Mekong River Commission
For Sustainable Development

# Procedures for Notification, Prior Consultation, and Agreement (PNPCA)


# TECHNICAL REVIEW REPORT

*Prior Consultation for the Proposed Pak Lay Hydropower Project*

Prepared by Mekong River Commission Secretariat
15 March 2019

# PREFACE

The Technical Review Report (TRR) has been prepared by the MRC in support of the prior consultation process for the Pak Lay Hydropower project (PLHPP). It provides an assessment of the potential transboundary impacts of the proposed water use based on documentation provided by the Lao National Mekong Committee when the prior consultation process was initiated, as well as documentation and comments received after the submission of the first and second drafts from the Joint Committee Working Group (JCWG). It considers the responses provided on the second and third drafts from the developer, and the actions that have already been taken to address some of the recommendations made in these drafts.

It is submitted to the Special Session of the MRC Joint Committee to discuss the PLHPP to be held on 4th April 2019, in Vientiane, Lao PDR[1].

The following Annexes support this draft Technical Review Report, and form part of the Report:

- 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 PDG2009
- Annex C: Hydrology and Hydraulics Review Report
- Annex D: Sediment and Geomorphology Review Report
- Annex E: Water Quality and Aquatic Ecology Review Report
- Annex F: Fish Passage and Fish Ecology Review Report
- Annex G: Dam Safety Review Report
- Annex H: Navigation Review Report
- Annex I: Socio-Economics Review Report

[1] Based on the agreed PLHPP Roadmap, it is originally agreed that the Special Session of the JC on PLHPP Prior Consultation process be held on 29 March 2019. However, due to its constraint to join on 29 March 2019, at the 3rd JCWG Meeting on 22 February 2019, Thailand proposed that this Special Session of JC on PLHPP Prior Consultation process be held on 4 April 2019, and other MCs agreed.

# TABLE OF CONTENTS

## LIST OF FIGURES

# 1. BACKGROUND

## 1.1 Introduction

The Lao National Mekong Committee (LNMC) notified the Mekong River Commission (MRC) of their intention to submit the Pak Lay Hydropower Project (PLHPP) for prior consultation on 13 June 2018. The Secretariat then, *inter alia* started the mobilisation of resources to undertake the process, and the preparation of an Internal Scoping Assessment Report.

The documentation provided by the Lao NMC was sent to the MRC Member Countries on *12 July 2018*[2], and the Internal Scoping Assessment Report was sent on *23 July 2018*. The Joint Committee Working Group (JCWG) met on *8 August 2018* and agreed that the meeting would mark the formal start of the prior consultation process. The 1st draft of this TRR was discussed at the 2nd meeting of the JCWG, and the comments and feedback on that draft were used to prepare the 2nd draft of the TRR which formed the technical basis for regional and national stakeholder consultations. Additional documentation was submitted by the Lao PDR on 9 January 2019, in response to some of the issues raised in the 1st draft. This additional documentation has been considered in this final draft of the TRR.

The prior consultation process will run until 4 April 2019[3], when a Special Session of the MRC Joint Committee will meet to discuss this draft of the TRR. This is just over the six-month initial period after taking the public holidays into consideration.

As with the previous processes there is an expectation that the Pak Lay process will further improve on the previous 3 cases: Xayaburi, Don Sahong and Pak Beng. The Pak Beng prior consultation process focussed on the commitment in Article 7 in which the Parties agree to make every effort to avoid, minimise and mitigate potential transboundary harmful effects on the shared watercourse. That process, for the first time, introduced a Statement that was agreed by the Joint Committee, which called on the Government of Lao PDR to make every effort to implement the measures outlined in the final Technical Review Report (TRR).

The Statement has subsequently been followed up by a Joint Action Plan (JAP) which outlines a process of ongoing exchange of information and dialogue through the final design, construction and initial operational stages of the Pak Beng HPP. This was intended to give confidence to the notified Countries that the Statement was being implemented, that the developer and Lao PDR were drawing on the all the available expertise, and that the project implementation process was being monitored and reported on. This was not intended to slow the project implementation process, and its milestones would be dictated by the developer's timeframes for the final design and construction of the Pak Beng HPP. The development of the Pak Beng HPP has been suspended while the power purchaser undertakes further studies. During this period JAP is undergoing a final review and discussion with the Lao PDR.

Some stakeholders noted that the focus on Article 7 in the Pak Beng case was overly narrow. The Pak Lay process will consequently pay more attention to how the measures to avoid minimise and mitigate potential impacts are reflected in the Article 5 commitment to the reasonable and equitable use of the waters of the Mekong River System, as well as the Article 3 commitment to protect the

[2] All the documentation provided by the LNMC has been made available on the MRC Website at: http://www.mrcmekong.org/topics/pnpca-prior-consultation/pak-lay-hydropower-project/

[3] Based on the agreed PLHPP Roadmap, it is originally agreed that the Special Session of the JC on PLHPP Prior Consultation process be held on 29 March 2019. However, due to its constraint to join on 29 March 2019, at the 3rd JCWG Meeting on 22 February 2019, Thailand proposed that this Special Session of JC on PLHPP Prior Consultation process be held on 4 April 2019, and other MCs agreed.

environment and ecological balance. Similarly, it is hoped that the Pak Lay process can take a broader perspective on what may constitute '*every effort* to avoid, minimise and mitigate harmful effects' as outlined in Article 7. This may include measures associated with the Concession and the Power Purchase Agreements. It is also hoped that the Pak Lay process will place more emphasis on addressing cumulative impacts and coordinated management of mainstream hydropower projects. This first Section of the TRR provides the context for this broader perspective for the PLHPP prior consultation process.

## 1.2 The 1995 Mekong Agreement

The prior consultation process is governed by the Agreement on Cooperation for the Sustainable Development of the Mekong River Basin (the 1995 Mekong Agreement or 'the Agreement'[4]), and its associated Procedures. Some of the responses to the Pak Beng process from external stakeholders appeared to arise from their understanding of the 1995 Mekong Agreement and the powers afforded to the MRC by its Member Countries. A more comprehensive Handbook on Understanding the Mekong Agreement and the Procedures is being finalised, which will help interpret the Agreement, and the TRR for the Pak Beng HPP[5] similarly provides more context around prior consultation and the Agreement. This section of the TRR aims to clarify key issues around external stakeholders' perceptions of the role of the MRC in the prior consultation process.

### *1.2.1 Establishment and Powers and Functions*

The 1995 Mekong Agreement was signed by plenipotentiaries from Governments of Cambodia, Lao PDR, Thailand, and Viet Nam on 5 April 1995, thus committing these Countries to the provisions of the Agreement. The Agreement established the MRC's 3 standing bodies, the Council, the Joint Committee and the Secretariat, and conferred powers and functions on these bodies. These powers and functions are outlined in Chapter IV of the Agreement. The MRC's standing bodies ***can only*** act within these conferred powers.

The Council provides political oversight and ensures that the MRC remains true to the intention of the Agreement, and therefore agrees the Procedures. The Joint Committee (JC) is the technical and functional body of the Commission and agrees the Technical Guidelines that outline how to implement the Procedures. The JC is also mandated through Article 5 of the Agreement to implement the prior consultation process. The JC may establish sub-committees to support its functions and the prior consultation process is managed by the JC Working Group (JCWG) on the Procedures for Notification, Prior Consultation and Agreement (PNPCA). The Secretariat provides administrative and technical support to the JC. As such the MRC Secretariat has provided this technical evaluation of the documents submitted, for the JC to consider. However, the PNPCA Technical Guidelines indicate that the Secretariat should play a pro-active role in supporting prior consultation. It is in this light that this section of the TRR has been prepared.

The TRR is subject to the JC's Rules of Procedure and is ultimately adopted through consensus in the JC and based on the technical evaluation provided by the MRCS. The MRCS is not empowered to adopt any recommendations or amendments made by any one of the Member Countries but may provide comment on these for the JC's consideration.

In Chapter III of the Agreement the Member Countries agree to hold themselves to certain principles and objectives for cooperation. These include *specific commitments* to act in a certain way towards

---

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

[5] The Pak Beng TRR is available from: http://www.mrcmekong.org/topics/pnpca-prior-consultation/pak-beng-hydropower-project/

one another, for example in Article 5 to use the waters of the Mekong River System in a reasonable and equitable way subject to notification, prior consultation and agreement under different circumstances, and *general commitments* to act in a certain way within their own territories, for example the general commitment to make every effort to avoid, minimise and mitigate harmful effects in Article 7 and to protect the environment and ecological balance made in Article 3.

Importantly, the Agreement does not allow the MRC to *instruct* the Member Countries to comply to these commitments. The Commission can, however, highlight measures that will assist the Member Countries in fulfilling these commitments. For this reason, the Statement agreed by the JC at the end of the Pak Beng prior consultation period calls on the Government of Lao PDR to *make every effort* to implement the measures identified in the TRR and summarised in the Statement.

### *1.2.2 The definition of prior consultation*

Prior consultation is defined in the Agreement as follows:

> *"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."*

In this context, any *"agreement"* reached on any proposed use of water is derived by consensus in by the JC. Article 5.4.3 of the PNPCA indicates that:

> *"The MRC JC should **aim at** arriving at an agreement on the proposed use and issue a decision that contains agreed upon conditions."*

Because the JC's Rules of Procedure require that decisions are made by consensus, all the Member Country delegations must agree on some compromise position in the TRR. This differs from an unanimity rule where all the Member Country delegations must agree (or vote) on a given position[6]. In all three prior consultation processes to date this process did not amount to an agreement that the proposed HPP is a reasonable and equitable use of the Mekong River System. However, in the Pak Beng case the JC's Statement does urge the notifying Country to implement certain measures. These measures are akin to the "*conditions"* referred to in Article 5.4.3 and would reflect a fairer use of the shared watercourse.

However, the notified Countries may separately submit any concerns and reservations, which are also placed on record. These are contained in the notified Countries' Reply Forms. These Reply Forms are not subject to the JC's Rules of Procedure and *need not* align with any agreement made by the JC. While the TRR is adopted by consensus during the JC's special session on the conclusion of the prior consultation process, the Member Countries may therefore present dissenting options or raise concerns in their Reply Forms.

Neither the Agreement nor the PNPCA prohibit the Member Countries from negotiation outside of the MRC on any proposed use. The notifying Country may also submit a separate comment on the TRR. This has been done in the PLNPP case.

---

[6] Article 27 of the 1995 Mekong Agreement indicates that the JC should reach decisions by a unanimous vote or as otherwise provided for in its Rules of Procedure.

In this context, '*agreement*' in the PNPCA Article 5.4.3 need not be a 'yes' or 'no' decision on the proposed use, and indeed this is not easy to achieve in a 6-month timeframe, given the JC's Rules of Procedure require a negotiated consensus. The prior consultation process is therefore, *in practice*, largely a cooperative mechanism leading to a better project with fewer impacts. This is consistent with the definition of prior consultation as "… *neither a right to veto the use, nor a unilateral right to use water by any riparian without taking into consideration other riparians' rights."*

Importantly, however, prior consultation and any post-prior consultation process, must also be underpinned by the commitment to good faith cooperation included in Article 3 of the PNPCA. In this sense it must be more than an administrative process and must reflect a genuine desire by the notifying country to address the concerns of the notified countries' in an open and transparent manner, and the genuine recognition by the notified countries of the notifying country's rights to a reasonable and equitable share of benefits arising from the use of the Mekong River System.

### *1.2.3 Rights, Interests and Responsibilities*

All the Member Countries have a ***responsibility*** to take all reasonable measures to fulfil the commitments they made in Chapter III of the Agreement, whether these result in transboundary impacts or not. Conversely, all the Member Countries have a ***right*** to expect that the other Member Countries make every effort to respect these commitments. However, the Member Countries' rights also extent to their ***legitimate interests*** in using the waters of the Mekong River System to support their development. Reaching consensus on the most appropriate balance between these *rights*, *interests* and *responsibilities* lies at the heart of the prior consultation process, and is inherent in its definition in the Agreement, and in Articles 1 and 2 of the Agreement. The Statement that is issued at the end of the prior consultation process expresses this balance.

## 1.3 Principles Governing prior consultation

### *1.3.1 The Principles in the PNPCA*

The preamble to the PNPCA includes the following:

> *"Reconfirming the commitment to work together to address the protection of the environment and the ecological balance in the Mekong Basin, including the prevention of harmful effects and taking actions in emergency situations as covered by other Rules/Procedures approved by the MRC Council*."

This specifically draws the links between Articles 5 (Reasonable and equitable use – and the PNPCA), Article 3 (Protection of the environment and ecological balance), and Article 7 (Prevention and cessation of harmful effects), as well as the other Procedures. These provisions underpin the recommendations made in this Technical Review Report (TRR).

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

a. Sovereign equality and territorial integrity;
b. Reasonable and equitable utilisation;
c. Respect for rights and legitimate interests;
d. Good Faith; and
e. Transparency.

The aim of prior consultation is therefore ultimately to determine whether the proposed project is a reasonable and equitable use of the Mekong River System. In effect this must balance all the 'uses' of

the waters of the Mekong River System, and the impacts that arise from these uses in all the Member Countries. However, this is a nuanced concept and requires assessing a range of factors that may impinge on any of the Member Countries' use of the Mekong River System. Many of these factors may result from developments in the Basin that are not subject to prior consultation, or which may not

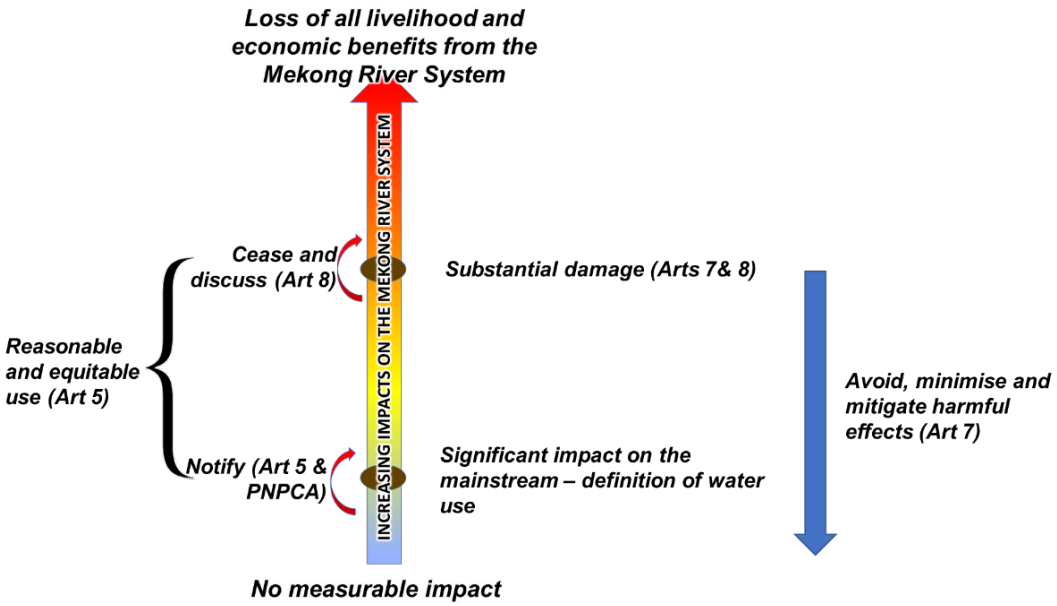



Figure 1.1. *The conceptual relationship between 'significant impact on the mainstream, harmful effects, substantial damage and reasonable and equitable use.*

have been considered in the Council Study. It would not be fair, for example, to find that a given use of the shared watercourse is not reasonable and equitable, while ignoring other impacts that may as, or more, significant. For all these reasons a final determination of whether the notified use is reasonable and equitable is difficult to agree within a six-month timeframe. However, a focus on identifying measures to avoid, minimise and mitigate harmful effects will result in a project that is better aligned with these principles, and this was hence the focus of the Pak Beng process.

For a proposed project to be defined as a "water use" it must have a *significant impact on the mainstream*. Member Countries have agreed to make every effort to avoid, minimise and mitigate *harmful effects (*Article 7), whether these impact on the mainstream or not.

Only when these harmful effects cause *substantial damage* as proven with valid evidence by the *affected* Countries must the host Country cease the activity. As such, there is no obligation in the Agreement to have no impact on the mainstream, but only to make any possible impacts as small as possible. The conceptual relationship between 'significant impact on the mainstream', 'harmful effects', 'substantial damage' and 'reasonable and equitable' use is illustrated in Figure 1.1.

However, these concepts must also be set against the general principle in international water law for Counties to take all rational measures to *prevent* causing significant transboundary harm. In this context "significant transboundary harm" may be analogous or even lower than the "substantial damage" referred to in Articles 7 and 8. Herein lies the complexity for prior consultation. While there is an expectation that project developers clearly identify transboundary harm, proof that this harm causes "substantial damage" and / or that the use is not considered reasonable and equitable must be set against all the impacts on the system, whether these have been subject to prior consultation or not. This is not a viable goal for a six-month consensus driven process. Moreover, Articles 7 and 8 refer to a Country-to-Country action and is therefore not part of the MRC's mandate.

For this reason, the prior consultation process must primarily focus on the commitment to avoid, minimise and mitigate harmful effects, but must also apply special effort to prevent transboundary significant harm. This is largely a process that will identify technically and economically viable infrastructural and operational measures that could be applied to the proposed use.

### 1.3.2 Not an impact assessment

The PC process is restricted to an initial 6-month process[7] and has limited resources. Studies that underpin a project of this size typically take place over several years and are costly. As such this TRR does not constitute an impact assessment or redesign of the project. The TRR is only an assessment of the documentation provided. It assesses the extent to which that documentation reflects the impacts expected from the MRC's long history of investigations on the Mekong Basin.

It assesses whether the design and studies are consistent with MRC and international guidelines for a project of this size and provides advice on due diligence in this regard[8]. The MRC Joint Committee makes recommendations for the Lao PDR to consider in its ongoing development of the project as it moves to the detailed design, construction and operational phase.

In this it recognises that the refinement of the PLHPP and the studies that underpin it are still under development.

### 1.3.3 Reasonable and equitable use

Reasonable and equitable use is a long-standing principle of international water law, and the factors that should be considered in this regard have been elaborated in detail over more than 4 decades and in several instruments of international water law. However, the Member Countries chose not to include these, or similar, factors in 1995 Mekong Agreement, agreeing in Article 5 to a more generic:

> *"… to utilise the waters of the Mekong River system in a reasonable and equitable manner in their respective territories, pursuant to all relevant factors and circumstances, the Rules for Water Utilization and Inter-Basin Diversion, and [notification, prior consultation and agreement]",*

The PNPCA derive from these "Rules" and were intended to promote reasonable and equitable use of the waters of the Mekong River System through cooperation and discussion. However, reasonable and equitable use concept has mostly evolved around sharing water. In this context, any use of water by one riparian may affect the other riparian Countries or the ecology simply because that water is no longer available for other users or to support ecological functioning. This applies in the upstream and downstream direction, as future use anywhere in the shared watercourse would affect the overall availability of water. It also means that any proposed use has some impact. This is inherent in the principle of the unity of the environment[9].

The transboundary concerns in the Lower Mekong Basin, in addition to water volumes, also include impacts on fisheries and reduced downstream sediment transport. The Procedures for the Maintenance of Flows (PMFM) on the mainstream to some extent accommodate existing and new downstream water abstractions and help manage high flows so that floods are not exacerbated by releases from storage. However, there are no similar provisions for sediment transport and fisheries

---

[7] While Article 5.5.2 allows the JC to extend the period of prior consultation, this has not been used in practice.

[8] *Due diligence* is an investigation of the potential investment to confirm all facts have been considered. It refers to the care a reasonable investor should take before making the investment.

[9] The principle of environmental unity holds that the air, the water, the land, people, fauna, flora, Earth's solar neighbourhood and all activities affect each and every other thing.

potential. This means that the impacts of tributary developments or other impacts on sediment availability, fisheries potential or ecological processes receive less attention. However, any assessment of reasonable and equitable use must still consider these impacts. The Council Study does include tributary impacts, and the results of these studies would have to be considered in any assessment of reasonable and equitable use.

None of the prior consultation processes to date have placed much emphasis on reasonable and equitable use largely because of these complexities. However, this section will explore the alignment between the Article 7 general commitment to avoid, minimise and mitigate harmful effects, and the factors underpinning reasonable and equitable use in other international water instruments. This is done to assist the Joint Committee should they wish to consider these aspects.

The factors underpinning reasonable and equitable use outlined in the UN Convention on the non-navigational uses of shared watercourses (the UN Watercourses Convention) can be summarised as follows:

- Physical or natural elements of the basin;
  - The ***length of the river*** lying in or on the border with the Member Country;
  - The ***area of the basin*** lying within the territory of the Member Country; and
  - The ***contributions made to the runoff*** by the Member Country.
- Social or human needs and economic dependency;
  - Existing and future ***Water demands*** exerted by the economy;
  - ***Population dependent*** on the shared waters;
  - ***Extent and History*** of that dependency;
  - ***Vital human needs***, the water required for basic human needs like drinking and sanitation; and
  - ***Environmental needs,*** the water required to maintain key ecological functions.

While only Viet Nam has ratified the UN Watercourses Convention, it is now regarded as customary international law and as such can be used to guide the JC's deliberations. Water courts and tribunals have generally favoured the social and human needs factors and the dependency on the use of the water when apportioning water between administrative entities. The potential loss of fisheries potential and reduced downstream transport of sediment, and the consequent socio-economic impacts have also generally been the focus of the prior consultation processes and the Council Study.

Here, it may be argued that each of the Member Countries is entitled to a reasonable and equitable share of the *'development space'* or the amount of development that would enable sustainable water abstractions, as well as *"sufficient*" downstream sediment transport, fisheries, and key ecosystem functions, particularly where there is a high dependency on these. This may, for example, be reflected in a reasonable and equitable 'use' of sediment or total fisheries potential, whether this is a direct or indirect use. As such, it may be argued that Lao PDR could use its "fair share" of the sediment and fisheries potential through hydropower development.

An assessment of reasonable and equitable use in this context would need to weigh up the national and regional economic and social benefits of hydropower development, with the cost of mitigation measures, and the lost economic and social benefits due to the reduced downstream sediment and associated nutrient transport and reduced fisheries. This should take the population that will be affected, the extent to which they would be affected (i.e. how dependent are the people on the lost benefits from fish and sediment), and lost ecological functions, into account. It should also incorporate other impacts on fisheries, sediment transport and nutrient loads, including those that are not subject to prior consultation.

This is the essence of a Transboundary Environmental and Social Impact Assessment (TbESIA). However, the TbESIA's for all the prior consultations to date have generally not provided sufficient details on transboundary socio-economic impacts to support an evaluation of reasonable and equitable use. However, providing this level of detail, without looking at the total sum of impacts from all the Member Countries, may place the developer in a position where they make themselves liable for compensation claims not necessarily associated with their particular project. Moreover, it would be difficult to provide this level of detail without being able to engage communities in the affected countries. These aspects are addressed further in the closing Chapters of this TRR.

Making every effort to avoid, minimise and mitigate any potential impacts is analogous to the UN Watercourses Convention's; "*Utilization of an international watercourse in an equitable and reasonable manner … taking into account all relevant factors and circumstances, including [inter alia]:*

> *"Conservation, protection, development and* ***economy of use*** *of the water resources of the watercourse and the costs of measures taken to that effect"*

Measures to avoid, minimise and mitigate potential impacts reflect a more economical use of the *'development space"*[10].

### 1.3.4 The role of the Concession and Power Purchase Agreements

In hydropower developments water flowing through the turbines generates power which is sold subject to a Power Purchase Agreement. The costs of designing, building and operating the HPP are recovered from the price of the electricity. These are the *"internal costs"* of power generation. These costs are recovered over a given timeframe, the "payback period". The payback period is shorter than the concession period, allowing the developer to make a profit on the investment. Thereafter the HPP is transferred to the host country. This is known as a Build–Operate–Transfer (BOT) arrangement, and this is central to Lao PDR's development model. A BOT has been put in place for the PLHPP. In the case of the PLHPP the planned payback period is 11.7 years. However, this may vary according to the power output and the interest rate charged on the loan financing. This arrangement makes hydropower development a viable option to support the planned Lao PDR development trajectory. Given Lao PDR's landlocked territory and limited mineral and other natural resources, this is one of the few ways the country can support its development, at least in the medium term.

The HPPs on the Mekong mainstream are run-of-river schemes with very little storage and little disruption to the annual flow regimes. There is, however, some impounded water behind the dam structure, and lower flow velocities in this stretch cause the coarse sediment and drifting fish larvae to settle out of the water column. Upstream and downstream fish migration will also be affected. These impacts will occur irrespective of the investments in sediment flushing and fish passage as no systems will be 100% effective. These make up *some of* the environmental, *or "external"*, costs of the HPP. HPP operators clearly wish to maximise their power output by pushing as much of the flow through the turbines as possible. This is done until the turbines reach their capacity, thereafter some the flow is diverted to the discharge gates, which can support sediment flushing operations and downstream fish migration. This continues until the total inflow gets too high and the turbines are shut down, and all the discharge gates are opened. When this happens, the operating levels decrease, and higher velocities are maintained throughout the impoundment and the river is closer to its natural condition[11]. These operations of the HPP, together with the efficacy of the upstream fish passage, largely determine the extent of the impacts of the HPP.
Because the Mekong mainstream flows are generally lower than the capacity of the turbines for most of the year, the opportunities to support larval drift and sediment transport are generally limited.

[10] This does not imply that if these measures are in place, that the use is reasonable and equitable.

[11] The specific operations of the PLHPP are addressed in Chapter 3, and elsewhere in this TRR

However, if the operating levels behind the HPP can be lowered before the turbines reach their capacity, higher flow velocities can be maintained in the impoundment, and larval drift maintained, and sediment transport improved. But this will reduce the total power output, increase the payback period and increase the costs of the loan financing. These challenges can be addressed by either increasing the Concession period, or increasing the price of the power, either uniformly, or just when operations are modified to address environmental issues. Some optimum between the environmental impacts, and economics of the HPP should therefore be explored and quantified using modelling. Monitoring regimes can be devised to optimise these operations on an adaptive management basis. This is explored further in Section 6.4 of this TRR.

Measures to adjust the price of the energy, or the concession agreement period as well as design changes are all part of making every effort to avoid, minimise and mitigate potential harmful effects (Article 7 of the Agreement). They 'internalise' some of the external environmental costs. The risks are that the payback period will get too long resulting in excessive interest charges, or that these measures would price the HPP out of the market. Nonetheless, the Lao PDR is encouraged to investigate the balance between maintaining the viability of the undertaking, while internalising some of the external environmental costs.

Increased interest charges will also result from delays to the ongoing project development process. It is therefore important that any post-prior consultation process that may be agreed aligns with the project development timelines.

## 1.4 Public participation

### *1.4.1 Background*

As with the previous prior consultation processes the MRC and the Member Countries have committed themselves to an open and transparent process. Taking lessons learnt from previous PNPCA process, actions have been taken to improve the public participation process for this project. This took several forms including building a better understanding of:

- Prior consultation as a cooperative rather than approval process;
- The powers and functions conferred on the MRC to support the prior consultation process, as well as the Rules of Procedure governing the Joint Committee;
- The role of stakeholder participation to guide and enrich the process, but not to direct it; and
- The limitations of prior consultation, but also the developing nature of the 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 took place at national and regional levels. National level engagements were conducted by the National Mekong Committees in each Member Country and were used to inform the Member Country's positions in the Joint Committee discussions. The outcomes of the national consultation processes were reported to the MRC via the NMCs and the comment matrices emerging from these engagements have been included in Annex A4. The Pak Lay process for the first time included support to the notifying country to undertake consultations and this has provided a more balanced perspective from external stakeholders.

The regional consultations are managed by the MRC and have informed the development of this Technical Review Report (TRR). The regional consultations are part of the MRC's Regional Stakeholder Forums. The outcomes of these processes are summarised below.

Stakeholders may also submit comments and feedback at any time through the MRC website at: http://www.mrcmekong.org/stakeholder-consultations.

### *1.4.2 Feedback from the 5th Regional Stakeholder Forum*

The 5th Regional Stakeholder Forum was held over 2 days, 20 and 21 September 2018. The first day was dedicated to presenting the Pak Lay HPP and seeking feedback on the Engineering and Environment and Socioeconomic aspects.

The Meeting was attended by 180 participants from private sector & consulting companies (25.5%), development partners (12.2%), University and Research Institutes (10.7%), NGOs (9.1%), Media (6.6%) and MRC Member Countries (27%). The discussion was focused on five technical aspects: hydrology & hydraulics, sediment transport, environment & fisheries, navigation, dam safety, and social economic issues. Questions have been raised regarding fish related issues and social economic impacts and dam safety. Like previous cases, stakeholders' concerns focussed on transboundary impacts, the operation of the cascade and standardized procedures for quality control during construction and operation of the dams. Several questions and comments referred to the progress and status of the Joint Action Plan for Pak Beng hydropower project and the Xayaburi design changes review as well as its linkage to the prior consultation process of the Pak Lay project.

The specific questions about Pak Lay HPP raised by the participants related to:

- Clarity they required with respect to the content of the documents submitted, as well as progress with the studies on the conjunctive operation of the cascade, and the ongoing Pak Beng process. These issues were addressed by the MRCS;
- The design process, and the ongoing improvements in the design that may follow the prior consultation process. Clarity on the design features of the PLHPP were provided where required;
- The use of 'unapproved' guidelines to evaluate the PLHPP;
- The method and process of the MRC's review of the documents. This addressed the use of the Chinese Standards, and how these were addressed. This included the compatibility of the Xayaburi HPP design and operations with those proposed for the PLHPP. (These aspects have been addressed in detail in this TRR); and
- The use of the Council Study results and the approval of the Council Study.

The questions and comments made at the meeting are recorded in the comment matrix and attached as Annex A4 of this Technical Review Report. The key outcomes of the stakeholder processes are reported on in more detail in a separate report.

## 1.5 The scope of the Review and end points

Any large project undergoes several phases, as illustrated in Figure 1.2.


Figure 1.2 *The conceptual phases of project implementation.*

Phasing in this way allows the developer to incrementally assess the viability of the proposed project before sinking additional resources into it and allows them to identify specific design requirements before finalising the design and assessing the bankability[12] of the proposed project. 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[13], preferably longer. The PNPCA notes that, ***in addition to a feasibility study report***, implementation plan, and development schedule; all available data required to evaluate the potential impact of the proposed use should be provided to support prior consultation. The list of documents provided by the LNMC are outlined in Annex A3.

The DG2018[14] recommends that notification is done between the feasibility and final design stages. This is because the notified countries are not able to determine the impact of the proposed use based only on a feasibility design. However, in the case of the PLHPP, Lao PDR has notified at the feasibility stage, which is consistent with the PNPCA requirements. These documents, as well as subsequent documentation received on 9 January 2019, and the discussions at a workshop with the developer on the 4th and 5th March 2019, were used as a basis for this TRR.

There are both advantages and disadvantages to notification at the feasibility stage:

- *Advantages*
  - Prior consultation takes place before the final design, and can directly influence the final design and operational plan for the PLHPP;
  - The Lao PDR and the developer can make an earlier decision on the viability of the proposed use based on the inputs from the MRC, before sinking additional resources into the project;
  - The prior consultation process supports the ongoing project development process, and allows earlier participation by the notified Countries in the impact assessments[15].

- *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 or make an evaluation of whether the proposed use is reasonable and equitable;
  - There may be insufficient information for the notified countries to assess the impacts on their use of the Mekong River System, and hence to formulate their replies;
  - The developer may already plan to implement many of the recommendations emerging from the TRR, and an unnecessarily negative impression of the proposed project may arise; and
  - Measures agreed by the JC may pertain to the final design and operations stages and may need to be made subject to review after the final design.

[12] Bankability = the ability of the project to attract loan financing. This may include its commitment to minimising environmental and social impacts.

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

[14] The DG2018 has not yet been approved by the JC, and the extract is used for information purposes only.

[15] The International Court of Justice has indicated that it is preferable for all the affected Countries to participate in the EIA of the proposed project. Notification at the feasibility stage allows for this.

The responses to the 2nd draft of the TRR as well as subsequent discussions have indicated that many of the initial recommendations are already being addressed and have indicated that many others will be addressed in the final design. Where the initial recommendations have been addressed, or where additional clarity has been provided, the recommendations have been removed from this version of the TRR so as not to create an overly negative impression. However, where discussions have only indicated the intention to address the issue, the recommendation has been retained, but explanatory text has been added.

Some of the disadvantages can be addressed through a 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. These discussions lead to better projects with potentially fewer impacts, and in the Xayaburi case Lao PDR and the developer have announced considerable additional investments to address the issues emerging from the prior consultation process.

In the Pak Beng case, a post prior consultation process has been formulated as a Joint Action Plan (JAP). This will track the implementation of the Pak Beng Statement across the final design, construction and initial operations phases. This JAP is currently being finalised. It is also anticipated that some of the measures agreed through the JAP process will be taken up as part of the PWUM and hence will be reported on annually (see section 6.5 for additional information in this regard). Similarly, a Joint Environmental Monitoring (JEM) programme will assess the efficacy of the measures applied at all the mainstream HPP's, potentially allowing for adaptive management to be applied to the operations.

A Statement on the PLHPP has been agreed by the JC, and a post prior consultation JAP will be prepared for discussion. The post prior consultation process is particularly important when notification takes place at the Feasibility Stage. This allows the notified countries to remain engaged, and demonstrates that their concerns have been identified, recorded, and are being addressed to the fullest extent possible. The ongoing exchange of information through the Final Design and Operations also helps increase the level of confidence the notified Countries have in the process, and this forms part of the cooperation continuum addressed in the following section.

## 1.6 Prior consultation as process of building confidence

"Water Diplomacy" has been defined as:

> *"an approach that diagnoses water problems, identifies intervention points, and proposes sustainable solutions that are sensitive to diverse viewpoints and values, ambiguity and uncertainty as well as changing and competing needs"*
>
> (https://waterdiplomacy.org/).

This is exactly what the prior consultation process and this TRR aims to do. The potential adverse impacts of the PLHPP have been identified, and measures to further avoid, minimise and mitigate these impacts, that are sensitive to the viewpoints of both the notified and notifying Countries have been proposed. The ambiguity and uncertainty are recognised and addressed through a combination of the precautionary principle and proposals for adaptive management to accommodate changes moving forward.

The PNPCA itself mirrors a cooperation continuum of cooperation as outlined in Figure 1.3.


Figure 1.3 *The conceptual continuum for the PNPCA, showing that each step builds confidence among all the riparian Countries that their concerns are being addressed. In this context it is important that prior consultation does more than just identify measures, but that real steps are taken to implement those measures and monitor their efficacy.*

Notification on the tributaries informs the other Member Countries of an intended use of the waters of the Mekong River System but provides little opportunity for engagement. This, together with the PMFM, allows the Member Countries to coordinate their use of the system to accommodate the proposed use. In the prior consultation process, the intention is to discuss potential adaptations to the proposed design to accommodate the notified Countries concerns, which gives them more confidence in the outcomes of the process. Under the provisions of the 'Agreement' process all the Member Countries must agree on the proposed development, which enables all the Member Countries ensure that any changes proposed in the process are accepted before the project commences. The PNPCA process therefore provides the notified countries with increasing confidence that their concerns are being addressed, and ultimately provides the basis for an unanimity agreement that the proposed use can proceed. Thus, prior consultation must give a greater voice to the notified countries, without rising to the level that their agreement is required.

This means that prior consultation must be more than just an administrative process and this gives further credence to the need for a post prior consultation JAP where the Member Countries can remain engaged in efforts to further reduce any adverse impacts and track their implementation and efficacy.

## 1.7 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;
f. A six-month timeframe was too short to undertake a comprehensive review, and more time was needed to 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. The Council Study, initiated after the Xayaburi process, specifically aims to provide more information on the potential impacts of the Mekong mainstream dams, and the results from this study have been used to inform this TRR.

The Pak Beng process was guided by the lessons learnt in the Xayaburi and Don Sahong cases and was perceived by all stakeholders as more successful. This is primarily related to improved engagement with external stakeholders, and the JC's agreement on the Statement. Nonetheless, there were still valuable lessons emerging from the Pak Beng process, which have been taken up in this TRR. These are:

- Notification was done at the feasibility stage and there was insufficient information for the notified Countries to provide an assessment on the impacts of the final PBHPP design and operations.
  - Because the development and design of the PBHPP was ongoing, prior consultation was trying to catch a moving train. Some of the concerns raised in the review were already being addressed, and that created an overly negative impression of the possible impacts. This concern will be addressed in the tone of this TRR.
  - Many of the documents provided were preliminary and were considered to inadequately address the potential for transboundary significant harm, and were not up to international standards, nor consistent with a project of this magnitude. This TRR makes specific recommendations for the improvement of the TbESIA and CIA processes.
  - Towards the end of the Pak Beng process some recently completed reports were made available, but this was done late in the process, and there was insufficient time to take these new findings into the TRR. This has been even more prevalent during the PLHPP prior consultation process and discussions with the developer continued into March 2019. While every effort has been made to fully incorporate these discussions into the TRR, there has been little time to fully address some of the most recent exchanges. It is recommended that this aspect is addressed in future prior consultation processes.
  - In this regard the potential for a small extension of the prior consultation process for Pak Beng was not explored to deliver a better and more balanced outcome.

- The greater focus on identifying additional measures to avoid, minimise and mitigate harm provided the opportunity for the Statement.
  - The focus on Article 7 of the 1995 Mekong Agreement, rather than on a go / no go agreement largely allowed the development of the Statement concluding the process. This in turn allowed for a post-prior consultation process that is considered to be critical to achieving the objectives of prior consultation.
  - There is however still a need to focus discussion on the whole 1995 Mekong Agreement, and the intentions of the Parties in signing it. This TRR is addressing these aspects as highlighted in the preceding sections.

- As with the previous PC processes, external stakeholders still had a limited understanding the MRC's mandate with respect to prior consultation, and the implications of the JC's Rules of Procedure on reaching agreement.
  - Some stakeholders indicated that, in their opinion, the focus on Article 7 of the Agreement was an overly narrow interpretation of the requirements for prior consultation. As outlined above, this interpretation has been expanded to include the relationship with the reasonable and equitable principle in this TRR. Nonetheless, a full discussion of the principle of reasonable and equitable use still remains elusive.

- This TRR also includes text aimed at building a better understanding of the MRC's mandate and the constraints on prior consultation.

- **The inclusion of a post prior consultation process provided the opportunity for ongoing engagement towards refining any measures identified. But this was not recognised at the start of the prior consultation process.**
  - Recognising that there is likely to be a post prior consultation process creates the freedom for this TRR to propose measures that would require further studies to verify their viability.
  - However, the full benefits of a post-prior consultation process for all the Member Countries, and particularly the notifying Country need to be explored further.

- **There seemed to be an expectation that the MRC should fill knowledge gaps.**
  - The requirement for notification is that all *available* data and information should be provided. Notifying at a feasibility stage means that further data and information may still emerge.
  - However, this provides the opportunity for this TRR to propose additional monitoring and studies, for the developer to fill these gaps.
  - As with the Pak Beng process, many stakeholders still expected the MRC to fill some of the knowledge gaps as part of the prior consultation process. In the Pak Lay case, the recently completed Council Study has provided useful context. However, how the outcomes of the Council Study can be used to support the prior consultation process needs to be explored further.

- **There was limited attention to the cumulative impacts and conjunctive operations of the mainstream cascade**;
  - The PLHPP lies just downstream of the Xayaburi HPP which will be placed into operation soon. Much of the flow into the PLHPP will derive from releases from Xayaburi. This provides a greater opportunity to explore the potential for conjunctive operations between the two HPPs, and to align their infrastructure and operations to ensure compatibility.

The update of the PDG2009 in the DG2018 has shifted the focus of the advice offered from supporting the design of individual HPP's to a more transboundary focus. However, as the DG2018 has not been formally endorsed by the MRC structures, it is only used here to the extent that it reflects good practice which is recommended for the PLHPP, and not to 'evaluate' the design.

## 1.8 Key considerations

The following considerations are relevant to the interpretation of this TRR:

- The PLHPP prior consultation process links measures identified to avoid, minimise and mitigate impacts to the commitment to the *reasonable and equitable* use of the Mekong River System- highlighting that these measures make the HPP more reasonable and equitable than it may be without the measures;
- However, the determination of whether any proposed use is *reasonable and equitable* is nuanced and a socio-political construct. It is beyond the scope of a technical review process. This TRR, nonetheless, provides considerations in this regard, should the Joint Committee wish to explore this aspect;
- 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 the recommendations in this TRR;

- The PLHPP prior consultation process includes the expansion of the concept of *'every effort'* in this context to include investigations into the viability of internalising the some of the external environmental costs through the Power Purchase and Concession Agreements;
- The process takes greater cognisance of a potential post-prior consultation process and involvement of the MRC in supporting the ongoing design, construction and monitoring of the PLHPP. Recommendations for measures and monitoring have been made with this in mind;
- Because the documentation provided is at a feasibility level, measures have been proposed for the Final Design, Construction and Operational phases should the project proceed;
- Greater emphasis has been placed on building an understanding of the mandates conferred by the Member Countries, and the limitations of prior consultation; and
- Different perspectives are highlighted for discussion and consensus in the JC.

# 2 THE PAK LAY PRIOR CONSULTATION PROCESS

## 2.1 Background

The Mekong River Commission (MRC) Secretariat received notification from the National Mekong Committee of the Lao PDR, of their intention to submit the Pak Lay Hydropower Project (PLHPP) for prior consultation, on 13 June 2018. The Secretariat then started preparations for the prior consultation process, through *inter alia* the mobilisation of resources to undertake the process, and the preparation of the Internal Scoping Assessment 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, and as provided for in the PNPCA, the MRC Secretariat appointed several expert groups, made up of Secretariat, national and international experts, to provide independent specialist evaluations of any potential impacts associated with the PLHPP. In addition, national experts have also been engaged to support the Member Countries in reviewing the submitted documents and the drafts of the TRR and to help facilitating national meetings. The intention was to involve the national experts to a greater extent than in the preceding 3 processes. Participation by the Secretariat and international experts as well as national experts is outlined in Annex A2.

The documentation provided by the Lao NMC was sent to the MRC Member Countries on 12 July 2018, and the Internal Scoping Assessment Report was sent on 23 July 2018. The Joint Committee Working Group (JCWG) met on 8 August 2018 and agreed that the meeting would mark the formal start of the prior consultation process. The process ran until 4th April 2019 when a Special Session of the MRC Joint Committee met with the aim of making a decision in terms of Article 5.4.3 of the PNPCA.

