of the bank stability was proposed. When it is found instable, engineering measures, i.e. block or gabion protection, shall be taken.
- There is conflicting information about how the project will operate with respect to daily or hourly flow fluctuations. In various documents, daily water level changes ranging from 1 m to 4 m per day are discussed. The updated feasibility presentation states the project is 'run of river', but does not state over what time frame inflows equal outflows. Understanding the range of water level fluctuation is important for evaluating potential downstream impacts, and a detailed report on power station operations is required for additional analysis.

> The Government of Lao PDR has subsequently confirmed that water level changes in the headpond/in-channel storage would be kept to < 1m per day, and that the PBHPP will produce a constant power output over a 24-hour period.

- *Engineering options for bank erosion:* Commitments are made to implementing engineering works to address downstream or impounded reach shoreline erosion where required. What isn't clear from the documentation, is how the monitoring results and management actions are to be linked. The indicators and thresholds used to establish whether engineering options are warranted have not been identified, and the geographic extent and hierarchy of priorities has not been described. The Environmental Management and Monitoring Plan recommends the development of Watershed Management Plans which would be an effective way to prioritise and coordinate management activities, however it is unclear who is responsible for developing and implementing these plans. It is recognised that this level of catchment coordination can be developed during the design and construction phases of the project.

- The developer indicates that 22% of the annual incoming sediment load will be trapped in the first years of operation. The trapping rate is strongly dependant on the grain-size distribution, so this issue links back to the input data used for modelling (see previous sections). The impoundment is projected to achieve an equilibrium state in approximately 90 years. There are discrepancies between documents about the volume of the impoundment which would affect this estimate. The estimate of bedload contribution to the total sediment load would also affect the rate of sediment trapping and time required for 'equilibrium' to be achieved;

Catchment Coordination of Sediment Management

The PNPCA documents provide little context of the Pak Beng project with respect to the other hydropower projects operating or under construction in the region. Pak Beng sediment management is considered at a high level in the context of the Lancang Cascade, stating that sediment flushing at Pak Beng will occur if sediment concentrations increase due to flushing in the Lancang Cascade.

The PNPCA documents assume that Pak Beng will discharge into the backwater of the Luang Prabang hydropower project but provide little consideration of how operations at Pak Beng will affect downstream users in the absence of this project, or how Pak Beng operations will interact with the Nam Ou cascade or the Xayaburi mainstream dam for period until the Luang Prabang development is commissioned.

The Transboundary Impact Assessment states that coordination between projects is required, but no mechanism, time-frame or authority for establishing and managing an authority is provided.

4.4.4 Monitoring proposed by the developer

A comprehensive sediment-related monitoring programme is proposed in the Overall Design Report of Sediment Monitoring System, which includes the following: (1) monitoring sediment in/out the PBHPP, (2) monitoring of water surface line in the impounded reach and tail section of the impounded reach, (3) monitoring sediment deposition in the impounded reach, (4) monitoring of sediment deposition in the project area at a high resolution, (5) monitoring of downstream river reach, and (6) monitoring bank deformation.

Monitoring sediment in/out the PBHPP (sediment concentration and grain size distribution): LISST-100X automatic suspended sediment grain size distribution probes are to be installed in a controlled environment to monitor inflow and outflow sediment in the impounded reach. This approach will require extensive calibration and interpretation because sediment grain-size and concentration are not uniform over the length and depth of the water column such that no one location is representative of the entire river cross section. A spot measurement of sediment at one point has the potential to correspond to a range of total sediment loads and grain-sizes being transported in the river. The LISST instrument measures sediment volume in a sample, rather than sediment mass. To convert volumes to mass will require calibrated based on site-specific measurements of grain size and shape;

Monitoring of water surface line in the impounded reach **and tail section**: The monitoring strategy indicates that water levels will be compiled at a daily time-step for reporting. This time-step is too long to capture short-term fluctuations that can increase bank erosion due to scour and seepage process. Compiling data at an hourly time step in addition to daily and monthly intervals will provide better information about the operations.

Sediment deposition in the impounded reach: Sixty cross-sections in the impounded reach area were surveyed during the design phase, and will be re-surveyed to evaluate sedimentation. The underwater sections will be acquired by digital navigation fathometer and section above the water surface by total station equipped with GPS. The impounded reach shoreline, river course and terrace would be monitored using high resolution satellite imagery;

Monitoring of sediment deposition in the project area: detailed topographic and bathymetric surveys of 1-km upstream and 2-km downstream river sections from the project site would be conducted every year before and after the flood season;

Monitoring of downstream river reach: High resolution satellite imagery of 50-km downstream of the project site is intended to be purchased each year with image analysis software used to detect changes. It is also proposed to conduct pre- and post- flood season bank inspections. There is no inclusion of bathymetric measurements in the proposal, so channel deepening downstream of the dam site will not be captured. Channel deepening frequently precedes bank collapse, and would be a useful indicator for tracking channel changes. The inclusion of bathymetric mapping of the downstream channel would enhance the power of the monitoring program to predict bank changes.

Monitoring bank deformation: Prior to impoundment, bank stability in the area of inundation will be investigated. The monitoring strategy does not provide a time-line for commencement of monitoring and does not discuss the establishment of a 'baseline' prior to construction or operation of the projects;

Monitoring during construction: Contractors will be responsible for environmental management to ISO14001 standards, and expected to implement best practice environmental management during construction activities, with a dedicated Construction Monitoring Team responsible for providing guidance to the contractors. The EMMP commits to the development of an Erosion and Sediment Control Plan and outlines the development of an Environmental Management Information System by the Environmental Management Unit, which will be established by MONRE.

The proposed monitoring components and approaches are consistent with best practice monitoring. A 'gap' in the proposed monitoring is related to the link between sediment and nutrient transport. Determining the nutrient content of sediment and water entering and exiting the impoundment would provide useful information regarding the trapping of nutrients in the impoundment, and / or the release of nutrients from the impoundment. This information would be particularly useful during the first decade of operations as the inundated vegetation decays.

4.4.5 Alignment with the PDG

A detailed review of the Pak Beng proposal with respect to the sediment criteria contained in the Preliminary Design Guidance is contained in Annex D (specialist report on sediment transport and geomorphology), and should be consulted for a detailed discussion of each criterium. The criteria contained in the Preliminary Design Guidance for sediment broadly relate to the categories of sediment transport and river morphology, strategies to sustain storage capacity, mitigation and downstream sediment starvation and management of sediments in a cascade. Of the *21 general criteria*, the Pak Beng PC documents provides information that *partially or fully relates to 17*. The criteria that are partially considered generally address issues related to the infrastructure and / or impounded reach, but the criteria that are inadequately considered relate to the larger catchment or cascade setting, such as downstream geomorphic changes.

Three of the four criteria that are not addressed relate to the inclusion of large low-level gates (or similar) and the operation of the gates to maintain annual or seasonal sediment routing of coarse sediments through the impoundment. These measures are specifically aimed at maintaining sediment continuity in the downstream river, and the absence of information in the PC documents reflects the developer's focus on managing sediment to protect project infrastructure rather than maximising throughput for downstream environmental benefit.

The forth criteria that is not addressed to at least a partial degree is the guidance for a formal external engineering review of the project.

4.4.6 Other relevant issues

Hydropower projects operate over time scales of decades to centuries, and to be sustainable, operators need to be able to respond to future changes and challenges. The UMB and LMB are experiencing high rates of development and change, and it is not possible to anticipate the range of flow, sediment and water quality challenges that are likely to arise over the next century in the catchment. The key to long-term sustainable hydropower is to adopt an adaptive management approach and have project infrastructure that can provide operational flexibility to respond to changing conditions.

The proposed sediment management at Pak Beng is based on one operational pattern (open flood gates at flows >~5,900 m^3/s) , and the infrastructure for managing coarse sediment passage is limited to small sand outlets in the power house section, or sluicing through the flood gates once deposits reach the height of the dam sill. The flexibility of the project would be enhanced if larger, low level gates were included in the flood section of the dam to enable the creation of a wider range of hydraulic conditions at the dam. Specifically, larger low level gates would allow sediment routing to be implemented (return of river to near natural hydraulic as well as hydrologic conditions) which would promote the passage of coarse sediment sooner and in larger quantities as compared to the the project as propsed. The present design will likely require decades of sediment trapping before coarse sediment is accumulated in the area where flushing is effective.

4.5 Water Quality and Aquatic Ecology

4.5.1 Background

The water quality risks associated with hydropower development include changes to physical and chemical water quality parameters that can impact on impounded and downstream ecosystems. The water quality parameters that are important to consider in hydropower developments are identified in the Preliminary Design Guidance (MRC, 2009), and include temperature, pH, dissolved oxygen, Biological Oxygen Demand, nutrients (total and dissolved phosphorus and nitrogen) and coliform bacteria. These parameters can be altered during storage within a reservoir, especially under conditions where thermal stratification can lead to the development of anaerobic water at depth.

The focus of the review is on the impacts of the PBHPP on water quality and changes in flow, particularly in the way that they may affect the aquatic ecology of the Mekong River during construction, operation and decommissioning phases of the project. Whilst one of the main concerns of the Prior Consultation process is the transboundary impacts, the impacts on aquatic ecology can only be assessed from an understanding of the scale and extent of the more localised impacts within the Pak Beng area, before the river passes downstream towards Luang Prabang and the Xayaburi Hydropower Project dam area.

4.5.2 Data used by the developer

The developer has not reviewed the extensive data and reports available under the MRC programme. Baseline assessment of water quality and aquatic ecology in the PBHPP EIA and EMMP is limited and lacks the robustness to predict the overall impact of PBHPP on water quality and aquatic ecology. Data provided are highly provisional and some 5 years old. Updated information to the current period would be expected, based on a robust sampling design approved by independent agencies.

No modelling of the likely impacts on aquatic habitats, and thus aquatic biota, are provided and surveys conducted under the design phase are inadequate for all aspects of aquatic ecology, including fisheries, given the scale of the project and its downstream implications.

The main gaps and uncertainties concerning water quality and aquatic ecology data are:

- Absence of an adequate and updated baseline of water quality throughout each month of the year, i.e. at different flows and water levels.
- There is no assessment of the importance of the habitat lost beneath the impounded area, particularly in relation to importance to ecological functioning and contribution to biodiversity of the region.
- There is no baseline information on downstream water quality presented, and since there could be transboundary issues, such a baseline would be advisable so that if later changes occur in the water quality downstream as a result of construction or operation, their cause can be more clearly identified as resulting from the PBHPP or not. This will be critical information in the event of a pollution incident in Lao PDR and the attribution of liability. This may be seen as a risk management measure by the company and the Government of Lao PDR.
- There is no description of the different aquatic habitats and changes caused by the modification of the flow regime on fish migration. As a result, there is no identification of which aquatic habitats are important ecologically or rare or an assessment of how they will be impacted.

> The developer has indicated that the water quality investigation conforms to the Lao PDR's regulations, adequate of the day and there will be systematic monitoring on the water quality and flow at least half year before the construction.
> The baseline data are, however well below the standards expected of an international development project that will potentially have transboundary implications. The information is out-of-date and inadequate to make a full evaluation. Full use should have been made of MRC water quality and environmental data at minimum.

- There is inadequate attention addressing the wider biodiversity and critical habitat management and monitoring.

> The developer has indicated that the aquatic habitats will be described at the fish way in the detailed design report, which will also pay more attention to the biodiversity and critical habitat management and monitoring.
> This does not allow the PNPCA review to make any assessment and provide any contribution towards mitigating potential impact. As indicated, the reports provided lack rigour to make an impact assessment.

4.5.3 Review of the proposals by the developer

Water quality

The water quality samples taken and analysed, and reported by the developer are very limited, and the data available from the MRC has not been analysed. The water quality monitoring programme needs to be expanded in scope, including more sites, samples taken monthly over the wet and dry seasons, and relevant parameters need to be included to provide a better baseline against which to assess any potential changes.

Water quality problems typically expected with large hydropower reservoirs include: low or no oxygen in bottom waters, increased BOD and ammonia concentrations in the bottom water, and the release of methane. However, the run-of-river nature of the PBHPP, and the size of the storage means that these are unlikely to be a problem in this case. The developer has also indicated that the impounded reach basin will be cleared of vegetation, which may mitigate against these problems.

However, there is a potential for pollution during construction, and potentially increased pollution from a higher population in Pak Beng village during operations. The developer has indicated that the following measures will be implemented to mitigate against potential water quality problems;

- Installation of waste water treatment plant for worker camps;
- Safe disposal of vehicle maintenance oils;
- Safe storage of chemicals and disposal of used containers;
- Attention to concrete shuttering to prevent accidental spillage of wet cement into water courses, and prevention or washing cement mixing equipment in water courses;
- Attention to good earth moving practice when working near water courses; and
- Removal of surplus vegetation in the impounded reach area just prior to impoundment.

The EIA postulates that with these measures in place, there will be no significant impact on water quality during construction. The developer has provided a budget for ongoing water quality monitoring, but the budgeting process is not well described and more information is needed to assess alignment with the PDG in this respect **(PDG Para 167)**. Similarly, monitoring and procedures needed to deal with potential chemical spills during construction are not described.

The PDG (Para 165) notes that an international panel of experts should be established at the project feasibility stage to help develop the water quality monitoring programme. There is no evidence that this panel has been considered.

There does not seem to have been any attempt to tailor or target the water quality monitoring programme to identify potential water quality problems that may emerge during construction and operations.

> The developer has indicated that the water quality investigation conforms to Lao Government requirements but this remains superficial and inadequate to make a full evaluation. There is an indication that a supplementary monitoring programme will be implemented but no details of coverage and intensity of monitoring or budget are provided to evaluate suitability.

Aquatic biota and habitats

The developer has undertaken a very limited sampling programme for phyto- and zooplankton, and benthic macroinvertebrates, including only 6 sites and 2 sampling occasions (one in the dry season and one in the wet season). This is not consistent with international best practices or the methodologies employed by the MRC. Again, the MRC data have not been used to supplement the results.

The samples taken show a poor diversity of zooplankton and benthic macroinvertebrates, **but both the sampling methods and the limited number of samples preclude any definitive assessment of the current baseline status.**

Habitats will change from a lentic (flowing water) to a lotic (impounded water) in the impounded section upstream of the dam. The important flowing water habitat in this section is therefore lost to the biota adapted to these upper reaches of the river. Similarly, the habitats immediately downstream of the dam site will be affected by 'sediment hungry[14]' outflows, which will scour sediments potentially down to the bed rock. Releases of water to flush the accumulated sediments may then deposit sediments immediately downstream of the dam, smothering habitats and causing the loss of aquatic invertebrate fauna which acts as food for fishes. In addition, fish are vulnerable to smothering of eggs and spawning habitat, but also loss of habitat occupied by many of the species that inhabit this region of the Mekong and which contribute significantly to the fisheries.

Habitats immediately upstream and downstream of the dam site are therefore likely to be considerably altered, with concomitant loss of species. Importantly, there is a high degree of endemism[15] in this stretch of the Mekong River. While the immediate impacts of this lost habitat will be limited to the Lao PDR, the knock-on impacts through the ecosystem may extend beyond the immediate impacts.

