115002924
October 7, 2019
Rev 1

LUANG PRABANG POWER COMPANY LIMITED
LP HPP

Feasibility Study

Executive Summary

PÖYRY
Engineering balanced sustainability™

Contact

Pöyry Energy Ltd. (Thailand)
Vanit II Bldg, 22nd Floor, Room#2202 - 2204
1126/2 New Petchburi Road
Makkasan, Rajchthewi
TH-10400 BANGKOK
Thailand
Tel. +66 2 650 3171-2

"This report has been prepared by Pöyry Energy Ltd. ("Consultant") for Luang Prabang Power Company Limited ("Client", "LPCL") pursuant to the Contract signed between them ("Agreement"). This report is based in part on information not within Pöyry's control. While the information provided in this report is believed to be accurate and reliable under the conditions and subject to the qualifications set forth herein Pöyry does not, without prejudice to Pöyry's obligations towards the Client under the Agreement, make any representations or warranties, expressed or implied, as to the accuracy or completeness of such information.

Use of this report and any of the estimates contained herein by anyone else than the Client ("Third Party User") shall therefore be at the Third Party User's sole risk. Any use by a Third Party User shall constitute a release and agreement by the Third Party User to defend and indemnify Pöyry from and against any liability of Pöyry, whatsoever in type or nature, in connection with such use, whether liability is asserted to arise in contract, negligence, strict liability or other theory of law.

All information contained in this report is of confidential nature and may be used and disclosed by the Client solely in accordance with the terms and conditions set forth in the Agreement."

STRUCTURE OF THE FEASIBILITY STUDY

VOLUME 1: EXECUTIVE SUMMARY

VOLUME 2: MAIN REPORT

VOLUME 3: DRAWINGS

VOLUME 4: ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

VOLUME 5: TRANSBOUNDARY ENVIRONMENTAL IMPACT ASSESSMENT AND CUMULATIVE IMPACT ASSESSMENT

VOLUME 6: ANNEXES

VOL. 6.1: HYDROLOGY

VOL. 6.2: TOPOGRAPHY

VOL. 6.3: GEOLOGY

VOL. 6.4: PROBABILISTIC SEISMIC HAZARD ASSESSMENT

VOL. 6.5: HYDRAULIC MODEL TEST

VOL. 6.6: ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

LIST OF ABBREVIATIONS

Units and Symbols

dBA	Decibels
GWh	Gigawatt hour
km	kilometre
km^2	square kilometre
kPa	kilo Pascal
kV	kilo-volt
m	metre / metre
m^2	square metre
m^3	cubic metre
m/s	metre per second
m^3/s	cubic metre per second
m asl	metre above sea level
M	million
M m^3	million cubic metrer
MW	Megawatt
MWh	Megawatt hours
PMF	Probable Maximum Flood
rpm	revolutions per minute
t	ton

Abbreviations

approx.	approximately
ARI	Annual Recurrence Interval
CIA	Cumulative Impact Assessment
COD	Commercial Operation Date
d/s	Downstream
EL	Elevation
EGAT	Electricity Generating Authority of Thailand
EMMP	Environmental Management and Monitoring Plan
ESH	European Society of Hypertension
ESIA	Environmental and Social Impact Assessment
FS	Feasibility Study

FSL	Full Supply Level
GIS	Gas Insulated Switchgear
GOL	Government of Lao People's Democratic Republic
HPP	Hydro Power Plant
HQ_{xx}	Flood with a return period of xx years
IFC	International Standardds
LAK	Lao Kip
Leq	Equivalent Continuous Sound Level
Lmax	Maximum Continuous Sound Level
LP HPP	Luang Prabang Hydro-Electric Power Project
LPCL	Luang Prabang Power Company Limited
max	Maximum
MAF	Ministry of Agriculture and Forestry
MEM	Ministry of Energy and Mines
MICT	Ministry of Information, Culture and Tourism
MOES	Ministry of Education and Sport
MOH	Ministry of Public Health
MONRE	Ministry of Natural Resources and Environment
MOU	Memorandum of Understanding
MPWT	Ministry of Public Works and Transport
MRC	Mekong River Commission
NA	Not Available
NBACs	National Biodiversity Conservation Areas
NTFPs	Non-Timber Forest Products
PAP	Project Affected Person
PH	Powerhouse
PM10	Particulate Matter 10 Micrometers or Less in Diameter
PNPCA	Procedures for Notification, Prior Consultation and Agreement
PV	PetroVietnam Power Corporation
RCC	Roller Compacted Concrete
REMDP	Resettlement and Ethnic Minority Development Plan
ROR	Run-Of-River
SIA	Social Impact Assessment
SMMP	Social Management and Monitoring Plan
SW	Surface Water
TBIA	Transboundary Impact Assessment

TL	Transmission Line
TOR	Terms of Reference
TSP	Total Suspended Particulate
TSS	Total Suspended Solids
u/s	Upstream
UNESCO	United Nations, Educational, Scientific and Cultural Organization
UXO	Unexploded Ordinance
VEC	Valued Ecosystem Component
WL	Water Level

Table of Contents

1 PROJECT FEATURES

The Mekong River possesses a huge hydropower potential both in its main stream and tributaries. A large part of this potential is in Lao territory due to country's favorable climatic and geographical conditions.

For development on the Mekong mainstream in Lao territory, the Government of Lao People's Democratic Republic (GOL) previously signed a Memorandums of Understanding (MOUs) with developers to study and implement hydropower projects at the Mekong Mainstream. The Luang Prabang Power Company Limited ("LPCL") is the "Project Company" which has been set up in the Lao PDR to undertake the project development of Luang Prabang Hydroelectric Power Project ("LP HPP") under the Memorandum of Understanding granted by the Government of the Lao PDR to PetroVietnam Power Corporation in October 2007, which has later been assigned to LPCL upon formation of LPCL. Allowing it to conduct surveys, investigations, and a full Feasibility Study (FS) for the development of the Luang Prabang hydropower project.

The Mekong River Commission prepared Design Guidance for Hydropower Project developed in the Lower Mekong Basin. The Preliminary Design Guidance became effective in 2009. In the meantime MRC is developing a revised Design Guidance. Both the in force Design Guidance and the new revision which has been published as a draft in 2018, have been considered in the design of the Luang Prabang Hydropower Project. Both provide an overview and define the issues the MRC will be considering during the prior consultation process according to the PNPCA rules set out by the MRC. The design of the LP HPP complies with both versions.

The LP HPP is located approx. 25 km upstream of Luang Prabang at kilometrage 2036. It is a barrage type hydroelectric run-of-river scheme which comprises:

- Powerhouse equipped with 7 Kaplan turbine/generator sets (200 MW each). The total installed capacity for the main units is 1,400 MW, and the maximum gross head is 36.80 m
- Auxiliary units using water from fish attraction flow for the upstream and downstream migration facilities (approx. 180 m^3/s), totaling to a maximum of 60 MW capacity
- Spillway structure with six (6) radial surface gates (19 m x 25 m, sill level 288.0 m). Three (3) low level outlets (12 m x 16 m, sill level 275.0 m asl)
- Two-step Navigation lock system for 2x500 DWT vessels
- Fish pass system for up- and downstream migration
- A left bank Closing Structure formed by an approx. 50 m high RCC concrete gravity dam, in total 281.23 m long.
- 500 kV transmission line with intermediate substation to Vietnam with an approximate length of 400 km to the Vietnamese border and 200 km to the next suitable substation. Alternatively to Thailand with an approximate length 250 to 300 km.

The LP HPP is planned to be developed from the right river bank, where space is available for the installation and construction of the main structures. The Navigation Lock will be located at the right river bank allowing vessels and ships a safe approach and passage. The Spillway is located between the Navigation Lock and the Powerhouse and comprises two blocks, one block with four (4) Surface Spillway bays, and the second block with the three (3) Low Level Outlets and two (2) Surface Spillway bays.

The Powerhouse will be in the centre of the river, and will have two erection bays, one at each end of the powerhouse. The split erection bay concept provides on the one hand advantages for assembly and installation of the equipment (lifting devices can operate independently from each other), and space (upstream and downstream of the erection bays) to host the facilities for upstream and downstream Fish Migration.

The natural hydrological flow regime at the LP HPP site is heavily impacted by the Lancang Cascade in China and its huge storage plants. A water balance model for the conditions without and with the Lancang Cascade has been established and calibrated based on observed data. The natural inflow series (1951 to 2018) has been transformed by a water balance model taking into account the operation of the Lancang Cascade, resulting in higher base flows during the dry season. The average flow at the barrage site is about 3,293 m^3/s; the 10,000 year design flood is about 33,500 m^3/s, the PMF has been determined with a rainfall-runoff model to 41,400 m^3/s.

The LP HPP site is located on a stable block between two branches of the Dien Bien Fu Fault Zone. The main bedrock units consist of dark green-grey andesitic basalts, volcano-clastics and subvolcanic intrusions, as well as thinly bedded calcareous clastic sediments. The contacts between the two different main units are mainly of stratigraphic and not of tectonic origin. The foundation conditions for the civil structures are moderate to favourable. No karst-features are to be expected, which would have been unfavourable regarding water tightness. Suitable construction material (massive limestone) for concrete aggregates could be identified in close distance to the dam site at the right upstream river bank; massy basaltic bedrock, which has to be excavated, can be used for purposes with lower quality demand, i.e. embankment fillings. The number of local and sub-regional fault zones documented in the previous studies could not be confirmed by the 2019 investigations in this extend and geometric layout. The current dam location at Alternative 1 can be classified from the geological-geotechnical point of view as feasible.

The construction of the hydropower plant is planned to be done within one major construction stage, i.e. all major structures will be erected within a large single construction pit while the Mekong River is diverted. After completion of the main construction works (concrete works and installation of the main hydro-mechanical equipment, Spillway and Navigation Lock operational, intake gates and draft-tube stoplogs at Powerhouse in place and set) the Mekong River will be diverted through the Spillway (Low Level Outlets) and the left bank closing structure (RCC gravity dam) will be constructed while wet testing and commissioning can start.

The construction works will be mainly done from the right river bank, which can be reached by an existing access road from Luang Prabang (Mekong River in Luang Prabang needs to be crossed by ferry boat). Transportation of bulk material to site can be done via vessels or by road.

The power will be exported via a 500 kV double circuit transmission line. The export to Vietnam would require a transmission line with a total length of approximately 620 km to 765 km of which 365 km to 470 km would be in Laos and the remaining length required to connect to either an existing or future substation of the Vietnamese 500 kV grid. For the connection three potential corridors, i.e. norther, middle and southern have been studied. Due to the length of this transmission line an additional, intermediate substation would be required. Additionally difficult, mountainous terrain would need to be crossed.

The closest connections to a 500 kV grid would be to Thailand either via Hongsa District or via Kenethao Xayaburi District. The estimated length of the transmission line is in the range of 250-300 km.

An initial optimisation of the installed capacity and energy calculations has been carried out based on the available hydrological data. The result of this optimisation study shows an optimum installed capacity of 1,460 MW. In order to minimise the number of units, the size of the Kaplan units have been optimised. The selected runner diameter is about 8.80 m, the maximum unit discharge is 765 m^3/s with a capacity of 200 MW per unit.

The mean annual energy generated yields to approximately 6,424 GWh per year, and the 90% percentile (P90) of the energy yield is about 5,986 GWh per year at Thailand delivery point.

The mean annual energy generated yields to approximately 6,231 GWh per year, and the 90% percentile (P90) of the energy yield is about 5,608 GWh per year at Vietnam delivery point.