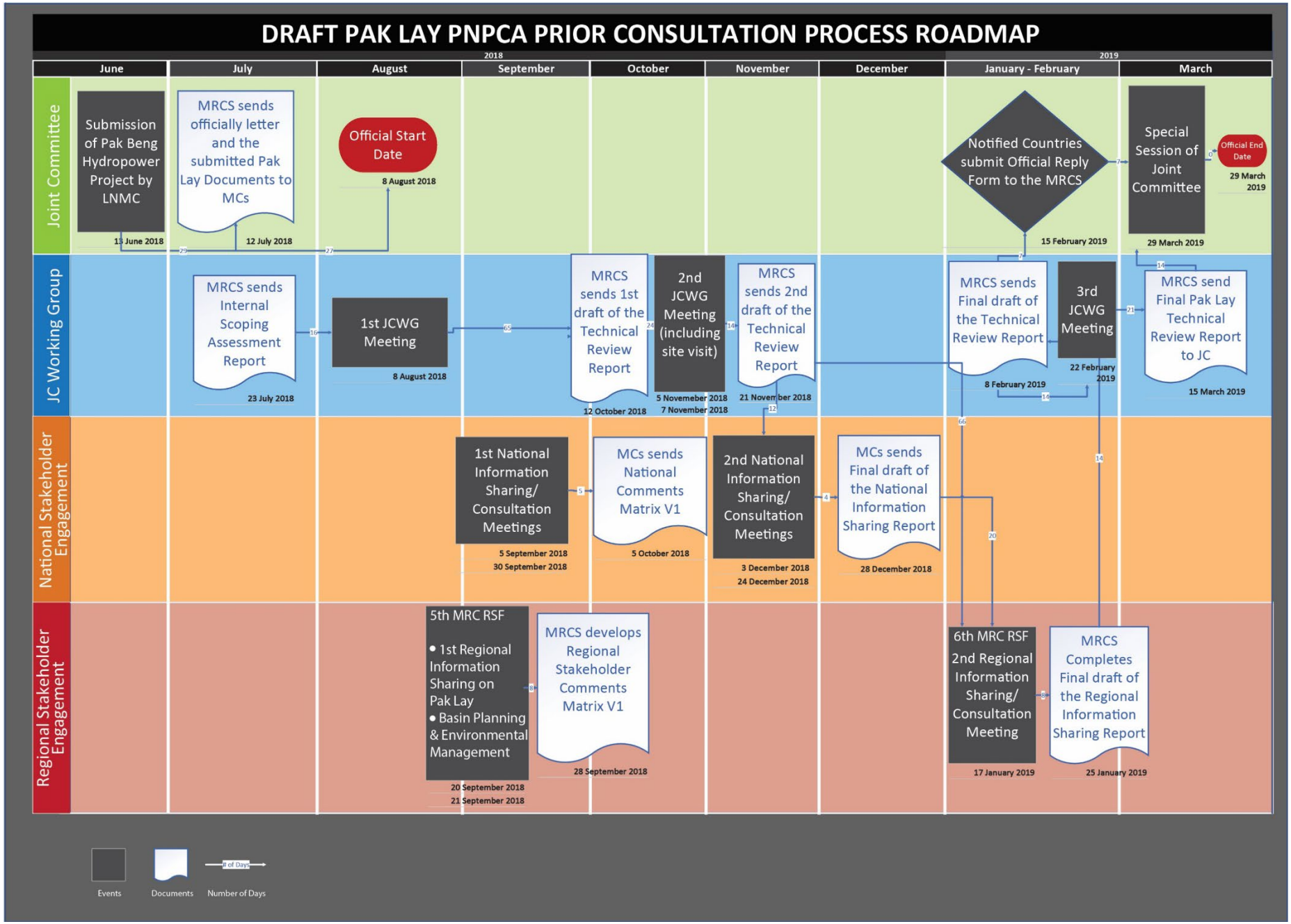
The 2nd meeting of the JCWG was conducted on 5 November 2018, where the first draft of the TRR was tabled and discussed. A second draft of the TRR was prepared based on comments and recommendations from that meeting and to be sent to the member Countries on 03 December 2018. The Lao NMC submitted further documentation on 9 January 2019 in response to some of the initial recommendations made. The 2nd draft also formed the basis for a final round of stakeholder consultations on 17 January 2019, and the feedback from those consultations as well as comments from the developer were taken up in draft V 3.0 which was submitted to the JCWG meeting of 22 February 2019. The feedback from that meeting, as well as the results of a workshop between the MRCS and the developer on the 4th and 5th March 2019 have contributed to the formulation of this final draft of the TRR. The Statement made by the Lao PDR delegation at the final meeting of the JCWG has also been taken into account.

However, while the active and ongoing discussions are consistent with the principle of good faith cooperation espoused in the PNPCA, it has meant that this TRR has tried to hit a moving target. Many of the recommendations made in the earlier drafts based on the initial documents submitted have subsequently been addressed, for others the intent of the developer has been clarified, and for yet others the developer and the Lao PDR have already committed to addressing the issues raised. These ongoing discussions have been included in this version of the TRR to the fullest extent possible in the limited time available.

All the documents submitted by the LNMC have been made available at http://www.mrcmekong.org/topics/pnpca-prior-consultation/pak-lay-hydropower-project/.

A matrix including all the comments received during prior consultation and outlining the responses to these comments is provided in Annex 4A.

This process is illustrated on the following page, and in Annex A1.


DRAFT PAK LAY PNPCA PRIOR CONSULTATION PROCESS ROADMAP
2018
2019
June
July
August
September
October
November
December
January - February
March
Joint Committee
JC Working Group
National Stakeholder Engagement
Regional Stakeholder Engagement
Submission of Pak Beng Hydropower Project by LNMC
13 June 2018
MRCS sends officially letter and the submitted Pak Lay Documents to MCs
12 July 2018
Official Start Date
8 August 2018
Notified Countries submit Official Reply Form to the MRCS
15 February 2019
Special Session of Joint Committee
29 March 2019
Official End Date
29 March 2019
MRCS sends Internal Scoping Assessment Report
23 July 2018
1st JCWG Meeting
8 August 2018
MRCS sends 1st draft of the Technical Review Report
12 October 2018
2nd JCWG Meeting (including site visit)
5 Novemeber 2018
7 November 2018
MRCS sends 2nd draft of the Technical Review Report
21 November 2018
MRCS sends Final draft of the Technical Review Report
8 February 2019
3rd JCWG Meeting
22 February 2019
MRCS send Final Pak Lay Technical Review Report to JC
15 March 2019
1st National Information Sharing/ Consultation Meetings
5 September 2018
30 September 2018
MCs sends National Comments Matrix V1
5 October 2018
2nd National Information Sharing/ Consultation Meetings
3 December 2018
24 December 2018
MCs sends Final draft of the National Information Sharing Report
28 December 2018
5th MRC RSF
• 1st Regional Information Sharing on Pak Lay
• Basin Planning & Environmental Management
20 September 2018
21 September 2018
MRCS develops Regional Stakeholder Comments Matrix V1
28 September 2018
6th MRC RSF
2nd Regional Information Sharing/ Consultation Meeting
17 January 2019
MRCS Completes Final draft of the Regional Information Sharing Report
25 January 2019
Events
Documents
# of Days
Number of Days

## 2.2 The drafting process for the Technical Review Report

This Technical Review Report (TRR) has been based on the template used for the Pak Beng process. However, recognising the need 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.

Chapter 4 - 'The Technical Review' the TRR was prepared by summarising the key findings of the individual expert team reports and to highlight the recommendations for additional measures to be considered in the post prior consultation process. The full reports from the expert teams have been included in an unabridged form as Annexes C to I. The other Chapters of the TRR were prepared by the Planning Division of the Secretariat and include inputs from the expert teams, as well as the MRCS management team. A separate TRR Summary Report has been prepared for those requiring less detail.

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. The following table outlines the version control process. This version is highlighted in **Bold.**

| Report | Version | Date | Comment |
|---|---|---|---|
| Scoping Assessment Report for Prior Consultation for the PLHPP | V 1.0 | 16 Jul 2018 | Submitted to the 1st meeting of the JCWG to define the scope of the assessments that would be undertaken |
| Drafts of the Technical Review Report | V 1.1 | 5 Oct2018 | This report: MRCS internal draft submitted to MRCS Divisions and CEO |
| | V 1.2 | 17 Oct 2018 | Includes comments from MRCS and CEO – submitted to the JCWG. It does not include inputs from the national experts. |
| | V 2.1 | 03 Dec 2018 | 2nd draft submitted to CEO for signoff. Includes inputs received from the JCWG and external stakeholders. |
| | V 2.2 | 03 Dec 2018 | 2nd draft submitted to the JCWG |
| Final Draft of the Technical Review Report | V 3.1 | 1 Feb 2019 | Submitted to the CEO for Final review – includes feedback from the regional and national consultations |
| | V 3.2 | 8 Feb 2019 | Final draft, Submitted to the JCWG meeting on 22 February 2019 |
| | V 4 | 15 Mar 2019 | Final, Submitted to the JC |

## 2.3 Documents used for the Review[16]

### *2.3.1 The submitted documents*

The Technical Review Report is based on the reports and their appendixes submitted by the Lao PDR, through the Lao National Mekong Committee (LNMC). These documents are listed below:

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

| No | | Document title | | |
|---|---|---|---|---|
| I | Doc # | Final Feasibility Study Report | No. of pages | 1,298 pages |
| | I. 1 | Executive Summary<br>- Overview<br>- Hydrology<br>- Engineering geology<br>- Project planning<br>- Project layout and main structure<br>- Electromechanical & metal structure<br>- Construction organization design<br>- Project management plan<br>- Cost estimation<br>- Economic evaluation<br>- Main conclusions and suggestions<br>- Project characteristics<br>- Drawing | 151 | |
| | I. 2 | Hydrology | 82 | |
| | I. 3 | Engineering Geology | 165 | |
| | I. 4 | Project Planning | 190 | |
| | I. 5 | Project Layout and Main Structures | 245 | |
| | I. 6 | M & E Equipment and Hydraulic Steel Structures | 156 | |
| | I. 7 | Construction Organization Design | 127 | |
| | I. 8 | Project Management Plan | 61 | |
| | I. 9 | ESIA | 79 | |
| | I. 10 | Project Cost Estimation | 13 | |
| | I. 11 | Economic Evaluation | 10 | |
| | I. 12 | Drawing | 21 | |
| II | Doc # | Final ESIA Reports | | ~1,553 pages |
| | II. 1 | Executive Summary | 78 | |
| | II. 2 | EIA | 270 | |
| | II. 3 | EMMP | 75 | |
| | II. 4 | SIA | 114 | |
| | | Appendix 1 – Public Participation | ~110 | |
| | | Appendix 2 – Gender & Vulnerable Groups Assessment | 27 | |
| | | Appendix 3 – Physical & Cultural Resources | 43 | |
| | II. 5 | HIA | 72 | |
| | II. 6 | SMMP (social monitoring and management plan) | 62 | |
| | II. 7 | RAP (Resettlement Action Plan) | 124 | |
| | II. 8 | IEE | 141 | |
| | | Appendix | ~130 | |
| | II. 9 | TBESIA & CIA | 307 | |
| III | Doc # | Final Review Reports from CNR | | 244 pages |
| | III. 1 | Pak Lay Feasibility Study Review Report by CNR | 121 | |
| | III. 2 | Pak Lay Feasibility Study Review – Fish Passage & Water Quality and Aquatic Ecology | 123 | |

On 9 January 2019 the Lao LNMC submitted the following additional documents:

- Dam safety evaluation and effects of dam breach;
- Hydraulic model test report; and
- Seismic hazard assessment.

Shortly thereafter translations of the Chinese Design Standards and Specifications for Concrete Gravity Dams were submitted. The PowerPoint slides from the workshop with the developer on 4 and 5 March have also been submitted.

In addition, the review draws on the information and data available in the MRC, 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.
- A range of reports produced for the Council Study.

The updated Design Guidance of 2018 has been referred to as it reflects the current understanding of good practice for HPP design in the Mekong Basin. However, as that document has not been formally approved, it has not been used to assess the extent to which the PLHPP feasibility documents align with the Guidance. The individual subject matter reviews are also supported by international standards and guidelines which are referenced in full in Annexes C to I and are referred in Chapter 4.

### *2.3.2 A comment on the quality and timing of the submitted documents*

In total over 3,000 pages of reports and PDF versions of the design drawings were submitted. The time frames to review all this material are tight. This process has been hampered by the fact that the documents cover several updates of the various studies, spread over several years. They have been subject to a separate review commissioned by the Lao PDR, and some of the recommendations made by those reviewers have subsequently been taken up. For others, it appears that there was insufficient time to address the proposals in the documentation submitted. This has meant that the submitted documents sometimes contradict each other. While every effort has been made to clarify these apparent contradictions to present a fair review, some misalignment may still be present.

Large sections of the TbESIA and CIA originally submitted also appear to have been copied from the Pak Beng documentation. While some elements of the transboundary and cumulative impacts will be

common to both projects, the intentions of the TbESIA and CIA are to highlight the expected impacts due to the notified project and assess the cumulative impacts it has over and above the existing (already notified) projects, as well as expected future developments. This is important for any determination of whether the proposed use is reasonable and equitable. The Lao PDR have committed to updating the TbESIA. However, this has not yet been submitted and hence the JC has been unable to make an evaluation of reasonable and equitable use.

The finalisation of this TRR has also been complicated by the very late submission of additional reports, and the comment on the 2nd draft of the TRR from PowerChina Resources limited. This has provided very little time to thoroughly consider and respond to these reports.

## 2.4 Scope of the Technical Review Report

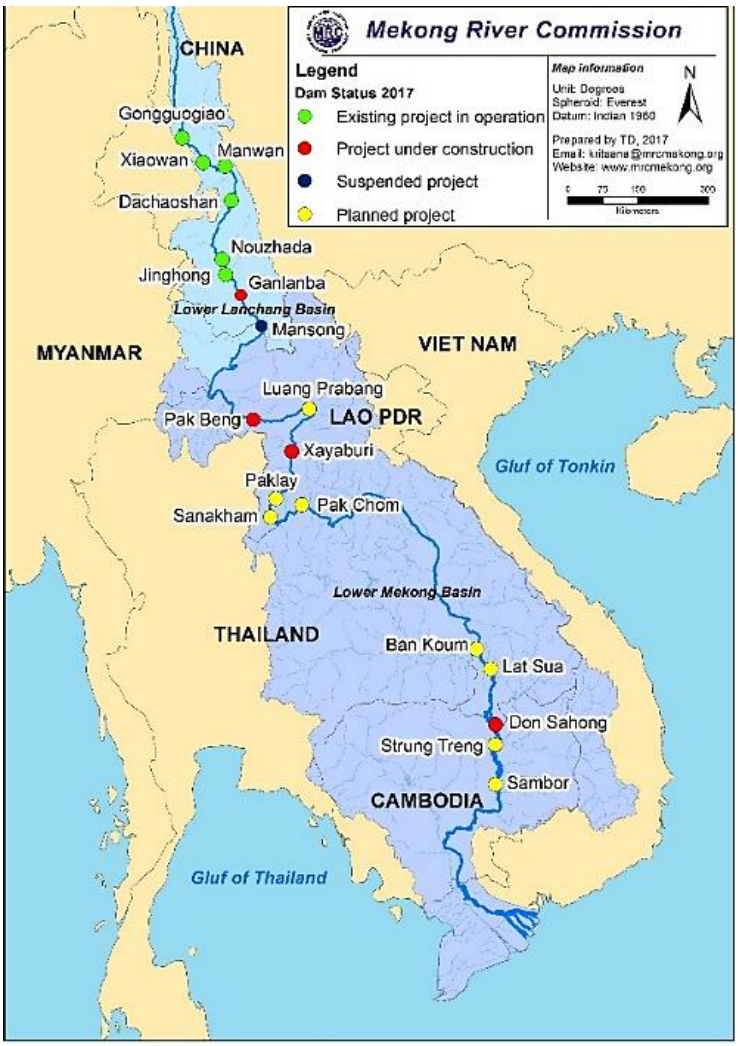
The TRR supports discussions between the Member Countries and provides the basis for the JC's deliberations. It aims to provide key information that is required to reach a decision under Article 5.4.3 of the PNPCA, or to support a possible postponement of the final meeting under Article 5.5.2 of the 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 measures that may be considered in the further design, construction and operation of the PLHPP. Those measures considered to be critical to further limiting any transboundary impacts have been included in a concluding Statement and will be supported by a post prior consultation JAP.

The conclusions drawn, and the recommendations made reflect sound scientifically based opinion from the expert teams, and a long history of experience in the Mekong River Basin. Where alternative opinion has been provided by experts appointed by the Government of Lao PDR or the developer, these are also reflected and have been considered by the JC.

# 3 THE PROPOSED PAK LAY HYDROPOWER PROJECT[17]

## 3.1 General description and location

The proposed PLHPP is a run-of-river scheme located in the Mekong mainstream in Pak Lay district, Xayaburi province, in north-western Lao PDR. The PLHPP is located about 1,829 km from the sea and 241 km upstream of Vientiane, some 100 km upstream of the Lao-Thai border, and some 20 km upstream of Pak Lay village. It is the 4th HPP (from upstream to downstream) of the 11 hydropower stations planned for the mainstream of the Lower Mekong River. It is also the 4th to be submitted for prior consultation. It lies downstream of the Pak Beng HPP (suspended), the Luang Prabang HPP (planned), and approximately 110km downstream of Xayaburi HPP (nearing completion) (Figure 3.1). The flows into Pak Lay will therefore be heavily dependent on the operations of the upstream mainstream and tributary HPPs, making conjunctive operations critical to minimising impacts.




The Sanakham HPP is planned downstream of Pak Lay and just upstream of the Lao PDR / Thailand border. The PLHPP Feasibility study states that the downstream Sanakham HPP will be operational prior to completion of the Pak Lay project (although the navigation documentation provided includes comments to the contrary). The upstream Xayaburi hydropower project is scheduled for commissioning in 2019, and a substantial backwater has already been created by the dam (as at September 2018). The northern Lao cascade is characterised by relatively low head, high flow volume projects with the tailwater of one project close to or abutting the dam of the upstream project.

*Figure 3.1 The Location of the Pak Lay HPP in the cascade of planned and existing HPP on the Mekong mainstream. (Note: The Pak Beng HPP is shown here as under construction, further development has been suspended while the developer undertakes further studies.)*

The power plant is planned to have an installed capacity of 770 MW, with 14 turbines, each producing 55 MW. The PLHPP is mainly intended for power generation, producing power mostly for export but also for domestic consumption in Lao PDR. However, it is hoped it will also serve to improve navigation and tourism.

[17] This Chapter has been extracted from a more complete summary of the Pak Lay HPP available at: http://www.mrcmekong.org/assets/Uploads/Overview-of-key-features-Pak-Lay-project-Final2.pdf

The infrastructure will create an impoundment with a depth of approximately 35 m at the dam wall. The length of the backwater will extend approximately 109 km upstream. The normal pool level of the PLHPP will be 240.00m, which creates an impoundment of 890.1 million $m^3$. The minimum pool level under normal operations is 239.00 m, and the regulation/effective storage is 58.4 million $m^3$.

Construction is planned to commence in 2022 and will take about seven years. The power station is expected to start operations in 2029. The project's total cost, prior to the adoption of any of the recommendations made in this TRR, is estimated at USD 2,134 million and is being developed by PowerChina Resources Ltd and China National Electronics Import-Export Corporation (CEIEC) in a form of Build-Operate-Transfer (BOT) scheme.

## 3.2 Engineering structures

The current project design consists of water-retaining structures, water-release structures, the powerhouse, navigation structures, and fish pass structures.

### *3.2.1 Water-retaining structures*

The water-retaining structures include an overflow section, a sediment-flushing section, a powerhouse section, a navigation lock section, and non-overflow sections on the left and right banks. The dam crest elevation is 245 metres above sea-level (masl), the maximum dam height is about 51 m, and the dam crest length is 942.75 m.

The overflow and the sediment-flushing sections comprise 11 open-type high-level surface bays (surface spillways), three open-type low-level surface bays (middle level spillways), and two sediment-flushing bottom outlets. The 11 spillways have a total length of 334 m and a crest elevation of 245 m. The minimum elevation of the foundation surface is 194 m. The water-retaining section of the powerhouse is 301 m long and consists of 14 sections, with a spacing of 21.50 m. The total width of the powerhouse section is 83.05 m.

### *3.2.2 Water-releasing structures*

The water-releasing structures consist of the high- and low-level flood gates, the sediment-flushing bottom outlets, the fish pass, and the navigation lock.

There are 11 high-level flood gates, located adjacent to the navigation lock, each 16 m wide × 20 m high, with a weir crest elevation of 220 masl. The three low-level flood gates, located to the left of the high-level flood gates, are 16 m wide × 28 m high, with weir crest elevation of 212 masl. The water-releasing structures are designed to safely pass a 1:2,000-year flood or a design flood of 34,700 $m^3/s$, and the check flood is based on a 10,000-year return period or 38,800 $m^3/s$[18]. The scour protection is designed for a 1:100-year flood. These parameters are consistent with the Chinese *Classification & Design Safety Standard of Hydropower Projects* (DL5180-2003). The suitability of these parameters is discussed in more detail in the Dam Safety review.

The sediment-flushing bottom outlets are located between the flood gates and the powerhouse with two gates of 10 m wide × 10 m high and invert elevation of 201.02 masl. Together, all the outlets have a length of 85 m along the water flow direction and a bottom elevation of 205 m. To ensure pressure flow at the outlets, section dimensions of the outlet mouths in front of the bottom outlets are 10 m

[18] The design flood will pass through without any damage to the infrastructure. The check flood may cause some damage, but not catastrophic failure.

wide × 12 m high. A pressing slope is set on the top exit of the outlet, whose section dimensions are 10 m wide × 10 m high.

### 3.2.3 Powerhouse

The powerhouse, containing 14 bulb Kaplan turbines, is on the left side of the main river channel, with a design discharge of 6,101 $m^3/s$. The main powerhouse comprises a generator hall and erection bay, with the dimensions of 400 m long × 22.50 m wide × 52.44 m high and unit spacing of 21.50 m. The auxiliary powerhouse is arranged downstream of the generator hall. The main components of the powerhouse are:

- *Generator hall:* This has a length of 301 m and a net width of 21 m;
- *Erection bays:* These are provided at each end of the generator hall. The main erection bay, located at the left end of the generator hall, has a length of 52 m and a net width of 21 m. The two sediment-flushing bottom outlets pass under the auxiliary erection bay;
- *Auxiliary powerhouse:* This is a five-story reinforced concrete structure on the downstream side of the generator hall. Its overall dimensions are 26 m long × 21.40 m wide;
- *Turbine passageways:* Each turbine is located within its own passageway under the generator hall and auxiliary powerhouse;
- *Powerhouse intake channel:* The intake channel runs along the full length of the generator hall; and
- *Tailrace channel:* The tailrace channel runs the full length of the generator hall. The lowest elevation of the channel is 203.06 m, with a slope of 1:4 over 60 m to drop down to the natural riverbed. This channel will be concrete lined.

### 3.2.4 Navigation structure

The navigation structure is a one-way, one-step ship lock capable of passing ships of up to 500-tonnes (t). Space has been reserved to upgrading to a double-way lock. The maximum working head of the navigation lock is 21 m, and the size of the lock chamber is 120 m long × 12 m wide × 4 m deep.

The ship lock comprises a head bay, a lock chamber, a tail bay, and a water-conveyance system. The head bay and lock chamber are integrated. The passing time of a ship is not expected to exceed 30 minutes. The access channel can generally accommodate two standard vessels of 500 t each with a pusher.

### 3.2.5 Fishway structure

The fish pass structure includes the fishway, a water-charging system, and a large resting pool.
***Fishway (channel):*** A bilateral vertical slot fishway has been designed along the left bank slope of the powerhouse, with a width of 6 m, a depth of 2.50 m, and a total length of 1,017 m. The average slope of the fishway is about 2.1%.

The downstream end of the fishway is about 250 m downstream of the hydropower plant tailwater canal, at an elevation of 217.5 m, which is below the normal operational water level downstream of the dam (219 m). The upstream end of the fishway is 100 m upstream of the hydropower plant. The bottom elevation is 237.50 m, which is below the normal operational levels upstream of the dam (239 m ~ 240 m).

Each fishway pond is 5 m long, with a drop between ponds of 0.14 m. A 10 m long resting pond is provided every 10 ponds and at all flow direction changes. The width of the vertical slots is 2 × 0.7 m,

and the depth of water in the fish pond is 2.5 m. The discharge of two vertical slots is 2 × 1.885 $m^3/s$, i.e. 3.7$m^3/s$, and the average flow velocity in the vertical slot is 1.08 $m^3/s$.

*Water-charging system (attraction flows):* The water-charging system is arranged along the right side of the fishway, with 1 m diameter pipes with a discharge of about 4.7$m^3/s$. The upstream intake of the water-charging system is close to the right side of the fishway and will draw water from the reservoir. The centre elevation of the intake is 236 m.

Model tests of the hydraulic structures suggest that the surface water flow velocity of the upstream intake area of the fishway will be about 0.5 metres per second (m/s). The discharge of the water-charging system and the fishway is 8.50 $m^3/s$ in total. Flow speeds of 1 m/s will therefore be formed at the upstream intake of the fishway, and as such the flow velocity of the upstream intake of the fishway will be greater than that in the reservoir, forming an apparent flow change, which is intended to attract fish.
Two outlets are set downstream of the water-charging system. Outlet #1 is at the end of the downstream inlet of the fish pass, with an outlet elevation of 226 m. The water drops into the river channel from the outlet and forms a 15 m wide artificial waterfall, which is intended to attract migrating fish. Outlet #2 increases the flow in the downstream section of the fish pass. During operations, different fish attraction flow types could therefore be used, according to the species migrating at different times.

*Large rest pond:* A large resting pond/pool is arranged in the middle section of the fishway. The resting pool is about 56 m long, 23 m wide, and 3~4.5 m deep. The natural slope will be replicated in the pond bank slope. Fishes can rest and catch prey in the resting pool to complete the migration. In addition to the large resting pool, a horizontal section, of about 10 m of length, is provided for the fishway every 50 m or so. The average flow velocity will be about 0.25 m/s. Fishes can slowly swim in the horizontal section and get a temporary rest.

### 3.3 Dam safety

The structures have been designed to withstand extreme seismic and flood events with design parameters of:

- *Flood standards*
  - normal operation (design flood)- 2,000-year return period with an
    - upstream design flood level of 239.02 m, and
    - downstream design flood level of 235.50 m.
  - abnormal operation (check flood)- 10,000-year return period with an
    - upstream check flood level of 240.53 m, and
    - downstream check flood level of 236.70 m.

- *Seismic standards*
  - return period of 475 years - peak acceleration is 0.13 g
  - return period of 5,000 years - peak acceleration is 0.384 g.

A detailed safety monitoring system has been proposed for the PLHPP, consisting of sensors and instruments to monitor horizontal and vertical movement in all the structures, seepage flow under the structures, stress-strain and temperature, slope, and other elements.

Outlines of the dam safety management system and the emergency preparedness planning for the operational period have been provided and are addressed in detail elsewhere in this TRR.

## 3.4 HPP Operations

The PLHPP is a low-head type hydropower station. This reduces the volume of the reservoir (less inundation), and facilitates sediment-flushing of the reservoir, flow conditions and reservoir levels in the flood season will be as close to natural as possible. Two reservoir operation modes are proposed to achieve this (Figure 3.2).

### *3.4.1 Reservoir operation for normal power generation*

Expected inflows will be forecast with an upstream near real time flow and rainfall monitoring network. If the forecasted inflow is less than the design discharge of the turbines (i.e. 6,100 $m^3/s$), the power plant will be operated at reduced load. However, to balance the generated load against the demand (hydropeaking), the reservoir level ***may*** vary between the minimum pool level (i.e. 239 m) and the normal pool level (i.e. 240 m). The minimum operating water level of the reservoir during normal operations will be 239 m.

### *3.4.2 Reservoir operation at higher flows*

The operating rule for the flood season is illustrated in Figure 3.2.

If inflow is forecast to exceed 16,700 $m^3/s$ all the flood release facilities will be gradually opened, and the pool level can go down to about 232.5 m. This will facilitate the routing of sediment. During drawdown, the outflow is limited to 1,600 $m^3/s$ ***more*** than the inflow to limit the daily water level changes to less than 3 m. If there is insufficient head (7 m) to generate power generation is shut down.

As flows start decreasing below 16,700 $m^3/s$ flood release facilities will slowly close again, Outflows will be limited to 1,600 $m^3/s$ ***less*** than inflows, and water levels will gradually be restored to 240 m. Generation will start when there is enough head. The developer has indicated that filling can take about 3 days and water level changes will be limited to less than 3 m/day.

It is assumed that downstream water levels will vary by less than 2.2 m/day, but there is no evidence provided for this determination. (This may be derived from a computational model used to estimate these water levels and discharges). The developer suggests that because the Mekong is still in flood at these times these downstream level fluctuations are acceptable.

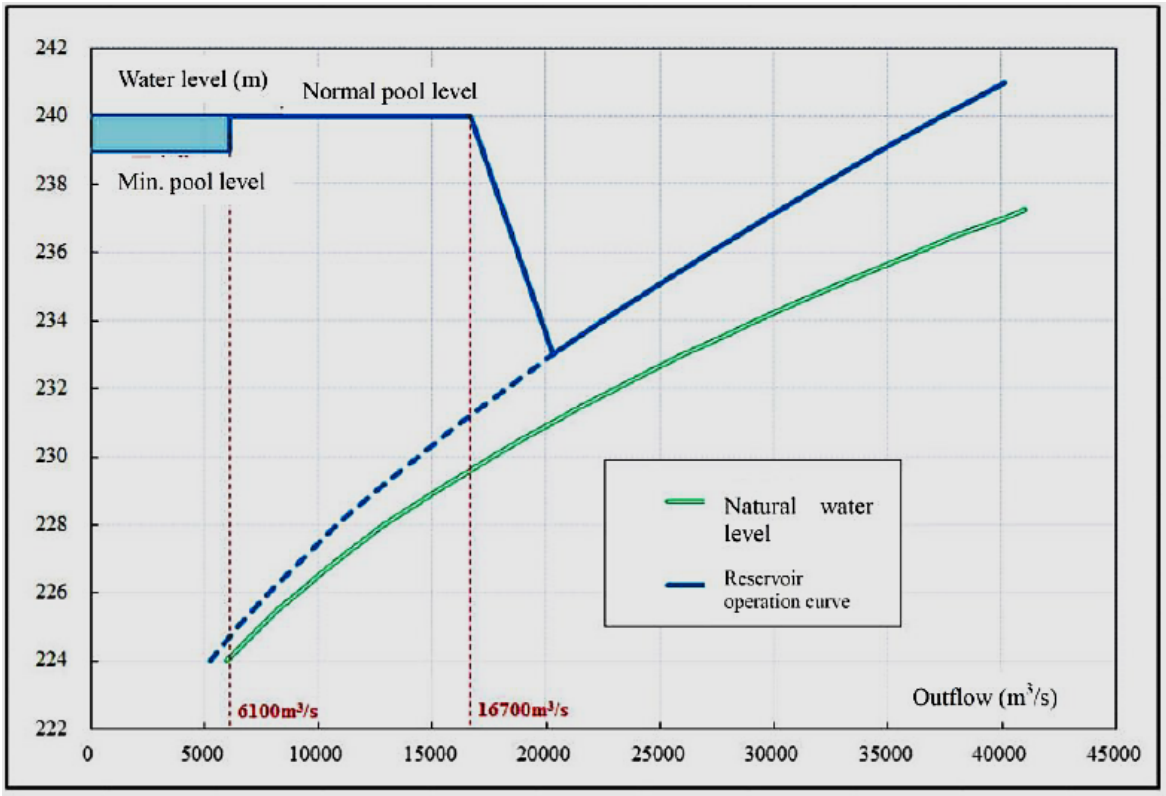



*Figure 3.2 The proposed operating rule for the PLHPP during normal and flood operations.*

### 3.4.3 Options for power generation and sales

For flows below 6,100 $m^3/s$, the power station will operate under the normal generation mode. According to changing daily electricity demands, the water level may be operated between 239 and 240 m under hydropeaking operations. Here minimum pool levels are chosen 1 m below normal pool level, based on achieving the maximum possible energy output. The planning document indicates that two options for supplying power to Thailand are being considered:

1) Direct point-to-grid power supply, where power is directly supplied to Thailand (EGAT): in this approach some regulating storage is reserved to provide energy according to demand (pricing based on demand), hence some hydropeaking.
2) Grid-to-grid power supply, where energy is produced for Laos and Thailand, with a single price and no hydropeaking.

Only Option 1, with peaking, is elaborated in the documents provided. Under this Option; EGAT will purchase primary energy for 16 h/day at 100% price, secondary energy for 5.35 h/day at 60% of price and excess energy at 55% of price. This purchase agreement is the basis for the economic feasibility of the project. The developer suggests that under EGAT's power policy, the highest priority is given to the primary energy, followed by secondary energy and then excess energy. Option 1 is only applied during the dry season at low discharges.

## 3.5 Internal Reviews

The Feasibility Study was reviewed and assessed by CNR before summitting the PLHPP for prior consultation. The four aspects addressed were Hydrology, Dam Safety, Navigation and Sediment transport and River Morphology. In addition, a Fishway Engineering Consultant and an aquatic ecologist and water quality expert from the Western Parana State University based in Brazil reviewed the

Feasibility Study for the fish passage and water quality and aquatic ecology. The main conclusions of these reviews are presented below[19].

### *3.5.1 Feasibility study review report by CNR*

The final review report of CNR is dated January 2017 and so there was limited opportunity to address the recommendations made before submitting the PLHPP for prior consultation. Nonetheless, some of the recommendations have been take up. The main conclusions of these reviews are summarized below.

*Hydrology*

- The design flood and check flood values have been reviewed against international standards and to ensure the consistency with the cascade of dams upstream of Vientiane. This point was a major concern in the CNR report and has been addressed by the developer.
- Some effort has been made to start monitoring the flow near the project site. However, there is still a lack of a quality assurance and quality control (QA/QC) process. The developer plans to add more QA/QC processes once at least one year of data have been collected.
- The operation pattern has been reviewed and is now consistent with the run-of-river concept. The developer still needs to demonstrate the efficiency of the operational plan for some ranges of discharge, but the run-of-river concept has been accepted and understood.
- The monitoring and forecasting system is consistent for flood management but has major limitations regarding power generation management. This can be addressed later and before construction starts.

*Dam safety*

The CNR Review found that generally, the design is sound and that the PLHPP design is about 71% aligned with the Preliminary Design Guidance (PDG2009). CNR also provided some recommendations for the developer, including:

- The feasibility study must be cleaned of former assumptions and designs so that design, design criteria, and drawings are consistent throughout.
- The developer must update the construction drawings at the feasibility stage to have a consistent design throughout the report and drawings.
- The general construction schedule was not updated in final documentation. It should be provided in the feasibility study.
- The comprehensive dam safety reviews must be mentioned.
- The broad framework of the Emergency Preparedness Plan is consistent with the requirements of the World Bank, Bank Procedure 4.37 Annex A, but needs to be detailed before construction.
- All mechanical and electrical control equipment must be backed/doubled up to ensure a high level of capacity in case of emergency. This shall be described in a specific document or chapter of the description of the equipment, mainly for the spillway, and even the powerhouse equipment shall also be fully equipped for cases of emergency.
- The proposed pattern for opening the gates must be provided in the feasibility study to check the capacity of the spillway. They should be adapted with regards to scouring tests on a physical model.

[19] These reviews are available at: http://www.mrcmekong.org/assets/Uploads/03.1-Review-CNR.pdf and: http://www.mrcmekong.org/assets/Uploads/03.2-Feasibility-study-review-MAKRAKIS-FONTE.pdf

- Great care will be needed when developing operational procedures for the cleaning boat manoeuvring just upstream of the dam to ensure safety.
- The design of coffer-dams must be completed with seepage assessment as curtain grouting is just in contact with impervious layers. A suitable monitoring system for watering and dewatering procedures is required.
- The material used for river closure is not specified. Its stability must be controlled.
- There is no emergency bulkhead for filling and emptying the system of the navigation lock.
- Hourly limits to upstream and downstream water level fluctuations should be set and used in operation policies, as they are relevant for both bank stability and riparian populations.

*Sediment transport and river morphology*

- The current design, with 11 surface spillways (220 m), three middle level spillways (212 m), and two bottom outlets (205 m) is relevant for a run-of-river scheme on the Mekong River.
- This design, with middle level and bottom outlets, potentially has the capacity to pass suspended and bed-load in a way that most closely mimics the natural timing of sediment transport in the river.
- The developer shall continue data collection as well as hydrological and sediment measurements in the future.
- The current on-site measurements of sediments are important to increase the knowledge of sediment transport on this part of the Mekong River.. This has allowed the developer to provide relevant studies of sedimentation impacts. However, additional information and simulations are still required to ensure the compliancy of the project and control its adverse impacts.
- Because of the new design, the new version of the reservoir operating pattern allows for potentially mimicking the seasonal distribution of sediment transport. The developer has to study specific operating conditions in more detail and liaise with the sediment strategy plan. Several modes of operating the reservoir are now possible in the future, from high flows when flood occurs, to low flows when seasonal drawdown of the reservoir water level is implemented, to facilitate sediment transport.
- All sediment management measures can be optimised by sedimentation studies, like releasing operations for each modes of transport by seasonal drawdown for instance, in coordination with upstream and downstream hydropower project operators. Adaptive measures can be evaluated at the feasibility stage, and if necessary and consistent, the reservoir operating pattern could be adjusted in the future.
- CNR concluded that the Pak Lay proposal was 48% compliant with the PDG 2009 and was 52% not fully compliant with respect to the sediment management facilities.

*Navigation*

- The issues identified for the lock design and navigation conditions have been improved. Most of the MRC guidelines have been fulfilled, even if there are still some points to be completed.
- The lock design has been well studied due to a physical model (1:20) and is suitable for the PLHPP. However, operating conditions need to be adapted for high velocities.
- Lock equipment is compliant with the PDG. Operation and maintenance policies have been described in greater detail, even if some points still need to be detailed.
- The flow conditions in the approach channels have been studied on a 1:100 physical model, which has indicated that:
    - The upstream lock approach seems to be safe, even if velocities higher than 0.8 m/s (threshold value in the Chinese guideline1) can occur for discharge higher than 13,500 $m^3/s$.
    - The downstream lock approach seems to be very disturbed (cross-current and backflow) and may raise problems for vessels.

    - The physical model study report is missing and would have brought valuable information for a better understanding of the results obtained during the test.
- The sediment accumulation concerns are briefly addressed through a two-dimensional numerical modelling study. It is strongly recommended that the approach channel areas be surveyed regularly (at least annually) in order to implement dredging operations if necessary.

CNR concluded that PLHPP is nearly fully compliant with MRC guidelines and international standards with respect to the aspects they addressed. They noted that remaining issues should be easily addressed in the final design stage. The final design of PLHPP, featuring spillway, middle level gates and LLOs (Low Lever Outlet), should allow for operations that efficiently mimic natural conditions upstream of the dam site. Furthermore, the design is very flexible and will enable operational adjustments whatever the inflow is.

This TRR concurs with many of these recommendations. There are, however, key areas where alternate views are presented.

### *3.3.2 Feasibility study review report by Fishway Engineering Consultants*

The consultants from the Western Parana State University based in Brazil reviewed the Feasibility Study for the fish passage and water quality and aquatic ecology.

*Fish passage*

The review report concludes that the information available on the fish pass facilities are insufficient for a conclusive assessment, and provides the following recommendations:

- Conduct more fish sampling to provide additional baseline data in the Pak Lay area to assess fish diversity and fishery resources—the current baseline data are not sufficient;
- Include sampling of drifting fish eggs and larvae to determine spawning and nursery habitats;
- Provide more information about fish species occurring in the project area (black, grey, and white species) and discerning target species;
- Clarify whether there are critical habitats (spawning, growth, food) above or below the dam and what the actual risks to populations of migratory fish are;
- Clarify if the habitats of migratory species will be affected or lost with dam construction, especially the deep pools;
- Provide a better description of migratory fish species, which must mention which species are long-distance migratory in the project impact area and how they will be affected;
- Provide more information on biological and hydrological requirements for fish species concerned, flow of operation in the fishway during seasons, adequate flow to attract fish at the entrance, and spillway designed to minimise fish injury and entrapment;
- Provide more information and details on fish-friendly turbines; and
- Consider providing training in new fisheries techniques, annual stocking of reservoir, and tributary fisheries.

This TRR concurs with many of these recommendations.

In addition, the CNR review recommended inserting information in the feasibility study report, under Chapter 5 on project layout and main structure, to address the following:

- Project site hydraulic conditions for the construction of the fishway;
- Design of the fish passages;

- Consider the construction of fishways on both banks of the river;
- Consider the design of the fishways with wider width and depths to provide dimensions suitable for the large species;
- Avoid level differences in the entrance of fish pass; it must be able to attract fish on the bottom—large catfish swims on the bottom;
- Considerations of fish movements—both upstream and downstream of the dam;
- Biological and ecological aspects;
- Information on hydrology, simulation of hydraulic conditions, and operations (flow velocity and discharge, slope, depth, etc.);
- Development of a reduced model of the fishway and swimming performance tests of the target fish species could be of great value;
- Design of an eco-hydraulics and hydrobiology laboratory may be one of the keys to success for the fish passage projects;
- Proposal for evaluation and monitoring of the fishway regarding hydrological and biological aspects (attractiveness and efficiency of fishway as well as fish swimming behaviour and swimming capacity);
- Consider a monitoring programme during the concession period;
- Consider the use of international experts and professionals with skills in biology and fish ecology to assist in the design and implementation of the monitoring programme.

This TRR concurs with many of these recommendations and proposes substantial changes in the design to accommodate these aspects.

*Water quality and aquatic ecology*

The review noted that in a run-of-river hydropower project, reservoir inflows and outflows are similar, but that the timing of flood pulses may be affected, which will impact the aquatic ecosystem. At the same time, the regulation of the water level may affect the downstream ecosystem.

The review report concludes that the cumulative effects from the PLHPP, as well as of other hydropower projects along the Mekong River, will be felt downstream in Cambodia, down to the Tonle Sap and even down to the delta in Viet Nam. Migratory fish have been shown to come from these areas.

The review recommends that monitoring of water quality should cover not only the physical and chemical parameters, but also some biological parameters such as macroinvertebrates, phytoplankton, zooplankton, macrophytes and fish, to fully align with the MRC PDG. The review report concluded with a proposed basic scope for a water quality monitoring programme and a description of environmental flows and management.

The review of the water quality and aquatic ecology suggests that the PLHPP is compliant with the PDG2009, provided that the recommendations made are taken up. This TRR concurs but proposes additional measures that should be considered.

### 3.3.3 Summary

This TRR concurs with, and reiterates, many of the recommendations made in the CNR review. The MRC notes that the developer and Lao PDR have committed to addressing these recommendations, but that not all of these had been addressed by the time the documentation for prior consultation had been submitted. However, this TRR provides additional recommendations and details for the Lao PDR to consider.

# 4 TECHNICAL REVIEW

## 4.1 Introduction

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

- Hydrology Expert Group (HEG);
- Sediment Expert Group (SEG);
- Fisheries and Environment Expert Group (FEEG)
- Dam Safety Expert Group (DSEG)
- Navigation Expert Group (NEG); 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, as well as national experts from each of the Member Countries. Additional efforts have been made to fully include these national experts in the review process. The Planning Division of the MRC Secretariat has coordinated the process and has established the expert teams 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 Annexes C-I and are considered as part of the Technical Review Report for the purposes of 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 to be considered in any Statement. The summaries provided below assess the extent to which the design and operation of the PLHPP will avoid, minimise and mitigate potential harmful effects, as well as the extent to which it aligns with the PDG2009. For the purposes of this TRR[20]:

- *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 like the promotion of alternative livelihoods strategies.

## 4.2 Hydrology and Hydraulics

### *4.2.1 Background*

The *hydrology and hydraulics* of the PLHPP will determine the most appropriate design for both the generation of power, and measures to avoid, minimise and mitigate any potential harmful effects. These aspects are therefore central to the review process and are consequently addressed up front.

[20] 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. The Annexes may refer to avoid, minimise and mitigate collectively as mitigation measures.

"*Hydrology*" refers to the properties, distribution and circulation of water in the atmosphere and on land. It addresses the amount and timing of water (volume) that reaches the project from runoff processes, and that is transferred through the project. "*Hydraulics*" refers to the flow dynamics of water and its practical applications, and addresses water depths, velocities, turbulence, the transfer of flood waves, and other properties of flow in rivers and reservoirs.

Project developers must have a detailed understanding of the hydrology and hydraulics to inform project planning, design, construction and operations, and ultimately the economic viability of the undertaking. The documents submitted by the Lao NMC recognize the broad principles the MRC uses to characterize the hydrology and hydraulics of the Lower Mekong Basin.

The documents referred to in this section are:

- FS: Feasibility study report, final report: 11 chapters and drawings.
- EIA: Pak Lay Hydropower Project Environmental Impact Assessment (EIA), date: Jan 2018 (Annex 2, hydrology is an exact copy of Chapter 2 of the Feasibility Report).
- EMMP: Environmental Management and Monitoring Plan (EMMP), date: Jan 2018.
- TBESIA&CIA: Transboundary and cumulative impact assessment, date Jan 2018 ((Annex 1, hydrology is an exact copy of Chapter 2 of the Feasibility Report).
- PLRev: Pak Lay HPP Feasibility Study Review, Final Report, CNR (by Benjamin Graf), Jan 2017
- Pak Lay Hydropower Project - Hydraulic Model Test Report, submitted 9 January 2019.