There has been no analysis of the value of any habitats that will be lost, or the potential impacts on the wider LMB ecosystem.

> The developer has indicated that the diversity of the aquatic fauna is poor, but there is little justification for this statement as the surveys lack rigour. They again indicate habitats will be described in the fish way detailed designing report.
> This does not allow the PNPCA review to make any assessment and provide and contribution towards mitigating potential impact. As indicated, the reports provided lack rigour to make an impact assessment.

Flow regimes

Aquatic ecosystems are adapted to and reliant on the natural flow regime, and changes in this regime will impact on the health of the system. However, the extent to which the PBHPP will change the flow regime is not clear from the documentation provided. Pak Beng is intended to be operated as a run-of-river hydropower plant, with little change between the inflow and outflow. However, the developer

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[14] When sediments have been removed from impounded water through settling, the water emerging from the headpond/in-channel storage has a greater capacity to carry sediment, and often river beds immediately downstream of dams are scoured down to the bed rock. The outflowing water is said to be sediment hungry.

[15] Habitats and biota that have a very limited range typical of this area.

reports that diel changes in water levels of up to 1-2m can be expected up to Pak Beng village – suggesting that operations will aim to provide peaking power. It was also noted that some storage may take place in the dry season. Nonetheless, the developer notes that operations will aim to minimise the impact on the visual perception of the Lao / Thai border on the reef of Keng Pha Dai in the upper reaches of the impounded section by maintaining water levels throughout the year close to the natural condition.

Habitats immediately downstream of the dam will be heavily impacted by the hydropeaking operations, as highlighted in the sediments review.

> The developer has indicated that only mild water level fluctuations <1 m/day in the headpond/in-channel storage but the magnitude of these on downstream flows water fluctuations has not been provided therefore impact on ecology and environment remains unknown.

The **PDG Para 168** addresses the impacts of changes in flows on the flow regime of the whole LMB, and notes that the impacts of changes in flows on the operations at other hydropower plants, and the ecological functioning of the river system. The PDG suggests that impacts of any changes need to be assessed using appropriate environmental flow assessment techniques. The developer proposes using the Tennant method, however, more comprehensive, holistic methods like DRIFT are recommended.

However, it should be recognised most of the flow in the Lower Mekong River is generated downstream of Pak Beng, and the impacts of flow regulation at the PBHPP on the lower reaches of the Mekong are not likely to be significant. Nevertheless, the cumulative impacts of the cascade of hydropower in the LMB, and those HPP on the tributaries could be significant.

> The Developers indicate that the Tennant method is adequate but hydrological methods, such as the Tennant methodology, have been criticized for their lack of ecological validity and high uncertainty with regard to hydrology-ecology relationships (Acreman and Dunbar 2004). Furthermore, the Tennant method effectively sets a 10% ecological flow and does not account for ecological components of flow variation thus has been rejected by the international community as it bypasses examination of the whole hydrograph and the functions of different flows.

The impacts of the short-term changes in flow regime on habitats immediately below the dam have not been analysed. The PDG (**Para 163 & 164, and 170 & 171**) notes that changes in the natural flow regime due to peaking operations should be minimised. An assessment of the localised impacts of hydropeaking operations must be made, and measures to avoid, minimise and mitigate these impacts put in place. Notably, the entire upper Mekong Basin could be considered as a 'critical habitat' under the World Bank's - IFC Performance Standard 6. This suggests that there should be no measurable adverse impacts on the biodiversity values, nor a net reduction in the populations of 'Critically Endangered' or 'Endangered' species.

4.5.4 Monitoring proposed by the developer

The monitoring proposed by the developers is largely to assess compliance during construction works. No long-term monitoring programme of water quality and aquatic ecology is formulated, nor are adaptive management responses to any severe impacts elucidated. There is a need for a well-formulated, robust, sampling programme for both water quality and aquatic ecology, that goes hand-in-hand with similar monitoring for fisheries, to be provided prior to any development, and mechanisms/protocol to respond to any severe, adverse changes defined and together with allocation of funding from the developers to enact any response required.

The developer has indicated that the water quality investigation conforms to Lao Government requirements but this remains superficial and inadequate to make a full evaluation. There is an indication that a supplementary monitoring programme will be implemented but no details of coverage and intensity of monitoring or budget are provided to evaluate suitability.

4.5.5 Alignment with the PDG

The documents provided show only partial alignment with the PDG with respect to water quality and aquatic ecological aspects. Provisions that:

1. Minimise any potential *water quality* problems are acceptable. However, more attention needs to be paid to the development and description of the water quality monitoring programmes, and the establishment of an expert panel in this regard.
2. Minimise the changes to the *flow regimes* is less clear;
    a) It is unlikely that the PBHPP will compromise the commitments made under the Procedures to Maintain Flows in the Mainstream, Article 6 of the 1995 Mekong Agreement, but this needs to be explicitly stated.
    b) The extent to which the operations at Pak Beng (in isolation) will affect flow regimes further downstream is not clear.
    c) However, despite the run-of-river nature of the PBHPP, it appears that some hydropeaking may occur. The guidance in the PDG in respect to minimising the impacts of rapid changes in water levels has not been followed.
    d) Changes in habitats due to these operations have not been addressed.
3. Address any potential loss of habitat have not been effectively addressed.

Moreover, there are no specific provisions to avoid, minimise or mitigate against the loss or critically endangered or endangered species, or to monitor these impacts.

4.5.6 Other relevant issues

- The EIA and EMMP are very deficient in their description of the aquatic habitats within the overall area, including the geomorphology and hydraulics of the channel likely to be affected, the habitats and their ecological significance. Without this information, it will be impossible to assess the impacts, and indeed to monitor the aquatic ecology of the river in this area. Since this part of the river is ecologically very sensitive, there may be indirect implications for a number of species on the IUCN endangered list of fish species, in the Mekong giant catfish, using the local area for spawning and recruitment.
- A programme for integrated monitoring of water quality, flows and habitats and aquatic ecology, coupled with in depth studies into the fisheries of the region, needs to be designed and implemented. There is no provision for monitoring flows or the quality of aquatic habitats, and this is an essential component of the risk management strategy of the company in the event of a pollution incident causing transboundary damages for which the company and the

government of Lao PDR might be held responsible. It is suggested that attention is paid to the aquatic ecology of the river in the Pak Beng area and its monitoring should be an important area of focus for the PBHPP.

4.6 Fisheries and fish passage

4.6.1 Background

One of the main impacts of dam development is disruption to the life cycle of migratory fishes and loss of fisheries production both downstream and in the inundated area. There are possible solutions and mitigation measures but the extent to which they are effective depends on integrating key information on the ecological characteristics with hydro-geomorphological characteristics and appropriate design and operation of fish passage facilities. The FEEG review on Fisheries and Fish Passage tests the extent to which the advice on mitigation and management measures in the Preliminary Design Guidance for mainstream dams has been taken up. The review attempts to provide assessment of potential transboundary impacts, risks and consequences of the proposed PBHPP on fisheries, particularly migratory species that migrate through the upper zone of the Mekong mainstream around Pak Beng to complete their life cycles.

4.6.2 Data used by the developer

Fish and biota monitoring was done in both the dry (January 2011) and rainy seasons (July 2011) at six locations in the project area. Sampling was restricted to a 50-m beach seine (although gill netting was apparently also used) plus market surveys for fish. There is no indication of how many replicates were taken at each site on each occasion or the duration of the sampling. The developer concludes that the species composition and abundance in the project area are already low, and that the PBHPP will not affect those species which can live in the impounded reach.

However, the survey programme undertaken was limited to 6 sites, and 2 times of the year. It did not target large sized species or larval drift life stages. The results are therefore unreliable as an indication fish diversity in the area, and several important fish species, known to occur in the area, have been overlooked. Although the precise number of species in the area is unknown, 167 species are listed in the MRC's fish species database, and fisher catch monitoring near Pak Beng found about 70 species caught in gill nets alone. These numbers are considerably higher than the number of species listed in the PBHPP EIA, and the species known to be present in the region are different to those reported in the EIA.

The EIA and fish migration studies concluded that the impact would be *"medium to high magnitude, and potential impact will be negative and moderate level during construction period"*. However, these conclusions are likely to underestimate the potential impact and more detailed studies are required to underpin the EIA.

The developers also suggest they will take an "adaptive approach" to mitigation by conducting studies during the construction. While this is an essential aspect of project management, it cannot replace a detailed mitigation study, which is required to assess the impacts and evaluate the effectiveness of any mitigation options before construction. This is because impacts are often not seen for many years after construction.

The documentation and data made available do not allow for a robust, comprehensive evaluation of the impacts of PBHPP, or the proposed fish passage solutions, and the EIA could be updated to provide more information on baseline conditions and fish migration behaviours.

> The developer has indicated that the fisheries surveys will be carried out as part of the revised fish way design. This does not allow the PNPCA review to make any assessment and provide any contribution towards mitigating potential impact. As indicated, the reports provided lack rigour to make an impact assessment.

Fish ecology and fisheries issues

It is generally accepted that there are three fish migration systems in the LMB: the lower zone below Khone Falls, the zone upstream from the falls to Vientiane and the third zone upstream of Vientiane. However, several species migrate between these zones, and some commercially valuable white fishes migrate over longer distances. The timing of these upstream and downstream migrations is variable, but there appears to be continuous spawning in the river with peaks, during the dry season (February-March) as the most important, followed by the onset of the flood (June-July) and then when the water is receding (November). Downstream drift of larvae occurs year-round.

Disruption of these migrations will affect the fisheries potential both upstream and downstream of the proposed PBHPP. Of concern are the rhithron fish species, which require flowing water habitats, and long and short distance migrating whitefish species, which make up most the fisheries catch in the Pak Beng region. The loss of the flowing water habitat in the 97-km long impounded stretch is consequently important. Moreover, the upper reaches of the LMB provide a spawning habitat for several important species, including the Mekong giant catfish which migrates from the middle Mekong Basin and Tonle Sap Lake to spawn in the Upper Mekong Basin in Chiang Rai Province – Thailand, between the end of April to May.

Fish larval drift studies at Xayaburi by MRC have shown that large numbers of larvae of several species drift downstream through this reach, and the numbers caught in the dry season suggest that downstream drift in the dry season could be equally as important as the wet season. These larval drift studies have not been investigated or reported by the developer.

Considerable fishing activity takes place in upper migration zone, and fisheries are mainly based on the migratory species. It is estimated that some 40,000-60,000 t/yr are caught in the upper zone, and it is highly likely this production will be compromised by the construction of the PBHPP. Fishing generally occurs during the upstream migrations, and is associated with increasing water levels during the onset of the rainy season. However, these species are not the only ones captured; a wide diversity of species is found in the markets, including the non-native species like the common carp and tilapia. A range of amphibians, snails and Crustacea also make up the total catch, but have not been considered as an important food source or livelihoods in the EIA.

There has been a proliferation of farmed tilapia and carp in the markets, which could partly substitute for any loss of native species in the capture fishery. However, fish farming will only benefit communities that have the capital and revenue to establish and maintain aquaculture production units.

Fish Passage

Data utilised, including MRC data:

On fish ecology and migration:

- MRC 2006, 2009
- NCG 2014
- Poulsen A.F. Ouch Poeu, Sintavong Viravong, Ubolratana Suntornratana and Nguyen Thanh Tung. (2002) Fish migrations of the Lower Mekong River Basin: implications for development, planning and environmental management. MRC Technical Paper No. 8, Mekong River Commission, Phnom Penh. 62 pp. ISSN: 1683-1489
- Halls, A.S. and M. Kshatriya (2009) Modelling the cumulative barrier and passage effects of mainstream hydropower dams on migratory fish populations in the Lower Mekong Basin MRC Technical Paper No. 25. Mekong River Commission, Vientiane. 104 pp.
- Baran E., Jantunen T. and Chong C. K. (2007) Values of inland fisheries in the Mekong River Basin. WorldFish Center, Phnom Penh, Cambodia. 76 pages.

Data not utilised:

On fishpass design:

- Principles of Fish Passage as outlined in Xayaburi PNPCA documents not utilised.
- Present designs for Xayaburi HPP not reviewed or analysed. There are significant findings to be learnt from this project. The FEEG acknowledges, however, that the developer may not have had access to the Xayaburi HPP documentation.
- MRC Fish Passage Review (Schumutz & Mielach 2015) not utilised.
- Standard fish passage texts (Clay 1995, FAO/DVWK 2002) and relevant scientific papers (e.g. Baumann) not used.
- Despite the reference to the life history of Mekong fishes and the importance of larval drift, this aspect is not addressed in the project.
- No review of tropical fish passage in large rivers, especially the South American experience which shows that the fishways are undersized for the biomass, are too steep, and have a small proportionof river flow (e.g. < 1%).

In summary, the PBHPP has used some publications from the MRC on fish migration but largely ignored downstream migration in the fish passage design. Significantly, no standard fish passage books or papers have been used, although the FEEG recognised some figures copied from Australian and European sources.

4.6.3 Review of the proposals by the developer

Key principles

The PBHPP is upstream of the Xayaburi Dam, which is a preceding Prior Consultation process. Any fish passage considerations for Pak Beng must therefore be compatible with Xayaburi. For example, a less effective fish passage at Pak Beng would negate the benefits of the additional investments already made at Xayaburi.

The developer seems to have paid little attention to the outcomes of, or lessons learnt from, the Xayaburi PC process, and it is recommended that they take these into account moving forward.

The documentation provided presents broad fishpass options, but does not rigorously compare the design with functional criteria. The result is a proposed fishpass design that will not function effectively, and at times during the migration periods, will not function at all. Constructability is considered in parallel with fish passage function, but this could be done sequentially, firstly considering how the fishpass must function, then designing to ensure those functions.

This review takes the latter perspective by firstly highlighting the functional criteria for effective fish passage, then reviewing the proposed design, and making alternative proposals, in that context.

Functional criteria for fish passage

There are two functional criteria for fish passage:

i. *attraction* – (i.e. will fish find the fishpass entrance, up and downstream), and
ii. *passage* – (i.e. will fish be able to swim up, or down, the fishpass).

These are interdependent: if fish cannot locate the fishpass they cannot use it; equally, if they can locate the fishpass, but can't swim along it, they cannot use it.

Effective *attraction* is dependent on:

i. *Proportion of flow*
The international standard is that 10% of the total flow should flow through the fishpass. However, higher proportions of flow in the fishpass provide greater the attraction for fish.
ii. *Upstream limit of migration*
Migrating fish swim upstream, attracted by the stronger flow, to the limit of migration. This is where a fishpass entrance needs to be located.
iii. *Discrete flow for fish to locate*
The flow from the fishpass needs to be readily distinguishable, and not masked by turbulence or competing flows.