The construction time has been estimated to about 84 months (1 year for preparation work and 7 years for construction) from financial close to COD. The first unit will be ready for operation 12 months before COD.

The environmental and social impact assessment follows national and international standards (IFC) and especially the MRC guidance and recommendations. The main focus is put on impact mitigation to fish migration, sediment transport and impacted villages. Besides, mitigation measures for identified impacts during pre-construction, construction, operation and transfer phase are proposed in the ESIA.

The Mekong River is an important habitat for many different fish species. At Xayaburi HPP around 161 different species have been identified. It is reasonable to assume that a similar amount of species will be present at Luang Prabang site as well with many of them being the same as in Xayaburi. Upstream and downstream fish migration facilities will be provided at the LP HPP. The facilities will be designed in consideration of the experience gained at Xayaburi HPP and follow the MRC guidance. Fish monitoring will take place which will include the biomass, the different species and the migration behaviour.

Around 26 villages will be directly impacted by the project since they are located at the riverbanks of the Mekong in submerged areas and/or the backwater area of the hydropower plant. These villages contain around over 2,000 households with over 10,000 inhabitants which will be affected by the project in one way or another. In the majority of cases only certain low lying houses within a village will need to be relocated rather than relocating complete villages. The inventory of loss is ongoing to identify how many households have to be resettled and how losses have to be compensated.

A risk assessment has been carried out for the LP HPP covering the main risks during construction and operation of the scheme. The identified risks have been assessed and adequate measures to control and manage these risks have been determined and proposed. Overall the risk assessment and the taken control and management measures result in an acceptable and manageable risk profile for the LP HPP.

2 PROJECT CONCEPT AND OPERATIONAL ASPECTS

2.1 Location of the Project

The Luang Prabang Hydro Electric Power Project (LP HPP) site is located on the Mekong River at kilometrage 2036, approximately 25 km upstream of Luang Prabang, at the village Ban Houaygno, in the Province of Luang Prabang. The reservoir area also crosses the provinces of Oudomxay and Xayaburi (see map in Figure 2-2).

Figure 2-1: Location map of LP HPP

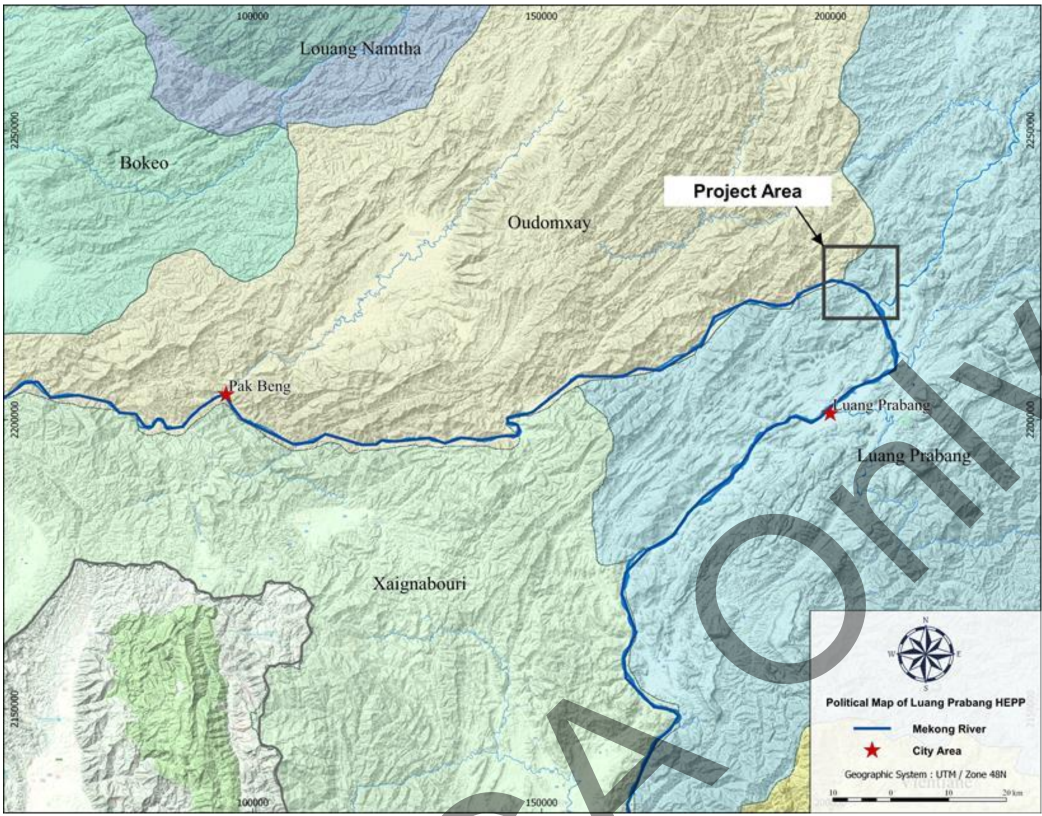

Figure 2-2: Political Map of LP HPP

2.2 Normal Operation

The LP HPP is a Run-of-River type hydropower plant, i.e. the discharge through the powerplant (Powerhouse, Spillway) equals the inflow, and the Full Supply Level will be maintained most of the time during operation (increase of decrease of the FSL might be required during spillway operation or other exceptional operating cases). For practical purposes (control system) an “operating range” for the FSL of around 0.50 m will be required, i.e. the FSL will vary between 312.00 and 312.50 m asl.

2.3 Spillway Operation

During Flood Operation the excess water (water not used for generation of electricity and/or operation of the Navigation Lock and Fish Migration Facilities) will be spilled through the Spillway. The Spillway comprise Low Level Outlets and Surface Spillway bays.

The operation of the Spillway will be such that the first bays in operation will be the Low Level Outlets in order to route “turbidity currents” through the spillway and to minimise sedimentation in the reservoir area. When the capacity of the Low Level Outlets is reached the Surface Spillway will start operation. All gates of the Surface Spillway will be equipped with flap gates to allow spill of floating debris in front of the Spillway into the tailwater area.

2.4 Operation of the Navigation Lock

According to the MRC Guidance the Navigation Lock has to be operated between a 30 years flood and 95% flow duration of the river in natural conditions, leading to an operating range for flows in the Mekong River between 1,100 m^3/s and 21,700 m^3/s. The maximum head difference between upstream and downstream is about 35.5 m.

The maximum upstream water level is at elevation 312.00 m asl, equal to Full Supply Level (FSL) or Normal Operating Level (NOL), and the minimum downstream water level is about 276.50 m asl. During impounding the Navigation Lock needs to be operational even when the FSL is not reached; the minimum upstream water level for the operation of the Navigation Lock is 294.25 m asl (Lowest Operating Level, LOL).

The filling of the chambers of the Navigation Lock is done via a gravity based feeding system from the headwater of the plant controlled by bonneted gates. The lockage time for a two-step ship lock is expected to be shorter than the required 50 minutes.

2.5 Operation of the Fish Migration Facilities

According to the MRC Design Guidance fish passage facilities have to operate from minimum flows to a 1-year flood, leading to an operating range for flows in the Mekong River between 1'170 m^3/s and ~10,650 m^3/s, or tailwater levels between 276.7 m asl to 287.4 m asl.

Facilities for upstream and downstream migration are provided at the following structures:

- **Upstream migration at the powerhouse:** When the spillway is not in operation (usually during the dry season), upstream migrating fish will be attracted by the powerhouse discharge and will enter into the upstream fish passing facilities at the powerhouse and left pier. This fish migration system will be operated throughout the year.
- **Downstream migration at the powerhouse:** The main downstream fish migration system provides entrances along the upstream face of the powerhouse and a collecting gallery, where the fish are guided to the right pier and released down to the tailwater through the terminal chute. This downstream migration system will be operated throughout the year. Additionally, fish friendly turbines are provided for fish small enough to pass through the trash rack of the power intakes.
- **Downstream migration through the spillway:** Downstream migration is also possible through the spillway (when in operation).
- **Upstream migration at the right bank (at the Navigation Lock):** When both the powerhouse and the spillway are in operation (usually during wet season), fish migrating upstream will be also attracted into the spillway discharge channel. Fishpassage through an additional upstream fish migration system at the right bank is foreseen to allow passing fish at the right bank during operation of the spillway. This system is only in operation when excess water is spilled through the spillway. In addition, an entrance on the spillway left side and connected to the powerhouse migration system will put in operation.

3 TRANSMISSION LINE

3.1 Assessment of Off-Taker

3.1.1 General

It is foreseen to export the generated electricity to neighbouring countries. Due to the geographic location of the LP HPP, possible off-taker would be Thailand or Vietnam. One important consideration is the cost to build transmission facility to the nearest interconnection point. The main criteria is the expected length of the transmission line, as this determines the costs for the construction as well as the transmission losses.

3.1.2 Transmission Line to Thailand

It is clear that Thailand has the advantage of proximity, due to the existing transmission line connecting to the Thai grid.

Export to Thailand could be realised following (partly) an existing TL route to substations in Thailand. The overall length of the transmission line is between 280 and 350 km and transmission line losses of about 3%.

3.1.3 Transmission Line to Vietnam

Power export to Vietnam would require construction of a new 500 kV transmission line to a Vietnamese substation, which would require to cross a mountain range with rather difficult terrain and environmental concerns due to the line route crossing protected National Bio Diversity Areas.

There are three principle options to connect with Laos which follow along existing Transmission Line corridors connecting to existing projects or those under development. It is noted that these Transmission Lines are 220 kV systems connecting to hydropower project in Laos, i.e.

- **Northern Corridor via Nam Ou:** This option is with 365 km to the Vietnamese border the shortest possible option. On the Vietnamese side the next connection would be the existing Hoa Binh 500 kV substation. The distance from Hoa Binh to the Lao border, passing the planned 500 kV substation of Son La, is approx. 400 km along national road AH13 road
- **Central Corridor via Nam Xam 1 and Nam Xam 3:** The estimated Transmission Line length to the Vietnamese border at Ban Som is approx. 470 km. On the Vietnamese side the nearest existing 500 kV substation Hoa Binh as in the Northern Corridor option. The estimated distance from the border is approx 150 km.
- **Southern Corridor via Nam Mo:** The estimated Transmission Line length to the Vietnamese border at Ban Som is about 470 km. On the Vietnamese side the nearest existing 500 kV substation Hoa Binh. The estimated distance from the Laos border is approx. 150 km.

On the Laos side the route has been estimated by following main road corridors leading to the border between Laos and Vietnam. For operational purposes a 500 kV substation is foreseen on Lao side between the LP HPP and the Vietnamese border.

While transmission lines do not need to follow road corridors somewhat shorter, more direct routes could be possible however it is noted that the terrain between Laos and

Vietnam is mountainous and difficult to traverse, so the shortest route might not be the most economical.

A summary of the Transmission Line lengths of the three corridors is shown in the table below. The length of the transmission line to connect the LP HPP to an existing 500 kV substation in Vietnam would be more than 600 km, resulting in transmission losses of about 6%.

Table 3-1: Length of the Transmission Line Options

Parameter	TL in Lao	TL in Vietnam	Total Length
Northern Corridor	365 km	400 km	765 km
Central Corridor	470 km	150 km	620 km
Southern Corridor	415 km	180 + 70 km	665 km

3.1.4 Conclusions

The substantial length of the transmission line to Vietnam would require an additional substation somewhere in the middle between the Luang Prabang project and the final 500kV substation in Vietnam to ensure continuity of the power supply and stability of the line. This intermediate substation is contributing to the estimated cost.