### 4.2.2 Characteristics of the PLHPP

After accounting for the regulation and storage impacts of the Xiaowan and Nuozhadu reservoirs in China at the upper reaches, the average annual reservoir inflow of the PLHPP is 4,090 $m^3/s$. The design flood flows are based on a 2,000-year return period or 34,700 $m^3/s$, and the check flood flows on a 10,000-year return period or 38,800$m^3/s$. The anti-scour and energy dissipation infrastructure is designed for a 100-year return period, as are the downstream guide wall and retaining wall for the navigation structures. The Feasibility Study notes that these design and check flood parameters are consistent with the *125-2003 Guide and Cases of Dam and Flood of International Commission on Large Dams (ICOLD) and Flood Design drafted by the French branch (CFBR, June 2013) of ICOLD.* The other design standards used by the developer are presented in more detail in Annex C.

The average annual precipitation is 1,298.1 mm, and the average annual maximum wind velocity are obtained from 13 maximum velocities at Xayaburi (16 m/s average annual, 31 m/s for 50-year return period).

### 4.2.3 Data used by the developer

The main hydrological data used by the developers are:

- Historic inflows from the Mekong and its tributaries into the impounded reach upstream and downstream of the dam location;
- Observed water levels and discharges at the dam site; and
- Approximations of the impacts on discharge for the future dam development in China.

These data derive from the MRC's Annual Flood Reports, and other publications.

*Hydrological data on inflows and water levels*

The Pak Lay HPP is located between the hydrometric stations at Luang Prabang and Chiang Khan. The Luang Prabang sites lies 181 km upstream of the dam site and includes data from 1950 to date, but the data from 1960 – 2015 (after extending the 1960-2005 series until 2015) have been used. The maximum flow recorded at this site during this period is 25,200 $m^3/s$ on 2 Sept 1966.

Chiang Khan is located 112 km downstream of the dam site and includes data from July 1964. The maximum water level measured is 18.22 m (assumed datum, on September 4, 1966). Discharge has been measured since Dec 1966, with a maximum measured flow of 24,400 $m^3/s$ (on August 15, 2008). Discharge data used for the analysis are for the period 1967-2015 (after extending the 1967-2005 series until 2015). The hydrology data is considered acceptable with regards to the number of stations used, including extra stations at the Pak Lay dam site and Vientiane, and the long-term records used. These should provide a good understanding of the hydrology in this stretch of the Mekong mainstream. However, there is insufficient information in the reports on the QA/QC procedures used to judge the quality of the dataset.

The stage-discharge relationships (discharge rating curve) for the two stations have been subjected to QA/QC processes and have been found to meet the design requirements for the project. However, the details of these design requirements, and the assessments made for these QA/QC processes, have not been shared.

The Pak Lay gauging station is located 29 km downstream of the dam site. The earliest water level records at this site were made in 1913, but the data record is patchy and incomplete. The maximum water level measured in 2008 is 15.12 m (assumed datum, on August 14, 2008).

A manual gauging station was established in mid-March 2016 at the dam site, and a hydrological station was established in June 2016 to measure the water level and flow. Earlier, in December 2007, Hydrochina Zhongnan constructed 4 gauging stations along the river reach between the 2 proposed dam sites. Two of them are located at the upper dam site, and 2 at the lower site. Water level data of over one year were collected at these stations, which captured the flood of August 2008. The data from the gauging station at upper dam site were recorded till March 2009. The details of these stations, and discharge measurements, as well as the details of the QA/QC process have not been shared. The MRCS has therefore not been able to determine the quality of these data and their harmonization with the MRCS data sets. Such an assessment would require a closer check of the measured data and approaches used, in order to gain more feeling of the accuracy and variability.

Some of the data used come from monitoring stations at Vientiane (249 km downstream of PLHPP) and at Chiang Saen (upstream) are considered. A range of other hydro-meteorological data are listed in the Feasibility Study.

Missing data in the records for water levels and discharges should be estimated using appropriate hydrological methods such as hydrographic and climatic comparison methods (for instance using precipitation and discharges from other stations); mathematical translation relations; flow routing methods (World Meteorological Organization WMO, 2010, Manual on Stream Gauging, Volume II – Computation of Discharge. WMO-No. 1044 Chapter 6.15).

Recommendations

- In order to undertake a thorough review of the hydrology data used, the information on the measurements at the dam site (exact locations, monitoring frequency, data ranges, and QA/QC procedures) should be shared. The developer has indicated that the measured data at the dam site will be shared during the PNPCA process, or at the final design stage.

- **The reports submitted at this stage should explain how the QA/QC procedures have been applied to assess and correct inconsistencies in data sets, errors, missing values and other data quality issues sets.**

### *Derived records for discharges at the dam site*

Discharge records for the dam site have been derived mainly from the data from the Luang Prabang and Chiang Khan stations. Both the monthly average flow data and the maximum annual flood data for the dam site have been determined through by a proportional (linear) interpolation between these stations based on the ratio of catchment areas. The CNR review notes that for the period 1960 to 1966 only data from Luang Prabang are available. Hence, the synthesized time series for the dam site for that period cannot be based on interpolation but must be solely based on Luang Prabang data. The flows for this period were consequently derived using a similar correction based on catchment area ratio. However, these data will be less accurate than those derived from combined use of Luang Prabang and Chiang Khan data. Nonetheless, extending the flow series at the dam site in this way may be considered justifiable for statistical analyses.

The linear interpolation methodology has been justified for the annual average flows. However, the comparison of annual averages for the three base stations is not representative of the monthly (or daily) discharges, as these are more sensitive to the local variations that occur between the base stations. Records with higher-frequency data will therefore show much more variation and scatter, than can be obtained by using this simple interpolation.

Observed water levels at the Pak Lay dam site have been correlated with water levels at Chiang Khan station to determine a discharge rating curve at the dam site. This assumes that the discharges between these locations do not differ too much, although they are 83 km apart. This also does not consider the considerable inflows from the Nam Heung and Nam Loei tributaries between the dam and the Chiang Khan station.

The developer presents how linear interpolation of, and correlation to, flow data from Luang Prabang and Chiang Khan are used to derive the discharge rating curve for the dam site. Based on this correlation, combined with the rating curves for Luang Prabang and Chiang Khan, the relationship between level and discharge at the dam site has been determined. The developer concludes that it is useful to adopt the rating curve that has been established in a previous phase of the feasibility study. This included extrapolation outside the measured range using a method based on cross-section conveyance, which is considered appropriate for this purpose. The developer recognises that it is possible to improve the rating curve when the data from the new station are checked and assessed for a full season (as was mentioned in the CNR Review Process).

Recommendations

- **The rating curve at the dam site should be checked and improved, using the recent observed data at the dam site, as the water levels are quite relevant for tail-water estimate and for analysing downstream hydraulic impacts. The developer has indicated that this check is currently in progress with ongoing measurements.**

The linear scaling approach used to correlate the discharges has not been evaluated thoroughly. It assumes that lateral flows from sub-catchments/tributaries are distributed evenly along the reach between Luang Prabang and Chiang Khan. However, rainfall in this region is not evenly distributed, and some large contributions enter the river through tributaries mostly on the right bank. As only the monthly averages were obtained in this way, it is acceptable to use the linear scaling. A comparison between MRC's and developer's monthly flows shows that they are similar.

The linear interpolation method is considered an oversimplification for determining daily-average flow. The reports do not present how the daily discharges were obtained using the scaling of discharges from Chiang Khan and Luang Prabang and compared to the observed daily discharges at the Pak Lay site.

It is important, even at the feasibility stage, to forecast the future hydrology to determine the PLHPP's economic and environmental risks over its lifetime. In the LMB the main drivers of hydrological change are hydropower development (notably storage schemes in the Lancang cascade and tributaries) and climate change. The developer predicts how the discharge at Pak Lay HPP will be affected by the upstream cascade, but only for the monthly average discharge, and only for the operation of the large storage HPP at Nuozhadu and Xiaowan. Since their catchments contribute 40 and 51% of the catchment area of Pak Lay respectively, their impact on monthly discharge is significant, increasing monthly average flows in the dry season by some 1,000 $m^3/s$, and decreasing wet season monthly averages by up to 1,600 $m^3/s$. Because monthly average flows do not provide an indication of the flood peaks, the impacts of the upstream HPP on flood peaks must be evaluated and reported on in the ongoing design of the PLHPP.

The developer postulates that a similar impact on monthly flows can be expected from the 25 tributary power stations in the catchment. At least 3 three reservoirs that will regulate annual flows (Nam Tha 1, Nam Ou 7 and Nam Khan 2) are mentioned. However, these impacts have not been quantified (due to the lack of data). It is assumed that this will have positive impacts on power production. However, the increased opportunities to mitigate environmental impacts are not explored. For instance, upstream storage regulation can reduce flood volumes to be less severe, which in turn decreases flushing effect for sediments. Conversely, higher flows in the dry season may provide opportunities to increase the potential for flushing sediments and to improve downstream larval drift. These considerations should be included in the ongoing design process. For this reason the CNR review has also recommended including the impacts of the tributary developments on the future hydrology.

The developer refers to the possible impacts of climate change on the hydrology, and general trends for the far future are mentioned, but these are not used anywhere else in the FS reports. Apparently, the expected trends are not included in the forecasted design discharges for the Pak Lay scheme.

The MRC Council Study and previous studies such as the Basin Development Plan and Climate Change Studies show that both hydropower development (definite future scenario) and climate change (various scenarios) will affect both low and high flows during the year. The TbESIA&CIA report (section 4.2.1.2) also provides some quantitative changes for changes up to 2030, based on simulations with the SWAT hydrological model. However, there are no details provided on the forecasted impacts on average monthly discharges (or daily discharges), and how this would affect the operation and economics of the PLHPP.

It is important that forecasts including both upstream hydropower development and climate change (despite the uncertainty) for the full concession period, and even beyond that, are included in the ongoing design of the PLHPP. This should include assessments of the impacts on the economics of the PLHPP, with a view to adjusting the operating rules to minimise environmental impacts without substantially risking the payback period. These assessments do not appear to be included in the documentation provided.

Recommendations

- The impacts of both climate change and upstream hydropower development on future hydrology should be addressed more comprehensively and for at least the full concession period.

### *Processed records for tailwater level at the dam site*

The tailwater levels of the Pak Lay dam will be determined by the Sanakham HPP operating level and backwater, if this is built. The rating curve at this location is used to calculate the head difference and is relevant for the design of the energy dissipation and scour protection works downstream of the water-release structures. It is also relevant for the ship lock and fish passage connections (see the following sections).

The rating curve for the Upper-dam site presented in the FS (section 2.5) has been derived from water level records at the dam site for January 2008 to March 2009, combined with discharges from Luang Prabang and Chiang Khan. Measurements of the discharges and stages at the dam site in September 2015 and between July and September 2016 confirm that this rating curve is reasonable (Figure 2.5-5). However, the FS report also mentions that the stages and discharges measured at the dam site have not yet been completed and analysed for a full year, and further processing is needed to verify the stage-discharge relationship. The developer notes that the planned Sanakham HPP will modify the tail water for discharges below 5,000 $m^3/s$, with a rise of water level from about 215 m to 220 m at the lowest recorded discharge.

### *Hydrological data for flood frequency and design flood*

The derivation of flood frequencies is essential for the design of the dam and spillways. The choice of design conditions should be based on accurate forecasts of daily flows at the dam site during flood periods and should be consistent with the design conditions used for the other dams in the cascade. Forecasting extreme flood conditions requires a long time series of historic flood discharges, corrected for the operation of the Lancang storage dams and the Laos tributary dams, and including the operations at Xayaburi. The records should include the flood of 1966. Because the Chiang Khan data showing the 1966 flood peak are not available, the equivalent 1966 flood peak at Chiang Khan has been based on interpolation using the Luang Prabang and Vientiane records, and found to be 26,000 $m^3/s$.

The developer has used a Log-Pearson Type III method for determining the design floods, in conformity with the Chinese Standards. Other distributions (such as Generalised Extreme Value GEV, log-normal or Gumbel distributions) have not been assessed. MRCS has concluded that the GEV method performs better for the statistics of the Mekong hydrology than other methods. Nonetheless, the resulting extreme values at the dam site have been found to be reasonably consistent with the other studies in the region, and for this stage of the design process they are considered acceptable. The developer has indicated that application of other methods will be done in the next phase of the project for detailed design. It is common international practice to select the appropriate method after assessing a few of the most common distributions.

Table 4.1 Peak discharges for different stations and from different studies up and downstream of the PLHPP.

| Return (yr) | 10000 | 5000 | 2000 | 1000 | 500 | 200 | 100 | 50 | 20 | 10 | 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| P (%) | 0.01 | 0.02 | 0.05 | 0.1 | 0.2 | 0.5 | 1 | 2 | 5 | 10 | 20 |
| DEVELOPER'S ESTIMATES FOR PAK LAY | | | | | | | | | | | |
| Q_FS | 38100 | 36600 | 34500 | 32900 | 31300 | 29100 | 27300 | 25600 | 23100 | 21000 | 18800 |
| Q_Final | 38800 | 37000 | 34700 | 33000 | 31200 | 29000 | 27200 | 25500 | 23000 | 21100 | 19000 |
| ESTIMATES FOR THE XAYABURI HPP | | | | | | | | | | | |
| Xayaburi CNR | 38500 | 36700 | 34200 | 32800 | | 28300 | 26500 | 24500 | 21800 | 19800 | 17700 |
| Xayaburi AIT | 45007 | 46621 | | 37083 | 34697 | | 29146 | 26744 | 24076 | 22033 | 18480 |
| ESTIMATES FOR LUANG PRABANG (UPSTREAM) | | | | | | | | | | | |
| Developer | 37000 | 35500 | 33500 | 31900 | 30400 | 28200 | 26500 | 24800 | 22400 | 20400 | 18300 |
| Pak Beng | | | 30900 | 29600 | 28300 | 26500 | 25100 | 23700 | 21600 | 19900 | 18100 |
| MRC 2008 | | | | | | | 26400 | 24400 | 21800 | 19800 | 17700 |
| ESTIMATES FOR CHIANG KHAN (DOWNSTREAM) | | | | | | | | | | | |
| Developer | 39200 | 37600 | 35500 | 33800 | 32200 | 29900 | 28100 | 26300 | 23700 | 21600 | 19300 |
| MRC 2008 | | | | | | | 27300 | 25400 | 22800 | 20700 | 18600 |
| ESTIMATES FOR VIENTIANE | | | | | | | | | | | |
| MRC 2008 | | | | | | | 27800 | 25600 | 23000 | 21000 | 18600 |

Table 4.1 shows that:

- The maximum peak floods are more or less consistent with those reported by MRC for Luang Prabang (upstream), Chiang Khan (downstream) and Vientiane (downstream).
- There is a large difference between flood design parameters for the Xayaburi HPP, and those from the PLHPP feasibility study.[21] International good practice recommends that consistent design criteria should be followed.

Small differences can also be explained from different time frames of the data sets used (some studies use series up to 2005, while the Feasibility Study uses series extended till 2015).

The shape of the design hydrograph used by the developer is based on floods of September 2000 and August 2008. They are proportionally amplified based on flood peak and flood volume. However, this assumes that there is linear correlation between the maximum flood and the flood volume at Chiang Khan (period 1967-2002). It is not possible to verify how the developer determined this relationship, or whether this comes from a specific approach for determining the flood volumes. Other studies have suggested that this relationship is not linear.

These analyses are used to determine the design flood (2,000-year return period) as 34,700 $m^3/s$, and the check flood (10,000-year return) as 38,800 $m^3/s$, with the shape of the hydrograph based on the September 2000 flood. The developer has subsequently noted that, according to 125-2003 Guidance for Dam and Flood and Cases issued by ICOLD and Flood Design issued by the French Branch of ICOLD (CFBR in Jun. 2013), the structures such as concrete water retaining structures, water releasing structures, riverbed type powerhouse, upper gate head of ship lock should have a design flood standard of 2,000-year flood (500-year flood in Chinese standard) and a check flood standard of 10,000-year flood (2,000-year flood in Chinese standard). For the energy dissipation and anti-scouring structures, their design flood standard shall be 100-year flood (50-year flood in Chinese standard). The flood

[21] It is not known whether this is related to the choice of the probability distribution. An earlier review of the Xayaburi design also noted that the MRC determined peaks were low but concluded that this did not have consequences for safety as the Xayaburi parameters were more conservative.

standard of the downstream guide wall and retaining wall shall be in consistent with the energy dissipation and anti-scouring structures.

Recommendations

- It is acceptable at this stage of the design process to base the design and check flood discharges only on the Log-Pearson method. However, the impacts of the upstream dams and climate change on the flood frequency analyses should be accommodated in the final design and operating rules as the flood frequency may be significantly altered by upstream (tributary and mainstream) developments. A synthetic discharge series could be constructed by modelling the upstream reservoir operation and applying this to the natural discharge series to demonstrate the impacts of these developments on flows.
- The probability of flood volume and flood discharge should be presented jointly to determine a proper flood hydrograph to accommodate both long-duration, low peak as well as short-duration, high peak flood events. The final design reports should explain in more detail how the flood volumes were determined, and how this is related to the bivariate GEV model for flood peaks used in other studies.
- While the design flood conditions for Pak Lay are lower than those used for the Xayaburi HPP, they have been derived using a sound methodology and a sufficiently long data series. However, it will nonetheless still be valuable to compare and explain any differences with the Xayaburi design parameters, since they will be part of a cascade of dams.
- The design parameters should be the same in all the documents submitted.

### *4.2.4 Reservoir operating rules*

The developer presents the proposed (preliminary) operating rules for the PLHPP. During high floods, to facilitate sediment passage and reduce inundation effects of the reservoir, the water levels are dropped close to natural condition. For median floods and at low flows the reservoir is operated at normal supply levels (full run-of-river) or operated with a daily regulation (hydropeaking operation), depending on the inflow rate, and the power purchase agreement. This broad outline of the operating rules is acceptable for the feasibility level design.

At flows greater than 6,100 $m^3/s$ but less than 16,700 $m^3/s$ the PLHPP operates at full power output, and outflow is maintained equal to inflow maintaining the normal pool level of 240 m. Flows more than 6,100 $m^3/s$ will be discharged through the flood and sediment gates.

As inflow starts exceeding 16,700 $m^3/s$ all the flood release facilities will be gradually opened, and the pool level can go down to about 232 m. This will facilitate the routing of sediment. During drawdown, the outflow is limited to 1,600 $m^3/s$ higher than the inflow to limit the daily water level changes to less than 3 m. If there is insufficient head to generate power generation is shut down.

As flows start decreasing below 16,700 $m^3/s$ then flood release facilities will slowly close again, Outflows will be limited to 1,600 $m^3/s$ less than inflows, and water levels will be restored to 240 m. Generation will start when there is enough head. Filling can take about 3 days and will be limited to less than 3 m / day.

It is assumed that downstream water levels will vary by less than 2.2 m/day, but there is no evidence provided for this determination. The documents further suggest that because the Mekong is still in flood at these times these downstream level fluctuations are acceptable.

As the expected downstream water level fluctuations are much larger than natural daily variations, it is important that their impacts are quantified. The developer has indicated that the choice of the maximum water level fluctuations (3 m/day and 2.2 m/day respectively) is based on experiences from the Xiangjiaba HPP and on a suggestion from the geological expert. This does not account for the impacts of the drawdown on the banks in the impounded stretch of the river. Rapid drawdown may cause bank failure and disconnection of riparian and fluvial zone. This risk can be reduced by restricting the rate at which water levels rise and fall. This is usually expressed in cm/hr (or m/s). Expressing the water level fluctuations in meters per day does not clarify whether the water level changes may take place over much shorter timeframes. The developer mentions that, based on similar hydropower stations in China, the fluctuations in the downstream reach will be sufficiently reduced by about 30 km downstream of the station, but does not present evidence that this would also be relevant for the Mekong River at this point. Some hydro-peaking calculations done by the MRC show that for a similar section of the Mekong River, a 3 m water-level fluctuation is damped out to a 0.5 m fluctuation after 120 km[22]. Similar analyses should be done for the PLHPP to confirm the assertation that any impacts at the Thai border and Vientiane would be small.

The threshold of 16,700 $m^3/s$ at the dam site for flood operations will correspond to higher discharges at Vientiane (in the order of 17,000 $m^3/s$). This is above the level of 16,388 $m^3/s$ defined in the Procedures for Maintenance of Flows on the Mainstream (PMFM) as *"stable with a need for caution"*. When flows exceed 20,144 $m^3/s$, the PMFM defines the hydrological conditions as *"unstable, and the possible cause(s) should be investigated, and possible mitigation measures considered".* The proposed additional release of 1,600$m^3/s$ to draw down the impoundment levels may therefore contribute to *"unstable"* flood levels near Vientiane, and options to manage this process together with the Xayaburi HPP should be investigated.

The developer also proposes a draw-down of reservoir level to a minimum water level for coarse-sediment flushing at intervals of 2-5 years irrespective of inflows. The documentation mentions that this operation should be coordinated with upstream and downstream cascade flushing operations and should be based on hydrologic and sediment monitoring results. Further details of these draw downs, and associated impacts are not elaborated.

For flows below 6,100 $m^3/s$, the power station will operate using the normal generation mode. According to changing daily electricity demands, the water level may be operated between 239 and 240 m under these hydropeaking operations. Here minimum pool levels are chosen 1 m below normal pool level, based to achieve the maximum possible energy output.

The reservoir will be operated at its maximum level of 240 m (full load, no peaking, no flood reduction) for only 20% of the time. In the future, the influence of upstream storage schemes will further reduce the occurrence of high flows. That means that actual draw down of water levels during flood conditions may be less frequent. Drawdown is important for sediment routing and fish larval drift, (see the relevant sections below and the supporting Annexes) and it is recommended that the impacts of potential changes in the future hydrology is analysed to determine a suitable drawdown frequency for future operations.

The developer has also noted that the impact of joint operations of upstream and downstream hydropower projects has been taken into account in the flood discharge operating rules for Pak Lay HPP. As for the power generation operation, the coordination of the power discharges of the upstream and downstream power projects has been considered for Pak Lay. Moreover, the documentation

[22] Based on the ISH036 study.

suggests that the upstream hydropower project Xayaburi is a run-of-river station, and the impact of its power generation on the power generation dispatching of Pak Lay will be small.

However, this does not appear to have been quantified, or how the operations from upstream dams have been considered in developing the operating rules. Water levels at Xayaburi are lowered when the inflow reaches 15,000 $m^3/s$ provide flood protection at Luang Prabang. This will cause an increase of inflow to the Pak Lay impoundment that is higher than inflows to Xayaburi, and as recorded at Luang Prabang. As the flow routing from Xayaburi dam is 7 to 14 hours, any daily fluctuations from operations at Xayaburi HPP will reach Pak Lay HPP within one day. Operations at Pak Lay should anticipate these changes in inflow.

Before the completion of the downstream hydropower project at Sanakham, the environmental flow can be discharged through the turbine-generator units. After the completion of Sanakham, since the linking-up with the water levels of Sanakham has been considered in the downstream water level of Pak Lay HPP, the operating rules of Pak Lay HPP can meet the environmental flow requirements.

The developer has based the minimal-flow requirements on observed extreme minimum flows. This is relevant for managing reduced flows during filling operations. However, it is important to note that historic extreme low-flow situations have occurred only occasionally, while downstream low-flows during filling are expected to occur daily in a hydropeaking operation. Meeting environmental flow requirements requires more than managing minimum flows but includes assessing the impacts of changing flow regimes on ecological functions and managing the flows to minimise these impacts as far as is feasible.

Recommendations

- Further insights, quantification (hydraulic modelling) and support for the proposed water level changes (max 3 m/day variation) in the impoundment and the downstream river must be provided. These water level changes should preferably be specified as cm/hr and related to the environmental impacts associated rapid water-level fluctuation for this stretch of the Mekong River (e.g. bank erosion, fish stranding, disconnection of habitats). The model extent should preferably cover the full reach from Pak Lay dam site to at least 20 km downstream of Chiang Khan hydrometric station to assess any potential transboundary impacts.
- The impact of flood regulation operations on water levels downstream to the Thai border and Vientiane should be investigated, and if needed operating rules to accommodate the requirements of the PMFM must be developed.
- The ongoing design of the operating rules should outline *how* joint operations of upstream and downstream hydropower projects will influence flood discharge operations, rather than just indicating that this has been done.
- The final operating rules should accommodate specific environmental flow requirements based on the potential ecological impacts as far as reasonably practical.

### 4.2.5 Comments on the proposals by the developer

#### *Risks and concerns*

The MRC recognises the risks and impacts associated with:

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

Changes in these flow regimes in turn affect the water quality and aquatic ecosystems, sediment transport processes, fish migration, navigation and dam safety which are addressed in the following

theme sections of the TRR. This section assesses the developer's analysis of the changes in the intra- and inter-annual flows, as well as the potential daily changes in flow regimes, in more detail.

The larger annual and inter-annual time scale changes are primarily affected by large storage schemes, such as the Lancang cascade and the larger tributary schemes. The mainstream run of river schemes in the Laos cascade do not affect the seasonal flows in downstream reaches but can still influence the local daily fluctuations for some distance downstream during operations. While there will be little opportunity to manage the seasonal flows from the HPPs in China, some seasonal flow regulation may be possible through the operations of tributary dams in the Lao PDR.

The hydraulic risks related to the PLHPP are mainly related to the possible impact on the tailwater (and energy head) at the upstream Xayaburi HPP. Indirectly, the impoundment affects sediment transport, fish and water quality through the changes flow conditions. The impact of the HPP therefore extends over the entire backwater (and pool) area of the project. During a reasonable range of low discharges, the Xayaburi tailwater will be affected by the PLHPP, and this may affect power output at Xayaburi.

Impact on tributaries from Thailand in the impounded section reach:

Water levels in the stretch of the Mekong river reach between Xayaburi dam and Pak Lay will be raised. Tributaries in this reach of the river will experience a rise in the erosion base, with impacts extending upstream in the tributaries depending on the length of the backwater (and hence the slope of the river). Because of the distance between the tributary mouths and the Thai border for the right bank tributaries, and the mountainous area (steep slopes), a direct transboundary impact is unlikely. However, it is recommended that this is verified to ensure that there are no significant transboundary backwater effects on the tributaries in Thailand.

The different reports provided are not consistent in their assessment of the potential impacts of the PLHPP. The CIA for instance suggests that for this run-of-river scheme no hydrological impacts will occur, while the Feasibility Study suggests that daily fluctuations can occur in water levels can have adverse impacts. This is most likely due to the mixing of the seasonal and long-range impacts, with the daily and short-range impacts. Nonetheless, it is recommended that this clarity is provided in the ongoing reporting.

### *Modelling tools for impact assessment*

Several modelling tools have been used to provide quantitative estimates to support the design process. The models relevant for the hydrological and hydraulic analyses are:

- A one-dimensional (1D) modelling tool, SUSBED-2, which has been developed by PowerChina Resources Limited and Wuhan University, was used for backwater and sedimentation assessments;
- A two-dimensional (2D) modelling tool was used for analysing flows and sediment close to the dam;
- A three-dimensional (3D) modelling tool SSIM was used for detailed scour assessments near the dam;
- A laboratory hydraulic physical model test has been carried out, with scale 1:100; and
- A SWAT hydrological model has been used in the (TBESIA & CIA report, section 4.1.3).

The 1D model:

The 1D sediment deposition calculation for Pak Lay Reservoir uses the 1D mathematical steady-flow inhomogeneous unbalanced total-sediment model jointly developed by the developer and School of Electrical Engineering of Wuhan University. The 1D model covers the 109.9 km from Xayaburi HPP to Pak Lay HPP and is based on 68 measured cross sections (average distance between cross-sect is 1,616 m). Boundary conditions are selected for 5 representative years (daily average discharges) and the modellers have chosen different approaches to establish the roughness values: 1) based on low flow condition - 1,150 $m^3/s$ in April 2008, resulting in significant variations in Manning roughness along the reach; 2) based on rating curves at Xayaburi and at Pak Lay, with average roughness values varying according to discharge; 3) based on flood profiles on August 26, 2016, for a reach within a few hundred meters of the dam site.

The reports presented suggest that the last method would be representative for the entire reach, and for the inundated conditions after Pak Lay HPP completion. However, the roughness from a short section (few hundred meters) during flood cannot be assumed to be valid for the entire 110 km long reach. It would, consequently, be useful to produce a few additional sensitivity runs to show what these uncertainties mean for the final outcomes of this model.

The 2D model:

The 2D overall sediment calculation for the project uses the 2D mathematical planar flow-sediment model developed by School of Water Resources and Hydroelectric Engineering of Wuhan University, which has been adopted in the 2D sediment erosion and deposition calculation for Tunaozi segment at the backwater end in Three Gorges Reservoir at its initial filling, bank collapse predication and preliminary countermeasure study for the Jingjiang River course after impoundment of Three Gorges Reservoir, sediment study for the dam area segment for Hutgyi HPP on the Salween River, and at other sites.

The 2D modelling is used for sediment studies close to the dam and includes a 2.1 km long sub-model upstream, and 1.85 km long sub-model directly downstream of the dam site. Although the details of this model are presented, there is no reference to any documented validation of this tool (for instance the reports and results from the above-mentioned projects). It is therefore difficult to judge if the quality of these simulations is influenced by numerical constraints or limitations in the way physical processes are handled in the software (such as momentum exchange, numerical diffusion versus physical diffusion, etc.).

The 3D model:

The 3D partial sediment calculation for the project uses SSIIM model, a software specially developed for hydrodynamic calculation for hydraulic projects. It can simulate sediment movement in the reservoir in the water level fluctuation process and is suitable for simulation of sediment deposition and reservoir sediment discharging, and it can be also used for sedimentation study for multi-intake cases. However, no sediment flushing model results have been provided using this model.

The hydraulic calculation for Pak Lay HPP is based on steady gradually varied flow model, which has been extensively used in the backwater calculation for large-scale projects in China and other countries, such as Xiangjiaba HPP in China and prefeasibility study of Sembakung HPP in Indonesia.

The 3D modelling tool SSIIM has been described in literature quite well and appears to be valid for the proposed type of applications. The backwater calculations are presented, as requested by CNR. The 1D model has been applied with the settings as mentioned above for bed roughness.

Recommendation

- Further analysis and a better motivation should be provided for the use of the hydraulic roughness in the 1D model for the impounded reach (supported by the data).
- A numerical hydraulic model for unsteady flow should be used to simulate the impacts downstream of PLHPP down to Vientiane. This should be used to model the propagation of the peak flows in the Lao / Thai border area of the Mekong mainstream to confirm that the impacts on water levels at this point will be negligible.

The physical model:

The detailed reports on the physical model have been provided on 9 January 2019. The developer notes that the overall hydraulic model test report for Pak Lay HPP (in Chinese) was completed in August 2016, and the overall hydraulic model test report for Pak Lay HPP (in English) was submitted in August 2018. The details of the physical model test and the test results are presented in that report however it does not present the assessment of the results of the comparison between the numerical calculation model and the physical model outcomes.

The results presented in the physical modelling report cover the following topics: discharge capacity of the release structures (u/s and d/s water levels at design discharges, 2.3.1); flow regime (qualitative flow patterns, 2.3.2); water-surface profile (water-level differences, level fluctuations, 2.3.3); flow velocity (velocities at spillway bays, bottom velocities, 2.3.4); downstream scouring (below aprons and stilling basin, 2.3.5); and navigation conditions at approach channels for the shiplock (flow velocities and circulations, 2.3.6). According to the other reports, the model has been applied to the overtopping under check floods, and the energy dissipation calculation. However, these are not shown in the physical modelling report.

The model tests are also carried out for Phase 1 (diversion channel) and Phase 2 (diversion through spillways) of the construction period.

The laboratory hydraulic model was constructed at a 1:100 scale and covers a section of 1,200 m upstream of the dam and 1,800 m downstream of the dam. Sediment with 8.5 mm grain size is used as the scouring material to withstand velocities of 5 m/s. Scale rules are properly applied for hydraulic Froude scaling. However, details on scaled roughness values and scaled sediment (for scour) are not reported, and hence cannot be reviewed. A proper evaluation of the accuracy of the results is not presented and therefore an assessment and review of the quality of this work is not possible. However, based on the details presented it can be assumed (but not concluded) that the results are plausible and properly obtained. A comparison of the numerical and physical model outcomes is currently being completed.

There is no specific section that addresses the design and design conditions for the aprons and stilling basins, and their consequences for the length and type of protection (with and without baffles, concrete or rip rap, etc.). Although scour depths are reported, it is not clear whether these are representative for the prototype (because of presence of bed rock, or scaling issues), and whether the laboratory tests have been used to minimize the risks of failure of the aprons and stilling basin with the observed scour depths.

Recommendations

- Details of scaled bed roughness and grain size for scour simulation should be presented to support a thorough evaluation.
- The comparison between the numerical and physical model outcomes should be presented as soon as these results come available. A proper assessment of accuracy should be provided if these results show large differences.

The SWAT model:

The calibration results are presented in the TbESIA&CIA report, but no explanation has been given on the resulting quality of the results. In some years the results simulate the measured discharges at some stations very well, while in other years the differences appear to be substantial (e.g. several thousands of cumecs for flood events). It is not clear whether these differences are considered acceptable, or what these mean for the outcomes of the assessments. The SWAT model is a water-balance model and cannot capture the full dynamics of HPP operations and the propagation and damping of fluctuations. This requires an unsteady-flow hydrodynamic model.

### *Mitigation of water-level fluctuations (impoundment and downstream)*

The impacts on the hydraulics in the impoundment and the downstream river are caused by rapid changes in flow and water-level due to regulating the discharges through the turbines and spillways. Furthermore, backwater effects upstream of the dam play a role in tailwater for Xayaburi dam and flooding of upstream areas.

These impacts are addressed by:

- The normal pool level of the reservoir is chosen to be 240 m to prevent a rise in tailwater at the Xayaburi dam; and
- The upper dam site has been chosen to prevent inundation of areas with large numbers of inhabitants.

The EIA does not recognise the occurrence of rapid flow variations, and consequently does not propose any mitigation options. However, the impacts of hydropeaking operations are addressed in the EMMP. Some mitigation options are outlined in the Feasibility Report but only in a qualitative way, and are mostly in relation to safety, and not environmental risks. The impacts and mitigation of flood regulation are also addressed qualitatively. The actions for minimising rapid flow changes are outlined as follows:

- Establish an automatic hydrological data collection and transmission system to predict inflow of the reservoir. Apply slow ramping to the outflow based on forecast flows, to control water levels downstream within a safe range. (This should include engagements with the Xayaburi operators to include expected changes in their discharge).
- Apply monitoring up- and downstream for water levels and discharge, to allow timely adjustment of operations if safety becomes an issue. Take necessary management actions.
- Control outflows to ensure that impoundment level changes are less than 3 m/d and downstream variation less than 2.2 m/day
- Monitor essential locations in the impoundment and river banks and take countermeasures when necessary. (However, no mention is made of what kind of measures can be applied or when it should be done.)
- Establish an emergency response plan and warnings for flood releases, in coordination with local governments.

In a written comment, the developer proposes the following approach for dealing with the impacts of flood operations:

In the flood regulation operations of Pak Lay HPP, the discharged flow will be controlled following the proposed flood regulation rules. The maximum daily reservoir water level change can be controlled within 3 m/d, and the corresponding maximum daily downstream water level change controlled within 2.2 m/d. Meanwhile, to minimize the adverse impact of reservoir flood regulation and flood flushing operations on the upstream and downstream reaches, it's suggested taking the following measures:

a) Predict the reservoir inflow, reasonably control the variation range and rate of the discharged flow based on the inflow predications and make the change of the discharged flow and the downstream water level (including the daily change and short-time change of the water level) be controlled within the safety range. It should be remarked here that the inflow prediction not only depends on runoff of the basin, but also operation of Xayaburi HPP during floods (see earlier comment).
b) Monitor the change of discharge and water level at any time by the discharge and water level monitoring stations, and when it's found the change of water level and discharge is excessive and may affect the safety of the upstream and downstream reaches, adjust the discharged flow timely and take necessary control measures.
c) Monitor the critical places of the downstream banks and take countermeasures timely when any problem is found.

The comments and approaches presented in the documentation only apply to operations during floods. There is no specific mitigation approach mentioned for the water-level fluctuations during hydropeaking operations in the dry season (ramping restrictions, etc).

Recommendations

- The approaches for minimizing the water-level fluctuations in the reservoir and in the downstream reach through ramping operations during hydropeaking operations should be further elaborated.
- The results of these calculations on ramping operations, and how they affect the economics of the hydropower scheme should be provided. The ramping requirements should be based on acceptable fluctuations, as close as possible to natural water level fluctuations of the Mekong.

### *4.2.6 Impacts related to hydraulics*

As the main channel is located on the left side, and as the ship lock is arranged on the right bank, the developer has proposed a relatively long downstream approach channel for smooth connection of the ship lock to the downstream main waterway.

The water-release structure is in the middle part of the dam, to minimize scouring impacts to the banks (downstream). It is designed as WES-type weirs with orifice flows (under radial service gates). These gates are undershot gates, which will hamper safe passage of fish. The downstream protection is arranged by concrete aprons (left and right side) and a stilling basin (middle part) that is able to dissipate energy by a hydraulic jump.

The energy dissipation calculations are based on the *"Design Specification for River-bank Spillway (DL/T5166-2002) and Manual of Hydraulic Calculation (2nd edition in 2006)",* which are Chinese standards. Some of the equations used are presented, but the results of these calculations (and values of different input parameters for different situations) have not been presented in section 5.7.4.4 of the FS. This section only presents the theoretical method (equations) and the test conditions for the physical model, and not the actual numbers calculated/measured for the different conditions.

The US Bureau of Reclamation (USBR) guidelines suggest that this is a Type 1 basin, with horizontal floor and without baffles, blocks or sill. The USBR shows that the length of the stilling basin should be in the order of 88 to 132 m. The design length (90 m) is therefore within the range (but on the lower end) of rough estimates based on available information. The use of baffle blocks and an end sill (Type II and III) will reduce the required length significantly. However, the reports do not explain in detail the characteristics and stability of the hydraulic jump in the stilling basin.

The designs of aprons and stilling basin were tested in the physical model. Normal practice would require that the conditions must be tested for different combinations of gate opening, tail-water elevation, and bottom level of the stilling basin, which has been confirmed. The developer suggests that the length of the aprons and stilling basin are sufficient and that they should be consistent with the USBR guidelines. However, quantitative proof has not been provided. The hydraulic model report does not contain a section on the hydraulic tests needed for this design. As mentioned above, section 5.7.4.4 of the FS does not show the results of the experiments.

The developer has considered details of operations that are relevant for stable hydraulic flows and safety during floods. For instance, the symmetrical opening and closing of the flood gates, monitoring for vibrations, and regular inspections are mentioned. It is not clear if models have been used to optimise the design of the gates to prevent vibration.

During construction cofferdams will be placed in two phases:

1. During the first phase of construction only the right part of the river is closed. A 20-year return flood standard has been adopted for the design, with discharge 23,000 $m^3/s$. (Only 10-year return flood is required as per specifications). During this phase the water-release structures and ship lock will be constructed.
2. For the second phase, during construction of the powerhouse on the left side, a 20-year return period is also adopted. For closure the 10-year flood occurrences in December and February are used. However, it has not been elaborated if these last occurrence probabilities already include the alterations from the upstream (Lancang) dams.

It is important that during closure works and impoundment, the minimum discharge downstream is preserved. Section 4.1.1.6 of the EMMP and the EIA (section 8.5.1) it is proposed to maintain a minimum flow that is 1/3 of the average flow in the respective season. For design of the cofferdams it is relevant that their slopes and toe are well protected against the scouring effects of high flows. The fish passage section also addresses impacts narrowing the river by the coffer dams may have on fish migration.

### *4.2.7 Comments on the Hydrological monitoring proposed by the developer*

Monitoring for hydrology and hydraulics is part of normal operations of the mainstream dams in the Mekong. Monitoring should provide the necessary information to operate the station in a run-of-river mode, but also to manage environmental impacts.

The developer proposes monitoring water levels upstream and downstream of the dam with automatic monitoring devices. A small-scale meteorological station will be installed at a suitable location at the dam abutment for monitoring temperature, rainfall and humidity. Additionally, an independent distributed automatic monitoring system and a remote communication management scheme will be employed at the dam. The monitoring centre is in the central control room at auxiliary powerhouse. A data acquisition unit (MCU) will be installed at each field monitoring station.

A hydrological telemetry and forecast system is needed to optimise operations for the full life cycle of the PLHPP. This provides both safety and economic benefits and can support mitigation of the adverse impacts of the PLHPP. This is also a valuable system for cascade flood control dispatching based on accurate and timely flow forecasting. Three alternative schemes are proposed; Scheme 1 is fully independently operated, while schemes 2 and 3 are to a lesser or greater extent dependent on data sharing from MRC stations or the Xayaburi telemetric network. For reliability and independence, the developer recommends Scheme 1. This includes 1 centre station and 12 telemetry stations, 4 hydrology, 1 water level and 7 precipitation stations, with the Luang Prabang station as the upper control station. CNR also correctly emphasise the need to consider the lead time of flow changes at Luang Prabang, and make sure that this is sufficient to perform the desired operations for flood protection and water-level ramping. If the lead time is insufficient, data from higher stations should be included. This should also consider the Xayaburi operating rules.

This is not elaborated well in the report. The proposed scheme does not provide a water level station at a reasonable distance downstream of the dam to monitor and environmental flows and minimum water-level fluctuations). The Chiang Khan station cannot be used for this purpose as it is too far downstream.

A combination of river system forecasting, and interval rainfall/runoff forecasting has been considered to predict runoff, using either conventional conceptual hydrological models or distributed rainfall/runoff models. The hydrological forecasting model proposed is widely applied to regions with similar runoff producing and concentrating conditions. Radar rainfall data and other sources of information could be explored, and a rainfall forecasting module may improve the lead time for prediction of inflows significantly.

The MRC and WMO guidelines (HYCOS system) should be followed for the technical details of the hydrometric stations and the telemetric system, as a consistent and uniform system over the entire LMB facilitates data exchange, integration into national systems, and a uniform knowledge base to establish a relevant pool of local experts and surveyors in the region. The developer has indicated that the MRC and WMO guidelines will be further taken into consideration in the design of the hydrometric system in the next stage.

Recommendations

- The developer should provide information on the QA/QC processes in their monitoring programme.
- An additional monitoring station some 10-20 km downstream of the dam site should be included to monitor possible fluctuations and environmental impacts, and to apply adaptive management to respond to the observations.

### 4.2.8 Alignment with the PDG

The original version of the Preliminary Design Guidance (PDG) does not contain clauses for hydrological and hydraulic parameters. It does, however, indicate that it is necessary to consider how much water needs to be released to maintain downstream ecosystems, determined through an Environmental Flow

Assessment (EFA) that must be introduced during the EIA stage. The EIA report proposes an environmental flow study, but it has not yet been initiated, and this will be done during construction. The new version of the Design Guidance (DG) 2018 contains a section and various clauses to guide the hydrology and hydraulics aspects of the design process, and this has been used to inform this section of the review. Annex C provides an assessment of the alignment of the design to the PDG 2009 and DG2018. This analysis suggests that most of the parameters have been considered to some extent, but some actions are still necessary as outlined above.

### 4.2.9 Transboundary impacts

The Thai border lies some 100 km downstream of the PLHPP. Hydrological and ecological impacts that extend beyond this point are considered transboundary and should be carefully predicted and possible avoided, mitigated or minimized. Although the Sanakham HPP is proposed just upstream of the border and may reduce some of the impacts of Pak Lay, it cannot be assumed that Sanakham HPP will be developed.

The developer recognises that the dam may affect the hydrological characteristics and sedimentation regime downstream all the way to the Mekong Estuary, and hence they recommend designing and operating the PLHPP as a true run-of-river dam.