Effective *passage* is dependent on:

i. *Fish behaviour*
Fish behavior relates to *attraction* and *passage*. A*ttraction* relates to how the fish search for migration routes below a structure based turbulence and different channel morphologies. *Passage* relates to the minimum depth that fish require across the profile of the fishpass, and the availability, spacing and depth of resting pools. Other behavioural aspects include the response to light and tunnels, and diel movement patterns, but these are not critical in the PBHPP case.

ii. *Swimming ability*
In rivers, channels and fishpasses, fish negotiate water velocity and turbulence. These characteristics need to be within the burst, prolonged, and sustained swimming ability of fish. These swimming modes vary between sizes and species of fish. In general, selection of well-known conservative design criteria is a prudent approach.

Upstream Fish Passage

Migration Flows

Fishpasses are designed to accommodate migration over a given range of flows at certain times of the year. The PBHPP Fish Passage Report makes the reasonable assumption that the main fish migration period at Pak Beng is April to October. However, there is likely to be some migration throughout the year and the migration patterns at Pak Beng are poorly understood. Downstream migration of adult and sub-adult fish is also likely to take place over this period, but larval drift downstream occurs all year.

Mekong fish use changes in flow as a cue for migration. While flow peaks up to 26,000 m^3/s can occur in this strech of the Mekong, flows of 5,000 m^3/s occur in most years, and can be considered a useful practical upper limit for fish passage at PBHPP. The powerhouse is likely to use most of the flows up to 5,771 m^3/s, with the spillway being used for higher flows. Migratory fish will consequently be attracted to the powerhouse for most of the time. Further information is needed in spilway use an whether it is engaged at lower flows to balance turbine usage but initally it appears that upstream fish passage is only required at the powerhouse.

Downstream migration will occur at a range of flows, including high flows when the spillway is in use.

The minimum flow within the migration season is not specified in the documents, but the lowest monthly average is 1,887 m^3/s, and can be considered an initial minimum until further analysis provides the daily minimum flow in April-October.

Most fish migration will therefore take place between 1,887 m^3/s and 5,000 m^3/s. However, further analysis is required on the minimum flow, and spillway usage during low flows.

Headwater and Tailwater Range

The tailwater range for flows of 1,887 m^3/s to 5,000 m^3/s is approximately 9m. The fishpass proposed for the PBHPP has an effective tailwater range of 2m. This means that the fishpass downstream entrance will lie above the water level at low flows, being inaccessible to fish, or will be submerged at high flows, so that fishpass flows would be diffuse and fish would be less able to locate the entrance.

Similarly, the exit upstream of the dam must cope with a 5m water level range. This will require more than the two-exit system proposed[16].

[16] At the 2nd Meeting of the PNPCA JCWG on 4th April, Lao PDR indicated the headwater at low flows would only operate at two levels but the documentation shows a transition between the two. Further clarification is required.

If the current design proceeds, the tailwater range of the downstream entrance needs to be increased to 9m to enable attraction during the migration periods, and the number of exit points upstream of the dam needs to be increased if there is variable headwater over the 5 m range.

> The Government of Lao PDR has indicated that the fishpass entrance was designed on the basis that the Luang Prabang HPP dam will be built, and that the downstream water levels would be regulated by that dam. However, in their response to the TRR they indicated that the design does not account for Luang Prabang. Critically, irrespective of the scenario, the position of the fish passage entrance is fundamentally flawed and the whole fish passage facility needs redesigning.
> It is recognized the developer has contracted SMEC to redesign fish pass, but many concerns remain about the fish passage facilities. It is therefore recommended that engagements with SMEC are included in any post prior consultation process.

Migrating Fish Assemblage

The PBHPP fish passage report describes the priorities for upstream passage for adult fish and target species only. In the Mekong River, many fish species migrate upstream to feed and seek refuge as well as to spawn. These migrations involve immature fish as well as adult spawning fish.

The fish passage design needs to therefore consider immature and adult fish as well as the whole fish assemblage, not just target species.

Fishpass Entrance location

Fish passage design must predict where migrating fish will be attracted to and aggregate. The PBHPP report on fish passage describes this behaviour, noting correctly that fish will be attracted to the dam and the tailrace of powerhouses. However, the fishpass proposed has an entrance that is downstream of the attraction zone, relying on an electric fish barrier to guide fish to the fishpass. These barriers do not work at sites with flows greater than 100 m^3/s and water velocities greater than 0.6 m/s. The electric barrier will therefore not function as intended. Moreover, electric guiding fences can only be tuned to a specific size range of fish, so that large fish may be prevented from passing, while small fish can swim through[17].

Migrating fish will be attracted to the powerhouse, and that is where the entrance needs to be located. This is a well-known phenomenon, and a *collection gallery* is commonly used, which is a channel on top of the draft tubes with multiple fishpass entrances. This is being installed at the Xayaburi HPP, and the same is recommended for the PBHPP.

Fishpass Flow

It is accepted that 10% of flow is required for effective fish passage (i.e. a restriction of 90% of pre-dam conditions). The current fishpass design flow for PBHPP is 14.4 m^3/s, which is between 0.8% and 0.3% of the flows during the migration period.

[17] At the 2nd Meeting of the PNPCA JCWG on 4th April, Lao PDR indicated they were aware of effective electric fences for fish. However, as stated above, these are not at high discharges sites like the Mekong River.

It is recommended that the fishpass flow be increased to 188 - 500 m^3/s.

Fishpass Gradient

A bypass channel fishpass is proposed, at a gradient of 1:54. For this type of design the fishpass gradient is too steep and would produce high water velocities and high turbulence.

It is recommended that if a bypass channel design is used, the fishpass gradient be decreased to 1:100 to 1:200.

Fishpass Concepts

The PBHPP documents submitted to the PNPCA show that the fishpass is conceptual only and is at a very early stage of design; as such, further investigation of alternative concepts is required. Twin fish locks and a large pool-type have as much merit as the bypass channel presented. The navigation lock can also be utilised for fish passage with extra gates for fish to ensure the entrance was not located too far downstream. Examining the navigation lock for fish passage might also involve relocating the lock to the middle of the dam or on left bank next to the powerhouse; the fishpass could then be in the middle and could include a spillway entrance.

It is recommended that further investigation be done of alternative concepts for fish passage.

Summary

In summary, the developer needs to consider the following:

- Remove the electric fence from the design.
- Move the entrance to powerhouse;
- Add a collection gallery;
- Cut and shape a channel from the fishpass entrance to the thalweg of the river;
- Do physical modelling to ensure fish attraction;
- Do a hydraulic design of the exit. Five or more exits are likely to be required.
- Change 'U'-shape in upper channel to a larger area.
- Increase fishpass flow from 14.4 m^3/s in the PBHPP design to 188 to 500 m^3/s to meet industry standards.
- Decrease fishpass slope to 1:100 to 1:200 to provide suitable conditions for fish passage.
- Provide detailed design of the internal channel of fishpass so that its efficacy can be reviewed.
- Investigate alternative fish passage concepts.

Downstream migration

There are five potential downstream migration routes for fish - through the impounded reach, turbines (and debris screens), spillway, fishpass and navigation lock. However, there is no hydraulic cue for downstream-migrating fish to enter the fishpass or navigation lock, so fish will rarely use these two pathways.

impounded reach Passage

Many Mekong fish have drifting larvae adapted to flowing water; these larvae typically require a minimum mean velocity of 0.3 m/s to be maintained in the water column. In the upper Mekong River, this threshold may be higher. The impounded reach is a 97-km long, lake-like environment and will have very low water velocities (e.g. < 0.1 m/s), which will *almost certainly result in the loss of drifting larvae*. This impact will be highest in the dry season at low flows and less in the wet season at peak flows, but the extent is unknown for the PBHPP as no hydraulic modelling has been provided. In other similar large tropical rivers with large hydropower dams, migratory fish populations with drifting larvae have generally died out upstream of the dam.

The impact on drifting larvae can be minimised by lowering the impounded reach level to maintain higher water velocities, in the same way as the impounded reach is proposed to be operated to protect Keng Pha Dai for tourism.

It is recommended that the operating rules be reviewed based on hydraulic modelling[18]. This will require water levels to be reduced for periods of time and that would impact energy production. This means that a balance between the financial viability of the PBHPP, and the concession and power purchase agreements, fish passage (and hence ecological and socio-economic) impacts could be found.

Turbine Passage

Fish experience three impacts *passing through turbines*:

i) pressure impacts (barotrauma),
ii) shear and
iii) blade strike (including grinding on the edge of the blade and turbine housing).

The physical attributes of the turbines in the PBHPP are described in the documentation, but there are no data on these impacts, and how this might reduce downstream migration of fish. The FEEG is unaware of any turbines for dams, similar to the height and discharge of PBHPP, that would protect medium to large fish from blade strike. All large hydropower dams have debris screens in the turbine intakes to protect the turbines; these screens prevent large fish entering the turbines but fish are pinned on the screens and die due to high water velocities[19].

Screens can be specifically designed for fish, which have a high surface area, low water velocities (e.g. 0.3 m/s) and an acute angle to the flow path. These screens direct fish to a bypass flow around the turbines and are the only effective measure to prevent mortality of large fish from impingement at the debris screens.

Blade strike on smaller fish that pass through a screen can be minimised by having thick blades. In general, if the leading edge of the blade is as thick as the length of the fish, and the speed of the blade is low (e.g. 6 m/s), blade strike is minimal.

Pressure impacts on fish can be mitigated by locating the turbines much deeper than the tailwater, which is very likely to be deeper than shown in the plans of the PBHPP. Shear impacts can be minimised in design, but whether this is sufficient for fish is unknown.

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[18] This may also affect the sedimentation patterns in the reservoir, and those impacts could also be modelled.

[19] At the 2nd Meeting of the PNPCA JCWG on 4th April, Lao PDR indicated that the debris screens would prevent large fish entering the turbines. This is true, but these fish are pinned on the debris screens and have high mortality.

It is recommended that a fish screen be included to protect large fish, and the turbines be: i) located deeper to prevent pressure impacts; ii) have thick blades to minimise blade strike; and ii) designed with low shear.

Spillway Passage

The spillway will be used when river flows exceed the powerhouse flows of 5,771 m^3/s. These flows are likely to occur every year for short periods (days), but these are likely to be key periods of downstream migration of adult fish and larvae. Passage through the spillway can be safe for fish, but further Computational Fluid Dynamics (CFD) and physical modelling is required to make a final evaluation. However, the spillway uses undershot sluice gates. These have a high risk of injuring fish if they partly open, but there is little risk when fully open. Further operational detail is required to assess the use of the gates[20].

It is recommended that the spillway is operated to allow for a few gates fully open, rather than all the gates partly open, or that overshot gates are used.

Fish passage during construction

The issues with fish migration during the construction phase have largely been overlooked. Provision needs to be made to facilitate fish passage during the construction phase, especially because the fish migration, navigation, and other in-stream uses will be restricted at different stages of construction.

[20] At the 2nd Meeting of the PNPCA JCWG on 4th April, Lao PDR indicated that the spillway sluice gates would only be operated fully open. However, the PBHPP hydraulic modelling report indicates that the gates would be partially open up to 10,000 m^3/s. Further clarification is required.

4.6.4 Monitoring proposed by the developer

Fish ecology and fisheries monitoring

The main empirical information provided to determine any likely impact, and therefore formulate, mitigation measures are from basic field monitoring studies and market surveys conducted twice, once in the dry season (January 2011) and once in the wet season (July 2011). The reports provide little baseline information on which to make a comprehensive evaluation of the impacts and measures to mitigate any likely impact.

The developers also suggest they will take an "adaptive approach" to mitigation by conducting studies during the construction phase. Ongoing studies and ongoing improvements are essential aspects of project management, but this approach cannot be a surrogate for a detailed mitigation strategy, which is required to assess the impacts and evaluate the effectiveness of the proposed mitigation measures. This is because impacts are often not seen for many years after construction, especially considering that many large species in the Mekong are long-lived (>10 years) and iteroparous (do not die after spawning).

Further information on baseline conditions and migration behaviours could be provided. The studies need to be more specific to what is known in the region as well as what the transboundary effects are likely to be of loss of fisheries production areas in the upper reaches of the LMB and loss of spawning potential for migratory white fish species. The present documentation and data made available do not allow for a robust, comprehensive evaluation of the impacts of PBHPP or the proposed fish passage solutions.

Throughout the EIA and Environmental Management and Monitoring Plan Reports, there is no comprehensive monitoring programme for the fish population dynamics and migratory behaviours that can be used to optimise fish passage and power generation. This limits the capacity to design mitigation measures for fish passage and offer opportunities to compensate for potential lost fish production and social disruption. **It is recommended that a comprehensive and well-funded monitoring programme is established before and after dam construction to supplement the MRC and national fisheries agency knowledge databases.** This must include:

- Composition, biomass, seasonality, diel patterns of migratory fishes i) approaching the dam from upstream and downstream, ii) locating the fish passes, iii) ascending the fish passes, iv) leaving the fish pass and passing through the impoundment.
- Composition of the fish community: i) upstream of the proposed PBHPP, ii) within the proposed impounded reach, iii) downstream of the dam.
- Migratory behaviour and fate (telemetry studies of large fishes) of upstream and downstream migrating fishes.
- Comprehensive review and field monitoring of shifts in hydrology and geomorphological characteristics of the river upstream and downstream of dam during and after construction compared with the actual situation, including options for environmental flows.
- Transport and fate of larvae drifting into the low water velocity found in the impoundment and at the dam and turbines.
- Monitoring needs to be linked to performance indicators and standards, and linked to dam operation.

- The monitoring should cover all biota, including plants, which are equally relevant as many fish species eat algae.

The monitoring protocol needs to be targeted and account for daily and seasonal variability in ecological characteristics related to hydrological conditions, as well as establishing an early warning system to be proactive to respond to potential impacts of the development.

Fish Passage Monitoring

The documents for the PBHPP mention generic methods of fish passage assessment and an "observation room" within the fishpass, but there are no specific hypotheses or questions described and no indication of how the different methods would be applied or how much resources (staff and funds) would be allocated.

It is important to note that there are several specific questions that need to be addressed in the monitoring:

Downstream Passage:

- Q1. To what extent do larvae maintain drift in the impounded reach; and can the PBHPP be managed to optimise drift?
- Q2. What is the behaviour and survival of fish at the fish screen or debris screen in front of the turbines; and can the design be improved to enhance survival?
- Q2. What is the survival of eggs (if present), larvae (if present) and fish of different sizes and swim bladder morphology, as they pass through the turbines; and can the turbines be operated to enhance survival?
- Q3. What is the survival of fish as they pass through the spillway?

Upstream Passage

- Q4. What is the attraction efficiency of fishpass entrances?
- Q5. What is the passage efficiency of the fishpasses?

> The developer has indicated that the fisheries surveys will be carried out as part of the revised fish way design. This does not allow the PNPCA review to make any assessment and provide any contribution towards mitigating potential impact.
> In the design, it should be recognized that 100% fish passage through the spillway and turbines is unrealistic and unachievable. Although turbines are labelled 'fish friendly' considerable mortality is likely to occur. No provision is made for downstream drift of larvae through headpond/in-channel storage and turbines.

4.6.5 Alignment with the PDG

Overall, the PBHPP documentation falls short of expectation of compliance with the PDG.

The fish passage components of the projects are preliminary concepts, hence for almost all PDG components there is inadequate information to make an assessment. The concepts as presented would not provide effective upstream or downstream passage.