Furthermore the longer a transmission line is the higher the related transmission line losses would be. As a rule of thumb 100km of line length equal to about 1% in energy losses. Hence not only the length of line is double but so would be the losses during the lifetime of the project.

Additionally it is noted that the transmission line to Vietnam would need to cross mountainous, difficult terrain which not only add to construction cost and time but also pose a risk for timely completion and would require additional monitoring and maintenance efforts during the normal operation.

For the export of the generated energy from LP HPP to Thailand (EGAT) a 500 kV double circuit transmission line to a Substation in Thailand (Nan or Tha Li) will be required:

- 500 kV Nan substation via Hongsa TPP, total length of about 280 km
- 500 kV Tha Li substation via Xayaburi HPP, total length of about 350 km

The connection point will be defined by EGAT. In this Feasibility Study, an allowance for the construction costs for this option is made in the cost estimate, and transmission line losses of about 3% are taken into consideration in the energy calculations.

4 COMPLIANCE WITH MRC DESIGN GUIDANCE

4.1 Design Guidance for Dam Design in Lower Mekong Mainstream

Mekong River Commission recommends a Design Guidance for Dam Design in the Lower Mekong Basin. This Guidance is available as official version since 2009. A revised version, taking into account the recent developments along the Mekong and during the past PNPCA process, is available as draft version since 2018 from MRC's website and provides an overview of the issues the MRC will be considering during the prior consultation process.

The MRC Design Guidance provide guidance in the following areas:

1. Hydrology and Hydraulics;
2. Sediment Management and River Morphology;
3. Water Quality and Aquatic Ecology;
4. Fish Passage Design and Operation;
5. Safety of Dams;
6. Navigation Lock Design and Operations; and
7. Riparian communities and river-based livelihoods.

The Guidance outline "performance standards" rather than prescriptive designs, so developers can innovate and propose alternative mitigation and operational measures to meet the stated objectives. They are built on experiences and knowledge within the Mekong basin and internationally good practice standards.

Therefore the Feasibility Design was elaborated in a way to be in compliance with the MRC Design Guidance.

The section summarises the compliance of the Feasibility Study with the MRC Design Guidance (draft version, June 2018).

4.2 Hydrology and Hydraulics

With regard to hydrological and hydraulics issues, the following objectives were raised by the MRC Guidance:

- Have a detailed understanding of the hydrological resource availability and reliability, while taking into account present and potential future trends (such as climate change).
- Support mitigation measures and cascade or project operating rules dependent on hydrology and hydraulics by sound hydrological and hydraulic assessments

Since LP HPP constitutes of a pure run-of-river scheme without storage capacities, no significant changes in flows further downstream are to be expected.

In general a state-of-the-art hydrology assessment is provided considering the cumulative hydrological impacts due to multiple hydropower developments, and in particular from projects with the ability to store water and make unseasonal releases. Additionally, a range of scenarios for dry, average and wet years shall be established.

Existing database of water levels and flows from gauging stations in the vicinity of the project were used (including MRC hydrometric stations).

Additionally, one new gauging station immediately downstream of the dam axis (but upstream of the Nam Ou confluence) is currently envisaged for monitoring and verification purposes.

Hydraulic numerical modelling (2D and 3D) to quantify flow conditions in the impoundment, in the impoundment backwater, near the dam infrastructure, the downstream river, and at major tributary confluences especially with regard to the sound elaboration of the tailwater rating curve and headwater level of the tailwater rating curve and headwater level development during flood occurrences is required. Additionally, the complex flows at inlet, navigation locks, spillway and fish passing facilities, shall be investigated.

Numerical modelling shall be supplemented by physical model tests (or vice versa).

Finally, operation rules are to be elaborated to mitigate environmental impacts especially with regard to sedimentation, ramping rates, inundation areas and navigation.

4.3 Sediment Management and River Morphology

Key issues in sediment management and river morphology (see Chapter 3 of the MRC Design Guidance) are mainly raised with regard to:

- Minimise changes to sediment delivery to the downstream environment with respect to sediment quantity, the seasonality of sediment delivery, and grain-size composition of the sediment load.
- Minimise deposition within the impoundment to prevent upstream river changes and maintain and protect project infrastructure.

Specifically, the following approach is required:

- Monitoring and modelling of the baseline conditions
  - The monitoring and modelling should be used to describe and quantify baseline conditions in the project reach and potential project operations.

    The description of the existing environment will include annual sediment budget, grain-size distribution on a seasonal basis, existing geomorphic characteristics and patterns of sediment deposition in the project area.
  - A basic numerical sediment transport model integrated with the hydrological and hydraulic transport model shall demonstrate the influence of the daily and annual operating pattern of the project.
  - The model should be capable of incorporating and demonstrating the efficiency of sediment mitigation measures over a range of conditions.
- Implementation of low level outlets for sediment routing or sediment flushing purposes as mitigation measures
  - The description of potential changes to the existing environment associated with the project development will include changes to sediment transport within and downstream of the impoundment over the life of the project including a discussion of how adaptive management will be implemented over the concession period.
  - Dam layouts, including the location of the turbine intakes, low level outlet and spillway gates should be planned to minimise deposition near intakes and maximise the potential for frequent sediment flushing.

- The gates should be located at maximum depth within the impoundment to maximise potential for sediment flushing.
- Flushing gates should be large enough to accommodate flows sufficient to entrain and transport coarse sand and gravel in suspension and prevent clogging.
- Surface Spillway gates should be included to allow dilution of the highly concentrated bottom waters that are released.

• Implementation sediment management and operation rules:

- The passage of sediment should be promoted during all flood events with low-level outlets opened in preference to high level flood gates.
- Sediment routing involving drawdown of water levels to below minimum operating levels should be implemented and coordinated between dams in a cascade during periods of high sediment inflows. This may include at the start of the wet season, or when sediment flushing is implemented at an upstream project.
- At least 70% of the fine-sediment (grain-size <63 µm) entering an impoundment should be discharged on an annual basis to downstream of the dam. This is to maintain a supply of fine-sediment and nutrients to the downstream environment, including the Tonle Sap and delta. A target of 70% is considered an operationally feasible target that would provide downstream benefit.
- In impoundments where a 70% target is not achievable under normal operations, sediment flushing should be implemented on an annual basis to provide sediment input to the downstream environment and to prevent the consolidation of sediment within the impoundment.

• Finally, a monitoring program during operation is to be implemented.

- Measuring sediment inflows to and outflows from the impoundment area, including the determination of sediment grain-size. The same monitoring parameters and monitoring frequency as foreseen for the pre-project monitoring is envisaged. Monitoring sites should include upstream of the backwater to quantify inflow and downstream of the dam to quantify outflows.
- Annual bathymetric surveys within the impoundment at a resolution sufficient to quantify the rates of sediment accumulation or scour.
- Cross-sections and bathymetric surveys should be conducted every year at the upstream extent of the backwater to determine changes that might affect navigation.
- Surveyed cross-sections of the river downstream of the dam should be completed annually for the first 5 years of operations and every two years thereafter. A downstream monitoring plan should be developed that takes account of the location of the project, location of other projects, and proximity to alluvial river reaches. Monitoring should extend from the project a minimum of 50 km downstream, or to the backwater of the next project downstream, with cross-sections spaced at 5 to 10 km intervals and targeting alluvial reaches. Cross-sections should extend above the maximum water level height of the river.
- River banks along the new flood level line of the impoundment should be monitored to establish rates of erosion.

The LP HPP foresees three (3) Low Level Outlets as the primary spillway devices. During flood events the floods (and turbidity currents with the highest sediment concentrations) will pass through the Powerhouse/turbines and the Low Level Outlets. The approach to the Powerhouse and the Low Level Outlet is designed accordingly. Only when the capacity of the Low Level Outlets is reached, the Surface Spillways will be used.

Based on the available sediment and flow data a sediment model was set up and the sedimentation process (with and without LP HPP) was simulated. The simulations also include sensitivity cases to take into account uncertainties in the available data. An additional sediment sampling campaign has been initiated, and the sediment model will be updated once the results of this campaign are available.

4.4 Water Quality and Aquatic Ecology

Key issues are mainly raised in Chapter 4 and Chapter 5 of the MRC Design Guidance with regard to:

- Reduce the risks that water quality within the impoundment will impact the use of the impoundment for other purposes, such as fisheries, or impact on human health
- Minimise water quality impacts downstream of the dam on fisheries, aquatic ecosystems and human health.

Specifically, the following approach is required:

- Monitoring of the baseline conditions
- Establishment of management plans for the construction period
- Water quality risks associated with sediment flushing include elevated concentrations of suspended solids, elevated nutrients, and potentially poor water quality if the impoundment is stratified, or if sediment pore water quality is poor. Water quality considerations and mitigation measures during flushing include:
  - Restricting sediment flushing to periods of high inflows when stratification risks are low
  - Implementing maximum sediment concentration limits during flushing and releasing large volumes of surface water during and following sediment flushing to dilute concentrations and transport material downstream
  - Implementing sediment flushing early in the monsoon season so subsequent high flows continue to transport sediment downstream
- During the operation stage, water quality monitoring should continue at a monthly frequency at monitoring sites upstream and downstream of the impoundment.

Water quality and aquatic ecology is being addressed in the ESIA. Baseline data to establish a clear picture of the current situation are collected. This data include analysis of water quality and surveys of aquatic ecology.

During the construction period a rigid waste management and construction site operation plan including regular monitoring of the water quality will be established and implemented to secure minimum impact on water quality and aquatic ecology.

During operation strict operation rules shall be enforced. These will include a sediment management plan to avoid sediment accumulation and/or high artificial sediment concentration downstream of the dam. A water quality monitoring plan will be implemented, which will include monthly analysis of nutrient parameters and suspended solids on selected sampling locations u/s of the dam covering the tail of the impacted river stretch and d/s of the dam. A fish monitoring program similar to the currently implemented monitoring program at Xayaburi HPP will be established.

4.5 Fish Passage Design and Operation

The following objectives are to be followed as outlined in Chapter 6 of the MRC Design Guidance:

- Minimise the impact of dam construction and operation on upstream migration of fish species through design of appropriate fish passage facilities, where necessary
- Minimise the impact of dam construction and operation on downstream movement of fish species through design of appropriate operational regimes, fish passage facilities, fish guidance systems and appropriate turbine designs.

Specifically, the following general criteria's need to be met:

- Conducting pre-project monitoring identifying species, size composition, and biomass required passage.
- Incorporation of fish passage facilities for both upstream and downstream migration, which are designed for specific target species
- Achieve a fish passage target accordingly:
  - For long-distance migratory species at a single dam, large fishes (>75 cm) require more than 90% passage (of numbers of each species approaching the dam) and medium-sized (50-75 cm) fish require more than 80% passage.
  - Small, short-distance migratory species moving between/along the river to floodplains, require more than 60% passage (upstream and downstream) between spawning and feeding/refuge habitats.
- The fish passing facilities need to incorporate a range of different passage options for up- and downstream migration. Multiple fishways are required to consider the range of species, volumes of migration and various flow conditions encountering at the dam site.
- Additionally, multiple entrances should be provided, which accommodate for fish species that will use surface, midwater, benthic zones and the thalweg (deepest channel). The thalweg needs to lead to the fishway entrance; the river channel may need reshaping during construction to achieve this.
- Fish passage facilities need to:
  - Operate all year.
  - Operate optimally from minimum flows up to flows equal to a 1-year Annual Recurrence Interval (ARI) with the capacity to operate up to flows with a 5-year ARI.
  - Pass migrating fish from 5 cm to 300 cm in length both upstream and downstream, as well as drifting eggs and larvae downstream.
- Fish passage facilities need to pass the peak biomass, which requires the appropriate sizing of fishways, and suitable cycle times of fish locks and fish lifts.