However, the figures in the TBESIA&CIA report refer to the Pak Beng Hydropower project according to the legend. The section on 'Seasonal flows and floods" in the EMMP also suggests that the Pak Lay under normal operation will be a storage scheme with filling in the flood season and emptying in the dry season, which is not the case. The section on "Detail analysis of flows" in the TBESIA&CIA suggests a large seasonal impact downstream of the dam. The comparison between the two simulations for the baseline scenario and Pak Lay HPP scenario are consequently incorrect and are not reviewed further here.

The impacts of the PLHPP have also not been separated from the other developments for the long term (2030, foreseeable future) changes in the Mekong Basin.

The reports should quantify the propagation and damping of water level fluctuations related to operations of Pak Lay HPP, for instance during daily regulation and during proposed draw down and filling at flood periods. Rapid water-level variations may reach the Thai border between several hours to 1 day. Such predictions are usually obtained from simulations using a 1D unsteady flow model.

The developer has subsequently noted that the data between 2009 and 2015, shows that the minimum measured discharge at Chiang Khan Station is 565m$^3$/s in 2009, and the minimum daily average discharges in several years are relatively small, i.e., 531 m$^3$/s in 2004, 681 m$^3$/s in 1989, and 775m$^3$/s in 2010. However, this leans further credence to the misconception that environmental flows are about maintaining minimum flows and not, more correctly, about the extent and rate of water level fluctuations.

The transboundary impacts of Pak Lay on its own therefore remain unclear and cannot be isolated from the cumulative impacts outlined.

Recommendations

- The transboundary impacts related to propagation and damping of water level fluctuations from operations of Pak Lay HPP in the Lao / Thai border reach should be quantified.
- The scenarios outlined in the CIA should be described in detail (list of included HPP's, data used, etc.)

- The requirements of time-dependent minimal flows and maximum flow fluctuations (downstream of Pak Lay HPP) needed to sustain and serve the downstream ecological functions and other functions must be established (an environmental flow assessment must be carried out for this purpose). The relevance of these flow constraints for initial filling and for hydropeaking fluctuations must be determined and used for defining mitigation measures.

#### 4.2.10 Recommendations

Apart from the TbESIA and the CIA reports, the documents submitted to support the PLHPP prior consultation process establish all required aspects of the HPP. However, if the project progresses to final design and construction additional details will be required. This should include a more detailed analysis of measures to avoid, minimise and mitigate any potential harmful effects, and the expected economic and environmental benefits and disbenefits of these should be elaborated.

The JC may wish to consider the following:

- Data and information should be collected, improved and shared.
- Some of the methods to determine key hydrological and hydraulic parameters should be revisited and updated.
- Downstream impacts on flows should be properly addressed. Clarity on the water level fluctuations in the reservoir and downstream of the Pak Lay Hydropower is needed, particularly as they may affect the Lao/Thai border reach.
- Operational rules need to be reviewed and improved since they have been largely based on the pre-Lancang Dams flow scenarios and with a rudimentary examination of the Lao tributary inflows.
- Discrepancies between the design flow discharge at Pak Lay HPP and at Xayaburi HPP needs further clarification.
- Further attention required with respect to joint cascade operations.
- Economics of operations that further reduce the environmental impacts by drawing down the impoundment more often could be investigated.

### 4.3 Sediment transport and geomorphology

#### *4.3.1 Background*

This section of the TRR analyses the developer's proposals with respect to sediment transport and geomorphic process, compares the proposed PLHPP with the PDG 2009 and makes comments and recommendations regarding additional information needs.

The initial review was based on documents provided by the LNMC at the start of the prior consultation process, including the following:

- Feasibility Study Report (Final) Chapters 1 – 8
- Engineering and design drawings
- Environmental and Social Impact Assessment Report (ESIA)
- Environmental Monitoring and Management Plan (EMMP)
- TbESIA and CIA Report

On 9 January 2019 additional documents were provided by the LNMC, with the following being relevant to sediment transport and geomorphology:

- Pak Lay Hydropower Project Hydraulic Model Test Report.

### 4.3.2 Data used by the developer

#### *Overview of data provided*

The Pak Lay Feasibility Study has been developed in several stages from 2007 to 2017. This includes initial work in 2007 -2008, an update based on a change in the normal pool level from 245 m a.s.l. to 240 m a.s.l. After the selection of the upper dam site as the preferred option, additional work was completed in 2012. The 2012 work was reviewed by CNR, leading to a range of additional investigations and analyses, which are included in the 2017 final Feasibility Study. This has resulted in different data sets being used at different periods and inconsistencies have been introduced in the reports submitted for the prior consultation process.

In addition, the developer has copied many sections of the Pak Lay TbESIA, CIA and EMMP reports from the documents submitted for the Pak Beng prior consultation process. Although there are similarities between the projects, and some of the transboundary impacts will be similar, there are also important differences in the composition of the sediments, the hydrology, the infrastructure and the operating rules between the two projects. Sediment transport and geomorphic process will therefore differ considerably. The Pak Lay HPP cannot therefore be said to have the same transboundary impacts. The duplicated sections also contain outdated summaries of sediment transport in the Mekong, which do not reflect the present status and understanding of sediment processes in the upper LMB.

The TbESIA report is consequently not used here to evaluate the potential adverse impacts of the PLHPP, or to propose measures to avoid, minimise and mitigate these. However, some discussion on this aspect is presented in Annex D. It is, nonetheless, recommended that a site-appropriate TbESIA assessing the impacts of sediment losses and geomorphic changes associated with the PLHPP in its own right is prepared. This must use the most current sediment data available and consider potential changes in the context of other hydropower developments in the catchment.

#### *Comments on data provided*

Sediment loads in the Mekong River have been changing over the last decade due to sediment trapping in the mainstream dams in China and tributary dams, as well as catchment degradation. The data reported from the earlier studies, and in the TbESIA and EIA are therefore no longer representative of the current conditions. However, the Feasibility Study is based on generally sound data sets that reflect the present conditions. This review, therefore, assumes the most recent data sets presented and discussed in the Feasibility Study represent the developer's present 'knowledge base' and will serve as the basis for future more detailed design work.

#### *Data: Suspended sediment load*

A significant reduction of sediment runoff at Chiang Khan is evident when the 1966 to 1974 and 2009 to 2015 sediment data sets are compared. The reduction may be attributable to various factors, including, but not limited to: sediment trapping in dams, sediment extraction (mining), and a change to land use changes.

The historical sediment transport data collected between 1967 – 1977 from Chiang Khan, reported in the TbESIA, were used to estimate mean and maximum sediment loads at *66.7 Mt/yr* and *131 Mt/yr*, respectively, with an average suspended sediment concentration of 0.*510 kg/m*$^3$. The Feasibility report

summarises the same information, but also presents and analyses 189 more recent sediment transport measurements collected at the Chiang Khan Hydrologic Station between 2009 and 2015[23]. The derived average annual and maximum annual sediment loads based on the more recent data are *16.5 Mt/yr* and *30.4 Mt/yr* resulting in an average concentration of 0.*129 kg/m³*, with 93% being transported during the flood season from June to November. While the Feasibility study presents a comparison of these data sets, it attributes the difference to improved sampling technologies rather than sediment trapping in upstream impoundments or other catchment changes.

The Feasibility report adopts this later data set as the basis for deriving suspended sediment transport estimates at the proposed dam site, including average monthly sediment loads, and the delineation of sediment transport by season. The Feasibility report does not discuss potential future changes to sediment transport due to catchment development.

The estimates assume that no additional sediment is added or removed from the system between the proposed dam site and Chiang Khan, a distance of ~112 km. The Feasibility Study also indicates that suspended sediment monitoring is currently being completed at the dam site and that over 20 additional measurements have been completed. Graphs showing results from ten dates from July 10 to Aug 14 (no year provided, although the developer has subsequently indicated the data are from 2016) from different depts are included in the report. The text reports maximum suspended sediment concentrations of 4.3 kg/m$^3$ (e.g. 4 g/L), but the accompanying graphs show substantially lower concentrations. It is likely there is an error in the reporting of units, or maximum value; a value of 0.*430 kg/m³* (e.g. 0.43 g/L) is consistent with maximum suspended sediment concentrations recorded by the MRC Discharge Sediment Monitoring Program. However, the report notes that the processing and analysis of the samples is ongoing, and that the updated data will be compared to the calculations of sediment concentrations at the dam site.

### *Comments on total suspended sediment loads*

The following comments can be made regarding the suspended sediment data sets used by the developer in the updated Feasibility Study:

- The developer uses the most up to date information available for suspended sediment transport. This appears to be derived from the MRC monitoring site closest to the proposed project site and is being augmented with additional measurements collected at the proposed dam site. This approach is consistent with good practice, however greater detail about the source of the information is required. Data from other sources, such as the Mekong Delta Study (MDS) should also be included in the data set, and all data used in the Feasibility Study should be provided;
- In Chapter 5 the older data sets are used, which are inconsistent with the sediment information presented in the Hydrology Chapter. Any calculations based on these older estimates should be revisited and corrected;
- Additional suspended sediment information that would be useful include:
    - Maps showing the locations of the existing monitoring locations and extent of inundation associated with the project;
    - Details about the methodology and equipment being used. Information is provided about the distance between sampling sites (50 m) and relative depth of sample collection, but not about the equipment, laboratory methods or QA/QC procedures;

[23] Presumably from the MRC coordinated Discharge and Sediment Monitoring Programme

- Details about the monitoring frequency and proposed duration of suspended sediment monitoring. The Project Planning study highlights that 93% of the sediment is transported during the flood season, and sampling should match the timing of sediment transport;
- The updated sediment monitoring report should be provided to the MRC when available, as committed by the developer in the PNPCA documentation.
- The large reduction in sediment transport at Chiang Khan is noted, but does not consider the contribution of the large dams in China and numerous upstream tributary dams and other catchment activities have had. Understanding the relationship between water resource projects and sediment loads is important for future management and adaptive management;

The sediment budget of the Mekong River is changing due to the rapid development of hydropower. Because of this, the present sediment loads may not reflect the conditions over the life of the project. Some discussion of how sediment transport is likely to change in the future, and what the implications for the Pak Lay project might be due to these changes should be included in the Feasibility Study. The recent commissioning of hydropower projects on the Nam Ou, and the commencement of operations of Xayaburi in ~2019 are particularly relevant in this context. These issues should be considered in a regional and transboundary context in the TbEIA.

### *Grain-size distribution of suspended sediment*

Suspended sediment samples were collected and analysed for grain size distribution on four occasions between 28 August and 15 October 2015, with results from 6-samples presented. Median grain-size results of the samples ranged from 0.04 mm (silt) to 0.10 mm (very fine-sand), and 80$^{th}$ percentile grain-size ranged from 0.09 mm (fine sand) to ~0.18 mm (coarse sand).

This was compared to the results of samples taken by CNR, although it is unclear in the Feasibility Study if the CNR results are from suspended material, or bed material. Using the combined CNR-developer data set, three grain-size distributions for suspended sediment are derived, reflecting 'coarse', 'average' and 'fine' sediment grain-size distributions. These results are used in subsequent sediment modelling to provide a range of potential sediment transport rates through the impoundment.

The coarse grain-size distribution has sand (> 0.063mm) contributing ~55% of the suspended sediment load, and the fine- distribution has <10% sand, with the average curve containing 30% sand. This is the size-fraction (and larger) that is likely to settle within the impoundment.

### *Comments on suspended sediment grain-size distributions*

The following comments are made with respect to the grain-size distribution data in the Feasibility Study:

- There is no detail about the sampling methodology for the data sets used in the Feasibility Study. This is critical information because unless appropriate sediment sampling techniques are used, the grain-size distribution will not reflect the environmental conditions. Samplers such as Van Dorn or Niskin bottles are not suitable for sediment sampling;
- The percentage of sand estimated at Pak Lay (average 30%) is low compared to the average grain-size distributions determined at Luang Prabang (75%) and Nong Khai (52%) from 2009 – 2013 by the MRC DSMP. This could be due to;
  - Inadequate sampling techniques being used to collect suspended sediment samples;
  - The removal of sand in the new tributary dams upstream of Pak Lay (Nam Ou, Nam Beng, etc),

- More sand being transported as bedload rather than suspended load near Pak Lay as compared to Luang Prabang or Nong Khai (unlikely), and / or
- a difference in the monitoring period over which the samples were collected. The DSMP data set includes samples collected throughout the year and show varying proportions of sand at different flows.

- The number of monitoring dates on which suspended sediment samples were collected in the Pak Lay reservoir area is low (4), which increases the risk of the results not being representative of the annual inflow. The lack of samples from the onset of the wet period, when suspended sediment concentrations tend to be highest is a notable gap in the data set;
- The comparison of results with other results from the area is a good approach given the low number of samples. However, the discussion of the CNR results is somewhat confusing and it is not clear when, where or how the CNR samples were collected. The CNR Review Report labels the results as 'Deposits' suggesting they are bed material rather than suspended sediment samples. This information is relevant to demonstrate that the two data sets are comparable and can be combined. This is important because the sediment transport modelling is based on the range of sediment grain-sizes obtained from this combined data set;
- The Feasibility Study does not suggest updating the grain-size distributions used in modelling based on the recent data being collected by the developer. Verifying the sand content of the inflow is important, as any under-estimation will likely result in an under estimate of the amount of sediment trapped in the impoundment.

### *Bedload and bed materials*

The Project Planning chapter of the Feasibility Study discusses bedload transport, and states that no direct measurements are available, and flume testing isn't practical due to the 'constraints of test conditions' and the low accuracy of the results. An estimate of 3% of the suspended sediment load is used for planning and modelling of bedload transport, based on experiences from large rivers in the Jinsha and Lancang catchments in China, but no references are provided.
Bedload in the TbESIA and CIA report is estimated at 10% of the suspended load, resulting in an estimate of 4 Mt/yr based on the estimated suspended sediment load of 40 Mt/yr (this estimate is much higher than the recently measured sediment loads – 16.5 Mt/yr).

Information about the grain-size distribution of bed materials in the reservoir reach is based on samples collected from seven locations spaced at approximately 15 km intervals between the proposed dam location and approximately 20 km downstream of Xayaburi. Samples were collected from pits dug on undisturbed river banks and mid-stream islands, with three samples collected per site. Median grain-size ranged from ~0.2 mm (medium sand) to 0.9 mm (course sand), with 80$^{th}$ percentile values ranging from 0.3 mm (medium sand) to 10 mm (medium gravel).

### *Comments on bedload and bed materials:*

The following comments are offered in this respect:

- Overall, the proposed approach to estimating bedload and the data related to grain-size distribution of bed material is consistent with MRC data sets and what is presently understood with respect to bedload in the region;
- The assumption that bedload transport is a fixed proportion of the suspended sediment load is a common approach. However, available data suggests that the proportion of bedload varies greatly within any catchment (e.g. in different high flow events) and between catchments. Greater justification of the use of bedload estimates from the Lancang or the Jinsha (Yangtze) catchments, where the slopes are higher, and geology differs from the Pak Lay area, should therefore be included;

- Bedload transport rates measured by MRC DSMP indicated bedload transport rates of ~2 – 4 Mt/yr at Nong Khai in 2009 – 2013. The averaged measured suspended sediment load at Nong Khai for the same period was 18.8 Mt/yr. These results suggest that bedload is between 10% to 20% of the suspended sediment load in the upper LMB. The likely reason for these elevated percentages is the reduction in suspended sediment load due to upstream trapping, without a similar decrease in bedload as this material is still available in the river channel for transport;
- Clarification and justification as to which sediment load is being used as the basis of the 3% estimate should be included. The average suspended sediment load at Chiang Khan has decreased from 66.7 Mt/yr to 16.5 Mt/yr, but it is unknown whether bedload transport has been similarly reduced. Because bedload travels at a much slower rate as compared to suspended sediment, there can be a long lag time before the impacts of sediment trapping on bedload is experienced downstream of hydropower projects;
- Bed material collected by Lao PDR and reported to the MRC for the DSMP in 2011 from the Pak Lay area consisted predominantly of fine sand (0.12-0.25 mm) with both the median and 80th percentile values falling within this grain-size range. These grain-sizes are smaller than reported in the Feasibility Study. The smaller maximum grain-size may be due to the 2011 samples being collected from the bed surface, whereas the Pak Lay samples were collected from pits, which are likely to have contained coarser material at depth. The difference may also be attributable to the 2011 samples being collected during the dry season, when finer material is typically deposited, and collected prior to the large increase in the dry season river flow that has occurred in subsequent years[24]. Higher flows will increase the grain-size of bed material by winnowing out finer material.
- Interpretation of the bed-material survey results with respect to the geomorphic characteristics of the area to be impounded could provide insights about sediment deposition and bedload movement in the reservoir.

### *4.3.3 Geomorphic information*

The Feasibility study provides a range of geomorphic information about the river channel, the area to be impounded, project area and downstream river characteristics. The Topography and Geomorphology section of the Engineering Geology chapter provides a good overview of the region and description of the underlying geology. The area to be impounded is divided into three separate reaches:

- Metamorphic hill – low mountain area close to the dam section, with a river width of 100 – 250 m and intermittent terraces located 13 – 18 m above the river surface;
- Metamorphic rock with limestone hill in the middle reservoir section, with a river width of 100 – 250 m and intermittent terraces located 13 – 18 m above the river surface;
- Sedimentary sandstone with varying degrees of metamorphism in tail water section, with a narrower river width of 80 -100 m.

The morphology of the river banks is identified as being controlled by the underlying geology, with steep slopes associated with limestone, and lower slopes upstream and downstream. The stability of the slopes surrounding the impoundment is discussed with respect to the geology, soil cover and depth of weathering and it is concluded that there is a low risk of landslips or debris flows under a regime of 1 m/day water level fluctuation in the impoundment.

The depth of alluvial fill and weathered strata in the vicinity of the dam site is documented, and implications for the susceptibility to weathering is discussed with respect to the potential for scour

[24] Due to the operation of the dams in China.

during operations. Potential impacts associated with the operation of hydropower projects, including a reduction in downstream sediment loads, increased deposition in the impoundment and scour downstream are recognised and discussed. The Hydraulic Model Test Result report provides estimates of water velocities on the bed of the river upstream and downstream of the dam site during periods of extreme high flow, and when coffer dams are in place. Estimates of water velocities on the downstream banks are also provided.

*Comments on geomorphic information:*

The following comments are offered

- In general, the developer provides a good overview of the landscape features and relationship to the underlying geology, and uses this information to understand how operations of the project may impact river stability both in the impoundment and downstream;
- The suggestion that the area to be impounded is close to the Myanmar-China border should be checked, in the light of the accuracy of other information provided ('close' may mean 'similar to');
- The geomorphic description of the channel does not discuss the deep pools within the area to be impounded which are evident in the longitudinal section of this area. These pools are some of the deepest in the area. These deep pools are an important feature of the Mekong mainstream, and consideration of these deep pools is included in the PDG2009;
- The geomorphic description of the river does not extend downstream of the project area and does not address the potential impacts on the long alluvial reach of the river located downstream of Pak Chum;
- The water velocity results provided by the Hydraulic Model are not interpreted with respect to sediment transport or geomorphology, e.g. how would the projected velocities affect sediment deposits upstream of the dam wall, or on the downstream bed or river banks.

### 4.3.4 Review of the proposed PLHPP

*Infrastructure and operating regime*

Attributes of the PLHPP infrastructure relevant to sediment transport and river geomorphology include the following:

- The proposed dam site is on a broad right-bend of the Mekong in a locally wide reach characterised by an outcropping rocky reef;
- Sediment inflow to the impoundment will be affected by the existing and new mainstream and tributary hydropower projects located upstream of the PLHPP. Numerous additional tributary projects are in the planning stage or under construction;
- Sediment management for the water inlet and power house section is based on a sediment control sill, which comprises a training wall and the phase 2 coffer dam. The base of the sill has a trench that connects the river bed with the low-level outlets in the middle section of the dam. No sand flushing facilities are incorporated at the base of the turbines in the power house;
- Two low level sediment flushing gates are situated next to the powerhouse section in the spillway section of the project. The base of the low-level gates is at 205 m a.s.l. The inlet of the low-level structure measures 10 m x 10 m leading to an 85 m long sand flushing unit that has an outlet measuring 10 m (w) by 12 m (h). The base level of the gates is close to the level of the natural river bed;

- The deep surface gates have a base level of 212 m and the developer indicated that these gates will allow the passage of sediment accumulated from the shallower right-side of the river channel;
- The final non-spill section has no provision for sediment management, except through the navigation channel.
- The infrastructure will create an impoundment with a depth of approximately 35 m at the dam wall. The length of the backwater will extend approximately 109 km upstream;

The operational aspects of the project relevant to sediment management include:

- Water level fluctuations within the impoundment will be maintained at <1-m/day during normal operations to minimise potential impacts on lake shore stability;
- At flows more than 16,700 $m^3/s$, gates will be progressively opened to allow the river to approach its natural flood flow level. During this time sediment will pass through the low-level outlets, and be routed through the surface outlets;
- When flows exceed 16,700 $m^3/s$ any increase or decrease in discharge from the project will be within the range of Inflow + 1,600 $m^3/s$ (during drawdown) and Inflow – 1,600 $m^3/s$ (during refilling of impoundment). These constraints will limit water level fluctuations in the impoundment to 3 m/day, and 2.2 m/day in the river downstream of the project (location of water level fluctuation measurement not specified);
- Additional reservoir drawdown may occur specifically for sediment flushing. The Feasibility study suggests this may occur at a frequency of 2 to 5 years, with the actual frequency guided by sediment accumulation and inflows to the impoundment. Sediment flushing will be coordinated with other hydropower operators (although the mechanism through which this will occur is not stated);
- Sediment removal from near the power house area will be done through mechanical dredging, and;
- The Feasibility Study states that sediment management will be guided by monitoring results, consistent with an adaptive management approach. This includes the scheduling of sediment flushing during periods when flow is <16,700 $m^3/s$.

### *Comments on infrastructure and operating regime*

The following comments are offered on the infrastructure and operating regime:

- The comparison between the upstream and downstream dam sites did not include any consideration of differences in sediment or geomorphic impacts at the two sites. If the other planned HPPs are completed, this is not a major gap as the full cascade will inundate the river between the lowest project close to Vientiane and Luang Prabang;
- The project includes infrastructure that is consistent with good practice sediment management, with the low-level sediment flushing outlets, and the trough at the toe of the sediment control sill, directing sediment towards the flushing outlets;
- The effectiveness of the low-level outlets may be limited by their relatively small size (10 m x 10 m) and low number (2) of units (200$m^2$ in total). The size of the gates limits the flow through the outlets and limits the area upstream of the dam that can be effectively flushed to approximately 60 m. In comparison, Xayaburi has four bottom outlets with a low-level discharge area of 768 $m^2$;
- The configuration proposed for Pak Lay will allow a sediment balance to be achieved once sediment deposition reaches the dam toe but will be limited in its ability to facilitate the movement of sediment through the full impounded reach. Having larger and / or a greater

number of gates that could pass a larger volume of water through the base of the dam would increase the sediment flushing potential of the project;

- The feasibility report describes two potential operating modes, one of which includes peaking power generation when flow in the river is less than full power station capacity. While the water level fluctuations in the impounded reach are estimated to be <1 m/day the range of water level changes downstream has the potential to be much greater (up to several metres per day based on discussions with the developers). These rapid and frequent water level changes will increase the risk of bank erosion in the downstream reach. During the PNPCA fieldtrip, extensive erosion of sand banks was observed, likely related to the previous high wet season, rapid drawdown and land use changes (plantations to the edge of the river). The potential rates of water level changes in cm/hour are required to better evaluate the downstream impact of hydropeaking;
- Operating in peaking mode may affect sediment deposition and the distribution of sediment deposits within the impoundment, and modelling of sediment trapping within the impoundment under peaking operations should be conducted;
- No details are provided about the frequency of dredging likely to be required behind the power house, nor about the fate of the dredged material; and
- Greater detail is required about coordination of operations between hydropower projects on the mainstream and in the tributaries, and about communication between the operators and the community regarding special operations, such as sediment flushing. This issue is beyond the sole responsibility of the operator of Pak Lay, and the GoL should provide an update to the PNPCA process regarding these important issues.

### *4.3.5 Sediment transport modelling*

Sediment transport in the impounded reach was investigated using a one-dimensional model, co-developed by Power China Zhongnan Engineering Corp. and the College of Water Resources and Hydropower Engineering of Wuhan University. The model, SUSBED-2, is described as a one-dimensional steady non-uniform non-equilibrium full sediment mathematical model.

The simulations were based on the following inputs:

- The flow is the daily average flow of 5 typical years, including the frequencies of 10%, 25%, 50%, 75% and 90% respectively. The annual average flow of the 5 typical year series is 4,054m³/s, with about a 0.15% difference from the annual average;
- The average annual sediment load of 16.5 Mt/yr was distributed over the flow series based on the average annual sediment concentration;
- The three-grain size distribution ranges discussed above were used for the suspended sediment load,
- The average bedload grain-size values were also based on the collected samples, however the volume of bedload incorporated into the model was not stated;
- The parameters for sediment carrying capacity of the flow were based on results from Nuozhadu, Jinghong and Pak Beng, although no references or discussion was provided to justify the parameters;

| |
|---|
| Derivation of the input parameters in the model were based on assuming that under 'natural' conditions there is no erosion or sedimentation in the Pak Lay reservoir reach. This is a valid assumption for a river in a natural condition, but the sediment load used in the calibration is far lower than the natural sediment load of the river, and it is highly unlikely the river is already in equilibrium with respect to erosion and deposition after the completion of the upstream HPPs |

- The roughness of the channel was based on water level measurements obtained on 26 – 27 August 2016 when flow ranged from 10,560 to 11,940 $m^3/s$.

Modelling included an initial calibration run using 'natural' conditions assuming no net deposition or erosion through the impoundment reach. Subsequent runs used the post-impoundment water level and flow conditions, and the three suspended sediment grain-size distributions. The volume of sediment trapped in the impoundment was presented at 20-year increments over a 100-year period, but no detail about the grain-size distribution of the trapped (or transported) material was included.

The results show that sediment trapping within the reservoir is directly linked to the percentage sand contained in the sediment load. The finest sediment grain-size distribution, containing only 10% sand, showed virtually no trapping of sediment, while the results using an estimate of 50% sand showed trapping of >30% over the first 20 years of operation. The impact of sediment trapping on reservoir storage was estimated to range from 1.5% for the finest grain-size distribution, to 12% for the coarsest grain-size distribution over 100 years of operation.

Sensitivity analyses were run using increased sediment inflows of 10% and 20% and the average grain-size distribution. The results showed that after 100 years of reservoir operation, the sedimentation volume will increase by 32% and 66% respectively. A similar sensitivity analysis increasing the percentage of bedload input from 3% to 10% was also completed and showed that the higher the bedload to suspended load ratio, the bigger the loss of the reservoir storage capacity caused by the deposition in the same time period. However, the difference is not high.

More detailed two-dimensional modelling was completed for the reaches 2.1 km upstream of the dam site and 1.85 km downstream of the dam site. A description of the fundamentals of the model is provided, but details about the software package used and the approach adopted to execute the model are lacking. (The Feasibility Study contains the same text for computing the grid downstream of the dam site as presented for upstream of the dam site, which is an error.)

Model simulations of 40 years were run to investigate sedimentation in front of the power intake, sediment sill, sediment releasing bottom outlet and upper approach channel, as well as the sediment concentration through the turbines, and scour downstream of the dam site. After 20 years of reservoir operation, the deposition at the low-level flood releasing outlets and its surface bays is about 3 to 6 m. In the next 20 years of operation, the deposition is projected to increase to 6 to 12 m. This may cause erosion to the area within an area of 60 m upstream of the low-level sand flushing outlets. There is a thick layer of sediment deposition 30 m upstream of the flood releasing surface bay or even further. After 40 years of operation, the sediment concentration passing through the turbines is projected to be 0.174 $kg/m^3$, with a particle sizes higher than 0.05mm accounting for 42% to 43% of the total throughput (based on the sediment loads and sediment grain-size distribution incorporated in the model).

Downstream of the dam site, local scouring of the bed of up to 2.7 m is projected to occur in the first 2 km downstream of the power house within the first 5-years of operations, and sediment deposition of up to 1.3 m is projected to occur at the inlet to the navigation lock over the same time-period.

A 1:100 physical model of the dam site extending 1,200 m upstream and 1,800 m downstream was constructed and used to investigate hydraulic conditions associated with hydropower operations. Scour was found to be greatest when the water level difference upstream and downstream of the dam exceeded 12 m and the gates were open 1 m. Substantial scour of approximately 3 m was also observed when water level differences were <12 m, with the gates open 2 m or more. Relatively low rates of

scour were observed during periods of flow equivalent to the 16,700 $m^3/s$ threshold for opening all gates. The physical model was also used to quantify potential bottom velocities during extreme flow events and when coffer dams are used.

### *Comments on the modelling*

- For all models, greater information and justification regarding the parameters selected is required. Estimated errors associated with the models is also lacking;
- The One-Dimensional model does not appear to have been calibrated by comparing simulated to observed results;
- The one-dimensional modelling was based on the average velocity in each cross-section. This simplification can lead to inaccurate results when there is a large variation in water velocity in the cross-section of the river. Two-dimensional modelling of the northern Lao PDR cascade by the MRC demonstrated that there are significant areas within each of the planned impoundments where water velocities would be <0.2 m/s for up to 8-months of the year. At these low flow rates, sand and coarse silt would not be transported, however it may be re-mobilised during the higher flow periods. This suggests that sediment trapping within the impoundment may be greater than indicated by the one-dimensional model output.
- The predicted sediment trapping in the impoundment is closely linked to the grain-size distribution of the sediment load. The coarsest grain-size distribution used in the modelling contained about 50% sand. The MRC DSMP grain-size results for Luang Prabang and Nong Khai have a sand content ranging from about 50% to 75%, suggesting the sediment trapping results could be underestimated. No sensitivity analysis was completed based on increasing the percentage of sand in the grain size distribution above 50%.
- The sediment modelling results show that sediment flushing is effective at removing sediment approximately 50 to 60 m into the impoundment under typical operations (e.g. opening gates only when discharge exceeds 16,700 $m^3/s$). However, no model runs are presented based on drawing down the reservoir level under other flow conditions. The erosion of sediment from the bed in the impoundment will increase at lower flows. Additional studies on the potential for dedicated sediment flushing by drawing down the impoundment should be undertaken.
- The sediment modelling used a composite 5-year flow record, which did include flow events more than 16,700 $m^3/s$ (and hence lower water levels in the impoundment and flushing operations). However, it is unlikely that this will occur every year, or even 2 out of 5 years, so sediment removal may have been over estimated in the model. Increasing regulation upstream due to tributary hydropower projects has the potential to further reduce the incidence of flows in excess of 16,700 $m^3/s$.
- Additional information about the setup and calibration of the physical model, and a more extensive explanation of the results would assist in understanding the downstream impacts, especially during periods of relatively low flow. These impacts are relevant to sediment flushing at flow rates <16,700 $m^3/s$, so could occur frequently if annual or bi-annual flushing was adopted without lowering the water levels in the impoundment.
- The physical model provided estimates of bed velocities upstream and downstream of the dam, and along the river banks downstream of the impoundment during extreme high flow events and during construction, but the velocities are not interpreted with respect to potential erosion.
- More information about the approach adopted for the Two-Dimensional modelling including the choice of sediment transport equations and number of grain-size classes incorporated is required.
- The Three-Dimensional model results and the physical model results should be compared.

### *4.3.6 Monitoring proposed*

The Hydrology chapter of the Feasibility Study outlines the proposed sediment monitoring strategy, which identifies the following objectives for the monitoring strategy:

- Understand the water flow and sediment loads entering and exiting the reservoir;
- Understand the loss of storage capacity and its impact on the dispatching of the reservoir;
- Understand the impact of sediment deposition on the hydropower infrastructure and its potential impact on energy dispatching;
- Understand the potential impacts of flood events on energy production; and
- Monitor scour in the river reach downstream of the hydropower station.

The following monitoring is proposed to achieve these objectives:

- Monitoring of water level, flow and sediment concentration in controlled cross-sections downstream of Xayaburi and downstream of the PLHPP, with the locations to coincide with the tailwater section of Pak Lay, and Sanakham, respectively;
- Bathymetric monitoring of 9 cross sections located approximately of 12 km apart. Monitoring will capture the pre-construction bathymetry, and be repeated during construction and operations, with the frequency to be guided by the rate of sediment accumulation. Additional surveys may be completed following large flood events to understand the relationship between these events and reservoir storage capacity;
- Material deposited on the bed, banks and bars in the impoundment will be collected along each cross section for grain-size distribution analysis;
- Water level monitoring within the impoundment at two or three locations; and
- Monitoring of river banks upstream and downstream of the project following flood events will be completed and any dangerous material, such as boulders that have been dislodged, will be removed.

The monitoring results will be used to establish the sediment budget of the impoundment, analyse the distribution of sediment deposition within the impoundment, and quantify water level fluctuations. The results will be interpreted with respect to how the operations affect sediment movement through the impoundment. An annual report will be produced summarising the results and making recommendations to address any adverse effects of sedimentation on the project.

In addition to the proposed monitoring strategy for sediment transport and geomorphology, the EMMP contains a generic description of Soil Conservation Monitoring that includes provisions to 'Ensure implementation of erosion control measures' during the construction phase, without any additional detail.

#### *Comments on the proposed monitoring*

The overall approach and monitoring strategy presented in the Feasibility Study are good. However, it is only a strategy at this point and lacks specifics about equipment and field and laboratory methods to be used, overall number and exact locations of monitoring sites, how far downstream the monitoring will extend and monitoring frequency. Similarly, there is only a general description of how the results will be used.

This is reasonable given the early phase of the project, however, identifying management objectives and potential thresholds to initiate management actions would be useful if the PLHPP proceeds to detailed design.

The potential for coordinated monitoring with the other HPP in the cascade should be explored. Having sediment inflows and outflows collected at the same time, in the same locations and at the same frequency would ensure that each of the hydropower projects was being managed based on the same understanding of sediment transport into and out of each project.

### *4.3.7 Alignment with PDG 2009*

The Feasibility Study has been reviewed with respect to alignment with the sediment transport and geomorphology clauses contained within the PDG 2009.

At a general level, the proposal aligns with the PDG, in that the project is based on up to date and relevant information about sediment transport in the river reach, there is infrastructure for the management of sediment passage through the impoundment, operating rules for sediment management are outlined, and a comprehensive sediment monitoring strategy is presented. Furthermore, the use of a range of modelling approaches to identify potential impacts, including sediment trapping in the impoundment, scour and deposition near the project infrastructure, and impacts in the first 2 km downstream of the project also aligns with the PDG 2009. The commitment to an adaptive management approach by the developer aligns with the PDG 2009, including the use of monitoring to guide management actions and cooperation with other hydropower operators.

Although these areas align with the PDG 2009, longer-duration or more detailed information is warranted for several topics, such as sediment characteristics, modelling or monitoring. The ongoing sediment monitoring will address some of these gaps, if the information is used to update and refine the models and refinement of operating procedures.

At a more detailed level, the Feasibility Study does not fully align with the PDG 2009, and additional information about operations, monitoring and mitigation is warranted. Examples include:

- The proposed sediment flushing regime is limited to flow rates that would not be expected to occur annually, whereas the PDG 2009 recommends sediment passing on an annual or seasonal basis;
- The relatively small size of the low-level outlets combined with the proposed operating strategy will only promote sediment removal from immediately behind the dam wall. Alternative infrastructure options and operating conditions should be investigated to maximise sediment transport using bottom gates that are 'wide enough' and in 'sufficient number' as noted in the PDG 2009;
- More consideration of the geomorphology of the river within and downstream of the impoundment is required, including discussion of the fate of deep pools within the project reach and greater detail about monitoring and potential mitigation strategies to address erosion along the banks of the impoundment or downstream;
- Greater attention to monitoring of the upstream extent of the impoundment back water to identify changes that may affect navigation is required;
- The potential impact of hydropeaking on sediment transport and geomorphic processes should be discussed in greater detail, including an assessment of the drawdown rate (cm/hour) associated with peaking operations, and an assessment of how far downstream these fluctuations may occur.

Many of these topics could be addressed in the report that is planned when more site-specific sediment results are available. It is recommended that this report is shared with the MRC once it has been completed.

### 4.3.8 Recommendations

The JC may wish to consider the following to support its deliberations:

- Greater information about the source(s) of data used in the in the feasibility study should be provided, along with the actual datasets;
- Larger low-level outlets would be likely to improve sediment throughput, and options to increase sediment transport throughout the impounded reach should be explored with operating rules that allow for drawdown and flushing at lower flows.
- A more robust assessment of potential transboundary impacts associated with the Pak Lay Hydropower Project based on the most up to date sediment transport and geomorphic information should be undertaken. The developer should be encouraged to incorporate all available transboundary data sets (MRCS, Mekong Delta Study) into the transboundary analyses;
- The impacts related to the additional trapping of sediment in Pak Lay should be quantified in the context of existing and future development levels in the LMB. This is particularly important if the PLHPP will remains the most downstream project;
- The additional sediment monitoring information being collected by the developer should be shared with the MRC. If the results differ substantially from the assumptions and parameters used in the modelling exercise, additional modelling should be completed. This is particularly important if the monitoring shows a higher sand content in the suspended sediment load;
- The coordination and communication between hydropower projects in the LMB is becoming increasingly important with each successive HPP in the cascade, and in the tributaries. An update on the progress of studies in this regard should be requested from the Lao NMC;
- Additional information about how downstream erosion will be monitored, identified and addressed is required, as it is potentially an important transboundary impact. The discussion should include a scenario in which Pak Lay is the final dam in the cascade.

### 4.3.9 Other issues / comments with respect to DG 2018

While it is recognised that the DG 2018 has not yet been approved, they are still relevant as a reflection of good practice, and hence a source of reference. In general, the developer has based the Feasibility Study on the best available on sediment transport processes in the LMB. They are continuing to monitor, and the information available to date has been used to guide the development of infrastructure and operating regimes.

The proposed infrastructure has the capacity to manage sediments, including sediment routing and flushing, although larger low-level outlets would be likely to improve sediment throughput. Sediment management in the cascade is proposed to be based on monitoring results, consistent with adaptive management.

These approaches are generally consistent with the PDG 2009 and with the objectives of the DG 2018, although the level of detail is less than suggested in the 2018 Guidance. Provision of additional site-specific monitoring results and analysis is important for demonstrating that the project is based on a sound understanding of conditions at the site.

Overall, the documentation provided for the PNPCA is considered adequate for understanding the project infrastructure, and potential operating regime and providing a general overview of localised impacts associated with the development, recognising the limitations and gaps in the modelling results provided. However, the documents do not provide an understanding of the potential impacts of the project in a larger, regional context, including the identification of transboundary impacts.

## 4.4 Water Quality and Aquatic Ecology

### *4.4.1 Background*

This section focuses on the potential impacts of the PLHPP on water quality and changes in flow, particularly in the way that they may affect the aquatic ecology of the Mekong River during construction and operation phases of the project. It addresses both localised impacts within the Pak Lay area, upstream to the Xayaburi HPP and downstream of the proposed site including transboundary impacts.

The documents submitted by the Lao NMC that have been used for this review include:

- 01 Paklay-Executive Summary-Final FS-20170321
  - 1 Paklay-Executive Summary-Final FS-20170321
  - 2 Paklay-Hydrology-Final FS-20170320
  - 8 Paklay-Project Management Plan-Final FS-20170320
  - 9 Paklay-ESIA-Final FS-20170320

- 02-Final ESIA Reports of Paklay HPP
  - 1. Paklay Exsum (Eng) Final Report - Jan 2018
  - 2. Paklay EIA -Jan 2018
  - 3. Paklay EMMP - Jan 2018
  - 4. Paklay SIA - Jan 2018
  - 6. Paklay SMMP - Jan 2018
  - 9. Paklay TBESIA & CIA - Jan 2018

- 03-Final Review Reports of Paklay HPP from CNR
- 02-An external review by CNR (Makrakis and Fontes 2017).

The information provided was supplemented by additional information and data contained in various MRC documents, as well as comments received from the LNMC and the workshop on the 4th and 5th of March 2019.

### *4.4.2 Water quality and aquatic ecology*

#### *Water quality and aquatic ecology issues at hydropower dams - overview*

Water quality and aquatic ecology are impacted by hydropower development in rivers, but the scale and intensity of impacts depends on the type of development, its operations and associated changes to physical and chemical water quality parameters. The PDG2009 and the updated DG2018 indicate the key water quality parameters that should be monitored and recommend the measures that should be taken if needed. These parameters include temperature, pH, dissolved oxygen, Biological Oxygen Demand, nutrients (total and dissolved phosphorus and nitrogen) and coliform bacteria. These parameters can be altered during the construction and operational phases due pollution and changes in the environmental conditions, especially in the impoundment. Further problems can arise from sediment trapping and management, especially downstream of the dam (see Annex D for the details).

Similarly, aquatic ecology and biodiversity can be altered by the dam development, especially by the change from lotic to lentic environments[25] in the impounded area and changes in hydrology downstream of the dam.

Other guidance for monitoring water quality, both during the construction and operational phases is available from the International Finance Corporation, and the International Hydropower Association, and further information is available in the MRC Technical Guidelines for Procedures on Water Quality (TG-PWQ). Furthermore, the PDG2009 states the necessity for site-specific water quality monitoring, with the results to be interpreted within larger scale trends provided by the MRC Water Quality Monitoring Network and Ecological Health Monitoring Network.

Water quality concerns differ between the construction, immediate post-impoundment and operational phases.

Water quality issues during construction mostly relate to:

- Increased sediment in the water due to excavation in the river bed, earth moving (e.g. construction of coffer dams and preparation of embankments), quarry workings, construction of roads and deforestation;
- Increased organic pollution from worker camps, canteens, development of ancillary industries and human population expansion;
- Accidental spillage of construction materials, including washing of concrete; and
- Accidental spillage of oils and grease, releases from vehicle and plant maintenance.

These can largely be managed through good practice, including sediment erosion control, treatment of waste waters and organic wastes, and storage of construction materials and chemicals, including fuel and oils, in appropriate compounds that contain accidental spillages.

Water quality issues during operations arise mainly from downstream sediment mobilisation caused by changes in hydrology, breakdown of vegetation in the reservoir, especially after impoundment until the reservoir has stabilised (usually after 5-7 years), and ancillary operations and human settlements around the reservoir, which can lead to eutrophication, and algal growth if the residence times in the impoundment are sufficient. Algal growth and decomposition of vegetation can, if the reservoir stratifies, result in a deterioration of the quality of the water below the thermocline. This is much more typical in large storage reservoirs where water is retained for long periods of time, and is less likely in run-of-river HPPs such as Pak Lay

### *4.4.3 Water quality at the dam site*

The PLHPP documentation includes a literature review and a field study for water quality sampling and laboratory analysis.

The literature review provides a general synopsis of global and regional (Asia and Pacific) environmental issues and puts it into perspective for the LMB as foreground for the PLHPP baseline study. The EIA highlighted the MRC's continuous water quality monitoring network that classifies water quality in the Mekong, and the upper Mekong in Lao PDR in particular, in the normal to good quality range, except some areas near urban centres or with intensive agriculture or aquaculture. However, the MRC's data also show that some areas are experiencing a decline of water quality. It was also recognised that

[25] This is the change from flowing (lotic) to standing water (lentic).

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

The Pak Lay EIA and TbESIA&CIA present the results of the water quality field sampling and analyses conducted at seven stations in the Mekong River and the Nam Xong confluence with the Mekong, upstream and downstream of the PLHPP site. (Note: the locations are provided as GPS latitude and longitude references but no map showing the spatial distribution is provided.) Two samples were taken at each point, one each in the dry and wet seasons. The field surveys comprise 4 days in the dry season (03-06 February) and 4 days in the rainy season (13-16 September). Unfortunately, there is no indication of the year in which the sampling was carried out, although the CNR review suggests that the surveys were pre-2014. No information is provided on the number of replicates were taken at each station. These data are potentially out of date, given the construction of Xayaburi HPP in the interim period, which may alter downstream water quality.