The fish passage facilities are highly superficial and (based on conversations with Ministry of Mines and Energy) are only indicative that a fish passage facility has been considered in the design (PDG

Paras 60-63). Consequently, there is no possibility of assessing whether the fish passage facilities will function as expected according to the PDG.

The planning and design of the fishways are thus not fully integrated into the dam design concept from the earliest stages of planning and relationship to downstream dams has not be explored (PDG Paras 64-65).

Weaknesses in the ecological appraisal of the fisheries around PBHPP preclude any assessment of whether the fish passage facilities will cater for the diversity of species that inhabit this region, the variability in timing of migration (all year round), the volume of fish that will utilise the fishpass facilities and accommodate both upstream and downstream (especially of juvenile life stages) (PDG Paras 66-71).

No information is provided on the hydrological and hydraulic conditions in and around the dam site and proposed fish passage facilities (PDG Paras 72-84). Although some modelling has been undertaken the outputs are not reported.

Information on monitoring and evaluation (PDG Paras 85-89) is superficial and needs a full specification to be provided and an indication that all information will be shared for external scrutiny. No adaptation programme is envisaged and no contingency funds indicated should adaptation of the fish passage facilities be required.

4.6.6 Other relevant issues

Section 4.7 addresses, *inter alia,* the socio-economic impacts of the reduced fisheries potential. The following contribution from the FEEG supplements that analysis.

The mitigation measures proposed to deal with reduced fisheries potential focus on management of fisheries production in the impounded reach by stocking and aquaculture, rather than other compensation mechanisms. The proposed measures are unlikely to compensate fully for the loss of fishery production, and will not necessarily be equitable. Aquaculture requires considerable capital investment and recurring costs (mostly for purchase of fish feed) to be sustainable. Most rural communities do not have the skills or capacity to invest, and only the more entrepreneurial people are likely to adopt these measures. Similarly, stocking is not considered an adequate solution because the impoundment will be shallow, has a short water retention time, and will be subject to 1-2 m daily water level fluctuations. This disrupts fish recruitment dynamics and food production in the impounded reach. Unfortunately, there is no definitive solution to mitigate the lost natural fish production and non-fisheries solutions must be found. If stocking of exotic or invasive fish species is conducted in this water impoundment, it would have significant negative impacts on natural fish stocks and aquatic ecosystems at the PBHHP site as well as downstream LMB.

4.7 Socio-Economic Impacts

4.7.1 Background

The social and economic review focused on the site-specific impacts and transboundary assessment of the Pak Beng Hydropower Project (PBHPP). The review was guided by the 1995 MRC agreement, which requires Member Countries make every effort to avoid, minimise and mitigate harmful effects on the Mekong River System. The review documented the process of establishing whether the social, environmental and transboundary information submitted for prior consultation by the Lao PDR

(LNMC) is sufficient to reliably support the MRC Joint Committee with their deliberations, and whether measures to further mitigate any potential impacts on the shared river system can be taken. The PBHPP documentation has been submitted by the Government of Lao PDR as a portfolio of Environmental, Social, Transboundary Cumulative and Specialist Impact Assessments combined with the respective Monitoring and Management Plans. The social and economic evaluation reviewed the following submitted documents:

- SIA: Social Impact Assessment;
- EIA: Environment Impact Assessment;
- TbESIA&CIA: Transboundary Environmental and Social Impact &Cumulative Impact Assessment;
- SMMP: Social Monitoring and Management Plan;
- EMMP: Environmental Monitoring and Management Plan; and the
- RAP: Resettlement Action Plan.

The social and economic review process combined an existing framework for the review of hydropower assessments for Lao PDR with the outputs from a scientific workshop that identified a comprehensive list of possible primary, secondary and tertiary impacts of hydropower in the Mekong. In addition, the review approach was presented to a stakeholder forum and feedback recorded to further refine the set of review questions. The social and economic review framework was designed and consolidated in four steps to suit the context of the PBHPP (and other Mekong mainstream dams).

These steps translated as a review framework comprised of a set of eight Review dimensions comprising 89 questions to systematically interrogate the transboundary socio-economic impact assessment of the PBHPP. The review dimensions were framed as a series of questions to investigate principles of design, data quality, stakeholder engagement, evidence for local and transboundary impact analysis and mitigation measures, opportunities for benefit sharing and the provision of non-technical summary.

For each of the following sections, the summary of the social and economic review of the PBHPP assessments are presented in bullet point format to assist the MRC Joint Committee in their deliberations.

4.7.2 Data used by the developer

The following concerns are noted with the data provided by the developer.

- The reported data sources are dated and informally or partially referenced.
- Upstream transboundary social and economic impacts on Thai households and communities are not adequately reported. The MRC Social Impact Monitoring and Vulnerability Assessment (SIMVA) 2011 and 2104 would be valuable reference sources.
- The PBHPP assessments acknowledge data limitations. Recent MRC data sets that resolve these limitations are accessible but have not been accessed nor referenced.
- The No Project scenario describes the status quo, not a projection of local and downstream livelihoods across the same time horizon as the other scenarios. There is no evidence reported to support the claim that livelihoods and the environment will continue to deteriorate under the No Build scenario.

- The surveying rationale and sampling regimes to assess impacts on material assets and water resource dependency are not detailed. The subsequent data and analysis for the villages is informally described and would not meet international standards for a project of this size.
- Details of current downstream land use and ownership are partially reported. The assessments rely on a 5km mainstream distance for 100 km from the PBHPP site for downstream assessments, in contrast to standard MRC SIMVA 15 km distance. The 100km distance corresponds to the estimated headwaters of the Xayaburi dam. Therefore, the numbers of people, assets and resources impacted are likely to be substantially underestimated.
- The TbESIA&CIA describes cultural attributes, ethnic diversity, demographics, generalized livelihoods at District level; public infrastructure, household income, health and nutritional status, access to services and income sources for selected zonal villages. The sampling rationale and subsequent data and analysis for the villages is not described and would not meet international standards for a project of this size. The characteristics reported for each Mekong zone are not consistent confounding rigorous comparisons.
- The assessment lacks Household level details on land ownership and specific livelihood activities, a critical aspect of fair, equitable and non-controversial resettlement compensation. This information can be derived from the MRC SIMVA 2011, 2014 surveys, although the analysis would need to address the differences in mainstream distance (i.e. 5km compared to 15 km).
- Data sources and dates are only partially reported. The attributes of vulnerable groups considered in the PBHPP assessments are not detailed.
- Consultations with a comprehensive list of National and local agencies to establish livelihood baselines are reported. The participants, number of meetings, whether these have occurred or remain as planned events are not reported.

4.7.3 Monitoring proposed by the developer

The developer has undertaken monitoring as outlined below;

- Social impacts in the PBHPP documents are classed by type, severity, duration and whether they are positive or negative. The TbESIA&CIA details a comprehensive list of the cumulative and transboundary effects for each of the five zones designated in the documentation, proposed mitigation strategies and the monitoring and assessment of residual effects.
- All the listed impacts including those listed as major are classed as having "no significant (residual) impact" if mitigation measures are implemented. The monitoring regimes proposed through time are not fully detailed. The designation of the magnitude of the impact and the effectiveness of proposed mitigation measures are not based on presented evidence. The assessment provides limited description of the process of classification of impact severity as minor or major and whether the classification corresponds with the claims and views of affected interests. For example, loss of land and housing (Loss of land, and Housing and resettlement need) are described as minor negative impacts and loss of existing infrastructure described as a positive impact.
- The Environmental Management and Monitoring Plan designates the Environmental Management Unit as the primary implementing and monitoring agency. The Unit's primary function is PBHPP site monitoring and ideally a similar monitoring unit would be established to monitor and report transboundary or cumulative impacts.
- The mitigation measures are inconsistently described. Sediment receives substantial attention and documentation as are impacts on fish and fish migration. There is no evidence presented how fish monitoring actually mitigates changes in fish migration. There is no empirically based evidence to support the claim that the fish ladder will be effective and that the bulb turbines will reduce levels of fish mortality. The review of the specialised fish mitigation and monitoring

assessment conducted by the Fisheries experts may reveal counterfactuals and arrive at an alternative conclusion.
- Uncertainty is mentioned in the sediment modelling sections and subsequent design and build recommendations: processes to manage social impact uncertainty and the efficacy of mitigation outcomes are not detailed. The monitoring of the resettlement programmes is described, but transboundary monitoring is lacking.
- The assessments describe a comprehensive list of recommended mitigation measures, including consultations with local, national, provincial and district stakeholders as well as downstream communities. The residual impacts are premised on implementation of the mitigation measures. However, there are no reported budget lines (except the RAP resettlement budget), timelines, required resources or processes described regarding field implementation and monitoring.
- Negative consequences of mitigation processes and measures are not reported
- Project level commitments do not take transboundary benefit-cost sharing into account and no funding has been specified for transboundary benefit-cost sharing arrangements.

4.7.4 Review of the proposals by the developer

The developer draws several conclusions with respect to the socio-economic impacts. This review notes that;

- The significance of impacts and how these conclusions have been derived, and on what evidential basis is not clearly explained. This is largely due a lack of detailed reporting on the expert panel approach, the lack of robust methodologies, inconsistencies in the submitted documents and the lack of evidence to support the key conclusions regarding eventual significance (and residual impacts).
- The TbESIA&CIA is stated to be preliminary and not the final assessment as the underpinning hydrological modelling had not been finalised at the point of writing the transboundary impact assessment.
- Residual impacts are a focus of the description of transboundary impacts. The assessment provides an inconsistent treatment of transboundary impacts. All residual impacts after mitigation are classed as no significant impact. Evidence and effectiveness criteria have not been detailed.
- Upstream transboundary impacts of the PBHPP focus on navigation (tourist, passenger and cargo vessels), and a partial fish survey at Chiang Saen. No Thai villages were surveyed to assess the current and future livelihood consequences of for example reduced fish catch.
- The definition of a future without the PBHPP, which could unfold into multiple scenarios given the uncertainty of other major projects has not been explicitly compared to the projection of a scenario with the PBHPP. The comparison would allow for an actual and accurate impact assessment. Unfortunately, these two critical steps have not been provided, at least not explicitly
- The downstream comparison of a future with the PBHPP and a future without the PBHPP is not reported.
- The qualitative methods, underlying assumptions and input data are only partially described.
- Impacts are classed according to type, severity and duration. The classification rationale and the process of ranking are not supported or explained with reported evidence.
- No worst-case scenarios have been reported, for example dam failure.
- The assessment states that the PBHPP will only have positive impacts on climate change by reducing CO_2 emissions. Methane emissions, are not mentioned despite the global debate about the link between reservoirs and methane emissions. Given that the reports provide inconclusive information about the proposed land clearing process this seems an important gap

- The assessment provides a quantitative assessment of sediment based on the hydrological modelling. Connected to this erosion is qualitatively discussed. Fish loss is discussed as the second large topic and qualitatively assessed. The assessment provides contradicting information as in some parts impacts on these topics are described as negative or major negative impacts while in other parts of the report the same impacts are assessed as of no significant impact. This seems partly due to the mitigation measures, although their effectiveness is not supported by any evidence.

4.7.5 Alignment with the PDG

The PDG does not provide any specifications for socio-economic impacts, and it assumes that these will be addressed by appropriate attention to the underlying causes of these impacts.

4.7.6 Other relevant issues

Impacts that have not been assessed

- The assessment of downstream livelihoods is most critical and has not been completed adequately. As a critical protein source, the change in fish catch and the efficacy of proposed mitigation efforts are especially crucial for downstream nutritional security. Considering that the transboundary social and economic assessment states the process was completed under time pressure and without the completion of the hydrological and sediment modelling, these parts of the assessment reports are draft submissions. The Joint Committee may determine i) whether to attach conditions to the final design stage, ii) whether to request an extension, or iii) whether to request that the assessments are resubmitted in the final design stage (or some combination of these).

Mitigation options that have not been considered

- Climate change related impacts based on vegetation in the area that would be inundated have been mentioned. But the mitigation is vague and contradicting. It is recommended that this is addressed.
- As mentioned above, the reports do not provide any evidence for the effectiveness of the proposed mitigation measures, particular for the mitigation of fish related impacts.
- Training programmes of local villages in new livelihoods or in an improvement of existing livelihoods to facilitate a sustainable transition.
- Participatory village planning with the affected communities is a critical process to improve the likelihood of successful resettlement and manage gender related problems.
- Implementing the fish nursery programme with international scientists and in coordination with other mainstream dams might reduce the impact on the fish population.
- The establishment of a fund for downstream compensation of effects that could not be mitigated would seem essential and could provide some important relief. Offset programmes to conserve critical wetlands and fish breeding habitats to address potential failures of fish passage ways are one example. The design of fund request processes and fund management could be designed in participation with international research Institutes and National Governments.

4.8 Navigation

4.8.1 Background

The following reference materials have been consulted in the preparation of the review of the navigation lock system;

- Preliminary Design Guidance for Mekong Mainstream Dams in the Lower Mekong Basin (PDG);
- An MRC study "*Review of International Ship Lock Dimensions and their Relevance to the Proposed Hydropower Developments on Mekong Mainstream dams*";
- PIANC[21] report: "*Final Report of the International Commission for the study of Locks*."
- PIANC report nr. 106-2008: "*Innovations in navigation lock design*"
- Various studies conducted by USACE engineers, amongst others the manual 1995: "*The manual for planning and design of navigation locks*", the "*Hydraulic Design of Navigation Locks*"-Engineering manual nr. 1110-1610 *(1975), "Planning and Design of Navigation Locks"*-Engineering *Manual nr. 1110-2602 (1995), the Dec*ember 2013 report of the USACE name*d: "Field Experience with lock culvert valves" and the* "*Repair and Replacement Guidance for Lock Culvert Valves*" and others (less relevan*t technical reports).*
  - *Documents and maintena*nce/repair *reports available on the internet.*

The harmful effects related to navigation mainly pertain to the slowing down of shipping due to unnecessary down time of the lock system for repairs. There may also be dangers posed to shipping from potential design flaws. Crew may also suffer some inconvenience while waiting to lock, especially if they need to moor overnight.

However, there may be positive effects related to easier and safer navigation along the impounded reach behind the dam, and the navigation lock design could make for safer mooring for crew to go ashore for provisioning purposes.

4.8.2 Review of the proposals by the developer

The main concern with respect to the design of the navigation lock, is the proposal for a single lift system. This system will, in the dry season, need to lift or lower shipping over more than 30m. The PDG notes that;

> *"The lockage, or raising and lowering operations, shall be performed in one or two consecutive steps, depending on the total maximum lift of the lock, using chambers designed and constructed for this purpose. The maximum head (difference between Highest Operating Level and Lowest Navigable Level or Lowest Operating Level if there is a backwater effect from a downstream development) of one chamber shall be 30m. Locations that require the ability* ***to traverse a height greater than 30 metres should use two locks in a series (tandem) arrangement****".*

While there are a few single lift lock systems lifting over 30m elsewhere in the world, most of them suffer problems associated with cavitation, noise, heavy vibration and damage to the valves and other infrastructure. The proposed lock system for the PBHPP appears to have been copied from the Yinpan

[21]PIANC = World Association for Waterborne Transport Infrastructure

lock on the Wujiang River in China. This lock has a lift of 36.46m, and model tests have been carried out on the segment valve for the filling of the lock chamber, located in a diversion tunnel. Substantial cavitation problems have been noted by several studies at the valve and the tunnel walls.