- Predation within the fishways should be minimised. Adequate shelter for smaller species while within the confines of the fishways should be considered, and residence time in the fishways should be minimized.
- Fish exiting upstream fishways should not be drawn back over the spillway during overtopping. Exit conditions should be sufficient to provide a stimulus for fish to exit the fishway. The combination of suitable attraction flows, substrate, and protection from predators is important.
- Incorporation of fish friendly turbines
- Fish passage should be provided during construction, with quantitative assessment of the migratory population approaching the site and the proportion of each target species that passes through.
- Monitoring programs commenced for the pre-project assessments should be continued during the construction and operation stages.

The fish migration facilities at LP HPP is widely based on the concept developed for the Xayaburi HPP, and provides the upstream and downstream migration possibilities over the entire width of the hydropower plant.

Upstream migrating fish will be attracted by the powerhouse discharge and will enter into the upstream fish passing facilities with multiple entrances over the entire width of the Powerhouse. The fish in the collection galleries are guided to two fish locks, where the fish are lifted up into the headwater of the reservoir.

During wet season (Spillway in operation), fish migrating upstream will be also attracted into the spillway discharge channel. Fish passing through an additional upstream fish migration system at the right bank shall be considered as a supportive means for attracting and passing fish at the right bank of the project.

The main downstream fish migration system provides entrances along the entire upstream face of the powerhouse, where the fish are guided to the right pier and released down to the tailwater through the terminal chute. Downstream migration is also possible through the spillway (when in operation), the Navigation Lock, and for smaller fish through the turbines of the powerhouse. The powerhouse is equipped with fish friendly turbines in order to minimise the mortality.

4.6 Safety of Dams

Key issues on dam safety as outlined in Chapter 7 of the MRC Design Guidance are mainly raised with regard to

- To protect life, property and the environment from the consequences of dam operation or failure, based on an understanding of the risk imposed by the dam and the consequence of failure.
- To ensure a consistent approach to design criteria for mainstream dams, specifically for the safe passage of extreme floods and seismic stability.
- To ensure that design, construction, operation and maintenance regimes, as well as institutional arrangements, are consistent with national requirements and international good practice for the safety of dams.

Specifically, the following key document need to be elaborated

- Seismic hazard assessment to design a OBE and SEE

- Geological investigation and interpretation of regional seismic conditions
- Safe spillway of floods up to a PMF
- Impacts of mal-operation of the flood gates and floods due to dam break
- Emergency Action (or Preparedness) Plan for construction and operation period

During operation an Operation & Maintenance plan need to be prepared, while a flood forecasting and waring system is to be developed and installed.

For the LP HPP a site specific Probabilistic Seismic Hazard Assessment is being prepared. Geological surveys and investigations at the site and wider project area are carried out, which ware used as an input for the PSHA.

A flood study has been carried out for the LP HPP site, providing design floods for a 10,000 year flood (design flood, design basis for the design flood is the (n-1) rule, i.e. one spillway gate is not operational) and PMF.

As basis for the Emergency Action Plan, a dam break analysis has been carried out based on the latest design and the downstream Xayaburi HPP. A main topic of the dam break analysis has been (i) natural floods and (ii) the development of a breach at the Luang Prabang barrage combined with a 100 year flood.

4.7 Navigation Lock Design and Operations

The MRC Design Guidance require to provide Navigation Locks on stretches influenced by hydropower, capable of raising transiting vessels from the downstream to the upstream water level and vice versa during periods of authorized navigation on the Mekong River.

The MRC Guidance provide a number of design criteria for the Navigation Lock design, such as:

- Location, alignment and type of the lock
- Dimensions for the lock and safety margins
- Requirement on the approach channel
- Requirement for a latter expansion
- Lockage time and availability
- Requirements on filling and emptying
- Service life time of lock, main structures and equipment
- Maintenance of navigation during construction
- Requirements on chamber equipment
- Requirement on the approach infrastructure

The Guidance emphasises the possibility to use the locks as an additional fish migration facility. Further considerations to this issue are given in the respective chapters.

The design and layout of the Navigation Lock closely follows the recommendations of the MRC Design Guidance, all requirements have been addressed adequately in the Design. The site for an additional second Navigation Lock is indicated in the design documents.

4.8 Riparian Communities and River-Based Livelihoods

Key issues are mainly raised with regard to

- Evaluate the residual impacts from the project on directly-affected riparian communities.
- Identify practical, feasible and long-term support measures to address consequences on these livelihoods.

The pre-project analysis should identify and characterise the geographical extent of directly affected riparian communities, and the composition of those communities in terms of river-based livelihoods. Consequences on riparian communities and river-based livelihoods with regard to residual impacts are to be identified and described, specifically with regard to water level fluctuations, sediment transport, effects on aquatic ecology, fisheries and navigation.

There concerns are greatly addressed within the ESIA as outline in the respective section.

The ESIA for LP HPP includes a detailed survey on the communities along the Mekong River which will be affected by the Project. The survey includes all settlements starting at the dam location upstream to the tail of the backwater area which will be either directly or indirectly impacted by the Project. The surveyed area reaches up to the Pak Beng dam site.

Environmental Impact Assessment covers data collection on physical and biological components. The social impact assessment covers the socio-economic profile including current infrastructure, occupational details, ethnicity and livelihood conditions. This information is used to develop adequate management plans, including Resettlement Action Plan and Livelihood Restoration Plan.

The impacts of the Project on these will be addressed in the Environmental and Social Management and Monitoring Plan. Mitigation measures will be taken in order to avoid, minimize or offset impacts throughout the life-cycle of the Project. The results of these measures will be monitored under the responsibility of Environmental Management Unit (EMU) and the social program will be under the Resettlement Management Unit (RMU), which are to be formed and operated through the joint support of MONRE and other related GOL agencies. Monitoring will be the responsibility of a panel of experts with consultations or other stakeholders to solicit information on the project’s progress and impact. Consultation will be sought from technical staff, NGO representative/ Consultant, local administration and legal counsel.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Based on the findings of the studies carried out and the results of the field investigations and laboratory testing the following can be concluded:

a) The available hydrological data basis, in particular the flow data for the Mekong River covering a period of about 58 years, provide a sound and reliable basis.

b) The impact of the upstream Lancang Cascade and their huge storage capacities was assessed based on a water balance model calibrated with flow data from the first years of operation of the entire cascade. The transformed inflow data series provide a sound basis for the assessment of the energy output of the LP HPP.

c) The geological and geotechnical investigations performed up to date are sufficient for this feasibility stage. The geological conditions at the proposed project site are generally suitable for the foundation of the proposed project structures. Suitable sources for concrete aggregates and other construction material have been identified. Further investigations in the next project phase (Tender Design) will be needed for the Geological Baseline Report.

d) The topographic survey carried out in the course of this feasibility study are sufficient in the extent and accuracy for an appropriate design of the hydropower plant, camps, construction facilities and infrastructure. Further topographic surveys in the upcoming project phases might be necessary for construction activities outside the project area, and will be limited locally (e.g. access roads, piers for ferry boats, etc.).

e) The proposed arrangement of the main structures, with the Navigation Lock and the Spillway on the right bank, and the Powerhouse in the central part of the river, is hydraulically well suited, and takes into account the morphological and geological site conditions. This arrangement allows the construction of the project within one single construction stage, and thus minimising the overall construction time. The river will remain in its original river bed during the construction.

f) The optimisation of the plant resulted in a design discharge of 5,355 m^3/s and a maximum output of the main units of 1,400 MW. A total of seven (7) vertical Kaplan units with a unit discharge of 765 m^3/s and output of 200 MW have been selected.

g) An auxiliary powerhouse is foreseen using the potential of the water used for the attraction flow system for the fish migration facilities (upstream and downstream migration). The capacity of these auxiliary units is in total 60 MW, provided by three vertical Kaplan units with a unit capacity of 20 MW and a design discharge of 60 m^3/s each.

h) The total installed capacity of the plant is 1,460 MW; taking into account own consumption and transmission line losses, the maximum power output of the LP HPP at the Thai border will not exceed 1,400 MW.

i) The average annual energy output from the main units and the auxiliary units is 6,424 GWh for export to EGAT and 6,231 GWh for export to Vietnam (net of transmission line losses, availability and own consumption).

j) The operation of this run-of-hydropower plant will not alter the flow regime in the Mekong River, as the inflow equals the outflow, no hydro peaking is foreseen.

k) The conditions for the navigation will be improved. On the one side a Navigation Lock for 2 x 500 DWT vessels will be provided, and increase of the water level in the reservoir allows for a safer and more economic navigation.

l) The possibility for the passage of fishes in both direction, upstream and downstream, is taken into account by providing state-of-the-art fish migration facilities. The foreseen fish migration facilities are fully compliant with the MRC design guidance.

m) The project would cause direct social impact upon the 26 villages with only 840 families to be relocated. The compensation and resettlement have been carefully planned and appropriately designed through participatory approach and consultation with all affected people and all concerned authorities.

5.2 Recommendations

Based on the findings of the feasibility study the following key recommendations are given:

a) Additional geological investigations are required in the upcoming project phase in order to formulate the Geological Baseline Report and to reduce the geological risks. Beside the foundation conditions for the main structures, the identified quarry sites should be further investigated.

b) In order to determine the deviation from the EGM2008 geoid a high precision levelling is recommended prior to commencement of construction works.

c) During a later project phase the possibility to split the spillway into two parts and construct the second part in a “second” stage at the left bank should be studied. The advantage would be in reduced excavation works, and reduced production rates for concrete works. This options could be proposed as an option for potential EPC Contractors.

It is recommended to export the generated electricity to Thailand (EGAT) due to much lower transmission line and intermediate substation costs, and two existing 500 kV substations in Thailand have been identified, namely Nan substation and Tha Li substation. Clarification with EGAT on the connection point is required for the design of the 500 kV transmission line.

6 ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT (ESIA)

6.1 ESIA Study Area

The study area for ESIA of Luang Prabang Hydroelectric Power Project (Luang Prabang HPP), in terms of location, covers the following main areas.

- Construction site boundary
- Reservoir impoundment area
- Immediate reservoir catchment
- Upper catchment area
- River downstream of Luang Prabang HPP
- Other areas (access roads, quarries, etc.)

6.2 Investigated Components of the ESIA

The ESIA has to analyse potential project impacts on all components of the natural and the human environment, by describing the present situation, identifying and characterising the impacts and identifying the required mitigation measures. This list of investigated components is provided in the following sections, where to each of the components the following information is provided in a summarised way:

- Present situation
- Impacts
- Mitigation

Physical components:

Climate

Present situation

The climate in the study area is dominated by two distinct monsoons, the southwest monsoon and the northeast monsoon. The southwest monsoon brings heavy rains to the study area with almost 75% of the annual rainfall. Intense rainfall occurs from June to September. Monthly rainfall ranges from 13.0-226.5 mm. The mean annual rainfall is about 1,248.2 mm. The northeast monsoon provides cool and dry air to the study area from November to April. The minimum daily temperature ranges from 14.2-24.0^{o}C, the lowest temperature being recorded in January, while the maximum daily temperature ranges from 26.5-34.6^{o}C, the highest temperature being recorded in April.