It was indicated that collection, handling, preservation and analysis of water quality samples used standard methods. However, the illustrations of water quality sampling in the TbESIA&CIA report (Figure 89) suggests that the water was filtered through conical nets, which typically occurs for plankton and not water quality sampling.

The developer concludes that surface water quality in the Mekong mainstream from Ban Pha Liap to Pak Lay town (just downstream of where the PLHPP is planned) was good in the dry season and there are no heavy metal contents over acceptable limits. Similarly, very good water quality was observed in the wet season, despite the heavy sediment loading and turbidity, which result from the higher flows. Nevertheless, concentrations of nitrates and ammonia are high in the range 1.87-4.28 mg/L and 0.07-0.52 mg/L, respectively. Which may result in eutrophication problems. However, the TG-PWQ specify target values of 5 mg/L for nitrates, and 0.2 mg/L for ammonia for the protection of aquatic life. Water in this area was also contaminated by coliform bacteria: total coliform bacteria are >230MPN/100 ml and faecal coliform bacteria >23 MPN/100 ml in all stations. The TG-PWQ propose a target value of 1,000 MPN/100 ml for faecal coliform bacteria for the protection of human health (for contact recreation).

Ground water quality was also reported as good, except for faecal coliforms, which were much higher than drinking water standards. Local communities apparently use streams for drinking water, so this is potentially not a problem at present.

While several parameters were analysed, the data provided are single spot samples and hence insufficient to establish a baseline against which to measure any environmental change or the targets for the PLHPP. General statements are made about the water quality in the Mekong River in the reach and near the dam site without much interpretation. There is no comparison against the water quality standards in the documents provided, although the CNR review provides a comparison against data from ICEM (2010). It would be expected that continuous monitoring of water quality parameters is undertaken for several years prior to the development to show diel as well as seasonal (beyond wet and dry season) variation in relation to the hydrological flood cycle.

Comment

- This general overview of water quality issues in the LMB is too broad and does not focus on the likelihood of synergistic or antagonistic effects of hydropower development in the basin and specifically does not model how the PLHPP will alter water quality status both downstream and upstream (in the impoundment) of the dam.

### 4.4.4 Aquatic ecology at the proposed PLHPP site

The developer undertook aquatic ecological surveys at what appears to be the same time and locations as the water quality surveys. It was indicated the surveys were carried out to address the following:

- Type and abundance of plankton, benthos and fish.
- Fish species, abundance and diversity in the concerned water bodies.
- Impacts of changing water levels and flow regime on fish habitats including floodplains, flood scrub-land, rapids and rock pools.
- Deterioration of water quality may lead to serious impact on aquatic ecological system during construction and operation.
- Impaired fish mitigation due to dam construction.
- Inadequate minimum flow downstream from reservoirs will lead to serious impact on aquatic ecological system.

Samples were collected for fish species, plankton, benthic invertebrates and aquatic plants. Sampling was restricted to using basic plankton net trawling (59 µm mesh) for plankton, Eckmann grabs (5 replicates) for benthic invertebrates, a 50-m beach seine plus market surveys for fish, and direct observation of aquatic plants. There is no indication of how many replicate samples were taken at each site on each occasion or the duration of the sampling.

All fish samples collected were identified, weighed and counted. Phytoplankton and benthic invertebrates were identified and counted and recorded as density in cells/$m^3$ and number of animals/$m^2$, respectively. It was indicated that further data collection would be undertaken in cooperation with LARREC and the Ministry of Agriculture before construction, but no indication of the intensity or expected outputs of that work is evident. Such collaboration will be essential for long-term monitoring but should also include MRC and other line agencies.

Results of the aquatic ecology sampling and related studies, excluding fish, which are discussed in the Fisheries and Fish Passage Review, can be summarized as follows.

a) Dry Season

- Five Phyla (Chlorophyta, Bacillarariophyta, Cyanophyta, Pyrrophyta and Euglenophyta) of phytoplankton and two zooplankton phyla (Protozoa and Mollusca) were collected during the dry season. Species diversity of diatoms (Bacillariophyta) was high compared with other phytoplankton. Ten species were identified.
- Phytoplankton densities were in the range of 0.076-0.344 million cells/$m^3$, which is on the low side for running waters.
- The density of zooplankton ranged from 4,300-60,720 individuals/$m^3$ of water and was very low at the upper sampling station.
- Very few benthic organisms were found in the river bottom and near shore sites. They comprised three phyla: two families of aquatic worms (Annelida: aquatic segmented worm), six families of Arthropoda (mostly insect larvae, small freshwater prawn and crab), and two families of Mollusca. Small freshwater prawns (*Macrobrachium lancesteri*) were found at all stations (44-110 ind./$m^2$). The total density of benthic invertebrate animals ranged from 110-220 ind./$m^2$.

b) Rainy Season

- Bacillarariophyta and Euglenophyta dominated phytoplankton samples, and the diatom *Synedra* dominated at all sites, with densities in the range 35,000-194,040 cells/ $m^3$.

- Four species of zooplankton were found, including three species of Protozoa and one Rotifera species. The density of zooplankton ranged from 5,000-15,040 individual/ $m^3$ of water.
- As in the dry season, three phyla of benthic fauna were found: Annelida, Arthropoda and Mollusca. No total densities of benthic invertebrate animals were given for the wet season, the developer suggests benthic animals are not abundant, but it is suspected this is due to sampling problems.

Comment

- **Overall the sampling timeframes and intensity and description of the biota are superficial, and the limited number of samples preclude any definitive assessment of the current baseline status.**

The sampling design and extent of the surveys are limited and not consistent with international or MRC standards. There is little attempt to relate plankton and benthic invertebrate surveys to previous results from MRC studies. (The CNR study does include some comparisons). The developer concludes that the aquatic fauna in the region is poor, which is considered unjustified due to the limited sampling undertaken, and the methodologies employed.

Comment

- **The survey design and implementation do not allow such a conclusion to be drawn and a well-designed and intensive survey protocol (monthly) carried out over an extended period (at least two years) should be undertaken before such conclusions can be made.**

Some attempt has been made to comment on the impacts of the PLHPP on potential changes in aquatic habitats in downstream reaches or in the inundated area of the reservoir, where the habitat will likely change from a lotic to a lentic environment. However, these conclusions – while correct for Pak Lay - appear to have been drawn from the Pak Beng documentation.

The river will be impounded for some 90-110 km and, despite being a run-of-river HPP, considerable reduction in riffle habitats, which are important spawning/production areas and dry season habitat for rheophilic Mekong benthic invertebrate and fish species, will occur. This is acknowledged in the EIA.

In this context, the EIA suggests the impacted area is a pool riffle, cascade habitat, but there is no analysis of the value and uniqueness of these aquatic habitats or an assessment of their ecological significance in the context of the whole LMB. There is also no analysis of the impacts of changes in flow regime in the channels, especially the potential inundated area.

Comment

- **There is no in-depth analysis of the value of any habitats that will be lost, or the potential impacts on the wider LMB ecosystem in terms of lost biodiversity or aquatic productivity.**

Studies were also undertaken of forestry products and wildlife in the Pak Lay area. The study reported that "The majority of significant wildlife species have been eliminated from the project area either due to indiscriminate hunting which has for generations been a part of local livelihoods or habitat losses through agricultural clearing mainly slash and burn for cultivation. Nevertheless, from village interviews, there are still some main species found within and around the project area." MRC studies suggest other aquatic animals and non-forest products contribute significantly to the diet of rural communities in the region (MRC Council Study, 2017).

### 4.4.5 Potential impacts on water quality and aquatic ecology

*Water quality during the construction phase*

The river and adjacent land ecosystems will be subject to considerable environmental changes during the construction phase, which could potentially impact water and habitat quality, with commensurate impacts on the aquatic ecology. Excavation and transport of construction materials can lead to substantial increases of suspended solids, oils and chemical spills. In addition, improper disposal of waste materials, especially organic and domestic wastes, can cause substantial environmental damage resulting in seriously degraded soil, and poor water and air quality. These impacts can be managed if strict criteria and well-established management protocols and good practices are established.

Another major issue that arises from dam construction is flooding of terrestrial environments and decay of vegetation, causing high BOD and lowering of dissolved oxygen in the impoundment and subsequently downstream if the water is released. This typically occurs in the first 5-7 years after flooding and is a major problem that should be mitigated.

The possible impacts of construction on water quality are considered in the ESIA, which notes specific construction areas and activities, and possible increase in erosion and sediment loading because of excavation of the banks and surrounding land as the main concerns. This is exacerbated by deforestation of the adjacent land, which can destabilise the soils. These are noted as potential negative impacts on water quality in the EIA, ESIA and EMMP. These impacts are considered controllable by good practice on site through, for example:

- Installation of a 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 excavation practices when working near water courses; and
- Appropriate training of workers in good environmental practice.

The mitigation measures proposed include the implementation of best management practices for soil erosion and sedimentation at all construction sites, as well as pollution control techniques and awareness campaigns.

The EIA considers that with these measures in place there will be no significant impact on water quality during the construction phase. This conclusion is endorsed if:

- Effective waste water treatment systems for worker camps and construction areas and good construction practices to minimise water pollution and with no accidental spillage of oil or hazardous chemicals are enforced;
- Contractors follow best practice soil erosion and disposal management measures during construction;
- Compliance monitoring of both the PLHPP and its contractors is effective;
- Water quality monitoring is upgraded to be more comprehensive than specified in the EMMP, and incidents of failure to comply with water quality standards are investigated and remedial measures followed up if necessary; and
- Adequate emergency response measures are in place with staff trained to respond. All accidents involving spillage and water pollution are investigated and remedial measures put in place.

Despite all these measures, soil erosion, bank side collapses, spillages and accidents and malfunction of waste water treatment plants may still occur. This will likely have a temporary impact on water quality downstream, perhaps as far as the Thai border and Vientiane. Any increased sediment loadings are likely to have greater impact during the low flow seasons, when the water is naturally clearer, and particular care should be taken during this time.

The water quality problems created by flooding of terrestrial vegetation will be addressed by removal of surplus vegetation in the reservoir area prior to impoundment. However, this action should be planned carefully as removal of vegetation can result in reduced productivity of the reservoir and poor potential fish production. It is recommended hard wood vegetation is removed selectively and areas left to enhance protection of the fish stocks by creating zones that are difficult to fish, and to enhance food resources for the fish.

The developers have proposed a water quality monitoring programme during the construction phase, but this is highly descriptive. Institutional arrangements for environmental management are well defined, but it is unclear how the plan will be implemented and enforced. Monitoring of the project as defined in the EMMP must routinely test for contamination according to the Agreement on the National Environmental Standards (No 2734 /PMO.WREA Vientiane Province, dated 7 Dec 2009). In addition, monitoring of waste materials, garbage and hazardous wastes is weekly at best and sometimes seasonal. Unfortunately, the only monitoring described for wildlife conservation is largely to make workers aware of the consequences of hunting.

With correct monitoring, mitigation and implementation, impacts on water quality during the construction phase are expected to be minimal, barring accidents, if the developer complies with international guidelines, and adopts the procedures they have outlined. The following recommendation is nonetheless made to provide a sound basis for water quality management during construction.

Recommendation

- The frequency and extent of monitoring should be increased significantly and procedures to respond to accidents and problems encountered should be outlined. Inspections should be daily and water quality should be monitored continuously using multiparameter probes, and outputs linked to well defined rapid response protocols, if problems are registered.

### *Water quality and aquatic ecology during the operational phase*

Several potential water quality issues were highlighted in the ESIA that may arise during the lifetime of the project. These are typical of HPPs on the Mekong mainstream, and the following drawn from the Pak Beng TRR also apply here:

- *Impacts due to erosion/sedimentation*: Erosion and sedimentation can take place in the impoundment where degraded forests exist. Accumulation of sediment could take place in the reservoir reducing the downstream transport of sediments. The 'sediment hungry' outflows from the reservoir may induce erosion and a scouring downstream. Periodic sediment release from the reservoir will minimise the impacts on the total sediment transported downstream. However, short term impacts on instream habitats are still likely.
- *Impacts due to degradation of biomass residue:* Degradation of vegetation biomass residue could take place in the reservoir during the early inundation period and further impact downstream river areas. It is proposed by the developer to manage this as far as possible by removal of the vegetation, but this can lead to increased erosion during the construction phase, but also leaves a reservoir with reduced productivity.

- *Impacts due to wastewater discharge.* Waste from human activities around the reservoir and along the river bank. Construction of the PLHPP may stimulate the expansion of communities, industries, agriculture, aquaculture and tourism along the Mekong River particularly upstream of the PLHPP. If the management of wastewater and solid waste is inadequate, new sources of pollution would negatively impact water quality. To address this, appropriate urban and land-use planning, and control measures are required to minimise potential impacts.
- *Impacts due to agriculture and aquaculture:* Following inundation, agriculture and aquaculture activities are likely to expand. These can have direct impacts on water quality through fertilizers and pesticides, which produce nutrients and toxic substances that contaminate the river. Aquaculture could also cause high organic and nutrient contamination in the river due to fish food that contains carbohydrates and proteins. High nutrient content can cause eutrophication and algal blooms, especially in the reservoir. This may be a problem in the dry season when residence times are longer and water clarity is better. The nutrient and chemical pollutants could be dispersed to other river reaches so there are potential transboundary impacts. Good practice in agriculture and aquaculture is necessary to prevent eutrophication as well as safeguard the ecosystem.
- *Impacts due to navigation and oil spills:* Impacts on water quality from navigation can stem from wastewater, grease and oil being discharged directly into the river from ships/boats. Oil spills might result from accidental leakages. Navigation and cargo trans-shipping could directly impact water quality if waste treatment and anti-oil spill measures are not provided. These impacts are likely to be transboundary and thus need strict regulation and control.

During the first 5-7 years after filing of the reservoir, it is likely that there will be times, especially during the low flow periods, when the water quality in the reservoir will be poor through decay of vegetation remaining in the impoundment. In addition, there are likely to be issues around sedimentation and flushing of sediments that may affect downstream reaches.

Sediment flushing can have serious impacts on the downstream habitats and biota caused by smothering of habitat and loss of aquatic invertebrate fauna which acts as food for fishes. Fishes are also vulnerable to smothering of eggs and spawning habitat of the many rhithron/rheophilic fish species that inhabit this region of the Mekong. These species may also be impacted due to inundation of their preferred habitat by the impoundment.

The water monitoring programme proposed for during the construction phase is presumed to be carried on through the operational phase. If so, this suffers the highly descriptive nature previously indicated and the frequency and scope is not well defined, nor are responsive modes described should problems arise. Institutional arrangements for environmental management presumably remain the same, but it is unclear how the plan will be implemented and enforced.

Comment

- The MRCS agrees with the CNR conclusion that water quality and aquatic monitoring protocols to be implemented during the operation phase must be provided by the developer for due assessment of appropriateness and rigour.

### *Protecting aquatic habitat and resources*

The TbESIA & CIA report provides a systematic overview of the most important biological resources in the Mekong and the upper zone of the LMB, and the EIA Final report provides information on exploitation of the other aquatic animals and non-forest products. These reviews are, however, largely restricted to exploited fisheries resources, although some information is provided on regional biodiversity. The reports recognise the Mekong as a biological hotspot and highlight the prevalence of

threatened species through reference to the IUCN Red List of threatened species. However, there is less recognition that fish species diversity increases from the headwaters to the lower sections, which explains why the upper reaches around the PLHPP host less species than the lower part of the LMB. Notwithstanding, this region has a high endemicity of aquatic species, particularly in the tributaries associated with the project area.

Whilst the TbESIA & CIA lists endangered and vulnerable aquatic organisms in the area and suggests potential impacts, it does do not recommend special studies or management plans. It highlights that the Mekong giant catfish migrates through the area to its spawning grounds but does not recommend any special measures to monitor and promote this migration other than suggesting the fish pass facilities may mitigate the problem. No information is provided on conservation activities for other aquatic animals.

Little attention is paid to the different aquatic habitats and their ecological importance, and the focus is mainly addressing the potential impacts on migratory fish. The mitigation measures proposed therefore do not follow international best practice guidance on critical habitats.

*Water quality and ecological health monitoring and baseline conditions*

Whilst information on the status of water quality and ecological health are provided, detailed water quality and ecological health monitoring programmes have not yet been submitted. The simple monitoring programmes suggested in the EIA and EMMP reports are the same during construction and operation, including the same parameters and methods and frequency, without any targeting to identify specific water quality and ecological health issues.

Although budget estimates for these monitoring programmes are presented in the EMMP and account for some #22,8 million (likely to be U$ dollars) shared amongst the pre-construction (6%), construction (43%) and operational (51%) phases, it is not specified how the funds will be spent. There is also #580,000 allocated as "Environmental Protection Funding" but there is no indication of the purpose of this contribution.

### 4.4.6 Modified flows in the impoundment and downstream

The ecological integrity of a river depends to a high degree on the hydrological regime. The magnitude, duration, frequency, timing and rate of change in flow are responsible for erosion and deposition processes that determine the local habitat structure and substrate types, water quality conditions (e.g. temperature, oxygen), availability of energy sources and biotic interactions (e.g. spawning). The hydrology of the river and the impacts on flow regimes have been considered in greater detail by the Hydrology Annex (Annex C), this review specifically considers the effects of altering flow regimes on the aquatic ecology only.

*Local impacts of flow changes*

The reservoir will create a 110-km long impoundment, and backwater analysis shows that mean water velocities will be reduced considerably, especially during the dry season. This will have a substantial impact on the aquatic biota, transforming the river to a lentic environment, thus changing the ecosystem functioning. This will be exacerbated by the water level fluctuations in the impoundment that will affect biological productivity. Furthermore, the reduced flow though the reservoir will compromise the drifting of aquatic organisms, especially the egg and larval stages of fish that use flows to disperse downstream to nursery and feeding habitats. This will have serious implications for recruitment of fish species that rely of drifting of early life stages to maintain their life cycle. This issue

is discussed further in the Fish Passage and Fish Ecology section (Annex F). Mitigation options similar to those proposed for sediment transport may be explored.

The developer notes that seasonal downstream flow patterns will be maintained as far as possible during the filling phase of the reservoir, but the actual discharge may be one third of the average wet season flows during filling. This will have serious impacts on river ecosystem functioning and aquatic ecology, both immediately downstream of the dam and further downstream (see section on transboundary impacts). The developer proposes that environmental flow studies should be carried out during the first two years of the construction period to develop appropriate flow regimes necessary to maintain the health of the river, its ecosystems and its productivity. However, this may affect the economics of the PLHPP, and this should be undertaken as soon as possible.

As outlined in the hydrology section, water level changes of up to 3 m/day in the impoundment may occur during the flood operations phase. If the hydropeaking option is implemented daily changes of up to 0.5 - 1 m may be possible. This will also result in downstream water level changes. Such changes could have serious implications for aquatic flora and fauna and river users, both locally and further downstream.

*Transboundary flow changes*

The TbESIA & CIA report notes the seasonal changes that may be caused by hydropower development in the LMB but does not describe the contribution of the PLHPP to these changes. However, the impacts of the PLHPP as a run-of-river HPP are not likely to significantly alter the seasonal flow regime. Although the Hydrology and Hydraulics section does note that the hydropeaking and flood response operations may be noticeable down to the Thai border (100 km downstream) and even to Vientiane, especially if the Sanakham HPP is not completed.

There is a clear need to explore the impact of multiple dams in the upper Lao cascade, given Xayaburi is nearing completion and Pak Beng has passed through the PNPCA procedure, on the hydrology and ecosystem functioning.

### *4.4.7 The impacts of the upper Lao cascade on water quality and aquatic ecology*

Whilst prior consultation is explicitly targeted towards individual water uses, each review should consider the impact of the specific HPP together with dams already constructed (dams in China), in construction (Xayaburi and Don Sahong) or already having been through the prior consultation (Pak Beng). Multiple dams can have cumulative impacts through several processes related to both altered erosional and deposition processes because of the modified flow regimes, and alteration of habitat characteristics and ecosystem functioning both in the newly impounded area and in the downstream reach.

For Pak Lay, it is particularly important to consider the cumulative impacts of the upper cascade of dams in Lao PDR, especially the Xayaburi and Pak Beng HPPs. These will likely have additive impacts on aquatic ecology and water quality because the reach between Pak Lay and the head of the Pak Beng impoundment will essentially be converted to a series of reservoirs, especially if the Luang Prabang HPP is developed. This will be further multiplied by the construction of the Sanakham HPP if this goes ahead. This will change the whole Mekong ecological zone in Lao PDR from a riverine habitat to a reservoir habitat. This will result in flooding of spawning and nursery habitats of fish, changes in aquatic communities and food webs, and alteration of the food web and ecosystem functioning. This may result in the loss other aquatic organisms on which many of the rural population depend.

The cumulative impact assessment on fisheries is largely focussed on the Mekong giant catfish (*Pangasianodon gigas*), although reference is made to construction of the dam causing long term impact on the quantity and size of fish (TbESIA& CIA p.240). The report acknowledges that the PLHPP would obstruct migration of this species and would reduce the numbers of the fish and possibly cause the fish to become extinct. It proposes a well-designed fish pass for Mekong giant catfish would minimise this effect. This is both aspirational and considered unattainable, particularly in the light of the construction of the other HPP in this reach. As yet, no specific design of fish pass facility is available for Mekong giant catfish and the current design of the fish pass for Pak Lay is unlikely to achieve this objective (see Fish Passage and Fish Ecology section).

The cumulative impacts of the PLHPP and upstream dams on water quality have been considered during both the construction and operation phases of the development and are largely considered to be the same as the transboundary impacts. Unless major urban or industrial development occurs in association with the reservoir, water quality problems are likely to be associated with nutrient enrichment and decay of vegetation and may accumulate through a series of downstream reservoirs. Perhaps the biggest issue is sediment trapping that will result on long-term geomorphological changes in the downstream reaches and reduction in potential nutrients associated with the sediments. The Sediment and Geomorphology section includes more details on the potential mitigation measures in this regard.

Comment

- There should be more discussion on the implications of multiple dams on water quality, aquatic ecology and fisheries in the TBESIA & CIA report.

### 4.4.8 Conclusions and recommendations

#### *Alignment with the PDG 2009*

The PLHPP documentation provides a reasonable review of the fisheries and aquatic resources in the LMB but is less explicit with respect to the resource assessment in the PLHPP impact area. Baseline monitoring is limited and based on sampling at seven locations in two seasons – wet and dry in what appears to be one year only. The conclusion that the water quality in the reach is good complies with MRC assessment. However, some anomalies in the data provided were found.

The developer's conclusion that the invertebrate fauna was poor is not justified based on the number of samples taken and the sampling methodology. Detailed water quality and ecological health monitoring programmes were not fully described in the documentation and are the same during construction and operation. There is no mention of targeting the monitoring systems to identify potential water quality and ecological health issues or responsive procedures should problems arise.

Recommendations

- Monitoring programmes, with a sufficient and well-defined budget, need to be designed to assess impacts. These must be targeted to the construction and operations phases. These should address issues of water quality and ecological health and evaluate performance of the mitigation measures.
- The MRC Water Quality Monitoring Network and Ecological Health Monitoring Network should be interrogated to provide the general trends and status of the water quality and ecological health.

The CNR review notes that environmental flow criteria will be developed after the compliance assessment and before impoundment. As environmental flows will form part of the power production business case, this information needs to be provided as early as possible.

Recommendation

- The developers and MCs should work with MRC to make full use of their data and tools to set environment flows. Any changes in flow regimes must be set against the cumulative impacts.

There are numerous comments and recommendations in the CNR review, which do not yet appear to have been adopted. Both the CNR and this review note that the PLHPP is not aligned with the PDG2009. The developer does, however, indicate that they will be addressed.
Specific issues related to non-alignment with the PDG2009 are:

- Hydropeaking operations will cause downstream water level fluctuations of 0.5-1.0 m, while the ramping of the *impoundment* water levels during floods of over 16,700 $m^3/s$ may result in daily water level changes of up to 2.2m. Effective ramping operations have not been considered.
- No modelling has been carried out to assess the impacts of flow alteration.
- The Environmental Flow Assessment has not yet been undertaken.
- A water quality and aquatic ecology monitoring programme is proposed but is not considered sufficiently robust.
- There is no evidence of an independent panel of experts to assist with the design and implementation of water quality compliance monitoring programmes.
- The budgeting process is not well described, and more information is needed to assess alignment with the PDG in this respect.
- No provision has been made for an independent review of environmental flows or impacts on the natural aquatic environment and provisions for the fish pass facilities are inadequate and need thorough scrutiny (see Fish passage and Fish ecology TRR).

### 4.4.9 Recommendations

The JC may wish to consider the following in its deliberations:

- The baseline assessment of water quality and aquatic ecology is limited and lacks the robustness required to predict the overall impact of PLHPP on water quality and aquatic ecology. There should be a comprehensive assessment of the status of the water quality and aquatic ecology for an extended period using internationally recognised protocols, approved by independent agencies, to establish a baseline against which any impact can be determined, and recovery measures formulated.
- No modelling of the likely impacts of PLHPP on aquatic habitats is provided and surveys conducted under the design phase are inadequate.
- Water quality issues during the construction period are to be managed through good practice and attention to compliance and enforcement of construction contractors for which the PLHPP holds the main responsibility. However, no responses measures and plans are provided should problems arise.
- Although limited impacts on water quality are expected, there is still potential for problems to arise from decay of vegetation in the impounded area, resulting in nutrient enrichment and low dissolved oxygen levels in the first 5-7 years of operation. No measures to address this problem are identified other than flushing the reservoir, which is not planned for the dry season. There is a need for protocols to detect and respond to these problems.
- The description of the aquatic habitats within the overall impact area, including the geomorphology and hydraulics of the channel likely to be affected, the associated habitats and

their ecological significance in limited. Since this part of the river is an ecologically sensitive zone, important to endangered species such as the Mekong giant catfish, it is recommended a habitat inventory is carried out to identify key zones and habitats that need protection or replacement.

- An integrated monitoring programme for water quality, flows and habitats and aquatic ecology, coupled with in depth studies into the fisheries of the region, is required.
- The TbESIA lacks any assessment of the implications of multiple dams proposed in the upper cascade in Lao PDR and the interrelationships between dams and their cumulative effects on flows, water quality and aquatic ecology, both in the local area and the transboundary effects.
- There is considerable duplication and repetition information provided in the PLHPP documentation with that presented for Pak Beng HPP. It is critical the information is updated for PLHPP specific impacts and account for upstream dams and recent changes in the aquatic ecology and ecosystem functioning.

## 4.5 Fisheries and fish passage

### *4.5.1 Introduction*

This section of the TRR provides comments from the Fisheries and Environment Expert Group (FEEG) on aspects related to Fish Passage and Fisheries Ecology (subsequently called "fisheries issues"). It is based on the following documents submitted by the Lao NMC:

01 Paklay-Executive Summary-Final FS-20170321

- 1 Paklay-Executive Summary-Final FS-20170321
- 2 Paklay-Hydrology-Final FS-20170320
- 8 Paklay-Project Management Plan-Final FS-20170320
- 9 Paklay-ESIA-Final FS-20170320
- Design drawings for fish passage facilities
  - 18 Layout of fish way Structure1
  - 19 Layout of fish way Structure2
  - 20 Layout of fish way Structure3

02-Final ESIA Reports of Paklay HPP

- 1. Paklay Exsum (Eng) Final Report - Jan 2018
- 2. Paklay EIA -Jan 2018
- 3. Paklay EMMP - Jan 2018
- 4. Paklay SIA - Jan 2018
- 6. Paklay SMMP - Jan 2018
- 9. Paklay TBESIA & CIA - Jan 2018

03-Final Review Reports of Paklay HPP from CNR

- 02-PL_FINAL REPORT_MAKRAKIS_FONTE An external review by CNR (Makrakis and Fontes 2017).

The information provided will be compared with data and assessments contained in various MRC documents. The comments provided by the LNMC on the 2nd draft of the TRR, and the outcomes of a workshop on the 4th and 5th of March 2019 are also considered.

### *4.5.2 Fisheries ecology and fisheries*

Considerable information has now been accumulated about the fisheries of the Lower Mekong Basin, which has been compiled in numerous reports. This section has been based on the information provided for the Pak Beng HPP fisheries TRR, which is also relevant to the PLHPP review.

*Fish biodiversity and migration*

The Mekong fish communities are characterised by high diversity of fish species with many exhibiting complex life cycles that involve migration between different areas of the river, particularly upstream migration to spawning and nursery areas. Three main groupings are recognised: 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 over longer distances. These are often commercially valuable white fish species. This is critical to maintain sustainable stock recruitment dynamics. These migrations require unobstructed passage upstream, as well as the capacity for adults, larvae and juveniles to migrate or drift downstream. The timing of these upstream and downstream migrations is variable depending on fish life cycles and appears to be mostly driven by the flood cycle. Importantly, there appears to be continuous spawning in the river with peaks, during the spring (February-March) as the most important, followed by the onset of the flood (June-July) and then when the water is receding (November).

The PLHPP is in Zone 1 of the Mekong's Ecological Reach, which is associated with the spawning habitat of several important species. Although the precise number of species in the region is unknown, 167 species are indicated to be present in the MRC's fish species database, which are categorised into ten guilds based on migratory and main habitat use. These records are more than the number of fish species (56 fish species from 17 families) recorded in the PLHPP ESIA from seine-netting.

Species that prefer faster flowing riffles interspersed with slower flowing deeper sections, and long and short distance migrating whitefish species make up most of the catch in this reach. Fish larval drift studies have confirmed the importance of these species in this region, and the developer should have undertaken similar larval drift studies. The Mekong giant catfish migrates from its habitat in the middle Mekong Basin to spawn at the Upper Mekong Basin in Thailand and northern Lao PDR between the end of April to May. Several other fish species are listed on the IUCN Red List of threatened species.

*Fisheries activities*

Considerable fishing activity takes place in the impact area, mainly based on the migratory fish species, and the MRC estimates that some 40,000-60,000 t/yr of fish are caught in Zone 1. Fishing generally occurs during the period of upstream migration of many species 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 finfish species is found in the markets, including the non-native species, plus a range of amphibians, snails and Crustacea (Other Aquatic Animals - OAA). In addition, considerable fishing activity takes place in the tributaries associated with this region.

### 4.5.3 PLHPP fisheries studies

*Fisheries ecological and socio-economic studies*

The fisheries assessment in the PLHPP documentation comprises a literature review and field studies largely assessing fish species diversity, and interviews with fishing communities. The field studies were carried out at seven sampling stations located in the Mekong River and the Nam Xong confluence with

the Mekong River, apparently using different types of fishing gears, particularly seine-nets, cast-nets and gill-nets, although no detailed information on the sampling method is available.

The literature review highlighted that the Mekong River basin is the second largest biodiversity basin following the Amazon Basin but did not stress that it is by far the largest inland fishery. The review drew on MRC information to highlight that the fisheries are highly dependent on migratory species.

Fifty-six fish species from 17 families were collected from the seven sampling stations during the dry and rainy seasons (listed in Annex F). This includes two non-native species which now make an important contribution to the fisheries, and are found in the Mekong mainstream, reservoirs and fish farm ponds. The TBESIA & CIA provides a comprehensive review of endangered and vulnerable aquatic organisms, mostly fish species, in the area and suggests potential impacts could rise from the obstruction to migration and change in environmental conditions. It does not, however, suggest that these species will require special studies and management plans. They suggest fish pass facilities may mitigate the problem.

Interviews confirmed that fishing occurs in the tributaries, and some 113 fish species were reported to be caught by local fishers, mostly of small-sized species, although medium-sized and large-sized fish species were sold at local restaurants. It was noted that fishing is not the main occupation among local villagers in the project area, largely because the fish stocks have decreased sharply. It is, however, the main source of protein in villagers' diet and a supplementary income activity for most villagers both upstream and downstream of the proposed dam sites. Despite these comments there is considerable evidence that fishing is an important activity and critical to food security of the region.

The developer made an approximation of the harvest potential of fishes and other aquatic "organisms" based on a simple area versus production figure. The results vary between 217.5 t/year and 913.5 t/year, which appears to underestimate the importance of fisheries in the region and conflicts with other estimates reported by the developer and the MRC.

### *Fisheries Impact Assessment*

A reasonably extensive review of the fisheries in the LMB is provided based on literature but does not make use of the most recent data available in the MRC. The MRC's Council Study estimated that a 40% reduction in short distance migrating whitefish was possible. Baseline monitoring of the fish and fisheries is inadequate. Reported species diversity was lower than expected for the region and no robust empirical measure of abundance and biomass of each species was provided. No study of drift of fish larvae and juveniles has been reported, which is considered critical.

The developer notes that fisheries will be adversely affected by the disruption of migration and potential loss of endangered and threatened species both during the construction and operational phases. However, the impacts of the change in habitat from a river to a 110 km long impoundment are not recognised. There appears to be an assumption that a run-of-river HPP does not affect habitats beyond the immediate dam area, which contradicts the hydraulic modelling undertaken for the sediment loss studies. As a result, little attempt has made to relate the fisheries stock dynamics to the expected environmental changes. The impacts of the isolation or flooding of the tributaries by the impoundment has not been considered, and this will likely compromise the wild capture fisheries and the livelihoods of the people that depend on them.

A full assessment of the habitat and environmental conditions both in the impact area and downstream should therefore be undertaken. Modelling of the likely changes in structure and functioning of the in-channel habitat features can better predict likely changes in the fish population and community

structures and overall impact on the fisheries. This is fundamental to designing mitigation options to compensate likely loss of fisheries. The conclusion that an effective fish pass will minimise the impacts on the Mekong Giant Catfish is premature.

No monitoring programme for fish passage is described. This is essential to enable evaluation and adaptive management of the fish passage facilities. This issue is discussed further in Section 5.

The developer has noted that a robust fishery monitoring system has been considered in the design period of the PLHPP, which will include a data collection and fishery monitoring system (including fish migration and spawning) for both the construction and operation period of the PLHPP. They note that it is necessary to get MRC to share the upstream HPP's fishery monitoring data[26], as well as provide necessary technical support to the fishery monitoring programme of PLHPP.

Recommendations

- A robust fishery monitoring programme should be set up to collect baseline data and information as the PLHPP progresses to final design. The programme should be designed to assess any potential impacts, and to propose effective impact mitigation measures.
- Data and information from the MRC should be sourced to inform this process, as well as the design of the fishpass facilities.
- An assessment of the potential impact of altering the critical habitat by inundation of, upstream riffle reaches that act as spawning and nursery areas needs to be provided.

*Socio-economic importance of fisheries resources*

The EIA, TbESIA and ESIA describe the importance of the fisheries resources to the livelihoods of the people both near the PLHPP and elsewhere in the LMB. However, it was concluded that fisheries are not important to the region where the PLHPP is planned, thus the effect of the dam on the fishing communities would be limited. These two conclusions are incongruous and the importance of fish to food and nutritional security in the PLHPP area seems to be underestimated. There is limited information on the socio-economic dimensions of the dam proposal in the impacted region with reference to the importance of the fisheries to rural communities. Information on the importance of fisheries in a regional context is outlined in generic statements and no attempt has been made to predict the likely impact of PLHPP on livelihoods and food security derived for the Mekong mainstream to the delta.

### 4.5.4 Fish passage – Impacts and mitigation

*Introduction*

Any evaluation of impacts of HPP in the Mekong mainstream needs to consider all the factors impacting on the fisheries and the cascade in a consolidated manner. Because the PLHPP is immediately downstream of the Xayaburi HPP any fish passage considerations will need to consider these dams together. For example, it would be impractical to have a much higher standard of fish passage at Xayaburi combined with a lower standard at Pak Lay, which would then become the bottleneck for migratory fish. As is outlined below, this TRR does not consider the proposed fishpass facilities for the PLHPP to be adequate, and recommends that the design should adopt many of the features of the Xayaburi fishpass.

[26] The MRCS is developing a Joint Environmental Monitoring (JEM) programme, which will address all the mainstream HPPs. These data will be made available. However, any request that the other HPP's share their data must come from the GoL.

This section firstly outlines the principles of fish passage design (which is drawn from the Pak Beng TRR) then the PLHPP fish passage facilities are reviewed in detail.

## *Principles of Fish Passage Design*

### Background

There are two criteria underpinning fish passage design:

- *attraction* (i.e. the fishpass entrance), and
- *passage*

These criteria are interdependent: if fish are not *attracted* to the fish pass or cannot locate it, they cannot use it; equally, if they can locate the fish pass but passage conditions are poor fish cannot use it.

Effective *attraction* is dependent on three characteristics:

*i.* *Proportion of flow*
The higher proportion of river flow in the fish pass the greater the attraction for fish.

*ii.* *Upstream limit of migration*
Migrating fish swim upstream, attracted by the 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 a fishpass needs to be readily distinguishable to migrating fish and not masked by turbulence or competing flows.

Effective *passage* is dependent on knowledge of:

*i.* *Fish behaviour*
Fish behavior relates to *attraction* and *passage*. In *attraction*, it includes search patterns below a structure, response to turbulence, and response to different channel morphologies. An important aspect is the minimum depth that fish require; this is not a single figure but interacts with width (e.g. channel width) and longitudinal spacing of different depths (e.g. resting pools). Other behavioral aspects that can be important include the response of fish to light and tunnels, and diel movement patterns.

*ii.* *Swimming ability*
Fish need to negotiate water velocity and turbulence. These characteristics need to be within the burst, prolonged and sustained swimming ability of fish, which vary between sizes and species. There is also a behavioural element to consider where some species use low water velocities adjacent to surfaces more effectively than others.

The fish passage design process needs to consider all these elements within the hydraulic and hydrological and ecological context of the proposed HPP.

## *Evaluation of Measures Proposed by Developer*

### Hydrology and Ecology – criteria proposed for fishpass design

The developer indicates that the fish migration season in the Pak Lay reach of the Mekong is November to June based on data from the Khone Falls over 1,000 km downstream, and not on any studies specific to the upper Mekong. The upper Mekong (Chiang Saen to Vientiane) migrations are very poorly studied but it is expected that there will be some upstream migration all year round. The PDG2009 suggests that the fishpass should carry flows for 95% of the time. However, the Xayaburi HPP has designed a

fishway to operate for 90% of the entire year, including the peak rainy season months of September and October, as well as the dry season (December to May). It is recommended that the PLHPP should aim to allow fish migration for 90% of the time to align better with the operational periods at Xayaburi (see figure 4.1)[27].

Downstream migration is more likely to occur at any time after the peak upstream migration in the dry and early rainy season and extend to the end of the rainy season. Hence the period of downstream migration could be from June to December. However, larvae have been shown to drift downstream all year.

Recommendation

- The fish pass designers should meet with the Xayaburi designers to understand the functional criteria the latter used in their design and should aim to design a fishpass that is operational for 90% of the time.

### *Migration Flows*

A critical cue for migration for Mekong fish is flow. Figure 4.1 shows the average monthly discharge for a wet year (2% annual average flow frequency), showing the likely months of upstream and downstream migration; the likely months of spillway operation; and the fishpass operating flows for both Xayaburi and Pak Lay fishpasses.

- mpatible.

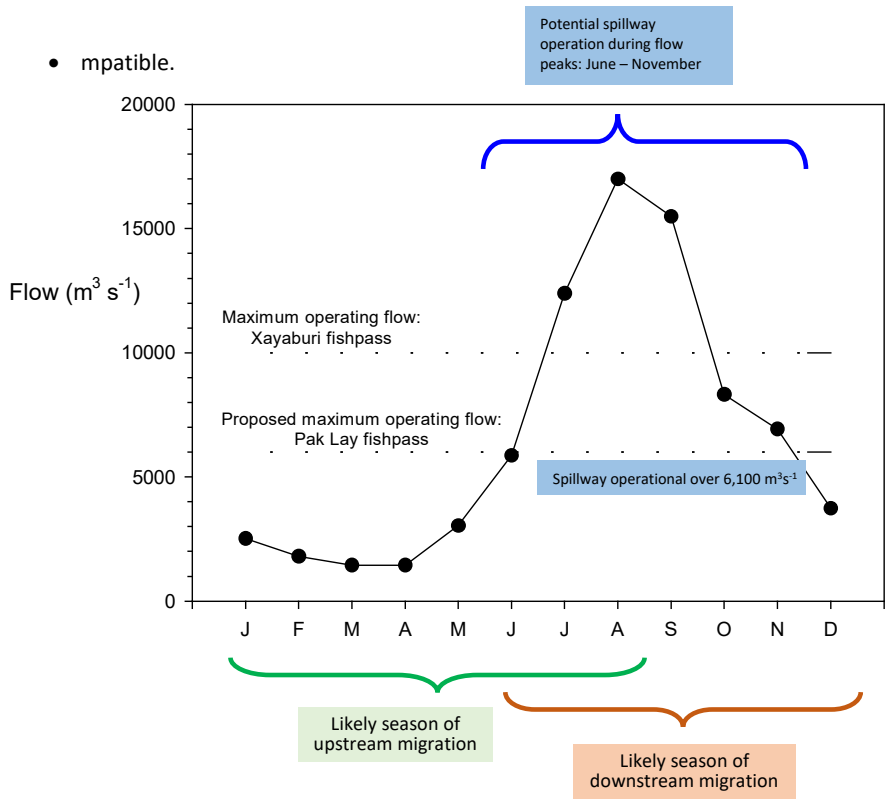



*Figure 4.1 Monthly average discharge for a year with an annual average flow frequency of 2% (data from the developer). The maximum operating flow for the Xayaburi fishpass and Pak Lay fishpass (proposed). The upstream and downstream migration season is shown with the*

[27] If the fishpass at the PLHPP is less effective than the one at Xayaburi, then some fish would not be able to migrate upstream, making the some if the investment at Xayaburi redundant.

*spillway operation that occurs at flows greater than 6,100 $m^3/s$ (maximum powerhouse flow).*

Figure 4.1 shows that:

- upstream and downstream migration is very likely to occur when the spillway or other release structures are operating, as well as when the powerhouse is operating (i.e. between 6,100 and 16,700 $m^3/s$),
- the fishpass operating flow at Pak Lay is much less than Xayaburi, and hence it will operate for a shorter time over the likely upstream and downstream migration period. .

This means that:

- Up to 6,100 $m^3/s$ all water passes through the turbines, and upstream migratory fish will be attracted to the powerhouse, and almost all downstream migrating fish will pass through the turbines.
- Between 6,100 $m^3/s$ and 16,700 $m^3/s$ both the spillway and powerhouse are operational, and upstream migrating fish will be attracted to the powerhouse and spillway.
- At flows greater than 16,700 $m^3/s$ only the spillway is used, and upstream migrating fish will be attracted only to the spillway.

In the *Pak Lay EIA – Hydrology* report the minimum daily flow for a dry year (90% annual average flow frequency) is 709 $m^3/s$. As fish migrate upstream at these low flows this should be considered the minimum design flow. This sets the minimum tailwater level, and the entrance to the fishpass must be below this level. However, as reported in the hydrology review further analysis of the low flows due to the operations of the Chinese dams is required.

Recommendation

- **Upstream fish passage should be enabled at river flows from 709 $m^3/s$ to 10,000 $m^3/s$, to provide for the migration season and align with the Xayaburi HPP[28].**

### *Headwater levels*

The PLHPP proposes a 1-m headwater range for upstream fish passage: from 239 to 240 m elevation, which covers all flows up to 16,700 $m^3/s$. A 1-m headwater range is very narrow and further consideration should be given to a wider range to allow for future changes to dam operation, particularly if consideration is given to draw down the impoundment at lower flows to promote downstream drift of eggs and larvae, and sediment flushing.

Recommendation

- **The developer should consider potential future dam operations when finalising the floor level of the fishway exit.**

### *Tailwater*

The proposed minimum tailwater level in the PLHPP assumes that the Sanakham HPP will proceed and back water up to a level of 219.0 m. However, until Sanakham HPP is fully approved and construction started, it is necessary for the PLHPP to assume a tailwater without the Sanakham HPP. In this case, based on the stage-discharge curve presented, the minimum tailwater level for the fishpass design should be 214.87 m.