It is recommended that the single lift system is redesigned to a double lift system. This is not expected to result in substantially higher costs, particularly when compared to the costs of remedying possible cavitation damage.

The Government of Lao PDR has indicated that the navigation lock was designed on the basis that the Luang Prabang HPP dam will be built, and that as a consequence, the total maximum lift required is less than 30m.

Other design guidance that may be considered to *minimise* the potential down time for repairs is as follows – based on the current design[22];

1. Miter doors; 12.50 meters high on the upstream end, and some 37m on the downstream end[23], have been proposed for the single lift lock. The hydraulic jack required to operate the door wing is attached at the utmost top level of the wing gate. The highly eccentric jack-force needed to operate the gate will produce enormous torsion on the miter door structure. If an object gets lodged inside the door chamber, or in front of the sill, substantial torsion damage may occur, and repairs may take several months. High pressure water jets are therefore recommended to clear the miter gate chamber during opening and the sill during closing.
2. All grouting curtains must be double and extended to the banks or under the barrage, and down into the impermeable soil layer. Grouting is required at the downstream and upstream ends, and may not impede the future construction of a second lock system.
3. The vehicle access to the navigation lock system must be able to accommodate a heavy-duty crane. With the current design this appears to be via a tunnel. This tunnel must therefore be large and strait enough to accommodate such a crane. It is recommended that the bridge over the lock have an air clearance of 15.00m, which is typical of the main bridges over the Mekong.
4. A minimum two of the upstream guiding pontoons nearest the lock should be fixed in the X – Y direction, while being vertically guided for the water fluctuations that can occur. It is recommended to change the anchoring system for these two pontoons close to the lock head to a fix dolphin system that keeps the floating pontoons by rollers in their position.
5. The PIANC guidelines are recommended for approach walls and guiding walls, including the accommodation for waiting barges and overnight moored barges.
6. The locking system is currently designed to accommodate shipping up to 500 tons. However, projections for navigation at this point in the Lower Mekong River suggest that shipping up to 1,500 tons to 2,000 tons could be expected during the lifetime of the dam. Fortunately, the

[22]If the single lift system is redesigned as a double lift, then the developer may need to redesign the gate system, rendering some of the comments moot. It is nevertheless recommended that the revised design is resubmitted for comments.

[23]The proposed system for the downstream end is not clear from the drawings. From similarity with the Yinpan lock it is presumed that this gate is a single wing swinging door.

lock chamber dimensions can accommodate vessels and barges of 1,500 to 2,000 tons in accordance with the European ship classification. The designs of all navigation related infrastructure in- and outside the ship lock must keep this potential in mind.

7. The mooring systems in both the upstream and downstream direction could conform with the PIANC guidelines. Three mooring areas are considered in these guidelines;
   a. A lay-by area where ships prepare to enter the ship lock chamber.
   b. A waiting area where arriving ships and barges moor before moving up to the lay-by area. Depending on the density of the forecasted traffic, this area should be able to accommodate several ships and barges. This area is also used for disassembling barge convoys from the pusher; and
   c. Overnight mooring area where the ships may moor without expecting to be ship-locked. These berths may also be equipped with garbage collection facilities, water supply, waste water disposal facilities, external power supply, lighting, electrical power supply, etc. They may either be connected to the waiting area or a few hundred meters away from them, but they could have access to the shore for provisioning purposes. Many self-propelled barges nowadays have their own vehicle on deck that can be transferred to the shore (access road) with a derrick.
8. The upstream entrance to the lock is close to the discharge sluices. If these are operational there is a risk that shipping will be sucked towards the sluice gates. The proposal to extend the upstream approach channel by 114m under a wider angle is therefore recommended.
9. The entire downstream entrance could be redesigned to align with the navigation channel axis, and to provide increased visibility (now hampered by the steep slope on the right bank).
10. It is recommended that a portal crane, running over the two ship locks, be provided for safety and purposes, like rescuing people in distress, lifting floating or sunken obstacles from the lock chambers, removing and replacing the tainter valves in the culverts, etc.

4.8.3 Alignment with the PDG

The proposed navigation lock does not comply with the recommendations for a double lift lock for heads greater than 30m in the PDG. (If the eventual operating levels for the possible LBHPP do not reduce the overall lifting head).

4.8.4 Other relevant issues

The issues relevant to the navigation lock are all addressed in the preceding sections.

4.9 Dam Safety

4.9.1 Background

The Pak Beng hydropower project dam is a high hazard dam. Failure of the dam will place users of the river and river banks immediately downstream of the dam at severe risk. The results of dam break modelling and impact assessment have not been made available as part of this review but are understood to have been carried out.

During the consultation stage, the developer provided a basic dam break calculation and downstream impact assessment. The calculation only considered the impact at Luang Prabang and not in section of river between Luang Prabang and the dam. There are several villages along this stretch of river and the villagers regularly use the river for washing, fishing, travel etc. Also, the river is used by other boats including tourism. These people would all be at risk of losing their lives during a dam break. A more detailed assessment of the dam break and downstream impacts would have been expected as the Laos Electric Power Technical Standards require such assessment so that the design loads can be confirmed.

During the visit to the dam site on the 5th April 2017, it was obvious that there are many regular users of the river and its banks. These include fishermen (in boats and on the banks), tourist and passenger boats travelling up and down the river (large slow boats and small fast boats), and local villagers washing their clothes from the river banks. It is considered that at least 500 people could be at risk from the failure of the dam; this is without taking into account villages or towns close to the river banks.

Operation of the HPP will also create a safety hazard as the large natural flows that pass through the turbines and spillway can create dangerous river conditions, if not managed safely. These flows can create a greater risk than that of the dam break flood wave due to the greater frequency of large flow releases. At this stage, no information has been made available on which to assess the safety impacts of the scheme operation.

Failure of the dam will also cause hydropower generation to cease and prevent the power being exported to Thailand.

It is therefore important that the dam is designed to ensure that failure of the dam does not occur and that operational procedures are also put into place to ensure that operation of the flood gates does not increase the safety risk for people downstream.

4.9.2 Data used by the developer

- Hydrological data - The available hydrological data is discussed elsewhere by the hydrology review team. However, the developer needs to review the flood design criteria in relation to the consequence of failure of the dam.
- Seismic risk data – The Engineering Status Report contains some information relating to earthquakes and states that a site specific seismic hazard study has been carried out. This has not been made available and therefore it is not possible to comment on the quality of this data. However, published seismic hazard data for the Pak Beng site provided by reputable regional agencies include peak ground accelerations that are more than twice those provided by the developer. This difference needs to be reconciled.
- Geological/geotechnical data – A summary of the geological investigation data is included in the Engineering Status Report and the drawing provided. However, this does not provide sufficient detail on which to provide a comment on the adequacy of the data.
- Design criteria data – No structural design criteria was provided in the documents provided for review so the adequacy of the structural load cases cannot be commented on.

During the consultation stage the developer provided a short report summarising the stability analysis carried out. The report did not provide sufficient information on which to fully assess the applied loads, and has not been evaluated for this TRR.

4.9.3 Monitoring proposed by the developer

Dam safety monitoring is a key part of a dam safety management plan. The developer has indicated that they will prepare dam safety documents in accordance with the World Bank Operational Policy. At this stage only a basic outline has been provided on the structure of the dam safety plans. The drawings provided for review indicate the layout of the dam safety instrumentation that the developer intends to include in the completed structure. However, this is primarily monitoring the stability of the slopes above the dam abutments rather than the dam itself. Additional monitoring will be required to identify movement of the dam, changes in uplift pressures under the dam and scour at the downstream end of the waterways. This monitoring system could be designed to permit early identification of the initiation of potential failure modes.

4.9.4 Review of the proposals by the developer

The review of the dam safety aspects of the developer's Engineering Status Report has highlighted concerns relating to the flood and seismic criteria. In both cases the design criteria are considered to be inadequate when compared to national and international guidelines (eg the Laos Electric Power Technical Standards) and increases in the flood and seismic loading could be considered. This is likely to lead to an increase in the flood capacity of the spillway and strengthening of the structures.

The developer has not presented a detailed failure modes and dam break assessment to identify the impacts of a hypothetical failure of the dam. Whilst this is expected to confirm that the dam is a high consequence dam, it is an important assessment as it will also direct a safe design and assist in the preparation of emergency plans.

The appointment of an independent Panel of Experts to review the dam design is also considered to be an important requirement of the PDG. The developer has indicated that a panel will be appointed but has not indicated when this panel will be set up. It is important that the panel are completely independent of the developer and the panel are provided an opportunity to review the main design criteria before the detailed design is developed.

4.9.5 Alignment with the PDG

At this stage in the project, the developer is generally in alignment with the PDG, except for their lack of compliance with the standards described by the PDG such as the Laos Electric Power Technical Standards and the ICOLD Bulletins in terms of flood and seismic design criteria. It is recommended that the developer establishes an independent expert panel to guide the final design stages of the project.

4.9.6 Other relevant issues

All the issues relevant to dam safety are outlined above.

5 TRANSBOUNDARY IMPACTS

5.1 Introduction

The Pak Beng dam site is situated in a region that is undergoing rapid development. Upstream of Pak Beng, the Lancang Cascade in China regulates the flow and reduces the sediment load of the Mekong entering Lao PDR, and the upstream tributaries within Lao PDR are being developed for hydropower.

The tributaries entering upstream from Thailand are not developed for hydropower, but have been modified for irrigation use. Downstream of Pak Beng, the Nam Beng, Nam Suong, and Nam Khan have been / are being developed for hydropower, and several projects in the large Nam Ou hydropower cascade have been commissioned with others under development.

The mainstream dams at Xayaburi and Don Sahong are under construction, with estimated commissioning dates of 2019 for both projects. Additional hydropower developments have been implemented or are under construction in many of the Lao PDR tributaries downstream of Xayaburi, and in tributaries in the 3S system in Vietnam and Cambodia. These downstream projects also capture sediment and alter mainstream flows. This is especially true for some of the larger storage tributary projects that have the potential to substantially alter seasonal flow patterns. These developments will also impact on fish passage, and hence ultimately on the current socio-economic dependence on fish and other aquatic organisms.

Within this context, the operations and management of the Pak Beng HPP will be dependent on and need to respond to the management of the upstream cascade and tributary dams. Similarly, the management of flow and sediment at Pak Beng HP will interact with the managed outflows from the Nam Ou cascade and other downstream tributaries to determine the flow and sediment regime entering Xayaburi. With or without the Pak Beng project, flows and sediment transport will be highly regulated and modified upstream of Xayaburi.

The preceding chapter 4 provided a broad review of the developer's proposals to limit the impacts of the PBHPP on the Mekong River System, and hence the extent to which the proposed use aligns with the commitments the Member Countries made in Chapter III of the 1995 Mekong Agreement. This has flagged several issues that the developer could consider which would further reduce the potential impacts of the PBHPP. Many of these relate to detailed design parameters, or to improved input sediment and hydrology data, or which may reduce maintenance costs, or which improve the efficacy of the operations. These may in turn provide greater flexibility to the developer to optimise the design and operation of the HPP on cost, social and environmental issues.

However, the notified Countries are primarily concerned about those impacts that may be transboundary in nature. These impacts primarily include;

- Increased inundation upstream of the dam in Thailand due to backwater effects;
- Changes to flow regimes and hence ecological functioning further downstream;
- Reduced fish passage and hence reduced fisheries potential further downstream;
- Loss of rare species;
- Reduced sediment flows downstream and the associated loss of nutrients for floodplain areas, and loss of habitat;

- Impaired freedom of navigation due to excessive down time of the navigation locks for repairs, and;
- Dangers posed by dam failure.

Potential transboundary effects may arise from the PBHPP in isolation, as well as from the multiplicative impacts of the cascade of hydropower dams on the Mekong mainstream, both with respect to the Xayaburi and Don Sahong HPP which are already in place, as well as the full cascade of 11 dams. Herein lies considerable difficulty for this review process.

The developer has not fully assessed the potential transboundary impacts of the PBHPP in isolation, or of the full development of the LMB. They have nonetheless referred to the cumulative assessments that were undertaken in the MRC's Basin Development Plan.

It is recognised that a broader review of all possible developments in the LMB is somewhat beyond the remit of the developer. However, some assessment of the potential transboundary impacts of at least the PBHPP in isolation could be done. A wide body of research is publicly available through previous studies by the MRC, the Basin Development Plans, Initiative for Sustainable Hydropower (ISH0306), as well as the Council Study to support such an analysis, and this body of research has been used to support this section.

5.2 Transboundary impacts only due to the PBHPP

5.2.1 Changes to the flow regimes

Backwater effects into Thailand

Water levels will rise above the operating levels for several tens of kilometres due to backwater effects. To prevent permanent submerging of the Keng Pha Dai reefs at the Thai/Lao border, the developer has proposed managing the operating levels of the PBHPP between 350 m to 340 m. These operating rules are primarily based on a one-dimensional steady-state numerical model from Wuhan University, calibrated for a measured low-flow water-surface profile, but without verification based on actual measurements for higher discharges.

Although the proposed measure (lowering of operation level to 335 m) minimises the backwater effects, it does not eliminate the increased levels at Keng Pha Dai, or in the tributaries – the Nam Ing and Nam Ngao, and other areas along the Thai/Lao border during other flow conditions. The backwater seems to extend up to Houay Xai. In the long term (decades) the water levels in this backwater reach will rise further in response to the deltaic deposits of sand and gravel in the impounded reach. The figure below shows these backwater impacts for different flow conditions along the river. The water-level results in this figure are obtained from simulations with Delft3D modelling system for the ISH0306 study[24]. The difference between the dashed lines (natural situation without dam) and the solid lines (with PBHPP at operational level 340 m) is the resulting backwater impact

> The Government of Lao PDR has indicated that separate discussions are underway with Thailand regarding the backwater impacts of the PBHPP.

[24] MRC, 2016, ISH 0306 Study - Development of Guidelines for Hydropower Environmental Impact Mitigation and Risk Management in the Lower Mekong Mainstream and Tributaries. Volumes 1 to 5.

that is caused by the dam operation. The results in Figure 5.1 show that at flows of 2,200 m^3/s, the operation of the PBHPP at 340 m can result in a water level increase in the order of 2 m near Keng Pha Dai, and a gradually decline of this increase upstream towards Houay Xai. These increased backwater levels are not as marked at higher flows.

Figure 5.1 does not present the results of the operation of the PBHPP at 335 m, and there is insufficient information to assess whether the operational rules will effectively reduce flooding in Thailand, or whether any cropland or villages will be threatened, including in the tributaries. 2D models are considered to be more suitable for simulating the extent of inundated zones along the banks/flood plains during high flows in the reach affected by the backwater. This includes the lower areas of tributaries that will be affected by the backwater at their mouth. 2D modelling is also required to demonstrate what infrastructure or fields may be inundated.