Impacts

There will be no impact on climate due to project activities during pre-construction and construction phases. The reservoir will have a somewhat larger open water surface than the river at present. However, the difference is too small as to have any effect on the local micro-climate.

Mitigation

No mitigation required.

Topography

Present situation

The topography of the study area is characterised by low to medium mountain ranges along the Mekong river valley. The hills have absolute heights between 270-1,053 m asl. The Mekong River in the project area flows in a rather narrow valley without any floodplains, flanked by rather steep hill slopes, primarily in a W-E direction and turns into NE-SW direction downstream of the dam.

Impacts

The project will have a marked impact on the topography and the visual aspect of the landscape in a very limited area, namely, dam and surrounding construction site as well as areas used for quarry, borrow and disposal areas. It will not have any further impact on topography during the operation phase.

Mitigation

Temporarily used areas (e.g. quarries, borrow and spoil disposal areas) will have to be rehabilitated at the end of the construction phase.

Geology and Seismology

Present situation

The geology of the dam site and its surroundings is described in the Feasibility Study. The geological situation is of high relevance for engineering aspects, as e.g., choice of dam type, dam foundations, dam safety etc. However, the project itself does not change the geology of the site.

The dam site is not located in a seismically active zone. However, there is a potentially active fault zone at a distance of about 10 km from the dam.

No important mineral resources are recorded from the project area.

Impacts

No project impact. The geology of the site will not be changed by the project. However, as expressed above, the morphology of sites used for construction purposes will change considerably, and this change will be of long duration.

Mitigation

Geology: No mitigation required.

Geomorphology: Main mitigation measure will be the renaturation of the quarry and all other sites used temporarily.

Seismicity: An elaboration of a seismic hazard study will be required. All parts of the project will be designed and built according to seismic design criteria.

Mineral resources: No measures required.

Soils

Present situation

Where the river banks are not formed by rock, there are rather narrow bands of alluvial soils of different types, made up by loam, clay, sand or gravel.

Impacts

During the construction period, soils on sites used for construction related purposes will be bared and thus exposed to erosion. This will lead to a higher input of suspended solids in the river. In addition, there will be an increased risk of soil contamination, e.g. with fuel and lubricants, during this period.

Soils located below the FSL elevation of the reservoir, i.e. 312 m asl, will be lost due to submersion. Some of these soils are presently used as river bank gardens during the dry season, most of them are temporarily inundated presently during seasonal high flows.

Mitigation

Monitoring and mitigation measures to be taken are shown below:

- Borrow pit material extraction shall be undertaken in sections with rehabilitation undertaken in stages to minimize erosion. Rehabilitation shall include the following:
  - Slopes designed to minimize erosion
  - Replacing stockpiled topsoil cover
  - Replanting grass, shrubs, and trees
  - Installing sediment runoff control structures
  - Providing ongoing erosion monitoring
- Impacts on temporarily acquired land shall be minimized by comprehensive rehabilitation work.
- Soil erosion and siltation shall be minimized by preventive measures implemented on a case-by-case basis, such as planting shrubs and grass and appropriately engineered storm-water diversions.
- Construction of the access road could result in increased soil erosion, which shall be minimized by appropriate road engineering, including appropriate road compaction, paving and stormwater runoff design.
- Soil contamination will be prevented by installing oil separators at wash-down and refuelling areas, and installing secondary containment at fuel storage sites.
- Hazardous Material and Waste Management Plans shall be prepared.

Where fertile and presently used soils will be submerged by the reservoir, compensation will be required (see under Land Use).

Natural Hazards

Present situation

Mekong floods are frequent, and they become more of a concern with increasing population density along the river. In the project area, flooding mostly affects Pak Ou district, located just downstream of LP HPP dam site.

According to the landslide hazard susceptibility map in the national risk profile of Lao PDR, 2010, the project site and project study area are located within the "low to medium hazard zone".

Impacts

The project does not cause any increase of natural hazards.

There is no impact on floods. As a run-of-river plant LP HPP cannot provide any flood control or mitigation. Only very minor actions can be undertaken such as opening the spillway, but cut of the flood peak is not possible since this is no storage power plant. The HPP is designed to respond to the PMF without any damage.

The project will increase the surface- and groundwater table in the reservoir. However, there is no danger that this will cause any landslide in this area.

As mentioned above, the danger of seismic activities will not be increased by the project.

Mitigation

No mitigation required.

Sedimentation

Present situation

A detailed sediment transport analysis is presented in the feasibility study (Pöyry, 2019). One main finding of this analysis is the fact that sediment load at the LP dam site was is reduced to a very considerable extent by the sediment retention in the Lancang Cascade. For this reason, total sediment loads (washload, suspended and bedload) of about 110 Mt/y pre-Lancang Cascade and 20 to 24 Mt/y post-Lancang Cascade are considered for the Luang Prabang HPP site. The latter mainly occurs as suspended fraction.

Impacts

The construction of the HPP including the required cofferdams will narrow the river in this section, causing higher flow velocities, increasing the site specific sediment transport capacity. The construction of the cofferdams and other construction activities will inevitably lead to a temporary increase of the sediment load.

During the operation period, the impact on sediment transport will be high, regional (transboundary) and of long duration. The reservoir will be an area where more sediments will be retained for some time, until sediment accumulation narrows the flown area to the extent that the flow velocity increases again, what will then be the new equilibrium.

Mitigation

Solids that remain suspended in the reservoir will go through the turbines. The operation of the low level outlets will ensure the sediment flow through the HPP. They will be operated in a way that they are first to be opened and last to be closed for flows higher than the turbine flow, which will happen during most of the wet season. Nevertheless and even with the low level outlets a change in sediment flow and transport cannot be prevented. Significant impacts are expected to be of high intensity, regional to transboundary extent and medium duration. They will decrease over time and long range impacts will occur for the same extent, but of low intensity.

Surface Water Hydrology

Present situation

The mean annual inflow at Luang Prabang HPP site which was calculated from the discharge time series 1960-2008 is 3,293 m³/s. It varies between approximately 1,200 m³/s in March and 8,000 m³/s in August.

The flow at LP HPP is influenced by the regulation capacity of the large storage reservoirs in the Lancang Cascade, as can be seen in the following Figure.

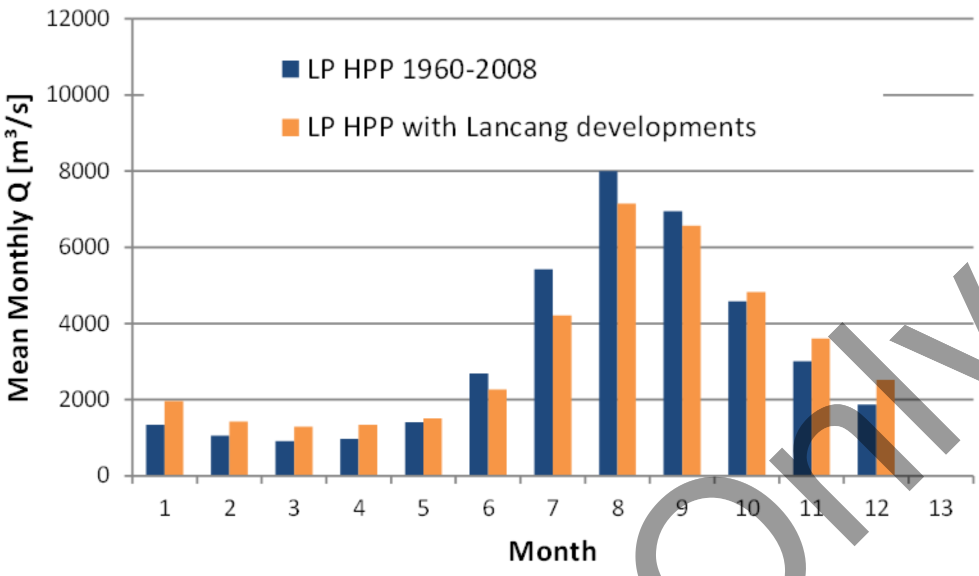

Figure 6-1: Mean monthly discharge

The Figure indicates a shift from the high flow to the low flow season (which is usually the purpose of seasonal storage). It is expected that this effect will be increased to some extent due to climate change, as the relevant studies predict an increase of runoff in all catchments upstream of Chiang Saen, and this predominantly in the low flow season.

Impacts

During the construction phase, the construction site claims around 75% of the river width at the dam site, starting from the right bank. The river will be diverted, flowing through the remaining narrow section at the left bank. This will cause lower flow velocities immediately upstream and higher flow velocities at the construction site.

The dam will elevate the water table upstream for all the backwater affected area (approx. 156 km upstream). Within this area, gradients change, lowering the flow velocity, downstream there will be no effect, since LP HPP as a ROR scheme does not retain water and therefore does not influence river discharge conditions downstream of the dam.

Mitigation

No mitigation required.

Surface water quality

Present situation

Water quality data for the Mekong are available from 17 monitoring stations operated by MRC between the Chinese border and the Mekong delta in Viet Nam.

The 2016 results of the 3 most relevant monitoring stations, two of them (Houa Khong and Chiang Saen) located upstream and one (Luang Prabang) downstream of the dam site showed that the overall water quality in the Mekong River for the protection of aquatic life and for the protection of human health are of good quality with three stations rated as either “good” or “excellent”.

This was confirmed by results obtained from water quality samples taken in the study area (2 upstream and 2 downstream of the dam site and one in Nam Ou), which revealed good water quality in all these stations.

Impacts

During the construction phase there is a risk of water quality being affected mainly by the following causes:

- Rise in the content of TSS (total suspended solids) due to increased erosion as a result of site clearance and earthwork activities, including quarry, borrow and dumping areas, construction of cofferdam structure in Mekong River etc. The construction activities will cause significant impacts. Therefore, mitigation measures must be strictly implemented during the construction period.
- Increase in BOD (biological oxygen demand) concentration due to additional organic matter in sewage water from the construction camps. Treated wastewater with remaining BOD will be discharged from on-site wastewater treatment facility or a settling pond.
- Change in pH, basically due to contamination with concrete.
- Contamination with oil, either from operation and maintenance of truck and construction machines, or from accidents involving the spilling of hydrocarbon fuel and other similar products.

Mitigation

The contractor will be the most important entity responsible for reducing these risks during the construction period. The main tools for achieving this will the preparation, implementation and continuous monitoring of all relevant site-specific plans, the most important of which are the following:

- Solid waste management plan, including hazardous waste management.
- Waste water treatment and management plan.
- Hazardous substances management plan.
- Camp installation and management plan.
- Emergency preparedness and response plan.

This list is not exhaustive. The plans will have to be prepared by the contractor and accepted by the project proponent before the start of construction works.

The risk will be much reduced during operation, mainly since there will no longer be a large construction site with a large work force. Still, all relevant measures as e.g. waste management and waste water treatment will have to be taken.

Groundwater

Present situation

The groundwater tables along the river are rather small and restricted to the narrow band of river alluvions at the foot of the hills along the river banks.

Impacts

There is a risk of groundwater contamination during the construction period.

The groundwater table will increase upstream of the dam due to the reservoir impoundment. No additional impact is expected due to the elevated water tables.

Mitigation

The contamination risk during construction will have to be minimised by applying the measures listed above for soils and water protection.