[28] The developer has noted that this is already the case, but no evidence has been provided.

Recommendation

- **The final design should ensure that level of the fishpass entrance considers the possibility that the Sanakham HPP may not be constructed and matches the higher flows in the fishpass provided at the Xayaburi HPP[29].**

### *Upstream fish passage*

#### Flow range and passage directly through the dam

The current design approach is to provide upstream fish passage through a vertical-slot fishpass up to 6,100 $m^3/s$, then very little fish passage from 6,100 to 16,700 $m^3/s$, followed by passage directly upstream through the spillway gates. However, the developer notes that velocities through the spillway will be 5 to 6 m/s through the dam, which is beyond the swimming ability of fish.

#### Selection of Fish Passage Options

The developer proposes a dual-slot, vertical-slot for the fishpass, which is considered inappropriate. The pool size, water velocity, depth need to be reconsidered. Other options that could be investigated are: fish lifts, twin fish locks or a large bypass channel fishway. Using the navigation lock for fish passage is not discussed, although the developer has indicated that both the navigation lock and flood discharge gates meet the requirements for fish passage. The navigation lock system could also be a very useful option for the right-hand abutment during spillway flow (discussed below), as well as during construction.

Recommendation

- **It will be advisable to review and report on other fish passage options, including using the navigation lock for fish passage.**

#### Entrance location

The proposed entrance location is 250 m downstream of the dam, and very few migratory fish will locate it, as most fish will be attracted to the higher flows from the turbines and spillways. While a "fish guidance system" is suggested, this is not feasible to guide fish across the entire Mekong River.

Fishpass entrances are therefore recommended at the powerhouse and spillway. It is becoming standard practice to use a *collection gallery*, which is a channel on top of the draft tubes with multiple fishpass entrances. This is being used at the Xayaburi HPP. Because the behaviour of migrating fish varies among species, the collection gallery should have bottom and surface entries. These can be below or to the side of the draft tubes. For the larger benthic species, the thalweg should be shaped toward the fishpass entries.

Fish attraction at the spillway depends on the amount of flow. When the spillway is initially engaged at low flows, only one gate would likely be open, and fish would move onto the apron. At higher flows all gates would be used, and fish would aggregate along the sides of each abutment. To accommodate this behaviour, fishpass entrances are needed on both sides of the spillway.

During spillway flows the navigation lock can potentially be used to provide fish passage on the right abutment, but the navigation lock would need to be specifically designed with a dual function of fish

[29] The LNMC has indicated that this has been planned.

passage and navigation, as there are different entry discharge, water velocity and turbulence requirements. Physical modelling (1:10 to 1:25 scale) is required to optimise the flows patterns near the abutments and create low velocity zones to guide fish to the fishpass entrances. It is likely that more than one entrance would be required on each abutment[30]. The developer has indicated that fish passage entrances are unnecessary at the powerhouse and on both sides of the spillway, but that they will consult the Xayaburi design their further design processes.

Recommendations

- It is very important that fishpass entrances are provided at the powerhouse and spillway. The thalweg needs to be shaped to guide fish to the fishpass.
- Fishpass entrances are required on both sides of the spillway and physical modelling is required to optimise these. The navigation lock has high potential to provide fish passage on the right abutment but would need to be specifically designed to do so.
- The Xayaburi design should be consulted in to inform any further design processes, and to highlight what options could be feasible[31].

### Fishway Discharge

There are two components to fishway discharge:

i) *Channel flow*, which passes along the entire length of the fishway channel. This determines the fishway capacity (numbers/kg of fish per hour) as most of the migratory biomass of fish in the river needs to pass through this discharge.
ii) *Auxiliary flow*, which increases flow within the lower sections of fishways to increase discharge at the entrance and improve attraction at high flows.

The PLHPP also uses an *attraction flow* external to the fishway to improve fish attraction. The fishpass channel has a design discharge of 3.7 $m^3/s$ and external attraction flow of 4.7 $m^3/s$, for a stated total of 8.5 $m^3/s$. An auxiliary flow system is also included in the plans but there is no description in the documents provided. While external attraction flow is a good design practice, the total discharge for the system is a very small fraction of flow in the river. Common industry practice is to use 10% of low river flow and this has been included in the DG2018 and is noted in the CNR Review. This would require a flow of 310 $m^3/s$.

The fishpass in the Xayaburi HPP approaches this figure and uses up to 200 $m^3/s$ in the fishpass facility, with a combination of auxiliary flow and fishway channel flow. The fishpass channel flow at Xayaburi is 13 $m^3/s$ at low flows and 40 $m^3/s$ at high flows. The proposed external attraction flow of the PLHPP could be modified to be auxiliary flow with a modified entrance pool. Physical modelling is required to determine whether the attraction flow is retained in a new location (see recommendations on entrance location above) or modified to be auxiliary flow, and ensure the flow is not too turbulent and distract fish from the fishway entrance or ascending the fishway.

To pass higher flows, the fishpass would need to be redesigned to ensure that fish can proceed along its entire length. To dissipate the energy of the additional discharge, larger pools and a lower gradient are required. The calculation of the fishpass discharge at the PLHPP also does not consider a low headwater case and assumes that the headwater is at 240 m. At 239 m the fishpass discharge is

[30] The Xayaburi HPP has included: a collection gallery for fish across all draft tubes of the powerhouse; a spillway entrance; physical modelling to optimise fish entry on the spillway; and a navigation lock modified for fish passage.

[31] This does not imply that the Xayaburi HPP fishpass should be used as the design standard, but rather to inform what may be possible at the PLHPP.

reduced from 3.7 $m^3/s$ to 2.4 $m^3/s$, which further reduces the capacity (numbers/kg of fish per hour) of the fishpass. Fishpass discharge needs to be calculated with the minimum and maximum headwater, which can then be used in fishpass design.

Recommendation

- **It is very important that the fishpass flow (channel and auxiliary flow) be increased from 8.5 $m^3/s$ to 310 $m^3/s$ to meet good design practice for attraction flows, or at least 200$m^3/s$ to align with the Xayaburi HPP.**

### Water velocity, turbulence, pool size and slot size.

The dual-slot, vertical-slot baffle is a standard design that should suit the behavior of Mekong fishes. However, the application of the design as proposed in the PLHPP will limit the passage of small fish, large fish and a large biomass because of the water velocity, turbulence, pool size and slot size.

*Water velocity*

Fish migrations in the Mekong involve immature fish as well as adult spawning fish. Hence, fish passage needs to include a range of fish sizes. The developer suggests that the size range of fish migrating upstream is 20-100 cm based on the PDG2009 and uncited sources. However, more recent work in the Mekong River has shown that fish as small as 20 mm migrate upstream and the DG2018 has been updated to include fish 5-cm to 300-cm in length.

The fishpass design for the PLHPP is based on theoretical maximum swimming speed. However, this is typically not used for fishpass design because fish need to navigate turbulent flows as well as the maximum water velocity; and it is not possible to estimate the necessary *ground speed* (i.e. the additional speed necessary to move forward against the flow. Moreover, the maximum water velocity through and just beyond the baffles is also underestimated. (See Annex F for details).

*Turbulence*

Turbulence in a fishpass is determined by the energy of water entering the pool (water mass times velocity) and the pool volume available to dissipate that energy. Turbulence is a critical design criterion and is absent from the PLHPP documents. However, it can be calculated from the information provided and is between 68 Watts per cubic meter ($W/m^3$) [if the slot width is 0.6 m and the Cd is 0.65] and 104 $W/m^3$[if the slot width is 0.7 m and the Cd is 0.85]. These values are too high for small and medium fishes.

*Pool size and slot width*

Fish in the Mekong River can be up to 2 to 3 m long and the proposed pool size of 4.5 m long by 6 m wide is likely to restrict passage of these fish. Pool length is usually 3 times the body length of the largest fish, which would be 9 m long. The slot width needs to be 0.5 times the body length of the fish, which is confirmed in the documents provided. In this case, to allow passage of fish 3 m long, the slot width needs to be increased from 0.6 to 0.7 m 1.5 m, which has been adopted in the Xayaburi fishpass.

The developer has indicated that the flow conditions of the fish pass for the PLHPP meets the requirements for passage of all fishes.

Recommendation

- **It is very important to reduce pool step height to 0.10 m (1.4 m/s maximum water velocity); apply turbulence of 40 W/m3; increase pool size to 9 m long; and increase slot width to 1.5 m.**

### Fishway Depth

The fishway depth is stated as 2.5 m. Large fish will enter water this shallow if it is a very wide channel (e.g. 50 m) and there is no other path. But 2.5 m is very shallow for large fish in a narrow fishpass channel. In addition, the depth assumes a headwater of 240 m. When the headwater is 239 m elevation the fishway depth is reduced further to 1.76 m, which runs the upper length of the fishway channel until the lower sections, which can be deeper at high flows. The lower section of the fishway also has reduced depth at low flows.

The Xayaburi HPP fishpass uses a minimum depth of 3.55 m in an 18 m wide channel, which exceeds the DG2018 recommendation. Similar criteria should be implemented at the PLHPP. Added depth in the PLHPP fishpass can be achieved by lowering the floor of the fishpass channel for the entire length. Exit gates may be needed to operate at different headwater levels.

The developer has suggested that experiences from similar projects indicate that a water depth of 2.5m can meet the requirements for passage of various fishes.

**Recommendation**

- **The developer should consider increasing the design depth to 3 m and to base the design on the lowest operational headwater and tailwater levels.**

### Resting Pool

The proposed resting pool is a suitable size and will have areas of static water with no water velocity that enable fish to rest. However, the fishpass is very long, so consideration should be given to an additional large resting pool. The resting pool will also need habitat such as rocks for small fish to hide from predators.

Sections of the fishpass are designed flat (i.e. no gradient) with no baffles, which are intended for fish to rest. These sections should be designed wider and deeper to ensure there are static areas of water. However, as with the previous sections the developer has suggested that the design of the fish pass is acceptable. The MRCS does not concur with this assessment, and additional justification for the recommendations made here is provided in Annex F.

**Recommendation**

- **The developer may wish to investigate the feasibility of additional resting pools and enlarging flat sections of the fishpass.**

## *Downstream fish passage*

### Background

The potential downstream migration pathways for fish are through the: reservoir, fishpass via a "fish guidance system", turbine debris screens, turbines, spillway and navigation lock. For flows up to 6,100 $m^3/s$, which is the majority of the time, flow passes to the powerhouse which will first guide downstream-migrating fish to the "fish guidance system" and then the debris screens and turbines. Between 6,100 $m^3/s$ and 16,700 m3/s both the powerhouse, spillway and other water releasing structures are used. Only the spillway is used above 16,700 $m^3/s$.

### Passage through the reservoir

Many Mekong riverine fish species have drifting larvae, which typically require a minimum mean channel velocity of 0.3 m/s to be maintained in the drift. In the upper Mekong River this threshold may be higher. If the water velocity is too low the larvae may either, settle to the bottom of the reservoir and die, starve from lack of suitable planktonic food, or are subject to greater predation in the static, less-turbid water of the reservoir.

Backwater analysis of the proposed reservoir shows that at discharges above 6,100 $m^3/s$ mean channel velocities are greater than 0.3 m/s, so larval drift will likely be maintained when the spillways and turbines are operational. However, in dry years flows less than 6,100$m^3/s$ can occur for 80% of the time and no analysis of these lower discharges is provided. The physical modelling for the navigation lock shows that at 1,940 $m^3/s$, the velocity in the reservoir immediately upstream of the dam is less than 0.2 m/s, which would not maintain larval drift. The discharge threshold which reduces water velocity in the impoundment to the point of impacting larval drift is likely to be between 2,000 and 6,000 $m^3/s$ and further analysis is recommended.

The impacts can be mitigated by lowering the reservoir level to maintain water velocity throughout the reservoir, and it is recommended that the reservoir management system is reviewed to assess the potential to maintain water velocities for larval drift at flows less than 6,100$m^3/s$, even if only for limited (and critical times). This will impact on energy production and hence internalise some of the external environmental costs. The optimum balance between power pricing the concession period and fisheries (and hence ecological and socio-economic) impacts should be found.

Recommendation

- The developer should conduct additional hydraulic modelling to assess the impacts of different operating rules on fish larval drift (this will also benefit the sediment passage). Review reservoir management to mitigate the impact at low flows.

### Passage through the "fish guidance system"

The developer indicates that a fish guidance system will be provided at the upper inlet of the fishway to prevent the fishes from entering into the turbines and guide them to the fishway. However, no concept sketches, detailed plans or descriptions are provided. Behavioural guidance systems – using light, sound or electricity - are used in shallow, low discharge environments that have a low water velocity, and are not suitable to divert fish away from a powerhouse using up to 6,100 $m^3/s$. A physical screen could be used but none have been designed for 6,100 $m^3/s$. The summary of costs provided also does not include any "fish guidance system." Hence, for the purposes of this review it is assumed that all fish migrating downstream that are approaching the powerhouse and turbines, will not be practically diverted. The MRCS believes that it is possible to design screens that can divert fish away from the powerhouse, and this is required under the PDG 2009. However, the developer has indicated that it is difficult to find suitable screens in the market place.

Recommendation

- It is very important to further investigate the feasibility of fish screens and the downstream fish passage facility.

### Passage through the fishpass

Downstream passage through the fishpass is possible but very few fish would locate the upstream entrance. There is no hydraulic cue for downstream-migrating fish to enter the fishpass at the upstream

end and the fishpass uses a very small flow compared with the flow through the turbines. While the powerhouse is operating without the spillway, almost all fish would migrate to the debris screens and turbine intakes where most of the flow occurs.

### Passage through the debris screens in front of the turbines

Fish approaching the turbines firstly encounter a debris screen. Detail of the debris screens in the PLHPP are not shown but they are typically vertical bars with gaps of 12 to 20-cm. The gaps allow eggs, larvae, juveniles and adult fish up to approximately 75-cm long to pass through to the turbines. However, larger fish can be trapped against the screens and die. This is a very high risk for adult fish in the PLHPP that needs to be addressed by developing the screen design with a fish collection system and diversion channel that safely passes fish downstream. The Xayaburi HPP presently has this type of system to divert fish in front of the turbines. Typically, the screens have low approach velocities of 0.3 m/s but designs with higher sweeping velocities may be applicable.

**Recommendation**

- **It is very important that the debris screen be redesigned, with a fish collection system and diversion channel that safely passes fish downstream.**

### Passage through the turbines

Fish can experience three impacts passing through turbines: pressure impacts (barotrauma), shear and blade strike (including grinding on the edge of the blade and turbine housing).

The extent of injuries and mortality from these impacts depends on size, swim bladder (gas bladder) morphology and the fragility of the species – and turbine design, including the number of blades (less blades – less injury), blade speed (lower speed - less injury), blade thickness (thicker blades - less injury), number and location of wicket gates (less gates – less injury), and depth of turbine (deeper – less barotrauma). The physical attributes of the turbines in the PLHPP are described in the documentation but there are no data on the impacts of blade strike, shear or pressure, and how this might potentially impact fish. There are no specific data of these impacts on Mekong fishes, but some aspects can be extrapolated from other species and are discussed below.

*Turbine Passage - Blade Strike*
Small fish (e.g. <50 mm) will have a low probability of suffering injury from blade strike on the bulb turbines in the PLHPP but medium to large fish (> 300 mm) have a significant probability of suffering blade strike. There are currently no turbines commercially available for dams similar to the height and discharge of PLHPP that protect medium to large fish from blade strike. A thick leading edge on the blade can reduce strike but the only effective mitigation for large fish is to prevent them entering the turbines by specifically designed fish screens and diverting them downstream via a bypass.

*Turbine Passage - Pressure Impacts (barotrauma)*
Species that have a swim (gas) bladder with a duct connected to the throat are more likely, but not always, to depressurise by releasing gas as they pass through the turbines. This applies to catfish species, which may be less sensitive to this type of injury that other fish. However, species than have a dual swim bladder or a closed swim bladder with no duct, do not readily release gas and have a high probability of suffering injuries and mortality. The extent of these impacts is dependent on the pressure profile through the turbine, which can be determined by computer modelling (Computational Fluid Dynamics [CFD]).

If benthic species with closed or dual swim bladders are acclimated to 20 m depth upstream, passing through the turbine to the tailwater would cause the swim bladder to double in volume – in some cases, protruding from the fish's mouth. If fish are acclimated to surface pressure, there can be less impact. However, turbines develop negative pressure on the downstream side of the blades, which can have high impacts on fish. This applies to larvae that have developed a swim bladder, as well as juvenile and adult fish. Therefore, it is critical to understand the pressure profile of the turbine to assess the impact and more information is required to make an assessment of these impacts. Designing the turbine to have a change in pressure of only 10% (pressure ratio of 0.1) between the lowest pressure and the acclimation pressure, would mitigate most impacts from barotrauma. [32]

Improving the pressure ratio is possible by: i) guiding all fish to the surface in the forebay so that they are surface-acclimated before passing through the turbines; and ii) having deep turbines to eliminate sub-atmospheric pressures.

*Shear*

Shear is the force generated by two bodies of water moving in different directions, most notably in turbulent flow. Shear can be modelled with CFD and there are some data on the impacts of shear on non-Mekong fish species that would provide an indication of this impact. An initial design criterion for shear is less than 150 cm/s/cm for 99% of flow paths through the turbine. More information on shear based on CFD is required before this impact can be assessed.

*The PLHPP turbine design*

The developer proposes 6.9 m diameter bulb turbines, which are a relatively large diameter turbine with a relatively slow rotation. These attributes reduce impacts on fish compared with small diameter turbines, but no data are provided on blade strike (including the size of fish expected to pass through the debris screen), pressure or shear to evaluate fish mortality.

The major risks for the PLHPP and downstream passage through the turbines are blade strike of large fish that pass through the debris screens and the pressure impacts, especially for carp species (cyprinids). The developer has indicated that they are communicating with turbine manufactures to study the impacts of pressure ratio and shear of flow paths fish survival rate to improve the capacity of the turbine for fish passing. However, no documentation has been provided so the following recommendations are provided.

Recommendations

- The communications with turbine manufactures should aim to modify the turbine design to have a pressure ratio of 0.1 and a shear of < 150 cm/s/cm for 99% of flow paths.
- Options to guide fish to the surface in the forebay, so that they are surface-acclimated before passing through the turbines or locating the turbines deep in the tailwater to eliminate sub-atmospheric pressures, should be investigated.

### Passage through the spillway

The spillway will be used mainly when river flows exceed the powerhouse flows of 6,100 $m^3/s$ but may be used at other periods to balance flow through the turbines. At flows above 16,700$m^3/s$ the spillway gates are fully lifted and the reservoir level drops. Larvae, sub-adult and adult fish are likely to be migrating downstream when the spillway is in use.

[32] Note that decompression impacts fish, not compression.

The spillway uses undershot radial gates. These have a high risk of injuring fish if they partly open, providing undershot flow, which will happen from 6,100m$^3$/s to 16,700 m$^3$/s. Injuries occur from pressure changes passing through the gates and shear may be involved as well. If the gates are operated fully open there is little risk for fish. The spillway has a relatively smooth profile with no dissipators, so there is no sudden deceleration or direct impacts. It is therefore preferable to operate with fewer gates fully open than more gates partly open.

If the gates are used in the partly open position, which is very likely, it is recommended to either replace the gates with an overshot design or include overshot gates within all the radial gates. These small overshot gates can then pass low flows until a radial gate can be fully lifted.

Gate operation has a significant influence on flow patterns downstream and the effectiveness of fishpass entrances. Various configurations of gate operation need to be tested in physical modelling to integrate flow patterns with the spillway entrances for the fish passes. The LMNC has indicated that these studies are underway.

Recommendation

- The studies being done should consider the impacts of replacing the gates with an overshot design or include overshot gates within all the radial gates.

### Passage through the navigation lock

Downstream passage through the navigation lock would provide safe passage for fish. However, as with the fishpass there is no hydraulic cue for downstream-migrating fish to enter the lock at the upstream end.

### *Fish passage during construction*

There are two stages to fish passage during construction: i) when the river is partially blocked by a coffer dam, and the river flows freely on the unblocked side; and ii) when the second coffer dam is installed, which covers the entire river, and flow passes through the completed spillway section. While the developer suggests that these processes will not impact fish migration, impacts are still highly likely.

In the first stage, the cross-section of the river is halved which will increase water velocity and could impede or block fish passage. Detailed hydrodynamic or physical modelling is required to assess whether alternative fish passage routes should be found during this stage of construction.

In the second stage, fish cannot pass upstream through the spillway because water velocities are too high. A dedicated fish passage solution is required at this stage. The Xayaburi HPP contractor used the navigation lock as an alternative fishpass during construction. Alternatively, for the PLHPP a separate fishpass could be used. It would be difficult to adapt the proposed vertical-slot fishpass as the exit would be at full supply level. The developer has indicated that the ship lock can be used for fish passage.

Recommendations

- It is important to determine the hydraulics of the constricted river for the Stage 1 coffer dam and to provide a dedicated fish passage solution for Stage 2, and Stage 1 if required.
- The developer should further elaborate the plans for using the the navigation lock to facilitate fish passage during construction.

### *Summary of Key Recommendations*

The key recommendations for the fish passage are summarised below and aligned with the numbers in Figure 4.2. An overarching theme is that fish passage at the PLHPP needs to meet the PDG requirements, or at least have compatible function with the Xayaburi HPP, which is immediately upstream.

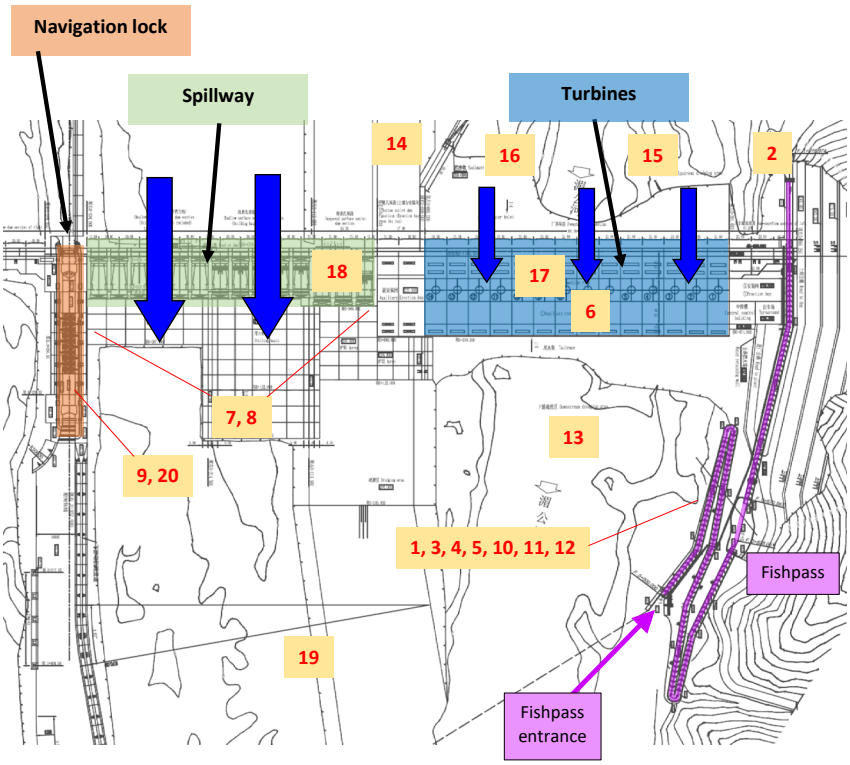



*Figure 4.2. Layout of PLHPP showing key recommendations.*

Key Recommendations for Fish Passage (numbers refer to Figure 4.2).

Upstream Passage

1. Expand operational flow range of fish passage to 10,000 $m^3/s$.
2. Review headwater range to ensure it does not limit future operation.
3. Expand tailwater range to match 10,000 $m^3/s$ and assume Sanakham will not be built until all approvals are completed.
4. Review fishpass design options.
5. Change entrance location and do not use a fish guidance system.
6. Incorporate collection gallery at powerhouse.
7. Incorporate spillway entrances for fish passage.
8. Do physical modelling (1:10 to 1:25) of entrances on spillway.
9. Investigate use of the navigation lock for fish passage during and after construction.
10. If vertical-slot design is retained, use: 0.1 m step heights, $40W/m^3$ turbulence, 3 m minimum depth, 0.15 m slot widths, 9-m long pools.
11. Increase fishway discharge to 200 $m^3/s$ minimum.
12. Investigate additional resting pool and modify flat sections of fishway channel.
13. Cut or shape a channel in the river bed to connect the fishpass entrance with the deepest channel of the river (thalweg).

Downstream Passage

14. Assess larval drift at low flows with hydraulic modelling and review reservoir management, if necessary.

15. A fish screen is required at the turbine intakes to mitigate the impact of blade strike and mortality of medium- to large-sized fish.
16. Investigate a simple pressure acclimation weir in front of the turbines.
17. Design turbines for 0.1 pressure ratio and 150 cm/s/cm shear. Computer modelling of the turbines is required to assess and mitigate the impacts of blade strike, shear and pressure.
18. Spillway: Use radial gates fully open to reduce impacts on fish, or replace radial gate with an overshot design, or include overshot gates within all the radial gates.

Passage during Construction

19. Do detailed hydrodynamic or physical modelling for the Stage 1 coffer dam and provide a dedicated fish passage solution for Stage 2, and Stage 1 if required.
20. Investigate using the navigation lock for fish passage.

### *Risk assessment of PLHPP Fish Passage*

Risk assessment is a qualitative analysis of the consequence or scale of risk and the likelihood or probability of the risk occurring. These two values are combined to produce an overall risk score. A risk management framework operates by establishing the context (i.e. proposed hydropower development); identifying the risks on the existing situation (consequences and likelihood); assessing the risks; and addressing the risks. It is a useful tool to prioritise actions and resources, and to identify knowledge gaps, which then inform the monitoring programme.

Annex F provides more detail on the development of the risk matrices. However, Figure 4.3 provides a visual assessment of the before and after mitigation risk profiles based on the following colour scheme:

| Low | Moderate | High | Very High |
|---|---|---|---|

In the present risk analysis the following risks are assessed: i) the Proposed Design) and ii) the Proposed Design after applying recommendations and mitigations from the TRR ; the latter assesses the *probability that the risk can be mitigated*, which not only reflects the recommendations but also assumes ongoing discussion between the developer and the MRC, which the JC may wish to propose as conditions, that would result in the optimal design being presented.

In these two risk assessments, only the most important risks have been examined so that the *consequence* of these is either *major* or *extreme* and hence, the risk scores, based on differing likelihoods are *Moderate*, *High* or *Very High*. The risk assessment of the Proposed Design reflects the issues raised in this review, but importantly it prioritizes where the design needs to be improved. Those risks that are *Very High* or *High* are the highest priorities to address in any final design process.

The risks can also be viewed as links in a chain for upstream and downstream migration – attraction into, passage through and exit of a fishpass are all essential to complete fish passage, as are the components for downstream passage. Hence, all risks in a horizontal block within the table need to be addressed to enable the full migration of that group to be completed. Other ecological links to complete life cycles are also essential, such as access to spawning and refuge areas, and these are addressed elsewhere in this report.

**Risks to fish migration before mitigation**

| | Upstream Migration | | | Downstream Migration | | | |
|---|---|---|---|---|---|---|---|
| | Limited attraction and entry into fish passage facilities | Limited ascent of fishpass | Ineffective exit – risk of fallback | Limited passage through impoundment | Limited attraction and entry into fish passage facilities | Mortality passing Pak Lay site – including spillway and turbines | Poor exit; risk of predation downstream |
| **Life Stage** | | | | | | | |
| Larvae & fry | N/A | N/A | N/A | Very High | Very High | High | Moderate |
| Small-bodied species (5 -30 cm) | Very High | Very High | Low | Moderate | Very High | High | Moderate |
| Medium-bodied (30-150 cm) | Very High | High | Low | Low | Very High | Very High | Moderate |
| Large-bodied (150-300 cm) | Very High | Very high | Low | Low | Very High | Very High | Low |
| **Behaviour** | | | | | | | |
| Surface | High | High | Low | Low | Very High | High | Moderate |
| Mid-water | High | High | Low | Low | Very High | Very High | Moderate |
| Benthic (including thalweg) | Very High | High | Low | Low | Very High | Very High | Moderate |
| **Migration Flow** | | | | | | | |
| Low (dry season) | Very High | Moderate | Low | Very High | Very High | Very High | Moderate |
| Moderate (early wet, late wet) | Very High | Moderate | Low | Moderate | High | High | Moderate |
| High (wet season) | Very High | Moderate | Low | Low | Low | Low | Low |
| | | | | | | | |
| **High Biomass** | High | High | Low | Low | Very High | Very High | High |

**Risks to fish migration after mitigation**

| | Upstream Migration | | | Downstream Migration | | | |
|---|---|---|---|---|---|---|---|
| | Limited attraction and entry into fish passage facilities | Limited ascent of fishpass | Ineffective exit – risk of fallback | Limited passage through impoundment | Limited attraction and entry into fish passage facilities | Mortality passing Pak Lay site – including dam turbines | Poor exit; risk of predation downstream |
| **Life Stage** | | | | | | | |
| Larvae & fry | N/A | N/A | N/A | Moderate | Moderate | High | Moderate |
| Small-bodied species (5 -30 cm) | Moderate | Moderate | Low | Low | Moderate | High | Low |
| Medium-bodied (30-150 cm) | Moderate | Moderate | Low | Low | Moderate | Moderate | Low |
| Large-bodied (150-300 cm) | High | High | Low | Low | Moderate | Moderate | Low |
| **Behaviour** | | | | | | | |
| Surface | Moderate | Moderate | Low | Low | Moderate | Moderate | Low |
| Mid-water | Moderate | Moderate | Low | Low | Moderate | Moderate | Moderate |
| Benthic (including thalweg) | Moderate | Moderate | Low | Low | Moderate | Moderate | Moderate |
| **Migration Flow** | | | | | | | |
| Low (dry season) | Moderate | Moderate | Low | Low | Moderate | High | Moderate |
| Moderate (early wet, late wet) | Moderate | Low | Low | Low | Moderate | Moderate | Low |
| High (wet season) | Low | Low | Low | Low | Low | Low | Low |
| | | | | | | | |
| **High Biomass** | High | High | Low | Low | Moderate | Moderate | Moderate |

*Figure 4.3 A depiction of the risks to fish migration and the potential risk profile before and after the recommended mitigation measures are implemented.*

### 4.5.5 CNR Review of Fish Passage

The fish passage facilities were reviewed by CNR. While MRCS review agrees with many of the recommendations made by CNR, there were several areas that were not addressed. Importantly, the CNR review concludes that the "PLHPP is nearly fully compliant with MRC guidelines and international standards, and that any remaining issues should be easily addressed during the next stage of the project". However, this TRR suggests that there is much that can still be done to avoid, minimise or mitigate some of the potential impacts of the PLHPP on fisheries issues.

The CNR review did not appear to appreciate the complexity and cost of some of the recommendations such as fish screens, or the size of the fishway that is required to pass 10% of low flows. The recommendations proposed - many of which CNR agrees with - require a complete redesign of upstream and downstream fish passage for the PLHPP. They are not minor changes and will require a major increase in the budget, and hence affect the economic viability of the proposed HPP.

#### *Conclusion*

The current fish passage solution for PLHPP has a very high risk of passing very few fish safely. Almost all migrating fish will be blocked from continuing to migrate upstream, and there are likely to be significant impacts on fish passing downstream. If the fish passage remains unaltered, it will very likely have significant transboundary impacts on migratory fish populations.

Following the recommendations in this review greatly reduces this risk but will significantly increase cost. The present budget for fish passage is USD 8.59 million, which is 0.4% of the total project cost. An effective fish passage solution would likely be closer to 10% of the project cost.

### 4.5.6 The implications of the cascade and transboundary impacts

#### Impacts of multiple reservoirs

Whilst the PNPCA procedure is explicitly targeted towards review of individual HPP schemes, placing this in the context of the other tributary and mainstream dams is central to any determination of whether it is a reasonable and equitable use of the water resources of the LMB. In the PLHPP case, it is particularly important to consider the cumulative impacts of the upper cascade of dams in Lao PDR, especially the Xayaburi and Pak Beng HPPs, which have already undergone prior consultation. These will likely have additive impacts on fish and fisheries because the reach between Pak Lay and the head of the Pak Beng impoundment will essentially be converted to a series of reservoirs, especially if Luang Prabang HPP is also developed.

This will change most of the habitat of the upper Mekong ecological zone in Lao PDR. It will result in inundation of riverine habitat and flooding of spawning and nursery habitats of fish, alteration of the food web and ecosystem functioning, and potential loss of fisheries and OAAs on which many of the rural population depend. Pak Lay will likely regulate movement of fish further upstream.

The developer tends to deal with the impact of PLHPP, not the multiple dams, and concludes it would obstruct migration of the Mekong giant catfish and possibly cause the species to become extinct. It is noted that long-distance migratory species will likely be affected, and non-migratory and short-range migratory species should not be adversely affected, largely because they can breed in the new environment. However, there is no evidence presented to justify this argument. Moreover, the ESIA suggests that there will not be any stagnation, which conflicts with the other documentation provided, which show that flow velocities in the impounded reach will be significantly reduce for most of the time. In addition, the biomass supported in impoundments is as low as 30% of the biomass found in the unmodified river system.

Evidence from elsewhere in the world where cascades of dams are found suggests that the flooding of spawning and nursery habitats is very likely to result in the collapse of the traditional riverine stocks and fisheries. The fish community structure will inevitably change, and productivity will most likely decline. If the full cascade is developed, the impoundments created will flood up to the next upstream dam leaving little free-flowing riverine habitat in which fish that bypass the dam can spawn and reproduce. The losses of productivity are unlikely to be compensated by stocking or aquaculture. This problem is further exacerbated if access to the tributary rivers is impeded by the construction or flow dynamics in the reservoir preventing fish from finding the mouth of the tributary.

It should be recognised that considerable data are held by the MRC and MCs to understand the impact of HPP developments on the fish and aquatic habitats and their importance to delivering ecosystem services, including fisheries, in the LMB. The developers should work with MRC to make use of these tools. The developers and MCs should also make better use of MRC data and capacity to develop simpler informative models prior to the PNPCA to ensure robust information on the baseline status and likely impact of the dam is provided.

The developer should therefore explore the impact of multiple dams on the hydrology and ecosystem function, with attention to the cumulative effects of the Xayaburi and Pak Beng HPPs on downstream ecosystems. The basin development scenarios envisioned in the MRC Council Study (MRC 2017) should be consulted in this regard. 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. This will highlight the implications of the impacts at both the local and basin-wide scales, so the relevance of the proposed projects is reflected for all riparian countries.

Although a TBESIA & CIA report has been prepared by the developer, the information on transboundary and cumulative fisheries impacts are generic and not specific to PLHPP. The developer has indicated that additional information about the fisheries impact will be supplied and more accurate data will be provided in a potential post PNPCA process to optimize the transboundary and cumulative impact assessment.

Recommendation

- A comprehensive transboundary and cumulative fisheries impact assessment is needed to fully understand the potential impacts on the other Member Countries.
- The developers and MCs should make better use of MRC data and capacity to assess the likely impact of the PLHPP on critical habitats and the impact on ecosystem functioning and services, including fisheries, in the LMB.

### Multiple interruptions to fish passage

Dams disrupt longitudinal connective by acting as barriers to movement, which can potentially be mitigated through provision of suitable fish passage facilities. However, fish passes are rarely, if ever, 100% efficient, especially for passing the highly diverse fish species fauna found in tropical rivers. Each dam will potentially reduce the number of fish that are able to move further upstream the cumulative effects of reducing migration success at each dam will not be additive but the product of success at each facility. In addition, the probability of bypassing several dams in series decreases with each successive dam, irrespective of the efficiency of each fishpass facility.

Substantial mortality is likely for downstream migration should fish and larvae pass through the turbines. The level of mortality is potentially high, irrespective of the assertion that the turbines are 'fish friendly'. Similar high mortalities are also likely to occur if the larvae pass over the spillway. However, without adjustment to the operating rules, most larval stages of fish are unlikely to bypass the impounded reach because they depend of drift with the current. Consequently, the cumulative

mortality rates past successive dams are likely to be considerable, to the detriment of fish recruitment and production, and ultimately catches.

The cumulative effects of disruption to fish migration at single and multiple barriers has been modelled in the MRC Council Study (2017). Even given that the eurytopic, generalist species and invasive species will fill vacant niches, the effects of multiple barriers on fish production was considerable. The developer should be seeking to undertake similar modelling to determine the precise impact of PLHPP and other HPPs in the upper cascade on fish production but using robust baseline data from the pre-construction phase for the analysis. The developers should work with MRC to make full use of their data and tools to support this requirement.

*Transboundary fisheries impact*

The developer provides a generic description of the fisheries in the LMB and the drivers, especially hydrology and sediment loading, on fisheries production. No comprehensive trans-boundary fisheries risk and impact assessment has been provided, it is more a description based on existing information, particularly the SEA (MRC 2010).

The developer does provide some description of the potential transboundary impacts, but this appears to have been copied from the Pak Beng case and is therefore not discussed further in this section (some discussion is provided in Annex F).

The modified hydrological regime due to the HPPs in China and larger tributary projects, linked with the depleted sediment loading expected over the longer term, is likely to have major impact on productivity in the LMB, with knock-on effects on fish and fisheries. This is described in the Final ESIA (ESIA pp. 9-55-9.58) where the main conclusions are:

- Pak Lay HPP would cause an obstruction to migration particularly of critically endangered species as Mekong giant catfish and the Mekong stingray and might cause a severe depletion of threatened fish species. However, negative impacts on the small white fishes and the Cyprinidae would be less as these fish could migrate to the tributaries (no need to pass through dam) for reproduction and spawning.
- Construction of dam would cause a limitation of fish habitat unless an appropriate fish pathway can be designed.
- The construction of the dam would impact on the fish population due to the change of water level downstream unless an appropriate fish pathway can be designed.
- The lower level of water would lower normal flood levels, and floodplains along the river bank.

However, this is a rather superficial assessment, which assumes that the fishpass facilities will address all the concerns. This is not likely to be the case, and there is a need for a dedicated transboundary impact assessment including the potential socio-economic impacts.

### 4.5.7 Monitoring, mitigation and compensation measures

*Monitoring programme proposed*

The monitoring undertaken provides a limited baseline assessment, which was also noted by the CNR review team. The CNR team recommended a more comprehensive monitoring programme, but this has not yet been adopted. The programme should run for a minimum of 2 years before construction. The same programmes should be maintained throughout the construction and operational phases, although additional activities will be required during the construction phase. The programme should establish clear objectives and establish sampling protocols to evaluate specific indicators of the status and trends in the fisheries and linked to dam operation. International standard protocols exist for these

monitoring components and MRC is establishing standard procedures as part of the Joint Environmental Monitoring project (JEM) and the Fisheries Abundance and monitoring (FADM) initiative and the develop should liaise and engage with the MRC to adopt these procedures to harmonise sampling methods and develop the capacity to share data and improve on the assessment results. (Further information on the recommended monitoring are provided in Annex F)

Recommendation

- A comprehensive monitoring programme should be implemented to establish the baseline status of the fisheries (based on the 10 MRC guild categories Annex F: Appendix 3) and OAAs before construction starts.

*Proposed fisheries management and mitigation measures*

The developer proposes several measures to manage and mitigate impacts on the fisheries including:

- Construction of fishpass facilities to limit impacts on migration.
- Release of a flood pulse at the onset of the wet season to encourage upstream migration of fish.
- A mobile fish transport unit with large aerated containers to collect fish from downstream or the resting pool in the fishpass.
- Fishery conservation management should be implemented in the project area, but no details are provided.
- Adoption of aquaculture within the headpond area and establish community fisheries in the reservoir and individual household fish/frog ponds. For farmers who have paddy fields the rice-cum-fish system (simple enhancements to increase the natural productivity of fish in paddy fields) will be introduced and promoted.

The mitigation measures proposed beyond fish passage facilities are largely aquaculture-based production which will require adjustment of fishing activities, and more related to management of fisheries production in the reservoir rather than true mitigation and compensation mechanisms. The flood pulse system needs in-depth understanding of the ecology of the fishes in the region to be effective and trap and trucking is unlikely to be effective given the cascade system of dams isolating the upstream segment of the river. Similarly, stocking is not considered an appropriate mitigation measure because the impoundment will be relatively shallow with a short retention time and subject to daily water level fluctuations. These operational characteristics of the HPP scheme disrupt fish recruitment dynamics and productivity in the impoundment, making it sub-optimal for stock enhancement activities.

These measures are unlikely to compensate for the lost fisheries production. They also do not address social and economic issues associated with the establishment of aquaculture, as most rural communities do not have the skills or capacity to invest in developing these activities.

Recommendation:

- A thorough situation analysis should be carried out to determine the capacity of the local fishing communities to adapt to the potential changes that will arise from the proposed dam.

### *4.5.8 Recommendations for the JC*

The PLHPP documentation provides a reasonable review of the fisheries and aquatic resources in the LMB but is less explicit with respect to the local resource potential. The reports provide little baseline information on which to a make comprehensive evaluation of impacts or to formulate measures to mitigate any likely impact. A monitoring programme has been proposed by the developer, mainly targeting the construction phase, but this lacks detail and does not appear to include assessments of

the efficacy of the fish passage facilities. Additional information on endangered fish species is needed to develop conservation strategies to protect both the species and their critical habitats.

The fishpass facilities require significant revision to account for the full range and sizes of species that are likely to use the fishways. Alternative fishpass designs may be required to determine the most effective approach; suggestions to optimise the design are included in Annex F.

Information on the socioeconomic and livelihoods dimensions specific to the fisheries sector are limited. There is a need for a detailed baseline study on the socio-economic impacts both in the immediate PLHPP reach and any transboundary areas likely to be impacted by the development. This is required to support the design of alternative livelihoods options, and the equitable distribution of the benefits within the impact area and in downstream reaches.

The EIA and TbESIA&CIA lack any assessment of the implications of multiple dams in the upper cascade proposed in Laos and the interrelationships between dams on fish and fisheries, specifically with respect to the contribution made by the PLHPP.

Budget estimates for the overall environment management and monitoring plan (EMMP) are provided (i.e. US$22,815,000 or approx. 1% of the total investment), but there is no indication of how the monitoring costs will be covered. The documentation indicates that monitoring will be assisted by regional experts, although details of this process are not provided. An external peer review process will improve experimental design and collection of appropriate data.

The JC may wish to consider the following in its deliberations:

- A robust fisheries monitoring programme to evaluate: i) the status and trends in fisheries and OAAs; and ii) the effectiveness and efficiency of the fishpass should be designed, with detailed methods and budgets. Mechanisms to ensure that the outputs of these studies are acted on, should be included;
- The documents submitted need to be supplemented with additional information to allow for scientifically sound decision-making regarding the extent of the impacts of the PLHPP on fisheries (local, transboundary and cumulative), and options to mitigate these impacts;
- A more detailed technical analysis of both upstream and downstream fish passage facilities appropriate to all species, life history stages and sizes, including benthic species, should be carried out and mechanisms to improve the design and efficacy of fish passage solutions should be integrated into the dam design;
- There is a need for dedicated socio-economic studies on fishing households and their dependence on fisheries for food security and livelihoods. In addition, there is need to determine dependency of rural and peri-urban communities on fish and OAA as primary dietary items and for nutritional requirements;
- A comprehensive assessment of the likely cumulative and transboundary impacts of the cascade of dams in the upper ecological zone in Lao PDR is required. The developers and MCs should work with MRC to make full use of the available data and tools to support this requirement;
- There is a need for dedicated socio-economic studies on fishing households (including part-time and seasonal fishing households) and their dependence on fisheries for food security and livelihoods. In addition, there is need to determine dependency of rural and peri-urban communities on fish and OAA as primary dietary items and for nutritional requirements;
- A comprehensive appraisal of measures to mitigate potential loss of fisheries and biodiversity, targeting both upstream and downstream fishing communities, together with realistic associated costs should be carried out. Alternative solutions to mitigation such as offsetting should be explored.