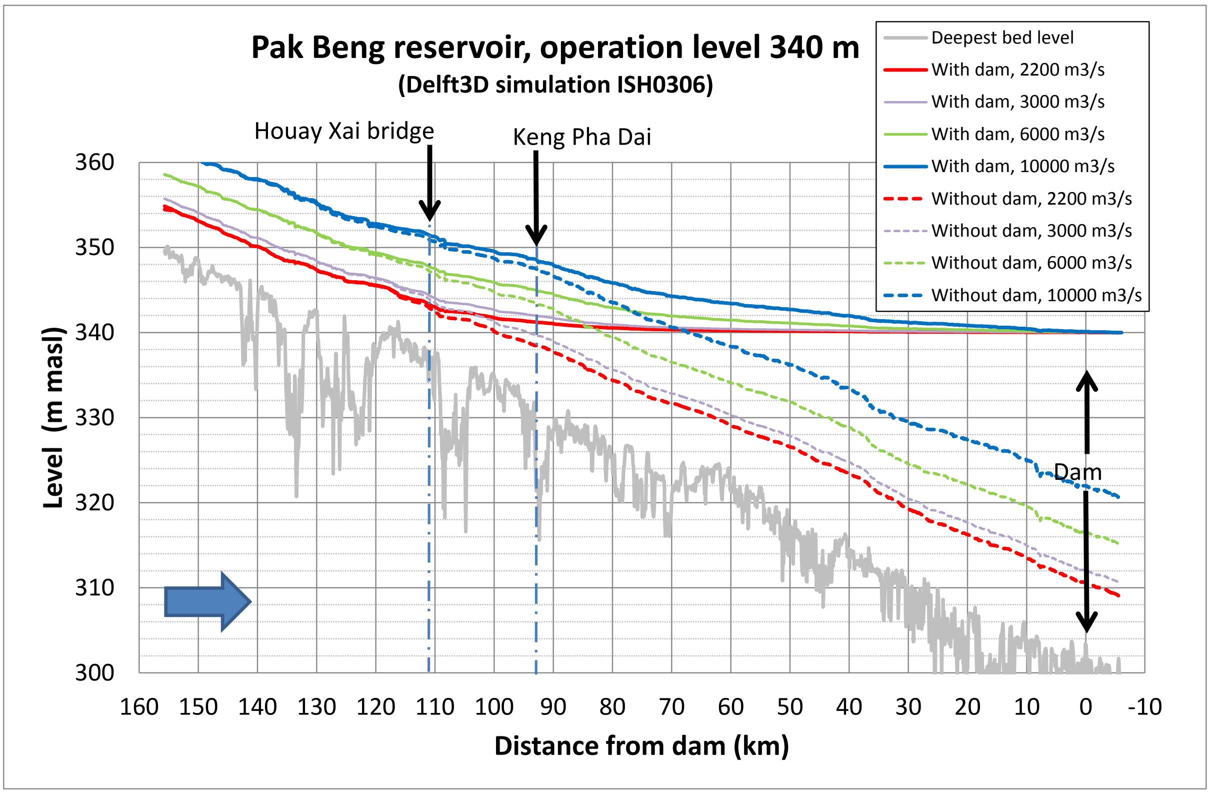


Figure 5.1 Computed water levels for different discharges, with and without the PBHPP, obtained from model runs in ISH0306 study of MRC (Delft3D model). The results in this figure are indicative.

As the Pak Beng is to be operated with only minor active storage, water level fluctuations in the downstream reach could remain within the bounds identified by the developer. Furthermore, constraints imposed to ramping (1m/day), will minimise rapid fluctuations in the downstream reach as much as possible. The downstream border with Thailand is roughly 450 km downstream of PBHPP. Since the remaining fluctuations through dam operation are dissipated quickly, and absorbed by the Xayaburi HPP, their remaining impact is not noticeable anymore after they have travelled over that distance of 450 km.

The operation of the PBHPP in isolation will not result noticeable in transboundary changes to the wet and dry season hydrology, over and above those caused by the operation of the dams in China. Neither will the initial wet season flood peaks be substantially reduced or delayed, over the changes that would occur due to the upstream dams. A reduction of 400 – 500 m^3/s may occur over 5 days, but this could potentially be further moderated if needed.

5.2.2 Changes in sediment, nutrient transport and geomorphology

Potential transboundary changes in the sediment dynamics of the LMB directly linked to Pak Beng include: (i) disruption to the transport of sand and coarser grained material (ii) an increase in sedimentation at the headwater of the impoundment that may increase sediment deposition and affect water levels in Thailand, and (iii) increased water level fluctuations that may affect Thailand, including tributaries.

The downstream 'starvation' of coarse material needs to be considered in the context of an ever-decreasing sediment supply. With or without the development of Pak Beng, the sand supply in the Mekong will decrease over the long term (years to decades) due to in the exhaustion of sediment available for transport in the mainstream channel downstream of the Chinese dams. The development of Pak Beng will increase the capture of the available bedload and course suspended sediment and reduce the quantity that is transported downstream. In effect, Pak Beng will hasten the long-term impact from the Chinese dams by preventing the sand located between Jianghong and the Pak Beng dam site from being transported downstream. The increased capture of sediment will reduce the quantity entering and potentially exiting the Xayaburi HPP. Xayaburi includes low-level sediment flushing gates and has the potential to pass coarse material downstream past the dam, however, if the sediment is permanently trapped upstream at Pak Beng this opportunity will be reduced.

The new long-term sediment equilibrium in the Mekong River, which will require decades to centuries to establish, will likely be similar with or without the Pak Beng project, but in the shorter term, downstream impacts will occur sooner than in its absence.

During periods when water levels are maintained at 340 masl, the headwater of the impounded reach will extend into Thailand. Although river levels are projected to remain similar to pre-dam conditions the flow velocity of the river will decrease as water enters the impoundment. The point at which this will occur will vary with water level and inflow. In areas where water velocities are reduced, there is a likelihood of increased sedimentation. Some of the sediment is likely to be re-mobilised as water levels decrease, but there is an increased risk of sediment accumulating the areas between 335 masl and 340masl. Deposition at the head of the Pak Beng impounded reach may infill the channel, leading to an increase in water levels relative to pre-dam conditions. Water levels associated with flood events could be higher if this occurs, increasing the risk of upstream flooding for a given flood volume.

Frequent water level fluctuations in the Pak Beng impounded reach have the potential to increase bank erosion through scour and seepage erosion processes and could increase erosion at the mouths of Thai tributaries entering the backwater of the impoundment during the flood period when water levels are maintained at 340 masl. An example of a tributary that may be affected is the Nam Ngao which has water levels in the flood season ranging from 339 to 343 masl.

5.2.3 Changes in water quality, aquatic ecology and fisheries potential

The PBHPP Transboundary report (PBHPP Report #19) provides analysis on how the scheme operation will modify flows downstream of the dam during the operational phase. The basic alterations given are from the BDP2 6-dam scenario (MRC 2010). The developers have not reviewed **the transboundary effects, especially the impacts in the productive floodplain reaches of Laos, Cambodia and the Delta.**

This is particularly important because significant effects are expected both in, and downstream of, the PBHPP that, if the scheme is treated in isolation, could impact on the ecological integrity and this will have considerable effect on the downstream ecology, biodiversity and fish productivity as described in the BDP2 (MRC 2010); (2) SEA MRC Strategic Environmental Assessment of hydropower on the Mekong mainstream (SEA, ICEM 2010) and MDS (Mekong Delta Study 2015).

The overall impact of PBHPP is to create a barrier to fish migration and modification of the riverine ecosystem into a lacustrine environment. This will result in flooding of riverine habitat and spawning and nursery habitats of fish, change in aquatic communities and food webs, and alteration of the food web and ecosystem functioning and potential loss other aquatic organisms on which many of the rural population depend. The fish community structure will inevitably change and productivity almost always declines, changing from large valuable riverine species to small still water species or a proliferation of alien invasive species such as carps or tilapia.

The problem that is faced in the mainstream Mekong is that the impoundments that are created upstream of many of the dams are not conducive to natural production of aquatic organisms, especially Mollusca and Crustacea, so there is the likelihood that yield from the modified river is heavily compromised and cannot be compensated by stocking, for example of prawn. The situation could be further exacerbated by accumulation of sediments in the impoundment that smoother gravel beds, key habitats for clean water species such as Ephemeroptera, Plecoptera and Trichoptera. Overall there could be loss of productivity and potential loss of long distance migratory species such as the Mekong giant catfish, which is on the IUCN endangered species list.

5.2.4 Risks of dam failure on other countries

It is understood that a dam break assessment has been carried out by the developer but this information has only recently been provided, and has not been reviewed. The results of this dam break modelling could be used to identify the impacts of a failure on the downstream areas. The extent of this impact is not expected to be transboundary nor the size of the flood wave sufficient to cause failure of the downstream dams. However, the documentation provided for prior consultation only included a simple dam break calculation and downstream impact assessment. This was basic in methodology and provided insufficient information on which to assess the impact on downstream dams and countries.

However, failure of the dam would prevent the power being exported to Thailand and other neighbouring countries and therefore the safety of the dam is considered to have a transboundary impact.

5.3 Cumulative transboundary impacts from all the hydropower development

5.3.1 Background

While this technical review, and the prior consultation process, must focus on the PBHPP, due diligence would require that the developer considers the likely impacts of future developments, both upstream and downstream, on the design and operations. Similarly, while the PBHPP may in isolation pose relatively small transboundary impact, it may amplify the impacts of future and existing developments. It will therefore be remiss of this TRR not to consider the cumulative impacts of all future planned developments.

5.3.2 Changed flow regimes

In the TBESIA & CIA report, the developer shows simulations for the cumulative impact on downstream flows considering the combination of dam cascades in Lancang, LMB, and tributaries (i.e. 2030 development scenario). This impact on downstream flows is mostly determined by the large storage reservoirs in the catchment, and the PBHPP has an insignificant influence on reduced and delayed flood peaks. The position of PBHPP as part of a larger collective of dams, opens opportunities for synchronization of operation of Pak Beng to the operation of the Chinese dams and the downstream dams in the cascade (joint operation). At the least, the PBHPP operations should provide improved warnings of changing flows in the mainstream for the downstream HPP, even in the absence of optimised operations with the Lancang cascade. Optimisation of both the hydropower output and reduced ecological impacts can also be done by looking at all the dams in the cascade.

5.3.3 Changed sediment dynamics and geomorphology

By the time the Pak Beng project is commissioned there will be at least 10 mainstream dams in the UMB and LMB, and most major tributaries will be regulated for hydropower and / or irrigation. The TBESIA provided in the PC documentation mentions a range of potential impacts, including transboundary sediment, morphology and nutrient changes leading to environmental impacts. The TBESIA states the impacts would affect the channel, floodplains, wetlands and seasonal lakes, the delta, the nearby coast of the sea, and the offshore sediment plume. No detailed information quantifying this assessment is provided.

Recent investigations by the MRC Initiative for Sustainable Hydropower included hydrodynamic and sediment modelling of the Lancang cascade, the tributary dams contained in the MRC BDP 2030 development scenario and the upper Lao PDR cascade. The input for the modelling was based on the recent MRC Discharge Sediment Monitoring Programme results. The modelling results for the final dam in the cascade, Sanakham (Figure 5.2) show a very large decrease in sediment supply associated with the Lancang cascade, consistent with the UMB being a major source of sediments to the LMB. Sediment trapping in tributary dams was projected to remove an additional ~10 million tonnes per year of sediment, resulting in a sediment load of approximately 21 million tonnes per year in the absence of the Lao cascade.

The northern Lao PDR cascade, consisting of five HPPs was projected to trap about 15 million of the 21 million tonnes per year (or over 70%). Following full implementation, the sediment load at Sanakham was reduced to about 6 million tonnes per year, or <10% of the natural sediment load. Coordinated sediment flushing and routing increased sediment discharge by about 30%, with the volume of sediment mobilised by flushing expected to increase over time as more material enters the cascade.

The modelling results also predicted a change in the composition of suspended sediments, with fine silt and clay readily passed through the impoundments, but fine sand and coarser material trapped (Figure 5.3).

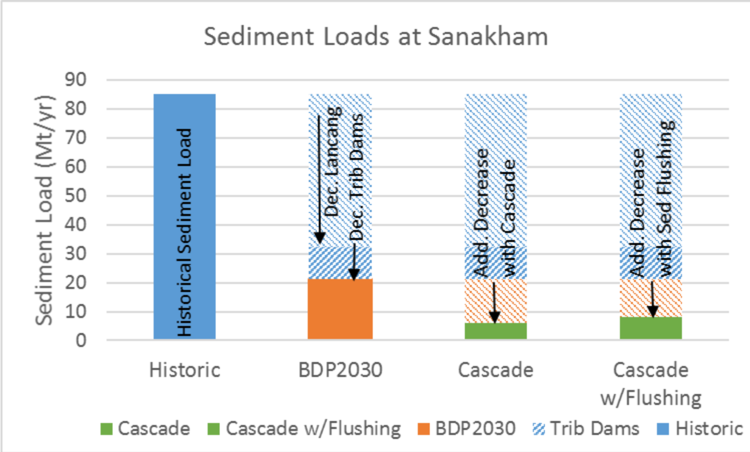
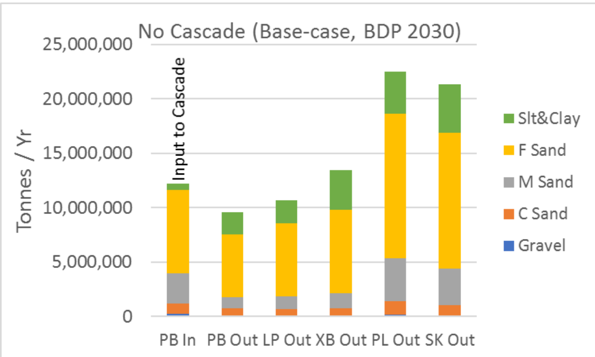


Figure 5.2. Modelled sediment loads at Sanakham after implementation of the Lancang cascade, the northern Lao PDR cascade and the tributary dams upstream of Sanakham contained in the MRC BDP 2030 development scenario. Note – the results showing flushing reflect only the first few years of operation, and flushing rates would increase as more sediment is accumulated in the reservoirs (if all dams had the capacity to rout sediments).

Downstream of the cascade, channel deepening occurred associated with the progression of an erosional wave downstream, with the 'wave' progressing approximately 100 km downstream in the first seven years, but the actual rate will be determined by the composition and quantity of sediment available for transport. This modelling exercise does not include other activities such as sand and gravel mining that can also affect sediment quantity and transport in the river.