Ambient air quality

Present situation

No major sources of air pollution can be found near the project site, and air quality was expected to be good. This was confirmed be a 3 days measuring campaign in the project area, where total suspended particles (TSP) and PM10 were measured; all the values were well below the relevant standards.

Impacts

The impact during the construction phase is medium, local and of short to medium duration.

Dust creation, decrease of air quality due to air pollutants from heavy machines and vehicles impacting construction workers, villages in the vicinity of project site and along truck hauling route.

Operation of the hydropower plant will not cause any impact on air quality.

Mitigation

The village located within the construction site (Ban Houaygno) will have to be relocated prior to the preparatory activities and there are only a few villages along the truck hauling route, thus, this impact can be considered as low, site specific and of medium duration. Vehicles and machines will have to be maintained in good working order for minimising emissions of air pollutants.

No further mitigation will be required during the operation phase.

Ambient noise

Present situation

The situation is basically the same as for air quality. However, during the 3-days measurements in temple compounds of Pay Ou and Mouangkeo (same sites as for air quality), some Leq-1 hr were recorded which are above the standards for residential areas; it can be assumed, however, that these were caused by activities related to the temples themselves. Lmax as well as Leq-24 hrs were below the threshold for residential areas.

Impacts

Noise will be an issue during the construction phase. There will be mainly two categories of noise, namely:

- Noise caused by vehicles carrying out transport to and from the site.
- Noise caused by vehicles, machines and construction related activities on site. This will include, e.g., noise from crushing plants and from blasting activities.

There will be no further impact during the operation phase.

Mitigation

Lorries and trucks will have to be well maintained in order to limit noise emissions along the access roads.

The same is true for traffic within the site. Where noise levels are high (e.g. crushing plants), workers exposed to it will have to use protective equipment. Noise in such places will have to be monitored in order to be kept within accepted standards.

Biological components:

Wetlands

Present situation

Due to the topography of the project area, with rather steep river banks all along the entire stretch of the river to be considered here, there are no wetlands of any importance within the area which is going to be submerged by the reservoir.

Impacts

No impacts.

Mitigation

No mitigation required.

Terrestrial Ecology

Present situation

Shifting cultivation and the clearing of forest for agricultural uses have removed as good as all of the original forest in the reservoir area; large areas of bamboo and other secondary vegetation are now present, at most some small patches of natural vegetation are left. Land which is not too steep is generally used for agriculture, some land is planted with teak trees.

Some more or less disturbed patches of mixed deciduous and riparian forest are present within the land earmarked as dam and construction site. Such patches of different forest types (dry dipterocarp, mixed deciduous and dry evergreen forest) can also be found in the areas chosen for quarry, soil borrow area, or resettlement site, but in all of them agricultural land, fallow and teak plantation make up the largest part.

The survey carried out revealed the presence of 98 fauna species comprising 16 mammals, 43 birds, 25 reptiles and 14 amphibians in the project area. A few of these are listed in the IUCN 2019 Red List, 2 as Vulnerable namely, the Asiatic softshell turtle (Amyda cartilaginea) and the king cobra (Ophiophagus hannah), and one as Near Threatened, namely the river lapwing (Vanellus duvaucelii).

Impacts

Some land will be occupied during construction, and vegetation will be cleared from this land. In addition, a strip of land will be submerged at reservoir filling. In both cases, this will mean a loss of habitat for animal species living there. However, the overall extent of these areas will be small, and no protected or high value habitats will be lost.

The afflux of workers to the site will increase the risk of illegal hunting in the surroundings of the construction site.

No additional impact will be cause during operation phase.

Mitigation

The following measures will have to be taken:

- Hunting, buying or trading of wildlife shall be prohibited.
- A biomass clearance plan has to be established and salvage logging and vegetation clearing has to be done in a way that animals have ways to escape the areas (e.g. by working block by block from the river going upwards).

- Vegetation clearance is suggested to be accomplished before nesting season of birds.
- Field investigation and a biodiversity offset plan should be done to evaluate and qualify the loss of biodiversity and check possible compensation approaches.

National Biodiversity Conservation Areas

Present situation

No NBCA is in the proximity of the project, hence there will be no project impacts on such areas.

Impacts

No impact.

Mitigation

No mitigation required.

Aquatic Ecology and Fishery

Present situation

The abundance of fish species in the Mekong river basin is the second highest in the world with 781 fish species compared to 1,257 species existing in the Amazon River. The ESIA studies carried out for HPPs (studies for Xayaburi, Pak Beng, and Luang Prabang HPPs) revealed the presence of 160 fish species in the part of the river where the LP HPP is located.

Mekong fish species are grouped into three categories where their migrating behaviour is concerned, namely:

- White fish: species carrying out long distance migrations along the Mekong.
- Grey fish: species carrying out short range migrations, mainly between a river and adjacent floodplains.
- Black fish: non-migratory, mostly living in lakes and swamps within floodplains, carrying out short seasonal movements into temporarily flooded areas during the wet season.

In the framework of impact assessment for a dam project, the white fish are of main relevance, since their migration routes are at the risk of being interrupted by such a project. Luang Prabang HPP is located in the part of the river that is characterised as the upper Mekong fish migration system, which stretches from approximately the mouth of Loei River upstream to the border between Lao PDR and China. This upper migration system appears to be relatively isolated, with little exchange to the migration systems located further downstream. According to MRC fishes mainly migrate into areas further upstream of Pak Beng for spawning.

Impacts

With the possible cascade of run-of-river plants comprising of Pak Beng, Luang Prabang, Xayaburi, Sanakham and Pak Lay a major part of the area identified as upper Mekong migration system will have a change in its hydraulic conditions. The cascade will provide more deep water areas, but the rapids will be lost. The migration route of white fish species in this area will be interrupted by these dams. This hindrance to fish migration will be the main impact of the project on the fish fauna of the project area.

Another potential impact will be the change in river dynamics and diversity in the future reservoir, as compared to the present situation. Annual fluctuations presently temporarily expose rocks, rapids, sand bars etc., all of which can be important habitat components e.g. for spawning. This situation will be changed into a more uniform one, with deeper and slower flowing water. This can have an effect on the composition of the future fish population in this part of the river, with fish requiring rapid flowing and oxygen rich water getting scarcer and species better adapted to reservoir conditions getting more abundant.

Mitigation

- State of the art fish up- and downstream migration facilities have to be installed in each of the hydropower plants in the cascade.
- Stretches with alternating rapids and deep pools upstream of Pak Beng should be protected to ensure future existence of spawning areas.
- The establishment of artificial spawning areas between the hydropower plants should be investigated.
- The annual flood pattern that triggers fish migrations and causes inundation of flood-plains has to be ensured.

The most important of these measures is to provide fish migration facilities, and this is already integrated into the project. The general arrangement of these facilities is shown in the following Figure.

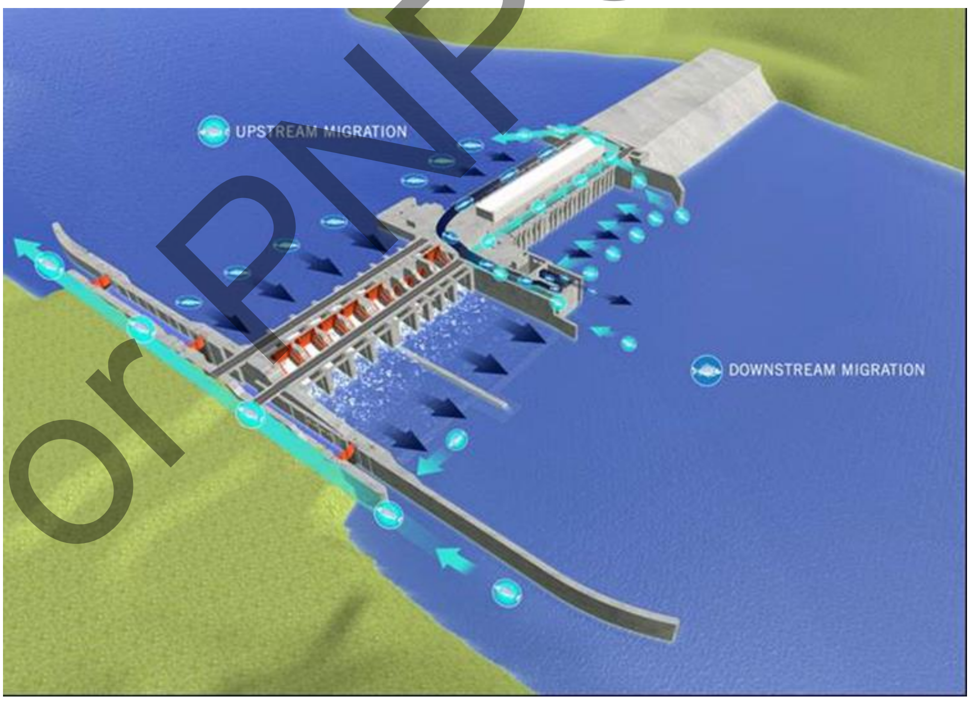

Figure 6-2: Scematic overview of the fish migration facilities

Fish migration will be handled in the following way:

- Upstream migration:

  - Fish locks at power house/left bank: fish will be attracted by the powerhouse discharge and will enter into the upstream fish passing facilities developed over the entire length of the powerhouse, with entrances at the right pier (towards the spillway), multiple entrances along the downstream face of the powerhouse, and at the left pier. The fish in the collection galleries are guided by attraction currents to two fish locks, where the fish are lifted up into the headwater of the reservoir.
  - Right bank: For fishes migrating along the right river bank, a possibility for upstream migration will provided near the navigation lock. This will comprise the following structures: a Fish Lock downstream of the stilling basin next to the navigation lock; a culvert crossing the downstream approach channel, providing sufficient clearance for the moving ships and vessels at the downstream approach channel; and an open channel at the left bank leading to the upstream approach channel. The fish entering the fish lock will be lifted up to the headwater level, and will be released into the upstream culvert and channel leading to the upstream approach channel of the navigation lock.

- Downstream migration:
  - Power house: collecting gallery above the powerhouse intakes and a downstream stepped chute (exit chute) to the tailrace channel.
  - Fish-friendly turbines to minimise lethal injuries during turbine passage for smaller fish that will pass through the trash rack of the powerhouse intakes.
  - Migration through the spillway when this is opened for spillage flows.

6.3 Socio-economic Components

Affected Villages

Present situation

26 villages that located along both banks of the Mekong River from immediately downstream of Luang Prabang HPP dam site up to the end of reservoir area will be affected by the project. They are located within Chompet District and Pak Ou District of Luang Prabang Province, Hongsa District of Xayaburi Province and Nga District of Oudomxay Province.

Impacts

These 26 villages can be spilt into four groups depending on the type and degree of impact they will experience, namely:

- Group 1: 6 villages which will be fully submerged (5) or totally affected by land acquisition for construction (1) and which therefore will have to be completely relocated. The affected population consist of 2,885 persons in 581 HH.

- Group 2: 9 villages which will be partially submerged, and where only the affected households will have to be relocated; in most cases, it will be possible to do this by removing the affected houses and moving them to higher grounds within the village area. The affected population consist of 3,855 persons in 692 HH, of which 259 HH will have to be relocated.

- Group 3: 8 villages which will lose only farmland; compensation will have to be made for this, but no relocation is required. The affected population consist of 2,330 persons in 671 HH.

- Group 4: 3 villages located downstream of the dam, which will not lose any assets, but which will suffer from environmental impacts (dust, noise, etc.) during the construction period. The affected population consist of 904 persons in 189 HH.