- There is need for a detailed budgetary breakdown into monitoring, mitigation and contingency during the construction and operational phases of the life cycle of the dam development.

## 4.6 Dam Safety

### *4.6.1 Introduction*

This section of the TRR addresses the:

- Overall content of the PLHPP documents for dam safety measures;
- Comprehensive dam safety reviews;
- Emergency preparedness plan; and
- Other information on the safety of dams.

The first draft of this report was prepared based on an initial review of the key documents. The report has subsequently been updated following a visit to the dam site on the 6th – 7th November 2018 and comments received from the PNPCA JCWG and stakeholders. The outcomes of a workshop on the 4th and 5th of March 2019 have also been considered.

### *4.6.2 Documents Reviewed*

This review is based on the following documents:

- Pak Lay Hydropower Project Feasibility Study Report, Final Report, March 2017, Powerchina and CEIEC
- Pak Lay Hydropower Project, Environment and Social Impact Assessment, Final Report, January 2018, PowerChina Resources Ltd
- Pak Lay HPP Feasibility Study Review Final Report, Final Version, January 2017, CNR Engineering

Additional documents provided during the consultation period include:

- Dam Safety Evaluation and Effects of Dam Breach – the authors and date of issue are not noted on this report
- Pak Lay Hydropower Project, Hydraulic Model Test Report – the authors and date of issue are not noted on this report
- Seismic Hazard Assessment for the Pak Lay Hydropower Dam at the Mekong River (Lite Version) – the authors and date of issue are not noted on this report. But it is understood that the report was written by Geoter SAS.
- Seismic Hazard Assessment for the Pak Lay Hydropower Dam at the Mekong River, Report GTR/PCH/1215-1388 Rev 2. This report was provided too late to be reviewed. It is recommended that Panel of Experts review this report in detail.
- Design Standard for Concrete Gravity Dams SL.319-2005 (English Version).
- Design Specification for Concrete Gravity Dams DL5108-1999 (English Version).

It is recognised that some of the issues identified in this review may have already been attended to by the developer and only require clarification at this stage. Other comments are important to the dam's safety and must be considered at an early stage in the detailed design process.

### *4.6.3 Relevant Compliance and Guidance Documents*

*Preliminary Design Guidance*

There is little mention of the PDG in the feasibility report and the developer does not indicate that they have considered the PDG in their design process.

However, CNR, in their review of the feasibility study conclude that the design was 71% compliant and 29% not fully compliant. The areas where CNR indicated there was not full PDG compliance are:

- *PDG clause 188*: The developer needs to comply with the requirements of the World Bank Operational Policy for safety of dams (OP/BP 4.37). The developer still needs to complete the plans described in the policy. However, it is noted that they have started on these plans.
- *PDG Clause 191*: Whilst an Emergency Preparedness Plan (EPP) has been initiated further work needs to be carried out to develop the full details required.

CNR do not comment on the requirements for an independent panel of experts as recommended by Clause 181. Their review also does not refer to Clause 11 of the PDG2009 that requires a consistent approach to the safe passage of extreme floods through any mainstream dams. Whilst the FS and CNR refer to the floods though Xayaburi (immediately upstream of Pak Lay) they have not identified that the peak flood flows they used for Xayaburi were smaller than those used by the designers of Xayaburi. As such the peak flow and hydrographs for the Check Flood used by the Pak Lay designers are not consistent with those used for Xayaburi.

The CNR review was also based on documentation provided in October 2016 and it is assumed that the developer has taken up some of their recommendations. Their review appears to have primarily been a review of the design in terms of compliance against the PDG2009. This is a similar role as that covered by this PNPCA process. It is difficult to assess if the CNR review included any significant interaction with the designers' as their report does not indicate any clarifications provided by the designers or attempts to mitigate differences of opinion.

However, a panel of experts would be expected to have detailed interaction with the designers with any concerns mitigated by the designers. It is also not known whether CNR will continue to have input into the design and construction. Nonetheless, it is unlikely that CNR satisfy the requirements for an independent panel of experts.

Annex B summarises the alignment of the design, as presented to date, to the existing PDG2009.

In addition to these aspects, the developer does not appear to have adequately interpreted the ICOLD guidelines (see further discussion below) that they have referenced and there is therefore uncertainty that they have adopted the correct design criteria for flood and earthquakes.

Therefore, whilst the developer has generally complied with the PDG in most areas, they have more work to do to demonstrate full compliance before and during the detailed design, construction and operation stage.

### *World Bank OP 4-37*

The PDG2009 note that the World Bank operational manual OP4-37 must be used (*PDG Para 187*), and this is given further weight by *Para 188* that indicates that all aspects should be applied by the Developer. Specifically, the PDG2009 refer to:

- An independent Panel of Experts;
- Preparation of dam safety plans;
    - A construction supervision plan;
    - A quality assurance plan;
    - An instrument plan;
    - An operation and maintenance plan;

- An emergency preparedness plan.

The requirements for dam safety plans are acknowledged in the Feasibility Report and relatively detailed descriptions of these proposed plans are included. It is assumed that these will be developed further during the detailed design stages. However, the need for a dam safety management system during the construction stage, and that all emergency planning (including consultation with people in the downstream dam break inundation areas) must be completed before impoundment of the reservoir, is not highlighted. This is an important issue that has raised concerns by some of the National MRC committees during the national and regional consultation process.

The developer does not indicate if an independent Panel of Experts has been appointed. This panel should be constituted at the Feasibility Stage of the proposed development, so that they can review and advise throughout the detailed design and construction. As discussed earlier in this report, the reviews by CNR and the PNPCA process are not considered to fulfil the purpose of the panel as their scope of works is more related to a review of compliance against the PDG2009 rather than a detailed discussion and interaction with the designers to ensure that any dam safety concerns are mitigated. The Panel of Experts must be independent of the developer and the designer although normally paid for by the developer. It is preferable that the panel have considerable relevant international experience. It is also recommended that all the reports and the minutes of any meetings be shared with the MRC as part of a post prior consultation JAP.

### *ICOLD Bulletins*

ICOLD bulletins provide guidance on a range of topics related to the design of dams including the design criteria for floods and earthquakes. The developer has indicated that they have used the following Bulletins in the selection of the critical design parameters:

- *ICOLD Bulletin 148, 2010* – Selecting Seismic Parameters for Large Dams – Guidelines[33];
- *ICOLD Bulletin 125, 2003* –Dams and Flood – Guidelines and Case Histories, and;
- *CFBR, 2013*, Dam Spillway Guidelines, Recommendations

However, they do not appear to have interpreted these correctly as discussed in more detail in Appendix G. The ICOLD Bulletins recommend that consequence assessments are used to define hazard categories for the dam and that these be used to select the relevant design parameters. This has not been done and the design parameters cannot, therefore, be confirmed as relevant for Pak Lay. They are also not consistent with those used for the Xayaburi HPP, immediately upstream.

The following ICOLD Bulletins have also been referenced but it is not clear how they have been used in the design:

- *ICOLD Bulletin 130*, Risk Assessment in Dam Safety Management, A reconnaissance of benefits, methods and current applications (*version not listed but latest is 2005*);
- ICOLD Bulletin 142, Bulletin on Safe Passage of Extreme Floods (*version not listed but latest is 2012*), and;
- ICOLD Bulletin 156, Integrated Flood Risk Management (*version not listed but latest is 2014*)

### *Other Documents*

There are three levels of standards and guidelines:

[33] The latest version of this Bulletin was made available in 2016, and the Developer should obtain this latest version.

- There *are high level documents* that recommend design criteria such as flood and earthquake return periods. These have been consulted and the LNMC have indicated it is reported that the designs comply with the ICOLD recommendations.
- The *second level of guidelines* and standards provide guidance on how to derive the design loads (flood hydrograph determination and seismic shaking loads) for a dam. The seismic hazard summary report submitted by the Developer and the flood hydrology discussed elsewhere in this report provides some of this information.
- The *third level of guidelines* and standards provide guidance on how the loads should be used in designing and assessing the stability and safety of the dam. Whilst a copy of the Chinese design standards for concrete gravity have been provided, this only covers a small part of these third level standards that are relevant to the design of Pak Lay. More critically these also require a consequence analysis to be done.

The Laos Electric Power Technical Standards (LEPTS) provide some details for all these levels.

The Developer acknowledges that the LEPTS must be followed. However, there are very few references to these in their documents and it does not appear that they have either followed these standards, neither have they provided evidence that they are designing the project to higher standards especially where Chinese standards are proposed.

The Laos Electric Power Technical Standards have recently been reviewed and it is recommended that the developer liaises with the Ministry of Energy and Mines to ensure that their final design complies with or exceeds both these new standards and the new Laos Dam Safety Guidelines that have recently been published.

### *4.6.4 Site Geology*

The Engineering Geology section of the Feasibility Report describes a band of karstic limestone through the reservoir basin site but suggests that, due to the low-lying nature of the river in the regional topography, water cannot escape from the reservoir. This limestone band is not clearly identified in the drawings of the scheme and further information should be provided to give confidence that the reservoir will not leak.

Whilst there are detailed descriptions of the rock at the dam sites, it is unclear whether this refers to the upper or lower dam site. A clear geological description and discussion needs to be provided for the upper (preferred) dam site.

The developer has identified that the geology of the dam foundation has potential for seepage under the dam through fissures in the rock and that the ground needs treatment to prevent seepage in quantities that could deform the rock. This takes the form of a grout curtain near the upstream face of the dam and consolidation grouting across the rest of the foundation area, including the stilling basins. Drainage holes are also provided immediately downstream of the grout curtain.

The cross-sectional drawings through the dam illustrate that there are several areas under the right abutment non-overflow section, the right-hand side of the flood gates, the middle of the powerhouse and on the left bank abutment, where the foundations are expected to be on strongly or moderately weathered rock, and one area where it is located on alluvial gravels. The area under the power station foundation is made up of gravels sitting on top of moderately weathered rock and has been identified as requiring to be backfilled with concrete whilst no additional treatment has been identified at the other two locations. This weaker rock was noted in the rock cores taken from the site. Discussions with the developer's engineers during the MRC' site visit on 6$^{th}$ November 2018 indicated that they intend to provide concrete slab protection over this weaker rock downstream of the power station outlets to prevent scour. This is not, at present, clearly shown on the submitted drawings.

The extent of scour downstream of the flood gates has been considered in the feasibility design and the report describes the results of the scour tests carried out as part of the hydraulic model testing. This indicates that scour depths of up to 12m could be expected under certain conditions but suggests that this will not impact on the integrity of the structures. However, 12m of scour is significant and is close to relatively thin concrete transition slabs. The rock cores for this area were inspected during the site visit and the rock appeared to be of reasonable quality and scour depths in this area may be less than anticipated. However, the extent of scour and its impact on the design must be reconsidered during the detailed design.

Whilst the construction of the dam does not require significant excavation on the abutments, the dip of the geology could potentially cause issues with slippage on the left abutment and the developer has identified that some rock support may be required. If these are not installed as the works start, then any slips could risk the workers underneath. It will also require larger excavations on the left bank to stabilise the works. If the slips occur after construction, then they are likely to affect the fish pass located on this bank. The Developer must consequently ensure that they provide adequate support during construction.

### *4.6.5 Project Layout*

The Feasibility Study Report was prepared before the decision was made to adopt the upper dam site as the preferred site. The documents therefore include references and comparisons of both sites. This is confusing in places and the drawings are not always clear which site is being illustrated. It is important that a final set of documents are prepared for the upper site and made available. The documents also refer to the feasibility study prepared for Xayaburi. However, as Xayaburi is almost complete, the feasibility study for Pak Lay should be updated to incorporate, where relevant, the final design criteria and operational parameters for Xayaburi.

The layout of the project is primarily based on the hydraulic performance of the various structures and waterways. The developer has used a physical hydraulic model to confirm the safe performance of the dam. This report was provided late in the PNPCA process, so it has not been possible to discuss the modelling with the developer. However, it appears that the model has a mobile bed immediately downstream of the dam and this is why they have identified significant depths of erosion in key areas. Given that the dam is generally located on rock rather than a mobile bed, it is important that the developer reconsiders their design based on the actual conditions downstream and design their energy dissipation appropriately.

Recommendation

- Review the design of the energy dissipation structures based on actual geological conditions.

### *4.6.6 Failure Modes Assessment and Downstream Impacts*

A detailed failure modes assessment is now standard international dam safety engineering practice. The results of this assessment provide inputs to dam break and downstream inundation modelling which in turn:

- Inform the owner of potential downstream impacts and risks created by the development of the dam;
- Guide development of the dam safety plans and appropriate instrumentation for monitoring the development of failure modes;
- Assist in preparation of emergency plans and the need for downstream evacuation plans, and;
- Assist emergency management of downstream areas.

In the case of Pak Lay, a dam break study with consequential inundation mapping is necessary to be able to identify any downstream transboundary impacts. The present information provided by the

developer does not allow any assessment of the impacts of dam failure to be made and in particular the extent of any transboundary effects. It is therefore difficult to tell if the dam forms a significant hazard to life and the downstream environment. The Laos Electrical Power Technical Standards use downstream impacts as a method of determining the design flood parameters.

Several villages lie along the banks of the Mekong immediately downstream of the dam site, the Mekong River forms the border between Lao PDR and Thailand some 100km downstream of the dam site, and it is likely that Thai citizens would navigate parts of that stretch of river. The impact of failure of the dam under worst case scenarios, must therefore be investigated. The extent of the breach in the dam should be based on a failure modes assessment that will identify the most credible form of failure.

The developer has provided a preliminary dam break assessment. However, this assumes that a significant proportion of the dam will fail which is not likely to be a credible failure mode and hence a failure modes assessment is recommended. The outflow through the breach has also been estimated ignoring the impact of the downstream water levels, which are likely to restrict the maximum outflow. The assessment already carried out only provides minimal consequence information downstream of the dam it is not possible to identify if the outflow from a theoretical failure will impact on Thailand and other local communities. Thailand have already indicated that their people are concerned over the impact of a dam failure. It is therefore important that a detailed dam break and consequence assessment is carried out as soon as possible to provide confidence to Thailand and the other member countries that the impact of the theoretical failure are not transboundary. This modelling and associated inundation mapping should also be used to prepare emergency preparedness plans for the construction and operational phases.

The assessment should include failure modes such as:

- Piping failure through weak zones in the foundations or abutments;
- Erosion of weak areas at the downstream end of the stilling basin causing instability of the main structure;
- Structural collapse of the one or more flood gates;
- Failure of flood gates to open causing increased flood levels;
- Flotation of one of the main structures during PMF (or lesser flood) due to failure of the pumped drainage system;
- Structural instability of the key structures, particularly the gravity dam section; and
- Seismic failure of the key structures.

The LNMC has subsequently provided comment that the preliminary dam break assessment does include these factors. However, this is not clear from the report submitted.

Recommendation

**Dam break modelling and inundation mapping should be carried out based on a failure modes review and an assessment carried out of the impacts of the theoretical dam break flood wave. Any transboundary impacts must be identified, and mitigation measures implemented.**

### *4.6.7 Comments on the Design Criteria*

#### *Flood*

The developer indicates that the design and check floods were based on ICOLD Bulletin 125, 2003, and the French CFBR document “Flood Design”, June 2013, and that these recommend that the design standards are the 1 in 10,000 yr for the check flood and 1 in 2,000 yr for the design flood. However, these documents do not provide this specific guidance, and recommend the selection of flood design standards based on hazard categories. In addition, the developer indicates that the design flood for the energy dissipation and anti-scour structures is the 1 in 100 yr flood. These structures are located close

to the main power station and flood gate sections. Therefore, if they become damaged during larger floods, the main structures may be undermined by back scour. There are several areas where the stilling basins are founded on strongly weathered materials, which makes this more likely.

The design and check floods have been estimated as being 34,700 and 38,800 $m^3/s$ respectively. The hydrology report also contains a comparison with the flows at the Xayaburi dam site. However, these design and check flood flows are significantly lower than those used in the detailed design of the Xayaburi HPP (Table 4.2). The design flow for Xayaburi was the Probable Maximum Flood (PMF). Clause 11 of the PDG requires that there is a consistent approach to the passage of extreme floods through any proposed mainstream dam, and as Xayaburi has already been designed for the PMF, this should also be adopted for the PLHPP.

The developer has subsequently noted that, according to the model test results, overtopping will not occur even if 1-3 surface bay gates cannot be opened when releasing a check flood, and consequently that the current design releasing capacity of the dam can meet the requirement to safely pass the PMF.

Recommendation

**The final design report should provide evidence that the PLHPP can safely pass the same Probable Maximum Flood as used for the design of Xayaburi Dam.**

*Table 4.2 Comparison of design flood flows*

| Flow Recurrence Interval | Pak Lay Dam Site | Xayaburi Dam Site (from Pak Lay report) | Xayaburi Dam Site (from Xayaburi reports)* |
|---|---|---|---|
| 100 | 27,200 | 26,500 | 29,146 |
| 2,000 | 34,700 | 34,200 | |
| 10,000 | 38,800 | 38,500 | 45,000 |
| PMF | | | 47,500 |

* Xayaburi flood information provided by the Xayaburi Developers during recent reviews by MRC.

CNR did not comment on the difference between the various studies and design flows used at Xayaburi. The size of the design floods is a critical dam safety design criterion that needs to be confirmed at the feasibility stage, and the discrepancies between the extreme floods at the two sites needs to be identified and agreed as soon as possible. At a minimum the design of the dam should be checked for the same flood as used by the Xayaburi developer, i.e. a PMF with a peak flow of 47,500 $m^3/s$ plus any increases due to the slightly larger catchment area.

### *Seismic*

The seismic assessment refers to a 2016 seismic hazard assessment report by Geoter SAS. A "lite version" of this report has been provided as part of the PNPCA documentation. This report confirmed the peak ground accelerations listed in Table 4.3. However, the report was only a summary of the full review and as such did not clearly identify the sources of the information used in the report. The full report was provided at the end of the review period, and there was insufficient time to carry out a review. It is important that this report is reviewed by any Panel of Experts that may be established. This panel should include a dam geologist with experience in seismic areas.

There is a reference in the report to a major fault in the near region to the dam site. However, there was insufficient information to include the modelling. It is important that this fault is investigated further, and the seismic loads updated if necessary.

*Table 4.3 Seismic Parameters Recommended in Pak Lay Feasibility Study Report*

| Return Period | Peak Ground Acceleration (pga) | |
|---|---|---|
| 475 yr | 0.133 g | Operating Basis Earthquake (OBE) |
| 2,475 yr | 0.290 g | |
| 5,000 yr | 0.384 g | Safety Evaluation Earthquake (SEE) |

The developer notes that the 5,000 yr earthquake for the SEE has been selected based on ICOLD Bulletin 148, 2010. However, the Bulletin recommends the selection of the SEE as either the 1,000yr, 5,000yr or the 10,000yr earthquake, again depending on the consequence rating for the dam, which has not been carried out for Pak Lay dam.

At Xayaburi the 10,000 yr earthquake was used for the SEE due to the expect high impact of failure of the dam. Without a specific consequence assessment for Pak Lay dam it has to be assumed that the consequences of a failure at Pak Lay will be similar to the failure, of Xayaburi and therefore it should be considered as a high hazard dam requiring a 10,000 yr SEE. However, provided that the developer can demonstrate that the dam can be classified as a moderate consequence dam then the adopted level of seismic design appears to be satisfactory.

For the OBE, ICOLD Bulletin 148 recommends that the 145 yr return period earthquake should be used as a minimum. The Developer has used a 475 yr earthquake for the OBE, which satisfies the ICOLD recommendations.

Recommendations

- The developer should carry out a dam break consequence assessment to provide further support to their selection of seismic design criteria.
- The panel of experts should review the full seismic hazard report to ensure that the uncertainties in the assessment are fully understood and that the assessment methods are appropriate for the hazard classification for the dam.
- Further investigations should be carried out in relation to the major fault near to the dam site that is referenced in the FS and the seismic hazard report.

### *Structural Stability*

The structural stability assessments for the key components of the dam should be closely reviewed by the Panel of Experts.

The design approach to structural stability appears acceptable; however, the design appears to rely upon a pumped drainage system to reduce the uplift pressure under all the dam components. It is recommended that the developer reconsiders the need for the foundation drainage during the detailed design stage. If the consolidation grouting is not effective in sealing most of the open joints in the foundation, then the pumped drainage can quickly become overwhelmed by seepage from the downstream side and flood the drainage gallery. The benefit of the drainage system in this type of structure is probably minimal and may become a dam safety issue if not adequately maintained. The developer should provide additional stability calculations to demonstrate the impact of the drainage system being overwhelmed.

If the drainage system is required, and is critical to the dam safety, then the developer should demonstrate that there is sufficient redundancy in the system and that there are several back-up systems to ensure that it will operate under all operational scenarios. The LNMC have noted that there are provisions to include a backup system.

### 4.6.8 Comments on Dam and Reservoir Operation

The key hydraulic loading conditions will occur when the dam is operating at less than full power generation as this creates the greatest water level differential between the reservoir and the downstream river. Operation of the dam in flood conditions is described along with the anticipated gate operation at all stages of the flood, rising and falling limbs of the flood wave.

The impacts of the dam operation during both normal and extreme flood has been modelled in the report, although there are no clear maps showing the extent of inundation due to the impoundment of the reservoir and no maps to show the extent of downstream flooding, which are important for emergency preparedness.

Safety monitoring of the dam has also been described, and the proposed monitoring appears to be comprehensive. However, again it does not appear to have been based on a detailed failure modes assessment for Pak Lay, and some of the proposed monitoring may not be effective in identifying the potential failure modes for the PLHPP. It is recommended that the monitoring system is optimised based on the failure modes.

The proposed operational strategy must be consistent with the operation of other existing (or under construction) hydropower schemes on the Mekong. This will require operational information sharing with Xayaburi to ensure that releases from Xayaburi do not affect the safety of Pak Lay. In the future, this strategy will need to consider the Sanakham project if it is developed.

### 4.6.9 Dam Safety Management

Details of the proposed dam safety management system, including an Emergency Preparedness Plan have been made available. In general, these appear reasonable for the feasibility stage of the project.

Further areas that require development during the detailed design are:

- The Emergency Preparedness Plan needs to be developed in consultation with the local Lao and Thai emergency disaster management teams in the areas that could be affected by any dam break flood wave;
- Inclusion of downstream inundation mapping for dam breaks and large natural floods; and
- The instrumentation and dam safety monitoring must be targeted to a failure modes assessment so that monitoring can provide an early warning of initiation of the dam failure modes.

It is important that the developer ensures that their dam safety management system complies with the requirements of the new Ministry of Energy and Mines dam safety guidelines. The dam safety management system and in particular the emergency preparedness plan must cover both construction and operational scenarios and be implemented at the start of the construction period.

### 4.6.10 Transboundary impacts

Failure of the dam could potentially create transboundary downstream impacts due to sudden variations in water levels. However, the Developer has not carried out any dam break assessments, that are based on a failure modes assessment, and associated inundation mapping to assess the downstream consequences and impacts. As recommended elsewhere in this report, dam break assessment and consequence modelling should be carried out to confirm if there are any potential transboundary impacts due to dam failure.

### 4.6.11 Recommendations

The Feasibility Study for Pak Lay provides a comprehensive description of how the dam has been designed and the plans for integrating a dam safety management system. The level of study generally appears appropriate for the feasibility design stage. However, there are some critical aspects that must be addressed in the ongoing design and construction of the PLHPP.

The JC may wish to consider the following in their deliberations:

- *Uncertainty on any transboundary impacts due to failure of the dam.* A dam break assessment and inundation mapping should be undertaken to identify areas of Thailand that may be affected by a failure. The dam break assessment and inundation mapping are also key inputs to the definition of design criteria and emergency preparedness planning.
- *The need for the early appointment of the independent dam panel of experts as recommended by the World Bank and the PDG*. The design criteria are important to the design and safety of the dam. Given the uncertainty over the design criteria and loadings, it is important that the independent dam panel of experts is appointed as early as possible to review and agree the design criteria on which the detailed design should proceed.
- *Importance of dam safety management.* The recent dam failures around the world are good reminders of the importance of dam safety management. Laos is in the process of implementing a detailed set of guidelines for dam safety. The panel of experts should also assist the developers in interpreting the needs of these guidelines and advise on their implementation. This should be carried out early in the design process so that appropriate monitoring procedures can be included in the design and detailed emergency preparedness plans are developed.
- *Uncertainty over the suitability of the design criteria:*
  - The developer needs to demonstrate that their design is being developed in accordance with the latest international standards. Where Chinese standards are proposed the Developer must demonstrate that these standards meet the requirements of the local guidelines such as the LEPTS and relevant ICOLD Bulletins.
  - *The ICOLD and Laos guidelines for design criteria are based on the consequences of dam failure.* A dam break assessment has not been carried out and a consequence classification has not been established for the dam. These assessments must therefore be done.
  - *The flood criteria are lower than those used for Xayaburi and are also not in accordance with ICOLD recommendations.* Clause 11 of the PDG requires that there is a consistent approach to the safe passage of extreme floods through any proposed mainstream dam. Pak Lay has been designed for smaller floods than Xayaburi, which is immediately upstream. The flood design criteria should be reviewed and upgraded if necessary.
  - The seismic design parameters are not in accordance with the recommendations in the guidelines that the Developer references. These should be reviewed following an assessment of the consequences of dam failure. Only a summary of the seismic hazard assessment report has been provided. The full report must be reviewed by the panel of experts and in particular the relevance of the major fault identified but not included in the seismic model must be assessed.

## 4.7 Navigation

### *4.7.1 Background*

The developer has submitted the following which have been used in this review:

1) Rough drawings and descriptions:
- A number of summary drawings
- Feasibility Study report – Final – Chapter 5-7: 5.9 Navigation Structure
- Ministry of Energy and Mines – Lao PDR. Pak Lay Feasibility Study Review – Final Report – final version – January 2017 – Chapter 8: Navigation Aspect, Ship lock – Navigation Lock System

2) **Drawings.**
- Layout of ship structure (1-2)
- Layout of ship structure (mostly consisting of cross sections)

This review has been hampered by the lack of drawings with clearly defined dimensions and levels. Much of the detail has been provided in lengthy text descriptions, but the intention of the developer is often difficult to understand. The lack of AutoCAD drawings has made it difficult to determine the exact metrics of the proposed design. This review has been based on the Adobe drawings, and hence the dimensions reported are approximate.

The navigation channel in the impoundment has not been described, other than to indicate that the water depths will be increased. However, there may still be sections where submerged rock outcrops lie close to the surface, especially when the impoundment is operated at 239 m or lower. These will be difficult to detect without any current, and the changing water levels will mean that memory of previous journeys may not suffice.

Recommendation

- **The detailed design reports should include a section describing the upstream navigation channel should be, and any rock outcrops that may pose a danger at the lowest operating levels should be clearly identified, marked or removed.**

The LNMC has indicated that aids to navigation will be addressed at the detailed design stage.

### *4.7.2 The review*

The following comments are made on the proposed navigation facilities. Additional details are provided in Annex I:

[1] Water level definitions have been standardized in the MRC and PDG2009, as Highest Operational Level (HOL), and Lowest Operational Level (LOL). The Normal Operational Water Level (NOL) is not commonly used. It is suggested that the developer standardises on the MRC terminology for consistency and alignment with the PDG2009.

[2] The bridge over the upper lockhead is too low. There is only 8 meters air clearance which is lower than the air clearance of all other bridges along the Mekong as outlined in the latest "Design of a Master Plan for Regional Waterborne Transport in the Mekong River Basin". Bridges on the Mekong usually have an air clearance of at least 10.00m at the highest navigable water levels. *The Lao PDR has indicated that this air clearance can be increased to 10 m.*

[3] The area for the second ship lock has not been clearly defined and is not shown on the drawing. It is assumed that the axis of the second ship lock will be parallel at 42.00 m from the first axis. Approaches must accommodate both accesses to the locks. This is unlikely for the both the upstream and the downstream approach in the light of the 5 dolphins which are placed along the second ship lock approach line. The final design should ensure that the Lao PDR is not left with considerable additional investments should they have to construct the second locking system.

[4] There does not appear to be enough space to install the stoppage cable just upstream the downstream miter gate. Stoppage cables requiring an elasticity of some 10-11 meter are designed to gently stop an oncoming vessel. It is advised that this stoppage cable should be operated automatically before the ship enters the lock chamber. The LNMC have indicated that a stoppage system has been designed, but this is not evident from the designs submitted.

[5] The ship lock is situated at the right river bank, which is in the shallow area of the river. The current navigation channel is on left bank aligned with the power house. While this is understandable in the light of maximizing power production, ships approaching the ship lock from upstream will have to cross in front of the powerhouse and spillway. This poses a danger if

this manoeuvre is done too close to the dam. Moreover, the hydrographic survey information provided does not stretch far enough up and downstream to assess the navigational conditions of the future navigation channel from the submitted design. This is particularly the case for the downstream channel which will be a "free flowing section". It is expected that substantial excavation work will have to be done to accommodate a wide, deep and straight downstream lock approach. This concern was also raised in the CNR review, and the LNMC have indicated that this has been considered. However, this was not evident in the documentation submitted.

[6] The exact position of the axis of the second ship lock is not shown on the drawing. It has been calculated at 42 meters parallel to the first axis in case a similar ship lock will be built next to it, but this needs to be confirmed and the axis should be outlined.

[7] There is an inconsistency between the drawings. Two of the drawings show the upstream plan view of the approach channel. However, it appears that the guidance wall on one drawing is curved inwards towards the right bank. The guidance wall should preferably be curved outwards to guide shipping away from the spillway and the powerhouse-intake. A straight guidance wall would also provide sufficient space for three zones in the approach of the lock: lay-by area, waiting area and overnight area as recommended by PIANC.

[8] The 5 dolphins included up- and downstream will hinder the entrance to the future second ship lock, which will be built parallel at 42 meters. These concrete dolphins should be repositioned or will have to be demolished during the construction of the second ship lock. The LNMC however contends that the existing dolphins will not hinder the approach to the second lock. It is therefore recommended that this is investigated further.

[9] The right-hand short approach guidance wall of the upstream approach channel should have an angle of approximately $12^{o}$ to $15^{o}$ with the ship lock axis. While this guidance wall (at least its upstream end) will have to be broken down when the second ship lock is constructed, it is likely to be in place for some time, and should be designed accordingly as is outlined in the PDG 2009.

[10] It is expected that additional excavation works will have to be done on the right bank to avoid strong side currents at the downstream end coming from the spillway canal. These have been confirmed by model studies and may produce eddies, whirlpools or vortexes, pushing ships off course. The CNR review and the recently provided physical model report have also raised concerns regarding the safety of the downstream approach.

[11] It is strongly recommended that the downstream guidance wall has a vertical front as is the case with the upstream guidance wall.

[12] The drawings also suggest a construction slope for the excavations at an angle of 1/1 ($45^{o}$). This is steep as most of these excavations will happen under the phreatic water surface, where soils are saturated with water. It is advised to have a closer look at this issue and to provide slope stability calculations.

[13] There is little information on the road connection to all parts of the ship lock, as is required under the PDG2009.

[14] The developer indicates that the European standards have been applied, but these are not referenced. Similarly, frequent mention is made to the Chinese standards. However, these are not in common usage in the Mekong System. The PDG2009 proposes the PIANC shipping association recommendations.

[15] The Feasibility Report notes that there is backflow at the end of the guidance wall. This is a normal phenomenon. However, a 1.63m/sec backflow for a discharge of 13,596 $m^3$/sec seems somewhat high, especially that such backflow is happening at the narrowed section of the downstream navigation channel.

[16] According to the drawings, there is only one culvert per side, not the two indicated in the text. There are two valves (reversed tainter valves) per culvert. Three ladders in each lock chamber wall are not enough. It is recommended that 4 ladders on each side of the lock chamber should be installed in wall recesses.

[17] The developer intends to construct "Six floating bollards are distributed along the lock chamber…". It is understood that this applies per side of the lock chamber, hence totalling 12 over the entire lock chamber. Xayaburi has 2 x 5 floating bollards per lock chamber. Pak Lay could use the same number of floating bollards.

[18] Contrary to the PDG2009, the DG2018 does not pay much importance/attention to the lockage time, but rather emphasizes safety during filling of the lock chamber. The shorter the lockage time, the greater the turbulence and flow patterns are more dangerous. It is more important to ensure safe lockage than faster lockage. The developer should outline these issues in the report (operational rules of the ship lock).

[19] With speeds of 12.0 a 14.0 m/sec during filling and emptying there may be a real danger of cavitation. The proposal to reinforce the concrete in the valve sections with steel linings is therefore laudable.

[20] The waterway classification is made according to Chinese norms. It would be useful to include a comparative table in the document which compares the Chinese classification with the PIANC guidelines.

[21] Cargo vessels of 2,000 t should also be included in the classification instead of only 500t push convoys. These 2,000 t cargo vessels (Type Va [large Rhine vessels] according to the CEMT inland waterway classification), may have dimensions of 110m x 11.40m x 3.00m, which can be accommodated in the ship lock.

[22] The design water levels should not assume that the Sanakham HPP will be constructed until it has completed the prior consultation process.

[23] The specification for the conveyance valves to be completely made of 304 stainless steel seems excessive and is not recommended in the PDG2009. Anti-corrosion treatment by galvanization or metallization and adequate painting would be sufficient.

[24] We understand that the steep slopes of 1/1 (45$^{o}$) during the construction phase will be anchored (and stabilized) by steel rebars of diameter 28mm. However, confirmation supported by a drawing would clarify the situation. If so, slope stability calculations should be provided.

[25] The following auxiliary systems should be specified (even though they are not specifically requested in the PDG2009):

i. Line hooks in the lock chamber and the guidance walls at various levels, not addressed or required in the PDG2009, but are strongly recommended. These line hooks should be adjacent to the ladders.

ii. The mechanism for the Stop cables upstream the downstream miter gate should be explained.

iii. It may also be useful to have some additional ladders in the upper and lower guidance walls. However, this is not an explicit guideline in the PDG2009

iv. It is advisable to provide fish passage structure[s] through the lock chamber during idle navigation time (see Also Annex F for the fish passage recommendations).

v. An emergency overhead rolling crane to remove floating or sunken heavy debris and to position the bulkheads in their recesses (which is needed for the repair or maintenance of the miter gates and tainter gates), should be considered. The design of a bulkhead element should be submitted including the indication of the total weight per element.

vi. Although the above are all valuable assets they are not an explicit guideline requirement of the PDG2009.

### *4.7.3 Recommendations*

The Joint Committee may wish to consider the following in its deliberations:

- This review does not concur with the developer's assessment that the navigation facilities *mostly* comply with the PDG2009. Although it is noted that many of the guidelines have been adopted, and that the pending DG2018 drops some of the requirements. Nonetheless there are issues that still need to be addressed to improve the safety of the navigation facilities. The main concerns are:
  - The bridge over the upper lock head and the rolling crane are too low.
  - The safety of the navigation in the shallower parts of the upstream impoundment where rocky outcrops can still pose a danger to shipping.
  - The area for the second ship lock has not been clearly defined.

- Ships approaching the ship lock will have to cross in front of the powerhouse and spillway, which could pose a danger, and it is likely that the downstream navigation channel will have to be enlarged and dredged
- The 5 dolphins will block the entrance to the future second ship lock, this may lead to excessive demolition costs for the Lao PDR should they have to construct the second lock.
- It is strongly recommended that the downstream guidance wall has a vertical front.
- There is no indication of a road connection to all parts of the ship lock, as is required under the PDG2009.
- The required auxiliary systems should be specified.

- Further details have been outlined in the paragraphs above. It is recommended that these measures are addressed in the final design.

The LNMC has subsequently commented that some of these recommendations have already been addressed. However, this is not evident in the documentation that has been submitted.

## 4.8 Socio-Economic Impacts

### *4.8.1 Introduction*

While large parts of the TbESIA and CIA have been copied from other projects (specifically the Pak Beng HPP), there are still some elements of the socio-economic issues that have been specifically developed for the PLHPP. These elements are reviewed here, together with those elements that are applicable to both projects.

This section of the TRR draws on the documents submitted by the developer and on complementary information, studies and guidance available from the MRC and internationally.

The set of documents submitted (Final ESIA Reports, dated January 2018) contain the following relevant socio-economic information:

*Table 4.4 Coverage of Socio-Economic Aspects in the ESIA*

| Volume and Section of the ESIA | Relevant Content |
|---|---|
| 2 - Environmental Impact Assessment (EIA)<br>6.4.7. General Livelihood Resources<br>6.4.8. Baseline Social Condition<br>7.2 Downstream Social Baseline Study | Dependence on natural resources for livelihoods<br>2006 statistics on school attendance<br>Data on villages up to 100 km downstream |
| 4 - Social Impact Assessment (SIA) | Methods, Legislation, Baseline, Impacts and Mitigation, Social Management Plan |
| Appendix 2: Gender and Vulnerable Group Assessment | Separated by project component and downstream |
| Appendix 3: Physical and Cultural Resources | Ethnic groups, spirit sites, temples |
| 5 - Health Impact Assessment (HIA) | Health status impacts and management plan |
| 6 - Social Management & Monitoring Plan (SMMP) | Programmes, arrangements, budget |
| 7 - Resettlement Action Plan (RAP) | Compensation entitlements, resettlement, livelihood restoration, arrangements, budget |
| 8 - Access Road Initial Environmental Evaluation (IEE) | Generic impacts, quantitative information only for land requirements |
| 9 - Transboundary and Cumulative Impact Assessment (TBESIA/CIA) | Baseline status and impacts in various zones, mitigation for project-level impacts |

The main document (SIA) provides:

- an overview of objectives and methods
- a description of the project
- a review of the regulatory framework of the Government of Laos concerning hydropower related environment and social issues

- social baseline information
- potential impacts, and
- potential mitigation measures and social development plans.

Complementary materials used for the review include:

- the SIMVA (Social Impact Monitoring and Vulnerability Assessment) 2011 and 2014/15 reports
- the Council Study, 2011-2017, on impacts of major developments including hydropower dams
- the ongoing update of Sustainable Hydropower Development Strategy
- the RSAT (Rapid Basin-Wide Hydropower Sustainability Assessment Tool)
- the recommendations of the Design Guidance 2018, currently being developed and including socio-economic issues
- lessons learned from the Pak Beng and previous PNPCA processes, and
- other international guidance for socio-economic issues related to hydropower dams, including guidance on good practices for social impact assessment.[34]

### *4.8.2 Analysis of Documents Submitted*

#### *Overview*

The documentation provided indicates that the objectives of the Pak Lay SIA are to:

- Assess the social issues and impacts on Affected Persons (APs) requiring targeted project investments and to identify the stakeholders and interactions among them;
- Help in the design of social services that may be provided to improve their quality of life, and achieving the project's economic and social goals through relevant technical and programmatic activities,
- Help in the formulation of a social strategy for participatory implementation.

To this end, a systematic SIA would describe the **baseline** situation (pre-project or without project), predict the **impacts** of the project (before mitigation), define **mitigation** measures, and present the **residual impacts after mitigation**. These would typically contribute to a decision on whether the project should proceed.

The core of this analysis should be the predicted impacts before mitigation. These would be based on changes to the bio-physical environment, which are addressed in previous sections. These changes determine who is potentially affected by the project, which aspects of the baseline situation need to be described, and how – for each of the subgroups affected – the impacts will be addressed to achieve the stated objective, improvement of quality of life.

This review covers each of these steps.

#### *Baseline*

The baseline methodology reported involved desk studies, field surveys (including a household census), and village interviews and meetings. Baseline information is spread out across the different documents, and covers:

- In Vol. 2 (EIA): livelihoods, education, tourism;

[34] For example, Vanclay et al (2015) Social Impact Assessment: Guidance for Assessing and Managing the Social Impacts of Projects. International Association for Impact Assessment (IAIA) and Kvam (2018) Social Impact Assessment: Integrating Social Issues in Development Projects. Inter-American Development Bank (IDB).

- in Vol. 4 (SIA): population and villages, ethnicity, villages administration, gender, livelihoods (agriculture, fisheries, handicrafts, hunting, water use etc.), infrastructure;
- in Vol. 4, Appendix 2: gender and vulnerable groups (focus on women);
- in Vol. 4, Appendix 2: physical cultural resources (focus on ethnic groups, spirit sites, temples);
- in Vol. 5 (HIA): health statistics and facilities, nutrition;
- in Vol. 7 (RAP): overview social situation in project area;
- in Vol. 8 (IEE): overview social situation along the right-of-way, preliminary list of affected communities and inventory of potential losses; and
- in Vol. 9 (TBSEIA/CIA): fisheries, navigation, social conditions in 5 zones along the Lower Mekong Basin.

The baseline information is most detailed for the population living close to and potentially affected by the project in four different zones as follows[35]:

- upstream of the impounded reach, five villages indirectly impacted by the project with a total population of 256 households and 1,377 people;
- in the impounded reach, 8 villages with 993 households and 4,852 people that will be displaced;
- downstream of the PLHPP, 12 impacted villages with 2,913 households and 15,363 people;
- the area of the potential resettlement sites, 3 villages with 354 households and 1,714 people (who will be impacted as host communities of the resettled population from the reservoir)

The total number of people directly affected by the project is therefore 23,306. Their main sources of livelihoods are cultivation of rice, maize and cassava, with some rubber and tea plantations, for 80% of the total work force. The developer notes that fishing is not the main occupation, but a supplementary source of income and the main source of protein. However, other findings reported in the fish passage section suggests that fishing is an important occupation. Household income ranges from US$ 2,800 to 6,900, averaging US$3,450 per family per year, coming from cropping, wage employment, trading, livestock, gold panning and others. Household expenditure ranges from US$ 1,400 to US$ 3,700.

Depending on baseline data availability, different documents cover different social aspects, for different groups of people. Several issues are covered repeatedly in several documents, at varying levels of detail. Baseline information about livelihoods and living conditions further from the project appears to have been copied from the documentation submitted for the Pak Beng prior consultation process. This is covered in Vol. 9, with a focus on the population within a 5-km corridor from the Mekong. This also refers to Zones, but those applicable to the whole of the LMB as defined by the MRC. These differ from the 4 Zones discussed above.

Zone 1, where Pak Lay is located, is defined as the river reach in Northern Laos, with a total population of 914,000 in the 5 km corridor. (This zone is the focus of the cumulative impact assessment, as it has several hydropower projects planned). Zone 2 has 2,616,000 people, Zone 3 has 571,000, Zone 4 has 8,466,000, and Zone 5 has 12,487,000, for a total of 25 million people potentially affected by transboundary and cumulative impacts.

Besides these population data, the documentation includes descriptions of ethnicity and culture, provincial-level socio-economic and health information, 'livelihood profiles' of selected villages or districts, and information on tourism. The details provided differs by zone. For some zones, for example, social infrastructure, household incomes, food consumption, or age composition data are provided, but not for others. For the downstream zone 4 in Cambodia, data are predominantly at a national level, and for zone 5 in Vietnam, data are predominantly from the delta region.

The documentation presents a 'degree of dependence' on the river in the different zones (Table 4.5).

[35] According to 2015-2017 surveys, as reported in the SIA, table 1.

*Table 4.5 Degree of Dependence on the Mekong River and Its Ecosystems*

| Zones | Degree of Dependence* | |
|---|---|---|
| | Left Bank | Right Bank |
| Zone 1: Northern Laos – Pak Tha (KM 2281) to Pak Heuang (KM 1736) | 3.7 | 3.8 |
| Zone 2: Thai-Laos – Pak Heuang (KM 1736) to Ban Woenbuk (KM 904) | 3.1 | 2.7 |
| Zone 3: Southern Laos – Ban Woenbuk (KM 904) to Cambodian border (KM 713[36]) | 3.3 | 3.2 |
| Zone 4: Cambodia – Cambodia border (KM 713[37]) to Vietnam Border (KM218) | 4.1 | 4.0 |
| Zone 5: Southern Vietnam – Vietnam border (KM 218) to Mekong Delta (KM 0) | 4.1 | 4.2 |

**Estimated by the Pak Lay project study team (Scale: 1=Very low, 2=Low, 3=Medium, 4=High, 5=Very high)*

### *Impacts*

The potential impacts on the people in the vicinity of the PLHPP are predicted by the developer as follows:

- The SIA contains short qualitative statements on a wide number of potential impacts on the APs close to the project area, mixed with mitigation and monitoring measures.
- The Appendix on "Gender and Vulnerable Group Assessment" contains short statements on the expected impacts, using categories such as 'highly positive', 'moderately negative' etc.
- The Appendix on "Physical and Cultural Resources" contains two sentences on impacts, confirming that both direct and indirect impacts are expected.
- The HIA lists on one page the health risks related to the project for six different groups of villages.
- The SMMP categorizes impacts in the immediate project area from 'major negative' to 'major beneficial'.
- The IEE for the access roads lists generic social impacts from roads.