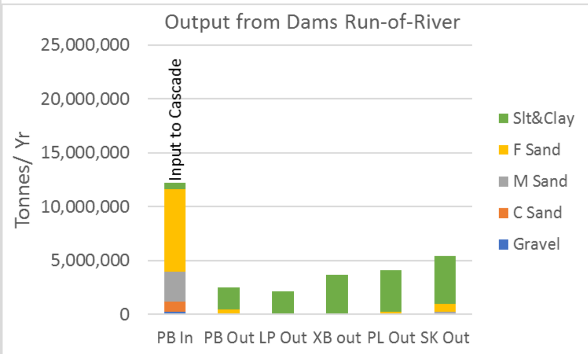


Figure 5.3. Comparison of the grain-size distribution of suspended sediment as Sanakham before (left) and after (right) implementation of the northern Lao PDR cascade. The No cascade base case includes the Lancang Cascade and the tributary dams I the BDP 2030 development scenario. Results from MRC Initiative for Sustainable Hydropower Case Study report (MRC 2016).

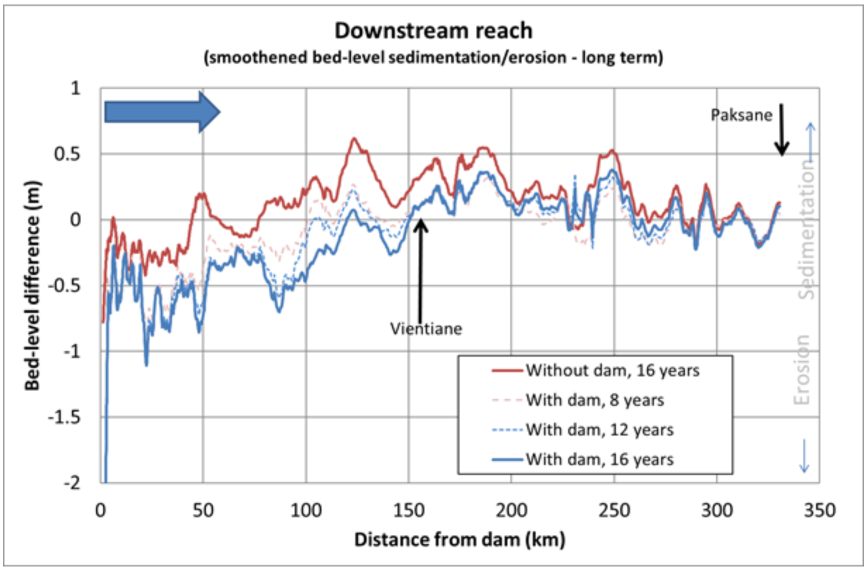


Figure 5.4. Geomorphic modelling of the river channel downstream of Sanakham following implementation of the Lancang Cascade, the tributary HPPs and the northern Lao PDR cascade. The red line indicates the depth of the river channel in the absence of any dams. The other lines show the decrease in bed level following 8, 12 and 16 years of HP operations.

As shown by these results, the cumulative transboundary impacts will include a reduction in sediment supply in the LMB, a change in the grain-size distribution of the sediment load and an increase in channel erosion downstream. Downstream transboundary impacts will be temporarily mitigated due to the presence of sediment in the river channel that can be transported by the 'hungry water' released from the dam. The final impacts will also depend on the degree of sediment retention in reservoirs on tributaries downstream of the cascade, the extent to which the tributary and mainstream dams are jointly operated to minimise downstream impacts, and other activities, such as sand and gravel mining.

5.3.4 Changed fisheries potential

Pak Beng is just one of 11 mainstream dams proposed or under construction in the LMB. In addition to 26 (40) new tributary dams are planned by 2015, and 56 (71) tributary dams by 2030. The impacts of each individual dam are likely to be similar to those outlined for the PBHPP, although the spatial scale and intensity of the impact will vary depending of the dam design and operation, and success of proposed mitigation measures. The key issues regarding the potential cumulative impact of multiple dam systems and their transboundary effects are as follows;

- Each dam will reduce the number of fish that can move further upstream. In addition, fish tire from continuous swimming up fish passes and the probability of bypassing several dams in series decreases with each successive dam. Substantial mortality is likely to occur through the turbines, even if the turbines are 'fish friendly'. The cumulative mortality rates through successive sets of turbines are likely to be considerable to the detriment of fish recruitment and production.
- Each impoundment will individually disrupt drift to replenish downstream fisheries. The scale of this disruption will depend on the hydraulic regime in the impoundments and downstream passage facilities.

- Studies have suggested that the cumulative barrier and passage effects of multiple mainstream hydropower dams on migratory fish populations in the Lower Mekong Basin would result in extirpation of populations.
- A cascade of dams modifies the riverine ecosystem into a series of lacustrine water bodies. This will result in flooding of spawning and nursery habitats and collapse of the traditional river stocks and fisheries. The fish community structure will inevitably change and productivity almost always declines, changing from large valuable riverine species to small still water species or a proliferation of alien invasive species such as common carps or tilapia.
- Impoundments created upstream of the many dams are not conducive to natural fish production so there is the likelihood that yield from the modified river is heavily compromised and cannot be compensated by stocking or aquaculture.

These effects are all multiplicative, not additive. In this context, it is critical the PBHPP EIA and Transboundary ESIA explore the impact of multiple dams on the hydrology and ecosystem function, with particular attention to the cumulative effects of the cascade of Chinese dams upstream and the construction and operation of Xayaburi downstream. Integration with the operation of Xayaburi is critical given its advance stage of construction, but more so that lessons that could be learnt from its design and operation that may be relevant to this scheme.

5.3.5 Optimised conjunctive management of the cascade

The sections on the cumulative impacts outlined above have highlighted the importance of considering and optimising the design and operations of all the proposed developments in the LMB for both hydropower production and to avoid, minimise and mitigate potential transboundary impacts. While the optimisation of the full cascade of dams is beyond the scope of the prior consultation process for the PBHPP, and beyond the mandate of the developer, some flexibility in the design and operations could be retained to accommodate future developments in this regard.

Of concern is the extent to which the developer has considered the possible completion of the Luang Prabang HPP. In places the developer appears to have considered the possible backwater effects from the Luang Prabang dam, for example with the placement of the fishpass entrance and the maximum head difference for the navigation lock. However, the extent to which the associated reduced hydropower output has been considered is not clear. This is important as any reduction in the energy output of the PBHPP may limit the opportunities to accommodate changes in operations to further minimise potential impacts.

6 COMMENTS, RECOMMENDATIONS AND WAY FORWARD

6.1 Background

This chapter highlights the broad conclusions of the review, and draws out some of the key findings of the review process as recommendations for the Joint Committee.

These recommendations include those that may place the developer in a better position to assess the potential impacts of the PBHPP, or to reduce operating costs (hence providing flexibility to consider operational rules that further minimise impacts); as well as those considered directly relevant to further reducing any potential transboundary impacts. It is suggested that the latter could be outlined as a set of measures in a statement concluding the prior consultation process.

6.2 General comments

The developer has made attempts to address the potential impacts of the PBHPP, and the provisions of the PDG, even at the feasibility stage, and interactions with the developer and the Government of the Lao PDR suggest that these efforts are ongoing and expanding. The documentation recently received from Lao PDR seems to indicate that some of the recommendations outlined in this section may already be being addressed.

In this regard, while there are certain advantages to notifying at the feasibility stage, this technical review has been hampered by the lack of detail in the documentation provided. The TRR notes where the review team has been made aware of these ongoing developments, no detailed review of these developments has been made as the details have not been provided in time. Moreover, to ensure that this current review process does not have to address a moving target, the focus has been on the initial documentation provided by the LNMC.

Discussions with the Government of the Lao PDR have also indicated that much of the design has assumed that the Luang Prabang HPP will be completed. This review has not been able to make that same assumption as it may be interpreted as agreement on the LPHPP and operating conditions before it has been made subject to prior consultation.

In this context, the PBHPP, if designed and operated as outlined in the documents submitted by the Lao PDR, will have some impact on fish passage, downstream sediment transport, and aquatic habitats. These will have knock on impacts on the people and economy of the LMB. Populations of the critically endangered Mekong Giant Catfish are likely to decline even further, and there is a considerable risk of extinction. Due to the interconnected nature of the shared ecosystem, some of these impacts are likely to be transboundary in nature, and are likely to be even more marked on top of the existing impacts from the Lancang Cascade, the tributary HPPs, Don Sahong HPP, and the Xayaburi HPP.

The single lock navigation system in its current design is likely to experience cavitation problems and hence excessive downtime for repairs, as the lifting head may be above 30 m at times. As outlined in the documentation provided, the proposed PBHPP only partly aligns with the guidance in the PDG.

The measures recommended in this TRR, if implemented, will go some way to minimising these impacts, and will further bring the PBHPP in line with the PDG. Measures to mitigate the residual impacts will partly address the impacts on the people and economy of the area. Many of the impacts are, however, unavoidable. Despite this, a functioning ecosystem will remain, albeit heavily modified, with the loss of key ecological goods and services. There will still be some capture fisheries, albeit at substantially reduced tonnages, and by extension loss of some endangered species.

The uncertainties that exist due to the wide range of other potential impacts on the system, including the impacts of the Lancang cascade, developments on the tributaries in all the Member Countries, as well as other changes like increased fishing pressures and climate change, makes determining clear cause-effect transboundary changes due to the PBHPP, impractical. Whether any potential impacts may rise to the level of substantial damage as contemplated in Article 7 is even more complex. Moreover, Articles 7 and 8 of the Mekong Agreement require that the *notified countries* must demonstrate such damage through proper and valid evidence. This TRR is therefore not able to make any recommendations with respect to these Articles, or whether the PBHPP reflects a reasonable and equitable use of the Mekong River System.

Moreover, these potential impacts need to be seen in the broader development context. The PBHPP, in isolation, will have a relatively small impact on the LMB ecology as a whole. Fish biomass and diversity (in the mainstream) is lower in these upper reaches of the Mekong mainstream. Much of the sediment from the upper basin will be trapped by the Lancang dams, and the PBHPP will not affect sediment loads from the downstream tributaries. Although the PBHPP will reduce the sediment loads mobilised by the sediment hungry waters downstream of the Lancang cascade, and as such will speed up the overall decline in downstream sediment loads.

Conversely, the potential benefits to the Lao PDR's economy through forex earnings and the associated development opportunities places that Government in a better position to provide improved services for all the people of Lao PDR. While these benefits will be restricted to the Lao PDR, benefits through increased trade opportunities may accrue to the other Member Countries, and Thailand benefits from the cheaper hydropower, and avoided environmental costs elsewhere. The key underlying question is therefore not whether the PBHPP will result in harmful effects, but whether all reasonable efforts have been made to avoid, minimise and mitigate those impacts.

Some of the measures proposed to minimise the impacts of the PBHPP may reduce the financial returns of the project. These measures are both capital and operational in nature. In particular, the recommendations to lower the operating level of the PBHPP could reduce the power output considerably. This will, however, not be a year-round requirement, and would not be needed at higher flows. The impacts of these operational measures on the longer-term power output must therefore be modelled based on the updated hydrology. Operating the impounded reach to maintain fish larvae in the water column and reduce sediment loss will, nonetheless, further minimise the impacts, and it is recommended that they are considered even if it means adjusting the provisions of the power purchase and / concession agreement(s). For these reasons, some of the recommendations pertain to placing the developer in a better position to optimise the balance between hydropower output and minimising potential impacts.

The developer has not paid attention to the lessons learnt and recommendations from the previous prior consultation processes, and in particular the ongoing process at Xayaburi. It is, nonetheless, accepted that many of the recommendations emerging from this TRR may have been taken up in any event in the final design stage, and the advantages and disadvantages of notifying at a feasibility level outlined in Section 1.5 are noted. However, this raises the question of the level of ongoing interaction required with the MRC if the project proceeds to final design, construction and operations, and more pertinently how that ongoing interaction will be funded. This is addressed in the following section.

As with the previous two prior consultation processes, the wealth of data and experience available at the MRC were not effectively used.

6.3 Recommendations

6.3.1 Background

This section addresses both those measures the developer and the notifying country may wish to consider to further limit the potential impacts of the PBHPP, whether transboundary in nature or not. All the recommendations, nonetheless, contribute to the commitment to make every effort to avoid, minimise and mitigate possible harmful effects. They also support improved input data for hydrology and sediment, to further optimise the operating rules for both hydropower output and reduced impacts. These recommendations are also intended to further build on the existing cooperation between the MRC Member Countries through sharing data and information.

6.3.2 Hydrology

Basic information underpinning the design and operation

- The flow data (notably ADCP profiles and water-level records) could be shared for further review and harmonization with the MRCS data;
- The synthesized daily discharges based on scaling could be compared with the actual measurements to verify the methodology;
- The developer could undertake a more detailed rainfall - runoff analysis on the Lao tributary catchments to assess the impact of the tributary inflows relative to the Chinese cascade. Sub-catchments that make significant contributions could be included in the automatic monitoring system. Similarly, the MRC's DSF rainfall-runoff tools could be employed;
- It is better to quantify the specific contributions from the upstream tributary hydropower in Lao PDR and the Lancang cascade in China, and the effect of climate change;
- Daily flow peaks could be assessed and used rather than the monthly averages in the final design stage. This was done for the Council, BDP and ISH0306 studies;
- The developer could consider the variability of flows for dry and wet years, and for passing floods in different parts of the season, and adapt he operation rule if necessary;
- Since only one method was proposed for design floods, it is recommended that other methods are investigated, or it is recommended to explain why the Log-Pearson III method has been selected over the other methods;
- The interpolation method for extension of the rating curve could be described more clearly so that a proper evaluation can be done on the accuracy of the higher flows;
- It is highly recommended to cross check values of design flood and security flood of Pak Beng with the values used for the design of Xayaburi Dam and for Chiang Saen and Luang Prabang floods as established and used by MRC;
- Due diligence will require that the developer considers the potential Luang Prabang HPP when assessing the operations and financial viability of the PBHPP; and
- The inconsistencies in values of active volume and turbine design discharge in the different reports, and the consequences of this on the design, need to be addressed.

Modelling

- The procedures used for the scaling in the physical model could be presented in more detail;
- The two-dimensional and three-dimensional model could be compared to the physical model outcomes to judge their value. In case of large differences, a proper assessment of accuracy could be provided (e.g. based on a scaling analysis for the physical model and a sensitivity analysis for the numerical models); and
- Validation documents for the used numerical tools could be made avaible to MCRS.

Dam design and proposed operations and mitigation

- A proper combination of gates opening and sand flushing gates could be addressed in more detail. The developer has not yet addressed how the flow through the sand sluices will influence the efficiency of the turbines. It is also important to address in more detail which frequency of opening of the sand sluices is expected;
- The developer could consider the hydraulics of the downstream shipping approach when addressing the recommendations of the navigation section;
- It is highly recommended to have the operational rules made available in a simple written form to support the dam operators;
- Clarification is needed on how the effect of reduced flood peaks from upstream dams will affect the operations for sediment sluicing (e.g., the occurrence of 'open discharge' and water-level lowering during flood conditions);
- It is recommended that the developer studies possibilities to improve the approach flow for the left turbines, for instance by removal of part of the slope in front of the turbines, and flow guidance. Similarly the outflow from the turbines could be improved by reconsidering the bank alignment. Furthermore, the operation of sand flushing gates could be tested and evaluated;
- Provide more clarification which approach can be used, and how this approach can be used to establish an appropriate environmental flow as alternative to the mentioned Q95 approach. The FEEG have suggested that the DRIFT model is used;
- Operating constraints need to include assessments of;
    - daily to weekly turbine operating ranges;
    - permissible water levels changes with respect to total water levels and ramping rates (PDG Para 170) ;
    - impact of flood flows on downstream river users;
    - minimum flow rates;
    - minimum number of navigation transits; and
    - fish bypass operating conditions (see the relevant Section).