Location of these villages is shown in the following Figure.

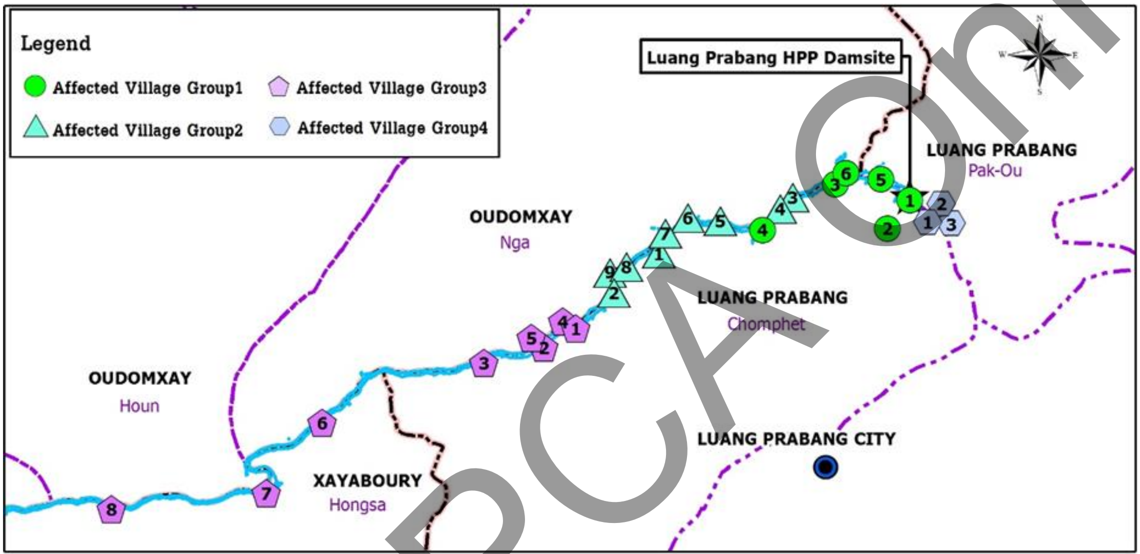

Figure 6-4: Location of affected villages in the project area

Mitigation

The mitigation measures for impacts on the socio-economic situation will be full compensation for the loss of land, river bank gardens, privately owned assets (including houses for PAPs who have to be relocated) and crops, besides support for livelihood restoration. The measures are presented in the Livelihood Restoration Plan of REMDP (Resettlement and Ethnic Minority Development Plan) report.

The community properties and cultural resources will be fully provided in the resettlement site to meet standard level of services.

The following measures shall be implemented to ensure benefits of the project implementation are properly shared with the local population.

- Priority should be given to hiring local people for the project construction works.

- The recruitment process should be fair and transparent and wage rates will need to be commensurate with experiences and qualifications.

- Employment terms and conditions will need to comply with the requirements in the National Labour Act 2013, the social security law and standard wage rates, and other applicable laws and regulations.

- Skill training should be provided to local people to upscale their employment potential and increase their chance to be employed in the project construction works.

The measures outlined here also summarise most of the mitigation measures to be provided for the socio-economic aspects described in the following paragraphs.

Vulnerable Groups

Present situation

The survey carried out in the affected villages indicated that as many as 31% of the households have to be considered as vulnerable. These are HH with disabled persons, elderly persons without support, and female headed HH.

Impacts

More detailed assessments will be required for accurately determining the degree of vulnerability of these HH, and the project impact on them.

Mitigation

A special Vulnerable Groups Plan will have to be established.

Ethnic Groups

Present situation

In the study area, Lao Loum is the major ethnic group followed by Khmu and Hmong. Some villages are mixed between Lao and Khmu and in some villages all the three ethnic groups are represented.

Impacts

There will be no difference in project effect on PAPs from different ethnic groups. However, ethnic minorities will require some specific measures.

Mitigation

Mitigation measures are required to respond to the needs of different ethnic groups, preserve their cultural identity, special measures, if any, required to be provided for each minority groups, avoiding any possible conflict or dominance of a bigger group on a smaller minority ethnic group. Specific measures are described in the REMDP.

Economic Condition

Present situation

The main occupation of most people in the affected villages is agriculture, particularly rice growing as a single annual crop in the rainy season. In addition, rice farmers also engage in fishing in the Mekong River and its tributaries, mainly for food and supplementary income. For some people fishing and animal husbandry is the main occupation. However, over 50% of the population is also engaged to some degree in hired labour, some working outside of the village area as manual labour or other types of employment. Boat traffic on the Mekong, either for tourism or transport of merchandise, is an important source of income, and so is catering for tourists in some villages.

The average yearly HH income in the affected villages ranges from USD 4,100 (LAK 36.4 million) to USD 5,371 (LAK 46.7 million).

Impacts

The project will create some additional income generating opportunities (mainly labour on the construction site), especially for inhabitants of villages close to the construction site. On the other hand, loss of land will negatively affect income and livelihood of many HHs, and any hindrance of boat traffic on the river, albeit only temporary, will have a negative effect on HH income.

Mitigation

If the livelihood of PAPs is affected in any way, these will have to be included in the Livelihood Restoration Program.

Land Use and Land Ownership

Present situation

Average land holding of the households in the affected villages is 3.29 ha/HH, made up by 4.09 plots.

Land use is done mainly in the following forms:

- Paddy fields: rice growing in seasonally flooded fields. Since there is very little flat land available in the project area, this form of cultivation is of limited importance.
- Upland rice cultivation: slash-and-burn cultivation on suitable slopes; the first crop grown on such fields is usually rice. In the following 2-3 years, other crops are grown, until the soils are too exhausted and have to be left fallow for a number of years for regaining fertility.
- River bank gardening: suitable river banks are used during the dry season, when the water in the Mekong is low, for producing a variety of cash or subsistence crops.
- Tree plantations: the main commercial timber tree planted extensively in the area is teak. Larger and smaller such plantations can be found throughout the entire project area.
- Livestock raising: buffalos, cattle, goats, pigs and chicken are the most important livestock species; animal husbandry is a major activity of farmers in the affected villages.
- Collection of NTFP: important activity of inhabitants of the project area, who get different products (food and non-food) from the forests surrounding the villages.

Impacts

At reservoir impoundment, a strip of land along the Mekong on both river banks will be submerged. This will be rather important just upstream of the dam, where some villages will be submerged completely, and it will be marginal towards the upper end of the reservoir, where the difference between present river level and future reservoir level is very small.

River banks – and with it land that is being or can be used for river bank gardening – will be the most affected type of land. However, in the lower part of the reservoir, closer to the dam, other types, namely also teak plantations, will be affected.

Mitigation

A detailed Inventory of Loss will have to be prepared, for identifying all losses for all affected households. Compensation will have to be made for all lost assets. In the case of HH who lose all or most of their land, and for whom land for land compensation will not be feasible, alternative livelihood options will have to be prepared.

Navigation

Present situation

The Mekong is used extensively for navigation. Three main types are of importance:

- Local traffic by small boats, for short-range journeys, fishing etc.
- Tourist boats of different sizes, doing mostly the stretch Luang Prabang – Pak Beng – Houay Xay; shorter or longer distance cruises are possible.
- Cargo ships of up to 500 tonnes, transporting different types of goods.

Navigation is an important component of the local and regional economy, not in the least for tourism.

Impacts

During most of the construction period, navigation will still be possible, since the Mekong will flow through the construction site in an part of the natural river bed along the left bank; however, flow speed may be higher than under natural conditions. When this part of the river will be closed for finalising the dam, and until the ship lock will be functional, there will be a temporary interruption of boat traffic across the dam site.

Mitigation

During construction, measures will have to be taken to make sure that flow speed is not too high.

Once the dam finalised and in operation, the ship lock will also be operational and boat traffic (including for cargo ships of up to 500 DWT) through it will be possible.

UXO

Present situation

The dam site is located within or at the limit of an area which experienced heavy bombing, and there is a risk, although much lower, of UXO to be found along the length of the reservoir.

Impacts

Risk of accidents due to UXO especially on the construction site.

Mitigation

The project developer shall secure a budget for UXO examination and clearance before any construction works begin.

Cultural Components

Present situation

The following sites or objects of cultural and historical interest are located within of close to the project area:

- Luan Prabang: the town is an UNESCO World Heritage object since 1995, mainly for is unique integration of traditional, mostly religious, buildings with colonial style buildings and the remarkable preservation of the ensemble.
- Pak Ou caves, located about 20 km upstream of Luang Prabang and 5 km downstream of the dam site on the right Mekong bank, which is an important site culturally as well as for tourism, due to its large collection of mostly small Buddha statues.
- An old stupa located in Ban Khokpho.
- Temples in some of the villages affected by the project.

Impacts

The impacts due to LP HPP will be the following:

- Luang Prabang: no project impact.
- Pak Ou caves: the dam site is located upstream from and out of view of this site; there will be no direct project related impact.
- Stupa
- Village temples

Mitigation

Affected temples will have to be relocated, taking into account requirements of the competent authority and the immediately affected population.

Visual Components

Present situation

The landscape on either side of the river is characterised by hills and mountains with often rather steep slopes, however, with few if any visible rock outcrops. All is covered by dense vegetation; however, no really primary forest or otherwise natural vegetation is left in the area.

The lower parts of the river banks, i.e. the strip of land between low and high-water level, is largely bare of vegetation or very sparsely vegetated, in contrast to the very dense vegetation above it. This makes the river banks clearly visible throughout the area of the future reservoir during the dry season. With the exception of a few fences, there are no man-made structures in this strip of land. Depending on the morphology of the river, the banks are either rocky, or they are made up by often thick layers of silt and sand.

Impacts

Impact is very low. The overall aspects of the landscape in the project area will not change. However, the aspect of the river as such and its immediate banks will change; the river banks will no longer be exposed during the dry season, and submersion of rocks and rapids, together with a generally reduced flow velocity, will lead to a more uniform aspect of the river, more resembling a lake.

Mitigation

No mitigation required.

Risk Assessment

The environmental and social risks assessment is a function of probability or likelihood of occurrence of an event and the level of consequence (impact) of its occurrence. The scale reaches from very low probability to almost certainty for likelihood of occurrence and insignificant to catastrophic consequences for the impact.

Environmental and Social Management and Monitoring Plan

The Social Management and Monitoring Plan (SMMP) is the commitment from Luang Prabang HPP Developer to undertake all necessary measures to mitigate all social impacts resulting from project implementation in all affected locations and groups of PAPs.

The objective of the SMMP is to document all mitigation measures, management plans and monitoring plans in a systematic and implementable manner. The SMMP will require frequent revisions and updates during the course of project implementation. It is prepared in compliance with MONRE's 2012 guidelines which state that "The SMMP is an essential tool for ensuring that mitigation of the negative impacts and enhancement of the positive impacts is carried out effectively throughout the life of the project".

Preparation of SMMP begins with identification of impacts on social components of each project phase. Mitigation measures for impact of each social component are then proposed. Location to implement the plan, implementing agency and monitoring agency are proposed for each plan. For the monitoring plan, monitoring parameters, method and frequency are additionally proposed. A detailed SMMP is presented as a separate report.

Public Consultation and Disclosure

Public consultation activities undertaken for ESIA preparation were meetings with concerned authorities and people in affected villages during January-March 2019, and meeting with officials of the concerned agencies, provincial and district offices.