The transboundary and Cumulative Impact Assessment has a more extensive section on expected impacts related to bio-physical changes to the river system and the dependence of people on river resources. However, this appears to have been largely copied from the Pak Beng case, and is not specific to the impacts expected from Pak Lay[38], and is not analysed further here (some additional information is presented in Annex G).

Cumulative impacts are defined as those arising from several hydropower projects within Laos. They are quantified by adding up land requirements and people resettled for all seven mainstream hydropower projects in Laos, which would result in the resettlement of 30,000 people and the loss of 18,000 ha of production land. These negative impacts, as noted in the submitted documents, are seen as of major significance. Beneficial changes such as improvement in basic social infrastructures and facilities, country revenue and local employment are not quantified, but are also seen as of medium-major significance.

Six categories of impacts are identified related to the cumulative impacts, and presented in matrices for each transboundary zone (2, 4 and 5); for zones 4 and 5, this is described as preliminary and depending on further hydrological and sediment modelling:

- Improved access to domestic and irrigation water due to higher water levels in the dry season;
- Improved cropping due to easier access to the river, but loss of some riverbank cropping areas;
- Improved health and nutrition due to improvement of infrastructure, facilities and communication, but some loss of protein due to obstruction of fish migration;
- Improved tourism due to improvement of infrastructure, facilities and communication, but negative impacts on some tourist sites such as rapids;

[36] This is incorrectly specified as KM 723 in the documentation provided.
[37] Same note as above.
[38] Some impacts will be similar to both the Pak Beng and Pak Lay cases.

- Socio-political conflict between groups of people who agree and disagree with the projects; and
- Mitigation of climate change due to displacement of fossil fuels.

### *Mitigation*

The Feasibility Study compared two options for the dam site, the upper and the lower options. It was found that the population impacted at the lower dam site would be significantly larger, by approximately ten thousand people, which is one of the reasons the upper dam site was chosen.

The ESIA describes several mitigation measures to address impacts on fish, sediment, water quality, and navigation, which will have indirect social impacts. Direct social mitigation measures are described across several documents in the SIA package.

Based on the identification of potential impacts, the SIA provides brief principles, recommendations or statements of intent, for a broad number of measures in the vicinity of the PLHPP. The proposed health management and monitoring plan in the HIA has the following components: health and safety during construction phase, health and safety during operations phase, water-borne diseases prevention and control, communicable diseases prevention and control, and emergency preparedness. It also provides implementation arrangements and a budget of US$ 880,000.

The SMMP is required under Lao legislation. The overall objective of the SMMP is to improve the welfare of the people living in the project area who might be adversely affected by the project. It contains descriptions of mitigation measures with different levels of detail. The SMMP also includes institutional responsibilities, implementation schedules, internal and external monitoring plans, and an estimated budget of US$ 90.6 million (including fees to be paid to Government of Laos for implementation).

The SMMP mostly covers the same measures as the Resettlement Action Plan (RAP), which describes mitigation measures under three programmes:

- "Compensation Entitlement Criteria – identifies measures for compensation and mitigation of resettlement impacts;
- Resettlement Development – describes the plan for resettling the whole village to a new place with better community infrastructure while considering the interests of host communities;
- Livelihood Restoration & Development – describes long-term plan to improve the quality of life of settlers."

The RAP contains more specific mitigation commitments than the SMMP. The developer notes that the Resettlement Action Plan (RAP) sets out the preliminary livelihood restoration plan, and that the GoL will be asked to set up Resettlement Management Committees, as required by the Lao regulations to assist the developer to implement the mitigation measures. It is also noted that the developer has previous experience with resettlement in Laos from the Nam Ou 1-7 and the Nam Ngum 5 projects, and hence believes that the process will deliver better livelihoods. The Concession Agreement will require improvement of livelihoods for resettled people, which will be monitored by the GoL.

The compensation and resettlement costs are estimated at US$ 87.9 million.

The IEE for the access road describes a number of mitigation measures, including specific social compensation (based on an entitlement matrix) and monitoring measures, and includes a budget of US$ 29,000 for social monitoring and US$ 105,000 for compensation and ritual feasting. As this process is an interim assessment, mitigation measures will be further developed before construction of the road.

The TBESIA/CIA contains sections on project-level and basin-level mitigation of physical impacts (hydrology, sediment, fish, navigation, water quality, dam safety), and a list of project-level social mitigation measures, but no specific social mitigation measures for cumulative or transboundary impacts.

*Residual Impacts*

Residual impacts are those that will remain after mitigation, and which are not addressed in the SIA package.

### *4.8.3 Comments on the socioeconomic assessments*

*Overview*

The overall quality of presentation of the SIA package should be improved in the final design stage. The organization of the material could be more systematic, and information could be better referenced to allow easy retrieval and updating. Text has been taken from other ESIAs (such as Pak Beng and the Lao Road Project). Sources of information should be properly referenced. A general recommendation would be a thorough edit to ensure that the information is accessible, consistent and reliable.

Most importantly, the information presented in the different steps of the SIA (baseline, impacts, mitigation, residual impacts) needs to follow a logical progression. If an impact is predicted, baseline data and mitigation measures related to that specific impact need to be presented. The mitigation measures need to be designed to achieve the objectives as formulated (e.g. improvement in incomes for resettled families). Information needs to be sufficiently precise to allow monitoring of social conditions over time, and if conditions deteriorate, to adjust and improve the effectiveness of the mitigation programmes as needed.

*Baseline*

While the study mentions data limitations in several places, it makes very little use of existing, more recent information at Member Country and MRC levels. Sources such as the baseline analyses for the Strategic Environmental Assessment (2010), the reports underpinning the Council Study, or the SIMVA 2011 and 2014/15 reports are not referenced.

The baseline information on the locally affected population has been selectively updated through surveys in 2015-2017.

The baseline information on populations in the downstream zones should be updated in next analyses and assessment stage. The index for 'degree of dependence' (Table 4.5) could be useful for highlighting areas of concern, and the figures should be substantiated with more evidence. These areas of concerns should be explored in more detail by the developer, for example, through modelling of changes in water uses, crop production or fish catch, and how those changes could impact on livelihoods.

Information is irrelevant in several cases (for example, on cultural practices) and could be more consistent between the different zones. Effort should be made to conduct a comparative analysis between zones, or to focus on information that can be used for impact predictions.

Data should be verified more thoroughly to be precise and consistent.

*Impacts*

Most of the typical direct impacts on local populations are covered, although they are spread across different documents and are described at different levels of detail. The final design documents address the following aspects:

- Wherever possible impacts should be more clearly quantified.
- The social impacts are described differently in the different documents. Some documents use a standard categorization approach, while others use verbal descriptions only. Even where a standard approach is used, the logic behind assigning categories such as 'moderately negative' should be explained more clearly.
- Impacts should be differentiated by gender, ethnicity, poverty or other categories, and vulnerable groups might require different approaches to mitigation.
- The definition of cumulative impacts was not explained. Cumulative impacts are variously described as those of mainstream dams in Zone 1, or in all of Laos.
- Potential cumulative impacts with hydropower projects in other parts of Laos (on tributaries) and in other parts of the Mekong basin, and with other infrastructure projects are not considered.
- Quantitative impacts (number of resettled people loss of production land) are simply added up, without discussing potential synergies and limits (for example, availability of land for resettlement). Ecosystem-related cumulative impacts are not addressed (details are provided in the Fisheries and Aquatic Ecology Sections).
- The scenarios used to model and compare cumulative impacts are outdated. It is also unclear how cumulative impacts have been considered in the description of transboundary impacts.

It would be preferable to compare future scenarios with the PLHPP in place to a possible future without the PLHPP, rather than comparing before- to after-project scenarios. It would be advisable to remain consistent with the approach taken in the MRC Council Study and other assessment tools developed by the MRC, which are based on the best available science. A comparison between the scenarios used in the Council Study can inform the assessment of the incremental impacts from PLHPP, against the background of other developments in the basin.

Other social transboundary impacts that have been the subject of much discussion in the Mekong region over the past years are not covered. For example, the potential reduction in sediment delivery to the downstream floodplains and delta may contribute to loss of land and fertility and reduce agricultural production.

### *Mitigation*

Mitigation measures related to the physical and economic displacement of people in the immediate project area are relatively well defined. While the RAP does not yet describe mitigation measures in detail (which will be covered in the RIP), it describes their objectives, principles and overall outline. The budget for the RAP amounts to US$ 24,458 per resettled person, which is broadly in line with international practice.

Less well defined are mitigation measures for villages that are not directly displaced but are upstream or downstream from the project or will function as host communities. It is uncertain whether the same objectives with regards to livelihoods and living standards apply to these villages as for resettled villages, and which mitigation measures they will benefit from.

The TbSEIA/CIA indicates that all the impacts identified can be mitigated by monitoring, management and technical measures. However, these measures are not specifically outlined in the context of the socio-economic impacts (they are outlined in the other documentation). These impacts are not

quantified either is a budget provided for this[39]. The measures outlined in the TbSEIA/CIA are therefore mostly aimed at minimising the harmful effects, rather than reducing the impact of these on the affected people.

*Residual Impacts*

For directly affected people within the Lao PDR, the objectives are: (1) to improve or at least retain the living standards, and (2) for those families entitled to livelihood restoration assistance, to improve incomes within 4 years after resettlement by approximately 50%. However, there is no discussion of the anticipated effectiveness of these mitigation measures and any risks that might impact these.

There is no discussion of mitigation measures to address residual impacts that may occur in the other Member Countries. However, the transboundary residual impacts that may occur just due to the Pak Lay HPP will be very difficult to separate from the cumulative impacts of all the development in the LMB, including those impacts that originate from within the notified Countries. This makes it very difficult for a single developer to effectively address transboundary residual impacts.

### 4.8.4 Recommendations

The Joint Committee may wish to consider the following on its deliberations.

If the PLHPP progresses to the final design stage, the following should be addressed in the updated documentation:

- Up-to-date information on locally affected populations, which includes detailed baseline data on all aspects of livelihoods and living conditions that could be affected, is a standard practice and should be provided. The documentation of the socio-economic baseline, impacts and mitigation measures should include information on methods and data sources;
- Up-to-date information on downstream/transboundary affected populations, consistent with MRC social monitoring protocols, including baseline data on all aspects of livelihoods and living conditions that could be affected should be provided as part of any updated TbESIA;
- Quantitative impact predictions should be provided where possible and be consistent with relevant MRC studies such as the Council Study;
- Any TbESIA should be based on the expected impacts of the PLHPP, and not generically stated;
- Targeted mitigation measures for all predicted impacts, designed to at least maintain, if not improve, the livelihoods and living conditions should be provided for all affected groups;
- Where practical, cumulative impacts should be addressed through joint mitigation and monitoring actions with other developers, government agencies, and the MRC; and
- Clear commitments in terms of budget, implementation plans, monitoring and adaptive monitoring responsibilities should be spelt out.

[39] For the purposes of this TRR, *mitigate* means the measure, if implemented, would reduce the *impact* of any residual harmful effects on other users of the Mekong River System.

# 5 TRANSBOUNDARY AND CUMULATIVE IMPACTS

## 5.1 Introduction

Contemporary approaches to sustainable development recognise the principle of a common but differentiated responsibility towards the environment. This acknowledges that all the world's nations have a responsibility to protect the environment, but also that developing nations have a right to develop, even though this may impact on the environment. This principle is inherent in the 1995 Mekong Agreement, which is an agreement to cooperate on the sustainable development of the Mekong River Basin. There was, consequently, an expectation that the river system would be further developed, that this would include hydropower development (Article 1), and that some of this development would occur on the Mekong mainstream.

However, the Member Countries also agreed to:

- Protect the ecological balance of the Mekong River Basin from pollution and harmful effects (Article 3);
- Use the shared waters in a reasonable and equitable way subject to the PNPCA (Article 5);
- Maintain flows on the mainstream (Article 6);
- Make every effort to avoid, minimise and mitigate harmful effects (Article 7);
- Cease any activity that causes substantial damage to another riparian when notified with valid evidence by the affected Country(ies) (Articles 7 and 8);
- Allow the freedom of navigation and to incorporate navigational uses in any mainstream project (Article 9); and
- Notify one another of any water quantity and quality emergencies (Article 10)

These include the general commitments to apply these objectives and principles in their own territories, as well as specific commitments toward one another. These specific commitments pertain to any potential impact development *may* have on the other riparian countries.

The prior consultation process is primarily a cooperative process whereby; firstly, the MRC and the notified Countries can assist the notifying Country to identify measures that could be applied to mainstream uses in the dry season that could help them conform to their general commitments. Secondly, it allows the notified Countries highlight their concerns with the proposed development, in so far as they affect the specific commitments, and for the notifying Country to take these concerns into account if it proceeds with the development. This must be more than an administrative process and must entail a genuine effort to address the notified countries' concerns, as well as a recognition of the development needs of the notifying country. Balancing these rights and responsibilities lies at the heart of reasonable and equitable use.

It is standard practice for developers to identify *all* potential impacts of the development, and to propose measures to avoid, minimise or mitigate these. This is an inherent part of the costs of the project, and the larger the project the greater the investment needed in this regard. The purpose of including an assessment of any potential transboundary impacts as part of the prior consultation process is to use the resources attached to the development to identify what impacts may be transboundary in nature, and in recognition of the responsibility to avoid significant transboundary harm, to take special measures to limit this risk. This must also recognise that these impacts occur on top of all the impacts from existing developments and raise the potential for unacceptable cumulative impacts from future developments.

It is therefore important for the developer to identify what transboundary impacts *may* occur due to the specific notified proposed use, but also to assess this as part of a cumulative impact assessment that considers the *additional* transboundary impacts that may occur due to the development, and the impacts on existing, planned of foreseeable future developments. This is also central to any

determination of whether the proposed water use is a reasonable and equitable use of the shared watercourse (see Section 1.2.2) and is necessary for the notified Countries to evaluate the potential impacts of the proposed use on their existing and proposed future use of the shared watercourse.

Unfortunately, the PLHPP developer has not undertaken a rigorous transboundary and cumulative impacts assessment and has copied much of the TbSEIA & CIA from the Pak Beng case. The Pak Beng impacts are only relevant in generic terms when assessing the overall impacts of hydropower development and is of limited use to assess the *specific impacts and contributions from the PLHPP*. The notified Countries are therefore not able to assess the specific impacts the PLHPP will have on their use of the shared waters. This makes it difficult to evaluate whether the PLHPP is a reasonable and equitable use based on the documentation received. This is complicated by notification at the feasibility stage of the development process, as the final impacts are not yet known.

However, there are as yet no agreed processes for undertaking a TbESIA in the LMB for the developer to follow. But in the absence of agreed TbESIA procedures due diligence requires that good international practice is adopted. The transboundary and cumulative impacts of hydropower development have been intensely investigated as part of the Council Study. While the Council Study has not yet been approved, it does reflect sound science, and the developer should have made use of these studies to support their transboundary and cumulative assessments. This should at the least include assessments of transboundary impacts using the PLHPP's proposed operations and infrastructure as a basis and should present the pre- and post-mitigation impacts.

It is nonetheless recognised that the complex interplay between the principles of reasonable and equitable use, avoidance of significant transboundary harm, cessation of activities that cause substantial damage, and compensation for potentially affected communities in the other Member Countries needs to be resolved in the Lower Mekong context, and it is recommended that the MRCS is tasked with addressing these aspects.

## 5.2 Potential transboundary impacts[40]

The PLHPP lies in the Upper Lao Cascade of planned and existing HPP. Upstream of Pak Lay, the Xayaburi HPP is nearing completion and is scheduled for commissioning in 2019. The Pak Beng HPP has undergone prior consultation, but development has been suspended while the power purchaser undertakes further studies. Two more potential HPPs have been identified in the upper cascade. The Luang Prabang HPP lies between Xayaburi and Pak Beng, and the Sanakham HPP is planned downstream of Pak Lay.

If all these mainstream HPPs are completed, the tailwaters of the downstream HPPs, will back up close to the next upstream dam, transforming virtually the entire upper Mekong stretch in Lao PDR from a flowing river, to a standing water ecosystem. This will affect the aquatic ecosystems, and as many of the species known to occur in this river reach are long distance migrators, this will have transboundary implications. This will also affect local fisheries which the Council Study suggests are expected to show a significant decline. Key species, including the Mekong Giant Catfish, are likely to become extinct.

These impacts cannot be avoided or minimised without stopping some of the planned developments, and proposals to mitigate the local impacts by fish farming or restocking are unlikely to compensate for the lost fisheries. However, because the upper migration Zone has a lower diversity and lower biomass of fish it is less clear what impacts these HPP will have on fisheries potential in Cambodia and Viet Nam, or on Thailand in the middle migration Zone (see Figure 1 in Annex F). Nonetheless, the interconnected

[40] The Council Study Reports provide more detailed accounts of the potential impacts of HPP development on the LMB and should be consulted for more information. This section only summarises the main impacts associated with the development of the Upper Lao Cascade.

nature of the shared ecosystem is likely to result in some transboundary impacts[41]. This is likely to have knock on socio-economic impacts.

The slowly flowing waters in the impounded reaches will affect downstream drift of fish larvae and will trap sediments upstream of the dams. The loss of fish larvae combined with impacts on upstream migration will quickly be reflected in lost fisheries potential in the upper Zone and on the long-distance migrators in the middle and lower Zones. The reduced downstream sediment transport may take decades to have transboundary impacts but impacts on ecological functioning are likely sooner. Again, these impacts on downstream larval drift and sediment transport cannot be avoided without foregoing some of the developments. However, they can be minimised through improved design and operations of the HPPs. Much of this TRR is focussed on the existing proposals made by the PLHPP developer in this regard and proposing changes in the design and operating rules to further minimise potential impacts. Section 6.4 in the following Chapter provides some proposals in this regard.

Upstream migration will inevitably be affected. However, improved designs of the fishpass facilities can reduce these impacts. But there are multiplicative impacts of the loss of some upstream migration at each successive HPP. This too can only be minimised by stopping some of the planned developments and ensuring compatibility between the fishpass facilities at each HPP. Downstream fishpass facilities must be as good or better than those further upstream. However, the fisheries and sediment in the lower zones will be affected (and potentially to a greater extent) by a range of other impacts, including tributary dams not subject to prior consultation and other impacts like pollution and the pumping of groundwater which have not been fully quantified in the Council Study.

The potential transboundary impacts related to dam safety issues can be minimised by the adoption of international (including Chinese) and MRC standards with respect to safety. Linking these standards to dam break and consequence modelling, as well as to effective local and transboundary warnings will mitigate the impacts in the event of a dam failure. Improved design of the navigation facilities can avoid the dangers of locking and can minimise locking times, and the safety of navigation in the impounded reaches may be improved. However, there appears to be a trend of developers paying inadequate attention to the requirements for a 2$^{nd}$ locking facility – as is proposed in the PDG2009. This could result in considerable costs to the notifying countries if and when the second parallel locks must be constructed.

The mainstream HPP are being planned as run-of-river systems and will not have long distance implications on the hydrological regime of the LMB. Nonetheless, hydropeaking and ramping operations will have impacts in the river reaches just downstream of the HPP. In the Pak Lay case, the potential impacts of these operations on the hydrology at the Thai border needs to be investigated. Operations to flush sediments and enable downstream larval drift should be coordinated between the HPPs. However, as larval drift occurs all year round, this will have less of an impact on downstream fish migration.

While no long-distance impacts on the flow regimes in the LMB are expected from run-of-river HPPs, the Lancang Cascade in China already regulates the flow and reduces the sediment load of the Mekong entering Lao PDR. The larger tributary schemes will also store wet season flows and release them in the dry season. This will delay the flow reversal into the Tonle Sap Great Lake and will delay the inundation of important wetland systems. This can be expected to have significant impacts on ecosystem functioning and fisheries in Cambodia and Viet Nam. This will be exacerbated by the development of HPPs in the lower reaches.

[41] The international principle of environmental unity holds that the air, the water, the land, people, fauna, flora, Earth's solar neighbourhood and all activities affect each and every other thing.

It is very difficult to assess whether the PLHPP, or indeed the upper Lao cascade, reflects a reasonable and equitable use of the shared watercourse system without fully understanding the relative impacts of all these factors.

## 5.3 Addressing transboundary impacts

The principle behind the PNPCA is that the notifying country informs the other Member Countries of its intention to use the waters of the Mekong River System in a certain way. In so doing it recognises that the proposed use may have a significant impact on the Mekong mainstream. If this use occurs on mainstream in the dry season, the use is subject to prior consultation. The notifying Country therefore suggests that the proposed use *may* have a significant impact on mainstream, but that it believes that it will not cause significant transboundary harm or substantial damage to the other Member Countries (otherwise it would make itself liable to cease the use and discuss compensation – Articles 7 and 8).

The prior consultation process allows the JC to examine the potential impacts, and to propose measures to further avoid, minimise and mitigate any potential impacts. The notified Countries' replies must indicate whether they believe that the proposed use is reasonable and equitable, and whether there is transboundary substantial damage. The burden of proof, therefore, shifts to the notified countries, and neither the developer nor the notifying country would be required to indicate whether substantial damage may occur.

The International Court of Justice, in the Uruguay Pulp Mills Case, indicated that all the affected Countries should participate in the EIA process to ensure that all the potential transboundary impacts are identified and addressed. Recognising that the prior consultation process has a limited timeframe, some transboundary River Basin Organisations are exploring a pre-notification process to allow all the riparian Countries to participate in a TbESIA. However, the Council Study and the Basin Development Strategy have addressed cumulative and individual impacts in some detail.

This TRR, as with the Pak Beng case, has noted that the transboundary impact assessment is rudimentary and does not adequately address the specific impacts that will result from the PLHPP. But, in the transboundary context the developer is not safeguarded by the public interest principle. Within any one country any residual impacts due to development and after mitigation may still be considered in the national interest when set against the benefits of the development to the country. In the absence of clear transboundary benefits, it is difficult for the notified Countries to accept any risk of harmful effects. This is further complicated by the fact that any transboundary harm will be a result of the cumulative impacts of the development of the whole Basin – including in China. This in turn would make it difficult for the developer to present a comprehensive TbESIA and CIA, for fear that it will make them liable for all damages, including those related to other developments.

However, the MRC has the skills, modelling tools and data to undertake an effective TbESIA and CIA – but not the financial resources. This would suggest that mechanisms to allow the MRC to work with the developer in a post prior consultation phase to undertake these assessments, and to test mitigation options should be explored.

## 5.4 Notification at the Feasibility Stage

Section 1.4 has already addressed the pros and cons of notification at the feasibility stage of the design process. This review has clearly demonstrated these pros and cons. The recommendations made in the previous chapter and in Section 6.4 (and illustrated in Figure 4.3) will make considerable inroads into reducing the impacts associated with the PLHPP. If these are taken up by the developer, and the economic viability of the revised design and operating rules tested, a PLHPP that internalises some of the external environmental costs can be proposed.

However, it is not feasible to do a comprehensive TbESIA based on a feasibility study, or a “work-in-progress”. The PNPCA imply that notification should be at the feasibility stage. However, notification at the feasibility stage requires some form of closing ‘Statement’, and a post-prior consultation process becomes critical for the notified Countries to gain confidence that their concerns are not only being considered by the notifying Country but also implemented to the maximum extent possible. This may require a further discussion on when, in the project development process, notification should be undertaken.

# 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 PLHPP using improved hydrological, sediment and ecological data, and will allow the developer to explore the technical and economic feasibility of revised designs and operating rules that further avoid, minimise and mitigate potential impacts;
- Improve the safety of the dam structure and navigation facilities; and
- Further minimise the potential for transboundary impacts.

## 6.2 General comments

The developer has made attempts to address the potential impacts of the PLHPP, and the provisions of the PDG, even at the feasibility stage. The review commissioned by the Government of the Lao PDR has already identified several issues many of which have been confirmed by this review. Some of these have already been addressed, and the developer has provided comments on the 1st draft of the TRR which provide further clarity on some of the issues raised. The workshop on the 4th and 5th March 2019 also provided additional clarity.

However, this review has identified a number of issues not addressed in the CNR review and does not concur with the general assessment that the PLHPP is *for the most part compliant* with the PDG2009, or that the outstanding issues can be easily addressed. The recommendations made in this review, particularly around the fish migration facilities will require a redesign and a considerably higher investment. The recommendations for revised operating rules made in section 6.4 will also require careful reconsideration of the economic viability of the PLHPP and are only likely to be feasible if some of the external environmental costs are internalised. Some of this may be offset by improving the hydrological data based on the likely future flows.

As with the previous processes, the developer has not paid enough attention to collecting baseline data on water quality, biota, aquatic habitats, fish migration behaviour and geomorphology. The ongoing monitoring programmes are not well described and may be underfunded. This was also noted in the CNR review. The transboundary and cumulative impacts are rudimentary and largely copied from the Pak Beng case, although the Lao PDR has committed to revising these reports. The descriptions of the hydrology and hydraulics, infrastructure and operating rules – which primarily determine the impacts – are specific to the PLHPP and appear to be rigorous.

There are opportunities to further minimise the potential impacts, and considerably improve the proposed project:

- Increasing the size of the bottom sediment flushing gates and timing the flushing process with actions at Xayaburi together with changed operating rules (Section 6.4) can pass considerably more sediment;
- Redesigning the upstream fish pass facilities may reduce the potential impacts of the proposed HPP (see Figure 4.3);
- Addressing the concerns raised with respect to the navigation facilities will make them more durable and safer to use;
- Designing the infrastructure based on international and Lao PDR safety standards will improve dam safety;

- Including dam break and consequence modelling would provide a firmer basis for the design and the development of appropriate emergency warning systems; and
- Better aligning the infrastructure design and operations with those at Xayaburi will lead to a PLHPP with fewer transboundary impacts.

However, even if these issues are addressed, some residual impacts will remain. The change from a flowing water to a standing water ecosystem are unavoidable. The cumulative impacts of this, should all the planned developments proceed, may be considerable. Some loss of some sediment is inevitable, and no fishpass facility will be 100% effective. Lowering the operating levels of the HPP in the cascade at critical times will reduce these impacts, but residual impacts will still be likely.

Whether these residual impacts may rise to the level of substantial damage as contemplated in Articles 7 and 8 is complex and beyond the scope of this TRR. This determination must, in any event, be made by the notified Countries. This said, notification at the feasibility stage means that the extent of any potential transboundary and cumulative impacts has not yet been clearly demonstrated. It is therefore not possible to provide a sound basis for any such determination.

## 6.3 Recommendations

### *6.3.1 Background*

This section summarises those measures the developer and the notifying country may wish to consider to further limit the potential impacts of the PLHPP, whether transboundary in nature or not. All these recommendations contribute to the commitment to make every effort to avoid, minimise and mitigate possible harmful effects. They also support improved input data to further optimise the operating rules to determine an optimum balance between the economic returns and reduced impacts. These recommendations are intended to further build on the existing cooperation between the MRC Member Countries through sharing data and information, and by building the confidence that all the Member Countries' concerns have not only been identified but are also receiving attention.

### *6.3.2 General*

The developer should make greater efforts with regards to the following:

- Update the hydrological data to better reflect the potential future hydrology including both the impacts of upstream storage development and climate change over at least the full concession period;
- Improve the establishment of a baseline for aquatic organisms, habitats and geomorphology and socio-economic considerations;
- Make better use of the data available in the MRC, and the Council Study findings;
- Share any data collected together with the meta-data with the MRC;
- Provide more detail on monitoring methodologies and QA/QC procedures, and wherever possible align with the standard methodologies employed in the Lower Mekong Basin; and
- The design and operating rules should be aligned with those for the Xayaburi HPP, and with the other potential mainstream HPPs. It is recommended that the Lao NMC is requested to provide an update on progress with those studies.

The developer has requested that the MRC provides data on the hydrology and sediment.

### *6.3.3 Hydrology*

The following comments are made with respect to improving the hydrological and hydraulics assessments:

- The impacts of the updated hydrology on the economics of the PLHPP should be investigated with a view to exploring operating rules that can further reduce the environmental impacts without substantially affecting the payback period.
- Ongoing work should recognise that monthly-average results will not provide sufficient information on the flood peaks.
- The final design should include assessments of other probability distributions for defining the extreme values for design floods.
- The probability of flood volume and flood discharge should be analysed jointly in the ongoing design to accommodate short duration high peak as well as long duration low peak events. The methodology to determine flood volumes must be explained.
- Further insights and support for the proposed daily water level changes must be provided for the hydropeaking operations. These should preferably be specified as cm/hr and be a close as possible to the natural water level changes in the Mekong in this reach.
- The impact of flood regulation operations on water levels downstream to the Thai border and Vientiane should be investigated and demonstrated in the ongoing work, and if needed operating rules to accommodate the requirements of the PMFM must be developed.
- The operating rules must be updated to provide for specific environmental flow requirements for the area immediately downstream of the dam site.
- A comparison between the 2-D and 3-D model and the physical model outcomes should be provided once these results are available. A proper assessment of accuracy should be provided if these results show large differences. (The developer has indicated that this analysis is currently underway.)
- An additional monitoring station some 10-20 km downstream of the dam site should be included to monitor possible fluctuations and environmental impacts, and to apply adaptive management to respond to the observations.

### *6.3.2 Sediment transport and river morphology*

The following comments are made with respect to the sediment analyses and, as well as measures to minimise this:

- The documentation provided for the PNPCA is considered adequate for understanding the project infrastructure, and potential operating regime and providing a general overview of localised impacts associated with the development at the feasibility stage.
- Larger low-level outlets of similar dimension to those included at Xayaburi would improve sediment throughput, including during periods when Xayaburi is flushing sediments. Options to increase sediment transport throughout the impounded reach should be explored with operating rules identified that allow for drawdown and flushing at lower flows. (The developer has suggested that the model tests and the management procedures meet the "requirement" on sediment flushing, but no detailed assessments have been provided. The Lao PDR has indicated a willingness to export these aspects)
- A more robust assessment of potential transboundary impacts associated with the PLHPP based on the most up to date sediment transport and geomorphic information should be undertaken. The assessment should consider timeframes of up to 100 years for geomorphic processes;
- The impacts related to the additional trapping of sediment in Pak Lay should be quantified in the context of existing and future development levels in the LMB. This is particularly important if the PLHPP will remain the most downstream project;
- Additional information about how downstream erosion will be monitored, identified and addressed is required, as it is potentially an important transboundary impact. The discussion should include a scenario in which Pak Lay is the final dam in the cascade. (The developer has stated that a detailed monitoring scheme for downstream scouring will be carried out in the next stage. This plan should be submitted to the MRC when it is complete.)

The Lao PDR have indicated that the recommendations made in respect of improving the sediment throughput are worthy of consideration.

### 6.3.3 Water Quality and Aquatic Ecology

The following comments are made with respect to the water quality and aquatic ecology:

- The general overview of water quality issues in the LMB is too broad and does not focus on the likelihood of synergistic or antagonistic effects of hydropower development in the basin and specifically does not model how the PLHPP will alter water quality status both downstream and upstream (in the impoundment) of the dam.
- The survey design and implementation do not support the conclusions drawn and a well-designed and intensive survey protocol (monthly) carried out over an extended period (at least over two years), and during the construction and operations phases, is required. This has also been noted in the CNR report.
- There is no in-depth analysis of the value of any habitats that will be lost, or the potential impacts on the wider LMB ecosystem in terms of lost biodiversity or aquatic productivity.
- The frequency and extent of monitoring should be increased significantly and procedures to respond to accidents and problems encountered should be outlined.
- Empirical methods should be used to set environment flows. Any changes in local flow regimes must be set against the cumulative impacts.

### 6.3.4 Fisheries and fish passage

Considerable fishing activity takes place in the impact area, mainly based on the migratory fish species, and the MRC estimates that some 40,000-60,000 t/yr of fish are caught in Zone 1. The developer made an approximation of the harvest potential of fishes and other aquatic "organisms" based on a simple area versus production figure. The results vary between 217.5 t/year and 913.5 t/year, which appears to underestimate the importance of fisheries in the region and conflicts with other estimates reported by the developer and the MRC. The MRC's Council Study estimated that a 40% reduction in short distance migrating whitefish was possible. The developer notes that fisheries will be adversely affected by the disruption of migration and potential loss of endangered and threatened species both during the construction and operational phases. However, the impacts of the change in habitat from a river to a 110 km long impoundment are not recognised.

The following comments are made with respect to improving the fishpass facilities:

- The fish pass designers should meet with the Xayaburi designers to understand the functional criteria the latter used in their design and to inform the final design at the PLHPP.
- The potential future dam operations when finalising the floor level of the fishway exit.
- The final design should ensure that the level of the fishpass entrance considers the possibility that the Sanakham HPP may not be constructed.
- It will be advisable to review and report on other fish passage options, including using the navigation lock for fish passage.
- It is very important that fishpass entrances are provided at the powerhouse and spillway, and the thalweg needs to be shaped to guide fish to the fishpass.
- Fishpass entrances are required on both sides of the spillway and physical modelling is required to optimise these. The navigation lock has high potential to provide fish passage on the right abutment but would need to be specifically designed to do so.
- It is very important that the fishpass flow (channel and auxiliary flow) be increased from 8.5 $m^3/s$ to 310 $m^3/s$ to meet good design practice for attraction flows, or at least 200$m^3/s$ to align with the Xayaburi HPP.
- It is very important to reduce pool step height and the pool size to nine m long and increase slot width to reduce turbulence and provide for larger fish.

- The developer should consider increasing the design depth to three m and to base the design on the lowest operational headwater and tailwater levels.
- Additional resting pools and enlarging flat sections of the fishpass could be considered.
- Additional hydraulic modelling to assess the impacts of different operating rules on fish larval drift should be done to support larval drift at low flows.
- It is very important to further investigate the feasibility of fish screens and the downstream fish passage facility.
- It is very important that the debris screen be redesigned, with a fish collection system and diversion channel that safely passes fish downstream.
- The communications with turbine manufactures should aim to modify the turbine design to have a pressure ratio of 0.1 and a shear of < 150 cm/s/cm for 99% of flow paths.
- Options to guide fish to the surface in the forebay, so that they are surface-acclimated before passing through the turbines or locating the turbines deep in the tailwater to eliminate sub-atmospheric pressures, should be investigated.
- The studies currently being done should consider the impacts of replacing the gates with an overshot design or include overshot gates within all the radial gates.
- It is important to determine the hydraulics of the constricted river for the Stage 1 coffer dam and to provide a dedicated fish passage solution for Stage 2, and Stage 1 if required.
- The plans and for using the navigation lock to facilitate fish passage during construction should be presented.

The Lao PDR has indicated a willingness to review the design of the fishpass facilities.

### *6.3.5 Dam safety*

Both the ICOLD and Lao guidelines for dam safety require that a consequence analysis is undertaken to determine the hazard category of the dam, and that the standards are selected accordingly. A consequence analysis has not yet been done, and the *Dam Safety Assessment and Dam Failure Impact Scope Report* does not fully address this requirement and is not based on a failure modes assessment. In this regard the following main recommendations are made with respect to the Dam Safety aspects:

- The design of the energy dissipation structures should be reviewed and based on the actual geological conditions.
- The developer should carry out a failure modes analysis at the start of the detailed design stage to identify any weaknesses in the design and allow mitigation measures to be incorporated at an early stage;
- Dam break modelling should be carried out based on the failure modes review and an assessment carried out of the impacts of the theoretical dam break flood wave;
- The developer should design the PLHPP to safety pass the Probable Maximum Flood;
- The developer should carry out a dam break consequence assessment to provide further support to their selection of seismic design criteria; and
- An independent review panel as outlined in the World Bank and ICOLD guidelines should be established.

### *6.3.6 Navigation*

The MRCS does not concur with the developer's assessment that the navigation facilities ***mostly*** comply with the PDG2009. Although it is noted that many of the guidelines have been adopted, and that the pending DG2018 drops some of the requirements. Nonetheless there are issues that still need to be addressed to improve the safety of the navigation facilities. The main concerns are:

- The bridge over the upper lock head and the rolling crane are too low.
- The safety of the navigation in the shallower parts of the upstream impoundment where rocky outcrops can still pose a danger to shipping.

- The area for the second ship lock has not been clearly defined.
- Ships approaching the ship lock will have to cross in front of the powerhouse and spillway, which could pose a danger, and it is likely that the downstream navigation channel will have to be enlarged and dredged
- The 5 dolphins will block the entrance to the future second ship lock, this may lead to excessive demolition costs for the Lao PDR should they have to construct the second lock.
- It is strongly recommended that the downstream guidance wall has a vertical front.
- There is no indication of a road connection to all parts of the ship lock, as is required under the PDG2009.
- The required auxiliary systems should be specified.

The LNMC have subsequently commented that some of these recommendations have already been addressed. However, this is not evident in the documentation that has been submitted. However, the review team considers that more attention to the requirements of the 2nd parallel lock is required to ensure that the Government of Lao PDR is not left with a significant investment to construct the 2nd locking system if and when this is required.

### *6.3.7 Socio-economic studies*

If the PLHPP progresses to the final design stage, the following should be addressed in the updated documentation on the socio-economic aspects:

- Quantitative impact predictions should be provided where possible and should be consistent with relevant MRC studies such as the Council Study;
- Any TbESIA should be based on the expected impacts of the PLHPP, and not generically stated;
- Targeted mitigation measures for all predicted impacts, designed to at least maintain, if not improve, the livelihoods and living conditions should be provided for all affected groups;
- Where practical, cumulative impacts should be addressed through joint mitigation and monitoring actions with other developers, government agencies, and the MRC; and
- Clear commitments in terms of budget, implementation plans, monitoring and adaptive monitoring responsibilities should be spelt out.

## 6.4 Alternative operating rules

The current operating rules for the PLHPP propose that the impoundment is operated at 240m for flows below 16,700 $m^3/s$ and are only lowered when inflows are forecast to increase above this level in the wet season. At higher flow the turbines may be shut down if the operating head becomes too low (< 7m). The capacity of the turbines is reached when flows reach 6,100$m^3/s$. This means that at inflows between 6,100$m^3/s$ and 16,700$m^3/s$ water is released through the lower sediment flushing gates and through the higher spillway gates to maintain the operating level at 240m. At these times velocities in the impounded reach may be high enough to promote sediment transport and larval drift.

Flow velocities above 0.3m/s are required to maintain drifting larvae and to promote the transport of sediment through the impounded section. In the case of the PLHPP flow velocities in the impoundment will most likely drop below 0.3 m/s with inflows below 3,500$m^3/s$ if operating levels of 240m are maintained. Flows are likely to be below this threshold for some 55% of the time (after considering the impacts of the Lancang cascade), thus increasing larval and sediment losses.

However, if the reservoir operating levels could be gradually decreased to 230m then it may be possible to maintain flow velocities over 0.3 m/s and reduce the loss of drifting fish larvae and transport more sediment through the reservoir, for much of the year. Interim operating levels that still address this issue for significant periods can also be explored. If the bottom sediment flushing gates are used to balance the inflows and outflows to achieve this, and if these gates were enlarged it is likely that

considerably more sediment would be transported through the impoundment. However, without similar actions at the upstream HPP the benefits of these measures will be limited.

But this will reduce the total power output, increase the payback period and increase the costs of the loan financing. These challenges can be addressed by either increasing the Concession period, or increasing the price of the power, either uniformly, or just when operating levels are decreased below 240m. Some optimum between the environmental impacts, and economics of the PLHPP should be explored. Monitoring regimes can be devised to optimise these operations on an adaptive management basis.

Recommendation

- **It is recommended that the developer assesses the implications of operating the impoundment at levels below 240m once inflows decrease to below 3,500m$^3$/s and that the economic and environmental implications of several options be explored and presented.**

## 6.5 What happens after prior consultation?

The first Chapter of this Technical Review Report introduced the basis for prior consultation in the 1995 Mekong Agreement, and the PNPCA. This highlighted that prior consultation is a cooperative mechanism aimed at giving all the Member Countries confidence that their concerns are being identified, discussed and acted on, and to promote the reasonable and equitable use of the Mekong River System. It supports the notifying Country's endeavours to make every effort to avoid, minimise and mitigate harmful effects. The overall process involves both actions by the MRC and specifically the Joint Committee to review and discuss the proposals made in this regard by the developer, and to suggest additional measures, and actions by the notified Member Countries through replies in which they may raise concerns, or suggest that the proposed use will result in substantial damage, or is not a reasonable and equitable use of the shared watercourse.

The end point of prior consultation is outlined in Article 5.4.3 of the PNPCA, which 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 previous 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[42]. In the Pak Beng case this set of measures was outlined in a "*Statement on the Prior Consultation Process on the Pak Beng Hydropower project in Lao PDR*[43]" which was agreed by the MRC JC. It is anticipated that the Pak Lay process will similarly end in an agreed Statement. This is particularly important in the light of notification at the feasibility stage.

However, for the notified Countries' to gain some confidence that these measures are being applied, some post prior consultation process is necessary. In the Pak Beng case this was proposed as a Joint Action Plan (JAP). The purpose of the JAP is multifaceted and aims to:

- Support the implementation of the Statement as agreed by the Joint Committee;
- Provide opportunities for the Government of Lao PDR and the LNMC, to engage with experts from the MRCS and the Member Countries with view to enhancing existing measures to avoid, minimize and mitigate the potential for transboundary impacts, and to enhance the benefits of the project and the sharing of knowledge and experience amongst the Member Countries;

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

[43] This is available at: http://www.mrcmekong.org/assets/Uploads/Statement-Final-PBHPP-PC-Conclusion-240617.pdf

- Provide a mechanism for the exchange of data between the GoL, the MRC, the other Member Countries, and other mainstream HPP on the monitoring of flows, sediment transport, fish and aquatic ecology, water quality, navigation, and socio- economic factors;
- Present regular updates on progress with the development and revision of the final designs and operating rules for the PBHPP; and
- Provide a forum for exchanging information and knowledge with other hydropower developers on the mainstream and tributaries, to improve the conjunctive management of HPP in the LMB and to share lessons.

It is only through the JAP that the notified Countries can remain engaged in the development of the project through its final design and development of the operating rules, which ultimately determine the impact of the proposed use on their use of the Mekong River System. It is hoped that a JAP be agreed for the PLHPP. However, it is also important that the JAP does not slow down the project implementation process, as this can lead to increased interest on the loan repayments. The JAP milestones must therefore be dictated by the final design and construction schedule, and not the converse.

Ongoing monitoring and adaptive management may also lead to ongoing improvements in the HPP. This too must be shared with the notified Countries. In this context the note in the preamble to the PNPCA is important:

> *"Reconfirming the commitment to work together to address the protection of the environment and the ecological balance in the Mekong Basin, including the prevention of harmful effects and taking actions in emergency situations* ***as covered by other Rules/procedures approved by the MRC Council****."*

This highlights the importance of all the MRC Procedures. This review has drawn on the PWQ and PMFM.

The preamble to the PWUM notes that:

> *"Recognising that the reasonable and equitable use of water resources will not be possible if water uses are not monitored"*

and,

Article 4.3.1 indicates that the roles of the MRC JC are to, inter alia:

> *"improve the monitoring system in a manner that is coordinated with the other MRC Procedures and consistent with the relevant MRC Standards."*

It is therefore important that in the longer term, many of the measures and standards proposed in this TRR should ultimately be taken up in the PWUM and reported annually to the JC.

**MRC Secretariat**
184 Fa Ngoum Road, P.O.Box 6101, Vientiane, Lao PDR
Tel: +856 21 263 263
Fax: +856 21 263 264
e-mail: mrcs@mrcmekong.org
www.mrcmekong.org