Impacts

- The developer could cross-check or clarify the calculations for the PBHPP impact on the 2010 hydrograph as shown in the report [19] figure 129. The storage capacity of the project is far too small to explain such a large impact due to the PBHPP alone;
- The presentation of more details of the results for changes in water levels, surface profiles, flow patterns near the turbines and spillways (flow lines, tracers, etc.) would help to understand and evaluate the conclusions.

Monitoring

- It is recommended that the developer considers other international best practices in the development of the flow forecasting system. These could use both river flow and rainfall data and distributed rainfall-runoff modelling. There is potential to use the system to improve regional hydrological forecasting.

Minimising potential transboundary impacts

- Considering the relevance of the backwater issues into Thailand, it is recommended that the developer undertakes further studies of the inundation at the Keng Pha Dai reefs, including into the Thai tributaries.
- It is recommended that 2D modelling is undertaken to assess what croplands or villages in Thailand may be threatened under the range of operating rules, and different inflows in the tributaries, and that this is used to inform any discussions between Lao PDR and Thailand in this regard.
- It is recommended that this analysis has due regard for the effects increased deposition of sediment at the head of the impounded reach on backwater levels.

6.3.2 Sediment transport and river morphology

Basic information underpinning the design and operations

- The 'basic' sediment data (suspended sediment load, bedload, grain-size distribution, seasonality of transport) upon which the modelling and design are based are largely estimated and may not reflect the present sediment load at the site. Additional sediment monitoring is recommended to confirm the sediment loads and characteristics, and to update models where appropriate. It is also recommended that sediment data is compared to the MRC sediment monitoring results;
- Increased information about the geomorphic characteristics of the upstream and downstream river channel could be collected. This will enhance the ability to predict potential impacts associated with impoundment and power generation, such as susceptibility to scour erosion or seepage erosion;

Modelling

- It is recommended that the range of sediment models be reviewed and updated once additional site-specific sediment information is collected through monitoring; It is strongly recommended that systematic sediment monitoring be initiated as soon as possible to provide input information for the detailed design phase of the project, and provide the longest baseline possible prior to commencement of the project
- More detailed modelling of sediment deposition within the impoundment and sediment transport through the impoundment is warranted. It is recommended that multiple grain-size classes be incorporated in the models (gravel, coarse, medium and fine sand, silt and clay) to provide a better of understanding of sediment processes affected by the development;
- Additional modelling of channel changes downstream of the project is recommended. This is linked with the need for a greater understanding of the geomorphic characteristics of the downstream channel. It is recognised that Pak Beng *may* ultimately discharge into the backwater of the Luang Prabang HP, so understanding potential changes is warranted; and
- Sediment modelling including climate change scenarios is recommended.

Monitoring and coordination of operations

- Monitoring of sediment transport, including sediment concentrations, loads and grain-size distribution is recommended to commence as soon as possible at a frequency that provides information about inter and intra seasonal variability;

- It is recommended that sediment monitoring should include the development of methodologies to convert LISST data to sediment concentrations and loads, and to extrapolate point readings to cross-sectional averages.

Maximising sediment transport through the PBHPP

- Additional investigations into the incorporation of large low-level sediment flushing gates in the flood-sluicing part of the project are recommended. The present design aims to manage sediment to reduce impacts on infrastructure, but does not maximise the potential for passing sand and coarser sediment downstream on a seasonal or annual basis, as is recommended in the PDG. It is recommended that large low-level gates that could create near pre-dam hydraulic conditions at the dam site be investigated for inclusion in the project;
- It is recommended that the sediment management strategy is reviewed to ensure that sediment is passed downstream on a seasonal or annual basis, and not only when flow levels exceed 5,961 m^3s^{-1}. This may require a revision of the project's infrastructure to enable sediment routing as well as pressure flushing;
- It is recommended that greater consideration be given to how sediment management and operations in general at Pak Beng will be coordinated with other hydropower projects in the region to minimize environmental impacts and optimize power supply;
- It is recommended that an external engineering review of the infrastructure associated with the sediment management aspects of the project be completed. This review should include a review of the underlying numerical and physical sediment modelling results.

6.3.3 Water Quality and Aquatic Ecology

- A full EIA, based on in-depth studies, is needed before any decisions on impacts can be made – currently the PNPCA is scoping analysis. **To achieve this the developers should carry out a full literature review and make full use of MRC reports and data.**
- To understand the impact of PBHPP on water quality and aquatic ecology, it is necessary to carry out more detailed surveys to get data on water quality trends upstream and downstream of the dam site, including above the impounded reach, habitat mapping, floral and faunal species distribution and ecology using relevant methodologies, appropriate expertise and at appropriate frequency to account for seasonal variability.
- It is recommended that all activities/ programmes are worked out in detail, integrated in a planned schedule that is transparent and linked with the dam construction and operation so changes can be evaluated independently to ensure a robust sampling protocol that is fit for purpose. Designing the scope of a monitoring programme is outside the scope of the PNPCA, but the sampling programme should be shared with independent experts and the National Mekong Committees for approval.
- Relationships between impact of PBHPP and other dams in the upper Laos cascade requires full assessment, and lessons learnt from other dams being constructed, especially Xayaburi, needs integrating into this assessment.
- Assessment of long-distance transboundary impacts of modified flows and sediments on change in habitat, productivity and aquatic ecology is required.

6.3.4 Fisheries and fish passage

The PBHPP project is the second main-stem hydropower project on the Mekong River that occupies the full width of the river. Xayaburi HPP is downstream and includes the largest fish passage facilities in the Mekong Basin and South-East Asia; and includes many innovations. These innovations will be assessed by the hydropower company and there are very likely to be many findings that would make the Pak Beng fish passage more effective.

It is suggested that consideration be given to investing the funds allocated for fish passage at Pak Beng and not constructing the fish passage until there are results from monitoring of the Xayaburi HPP.

- Scenario 1 is re-designing fish passage at PBHPP, which has two possibilities: i) adopting all the recommendations provided in this review, which would result in more effective fish passage, but may require adjusting the concession agreement and/or price of the power to maintain the financial viability of the PBHPP, or ii) only adopting the recommendations that are not costly, which would result in ineffective fish passage.
- Scenario 2 is waiting for monitoring results of Xayaburi fish passage. Funds for Pak Beng fish passage would need to be set aside and invested (or accepted as a delayed cost in the IRR calculation[25]); the capital cost of fish passage at Xayaburi HPP would provide a guide to the funds required. This scenario has two potential outcomes: i) Xayaburi fish passage is effective, and the findings can be applied to Pak Beng, or ii) Xayaburi fish passage does not sustain migratory fish populations sufficiently, and a more effective use of the Pak Beng invested funds would be to mitigate impacts by offsets to enhance other aspects of the fishery, although it should be recognized critically endangered species will likely disappear from the system. A potential offset would be multiple low-level fish passage projects which are a proven technology.

Minimising the impacts on fish migration

- The recommendations for improved upstream and downstream passage made in Annex F could be considered to minimise the impacts on migratory fish species, and hence on the shared ecosystem. In particular:
  - Fish passage experts should be appointed to support the design process;
  - The upstream fish pass entrance should be moved to the powerhouse, and a collection gallery added;
  - The slope of the fish pass should be reduced, and the flow capacities increased in line with international standards, and to better align with the PDG;
  - The electric fish barrier should be removed;
  - Consideration should be given to changing the operating rules to maintain drifting fish larvae in the water column throughout the impounded reach;
  - The operation of the spillway gates should minimise fish mortality in the undershot gates; and
  - A fish screen should be installed to divert larger fish away from the turbines.
- The designs could be optimised through both physical and numerical modelling.

6.3.5 Fish Ecology

- It is recommended that fundamental gaps in knowledge about the ecology of the fish, status of the fisheries, in relation to upstream and downstream fish passage are undertaken by the developer and made available to the MRCS. This should include evidence to justify the assumptions made in the design of the fish bypass channels.
- There is limited information on the importance of the fishery to food security and rural livelihoods, number of people affected and loss of ecosystem services to rural communities.

[25] In the latter case, options to ringfence the funds will have to be explored.

There is a need for a detailed baseline study on the socio-economic impacts both in the immediate PBHPP reach and any trans-boundary areas likely to be impacted by the development. Full social and economic impact analysis of livelihoods of those dependent on the fisheries coupled with an alternative livelihoods analysis to identify options to compensate the fishing communities is required.

- Only basic information is given on monitoring the fish populations and management of fisheries during and after the construction phase. It is recommended a detailed monitoring programme is developed, which addresses knowledge gaps in fish biology that can improve dam and fishpass design and operation and assesses the impact of the dam on fish and fisheries, together with a response strategy for adverse impacts.
- The mitigation measures proposed are weak and more related to management of fisheries production in the impoundment rather than true mitigation and compensation mechanisms. It is strongly recommended that a comprehensive appraisal of measures to mitigate loss of fisheries and biodiversity, targeting both upstream and downstream fishing communities, together with realistic associated costs is carried out as a matter of urgency.
- The EIA and EMMP lack any assessment of the implications of multiple dams in the upper cascade proposed in Laos and the interrelationships between dams and the effects on flows, water quality and aquatic ecology, both in the local area and the longer transboundary effects. It is recommended the longer transboundary impacts on flows further down the Mekong are modelled in relation to the change in habitats and implications on aquatic ecology and fisheries.

6.3.6 Socio-economic studies

- The assessment provides limited evidence for the possible impacts on downstream and upstream communities before and after mitigation, which should form the basis for determining whether the proposed measures are adequate. It is acknowledged that the feasibility level assessment introduces substantial uncertainty in this regard. Nonetheless, the assessments at minimum need to address this uncertainty, particularly as the developer indicates that all impacts will be “not significant” after mitigation. It is recommended that the developer could either provide robust evidence for the effectiveness of the proposed mitigation measures, or acknowledge the uncertainty and adjust the assessment outcomes.
- The criteria used by the expert panel to determine the significance of identified impacts and the effectiveness of mitigation measures should be clearly stated and justified.
- Upstream transboundary impacts of the PBHPP should assess the potential consequences of the PBHPP on riparian Thai villages. Rigorous surveys could be conducted to assess the current and future livelihood consequences of, for example, reduced fish catch and remedial compensation actions if required.
- The assessment of the present impacts of the proposed PBHPP should be reviewed and compared to a future without the PBHPP. This is common practice in assessments, and is necessary to establish a cause-effect relationship with respect to any possible transboundary impacts. This should include assessments of the benefits of the PBHPP to the economy of the Lao PDR, and region.
- We strongly recommend updating the socio-economic data and updating the assessments to correspond with the current portfolio of Lao PDR legislation.
- It is recommended that socio-economic modelling be undertaken to assess the consequences of the potential impacts of the PBHPP on downstream livelihoods, food security, and migration.

6.3.6 Navigation

The design suggestions made in Annex I will *minimise* the risks of structural and navigation problems, which hold the potential to slow down or even stop navigation for extended periods, and should be considered in the final design stage. In addition, the suggestions for mooring areas could *mitigate* against the time lost waiting to enter the lock, and could be considered by the developer. However, the potential for cavitation damage is considered important, and following measures should be considered to bring the navigation lock system in line with the PDG in this regard

- The single-lift lock, as a double lift tandem-lock. This would accommodate either a situation where the Luang Prabang HPP does not proceed, or if it is operated at a lower level to minimise the reduced hydropower potential at the PBHPP at times.
- Alternatively, the developer may consider water saving basins in the design to minimise potential cavitation problems

6.3.7 Dam safety

A simple dam break calculation and downstream impact assessment has been carried out by the developer which was provided towards the end of the consultation process. This provided an insufficient level of detail on which to identify the impacts of a failure on the downstream areas. The extent of this impact is not expected to be transboundary nor the size of the flood wave sufficient to cause failure of the downstream dams. However, failure of the dam would prevent the power being exported to Thailand and other neighbouring countries and therefore the safety of the dam is considered to have a transboundary impact. The failure could also place the river users immediately downstream of the dam at risk of losing their lives. In accordance with the Laos Electric Power Standards this would make the Pak Beng a high hazard dam and the design loadings need to take this into account.

As required by the PDG the developer should set up an independent review panel to assess dam safety.

6.5 What happens after prior consultation?

The first Chapter of this Technical Review Report aimed to remind external stakeholders of some of the core principles behind the 1995 Mekong Agreement and the powers and functions conferred by the Member Countries on the MRC to conduct the prior consultation process. This last section of the TRR is presented in the same spirit, and aims to reassure the public that there is a process that continues after the initial 6-month process.

Article 5.4.3 of the Procedures for Notification, Prior Consultation and Agreement (PNPCA) indicates that;

> *"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 Xayaburi and Don Sahong Prior Consultation processes have highlighted that its success lies in a focus on agreeing a set of measures that avoid, minimise and mitigate any potential impacts, and not a 'yes' or 'no' on the proposed use itself[26]. The post-prior consultation process rests the implementation of these measures.

The Member Countries have through the 1995 Mekong Agreement agreed that the MRC Council can establish "Rules for Water Utilisation" (now the 5 Procedures). Council, by approving the PNPCA, has conferred the power to propose the measures as the end-point of prior consultation, on the Joint Committee. These measures have therefore been crafted as a "Statement" which was agreed by the JC on 19 June 2017. This has been published on the MRC website. This guides the ongoing design and operation of the PBHPP, as well as the development of a Joint Action Plan.

Importantly, while the whole prior consultation process is an action by the MRC through delegated powers, it does not prevent the Member Countries from negotiating and agreeing anything outside the prior consultation process, such as may occur with the backwater issues at Keng Pha Dai. Those negotiations may also address mutual benefits beyond the scope of the prior consultation process.

The formulation and wording of the measures therefore establishes the process after the end of the initial 6-month period, and should take the PBHPP through final design, construction and into the operational phases. This would also establish the water use under the Procedures for Water Use Monitoring (PWUM), and the ongoing monitoring process would fall under the ambit of those Procedures, as well as the Procedures for Data and Information Exchange and Sharing (PDIES). Alignment with the Procedures for Maintenance of Flow on the Mainstream (PMFM) and Procedures for Water Quality (PWQ) are part of the prior consultation process itself.

The rollout of these measures may be detailed in a Joint Action Plan endorsed by the JC. This Plan will provide the opportunity for the developer to share the details of the ongoing design, and how the measures have been taken up with the MRC and other stakeholders.

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[26] See the MRC's pamphlet on Procedures for Mekong Water Diplomacy available at: http://www.mrcmekong.org/assets/Publications/PNPCA-brochure-11th-design-final.pdf

Mekong River Commission
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