In each meeting, the Consultant first briefed the participants on the project background, objective, scope, components and current status of development. The Consultant also pointed out potential environmental and social impact issues, and informed the participants of the Consultant's site visits/surveys for environmental and social survey in February to April 2019. Opinion of Stakeholders and information obtained from those activities can be summarized as follows:

• Villagers asked about the extent of backwater from Luang Prabang HPP. The exact increase of water level and coverage has been a serious concern because it determines the magnitude of impact on people

• Villagers asked about pertinent information of Luang Prabang HPP (location of dam site, type of dam, navigation lock, fish passage, increase of level of water upstream from the dam, potential impacts from project development).

6.4 Environmental Management and Monitoring Plan (EMMP)

The EMMP describes

- Relevant policies, legal and institutional framework.
- Organisation, roles and responsibilities for environmental management and monitoring.
- Stakeholders (mainly authorities involved in the process)
- Environmental management and monitoring obligations during construction and operation.

The main part of the EMMP is the list and short outline of the relevant Environmental Management and Monitoring Sub-Plans that will have to be prepared in detail. This list is provided in the following Table:

Table 6-1: List of Environmental and Social Sub-Plans

Sub-Plan No.	Title
01	Erosion and Sediment Control
02	Water Availability and Pollution Control
03	Wastewater and Runoff Management
04	Solid Waste Management
05	Landfills and Spoil Disposal Management Plan
06	Hazardous Substances Management
07	Fuel and Hazardous Material Storage and Station Management
08	Mechanical and Electrical Equipment Depots Management
09	Air pollution and Dust Control
10	Noise and Vibration
11	Unexploded Ordnance (UXO) Survey and Disposal
12	Vegetation Clearing
13	Landscaping and Re-vegetation
14	Biodiversity, Wildlife, and Aquatic Life Management
15	Processing Plant, Quarry, and Borrow Pit Management Plan
16	Transport, traffic, and road/river/reservoir safety
17	Training and Awareness
18	Dam Site and Camps Management Plan
19	Labour and Personnel Management
20	Emergency Management and Planning
21	Capacity Building Plans and Programs
22	Community Relations
23	Health and Safety
24	Transmission Line Corridor Management Plan

6.5 Social Management and Monitoring Plan (SMMP)

The SMMP provides the following information:

- Overview of SMMP related of policy, legal and institutional framework.
- SMMP organization, roles and responsibilities, describing the roles of the various actors involved in the process of resettlement, compensation and monitoring.
- Social management and monitoring plan during the construction phase, emphasising the main steps of the process like the development of a Compensation, Resettlement and Livelihood Restoration Program and the related monitoring programs.
- Social management and monitoring plan during the operation phase; the most important activity during this phase will be the implementation and monitoring of the Livelihood Restoration Program.
- Management procedures; one of the central procedures during the entire period of project development, from the start till the confirmation of a satisfactory outcome, is the Grievance Redress Procedure.
- Auditing / compliance assessment; outlines the process for carrying out the compliance audit of the entire resettlement and compensation procedure.

6.6 Resettlement and Ethnic Minority Development Plan (REMDP)

The development of the Luang Prabang Hydropower Project will affect a number of villages located along the Mekong riverbank. 26 communities are directly affected by the project, out of which 6 communities needing full relocation, 9 communities needing partial relocation, and 8 communities needing no relocation but compensation for lost assets, mainly land. This means that a total of about 840 households from 15 villages will have to be relocated. The affected population consist of three ethnic groups, with Lao Loum being the most numerous, and smaller numbers of Hmong and Khmu. Therefore, a Resettlement and Ethnic Minority Development Plan (REMDP) is required as a basis for fully assisting those affected people by incorporating all resettlement and rehabilitation measures necessary to ensure compensation for the lost assets and restoration or enhancement of livelihood for all Project Affected Persons in line with all concerned ethnics interests.

Formulation of this Resettlement and Ethnic Minority Development Plan of Luang Prabang Hydro Power Project is in compliance with the provision of the National Policy on Resettlement and Compensation, Decree on the Compensation and Resettlement of the Development Projects, Environmental Management Standard for Electricity Projects and Technical Guidelines on Compensation and Resettlement in Development Projects following three basic principles:

(1) To mitigate all possible adverse social impacts among PAPs of all ethnic groups.

(2) To the extent possible, restore their livelihood at the new resettlement communities, and

(3) To enhance the quality of life for all PAPs after settling at the new resettlement communities.

REMDP presents the following main topics:

- Overview of policy, legal and institutional framework.
- Stakeholder involvement process.
- Proposed resettlement and ethnic development plan. This includes a discussion of entitlement of the different groups of PAPs, a short description of the envisaged resettlement sites, and it outlines the detailed property survey done and still to be done, the livelihood restoration program, and the specific measures to be taken for the ethnic minorities.
- Organizational structure and management arrangement to be put in place for detailed planning and implementation of the resettlement plan and related activities.
- Implementation schedule and budget. The resettlement of the 2 villages situated in the construction area will be carried out during the pre-construction phase, while the partial relocation of 9 villages and the resettlement of 4 villages will be carried out during the construction of the dam; these activities will have to be finalised one year before reservoir impoundment. The budget estimation for integrated REMDP implementation is primarily based on the number of PAPs, number of resettlement villages to be developed and social development programs to be implemented. These components are to be finalised during the detailed public consultation process that shall be conducted in the next phase of project implementation.

7 CUMULATIVE IMPACTS ASSESSMENT

As there are several HPPs upstream and downstream of LP HPP, which are currently either in operation, under construction or being planned, the cumulative and transboundary impacts of this cascade have to be identified and valued, and the incremental part of these cumulative impacts attributed to LP HPP have to be pointed out.

Impacts which can occur to be cumulative and/or transboundary are as follows:

- Hydrological and hydraulic impacts such as change in flow pattern, flow velocity, backwater effects etc.
- Water quality
- Erosion, sedimentation and sediment transport
- Impacts of the HPP under climate change conditions
- Impacts to fish migration and fishery
- Food and nutrition
- Impacts related to construction
- Social issues

Based on project description and baseline environmental and social condition of LP HPP study area, Valued Ecosystem Components (VECs) for the proposed LP HPP are likely to include mainly the following:

(a) Hydrology
(b) Water Quality
(c) Erosion and Sedimentation Transport
(d) Fish, Aquatic Habitats and Fisheries
(e) Food and Nutrition
(f) Social Impacts

7.1 Hydrological and Hydraulic Impacts

The LP HPP is a run-of-river hydropower plant (ROR). Its inflow is equal to its outflow and no storage is used. However, to increase the potential energy the dam increases the water level of the upstream area, creating a reservoir with a surface area of around 49 km^2, reaching back to the planned Pak Beng HPP. The increase of the water depth increases the surface of the submerged area, leading to decreased velocities. This causes local impacts (reduced sediment transport and slightly different habitat conditions for aquatic life), which are discussed in the ESIA.

The backwater will affect the tailwater level at the Pak Beng HPP. Effects of ROR plants to their upstream and downstream hydrographs are marginal since they do not store water. Only during the start phase a storage takes place while the reservoir is being impounded to reach the FSL (15 to 20 days). Afterwards the operation maintains the water level at FSL with minor changes in elevation of approximately 1 m for minor floods, up to an increase of 2.2 m for the PMF. An impact to the flow pattern of the river only occurs with storage plants as they change the flow pattern of the river.

7.2 Impacts on Water Quality

Since the residence time of the water is rather short (range of approx. 3 to 9 days), the whole water volume will be exchanged due to the permanent operation of the turbine and the frequent operation of the low level outlets. Therefore, no dead zone (zone below minimum operation level in a storage power plant) occurs, and this also excludes the formation of a deep water zone with deteriorating water quality.

A proper cleaning of biomass and waste in the reservoir area before impoundment is mandatory to ensure the water quality can be maintained. Once this is considered there will be no additional significant impact to water quality during normal HPP operation.

7.3 Impacts on Erosion, Sedimentation and Sediment Transport

In the past some sound studies upon sediment transport of Mekong River have been carried out from different organisations and experts. Due to the high trapping efficiency and a very large storage volume of at least some of the Chinese reservoirs within the Lancang Cascade it is reasonable that sediment inputs from upstream the Chinese border are extremely reduced and this situation will last for a very long time (estimations indicate time spans of several hundred years).

In 1993 the first reservoir, Manwan, of the Lancang Cascade came into operation and trends for total sediment load can be split into a phase before and after that significant turning point of the Mekong’s sediment system. In the meanwhile, at least 6 mainstream dams of the cascade are in operation. It is clearly indicated that for the Post-Manwan era a significant and likely to be ongoing reduction of the suspended sediment concentration has been measured.

As a run-of-river plant LP HPP has no storage reservoir and no big head. The velocity near the dam ranges between 0.05 m/s with river flow of 1,000 m^3/s to 0.2 m/s with average river flow (about 4,000 m^3/s) to 0.5 m/s with river flow of 10,000 m^3/s, being generally higher further upstream along the reservoir. The velocities in the reservoir are sufficient to prevent the development of significant turbidity currents. For average turbine operation flow (about 3,000 m^3/s) flow velocities in the main channel area of the LP HPP are between 0.2 and 0.4 m/s.

However, due to the fact that the barrage will increase the water table upstream and reduce the flow velocity some sediment will accumulate in some parts of the reservoir until a new equilibrium is reached. Once the accumulated sediments have decreased the flowed area, the velocity will increase again and more sediments will stay in suspension, being transported downstream eventually.

The results from the sediment modelling (see feasibility study, Poyry 2019), show in general a potential for sediment deposit along the entire reach, with a higher potential for deposition between km 2052 and 2164. Sediment is deposited in the upper part of the reach, thus less sediment deposits are shown further downstream near LP HPP. Results of transported material show for the condition with LP HPP a significant content of fine silt/clay material, while coarse silt is still transported out of the reach, whereas most of fine sand material is deposited.

7.4 Impacts on Fish, Aquatic Habitats and Fishery

With the possible cascade of run-of-river plants comprising of Pak Beng, Luang Prabang, Xayaburi, Pak Lay and Sanakham a major part of the area identified as upper Mekong migration system will have a change in its hydraulic conditions. This will have an effect on fish migration and habitat availability. Given the high biodiversity and the limited information on fish migration in the Mekong River, the full extent of this cannot be assessed in detail. However, if spawning areas are lost this will have a major effect to the fish population. A fish monitoring program will have to be implemented, and mitigative measures will have to be taken if required. The cascade will provide more deep water areas, but the rapids will be lost. According to MRC (MRC Tech. paper No. 8 **Error! eference source not found.**) fishes mainly migrate into areas further upstream of Pak Beng for spawning.

Only little is known about the spawning habitat requirements for most Mekong fishes. Generally spawning habitats are believed to be associated with rapids, pools and floodplains. In its natural stage this area has not many floodplains, but rapids and some deep pools. The loss of deep pools might be compensated by creation of the reservoir which will provide more and larger deep areas.

The flow velocities in the main channel area of the LP HPP are around 0.2 to 0.4 m/s. This ensures drifting of eggs and larves during normal operation conditions.

With the cascade of ROR plants (Pak Beng to Pak Lay) in place, the variety of flow conditions and habitats within that part of the Mekong is mostly lost.

7.5 Impacts on Food and Nutrition

Considering the fact that LP HPP is a mainstream project with affected communities living along the Mekong and huge reliance on rice and fish for their dietary requirement, the project is expected to cause impact on the nutrient intake of the PAPs and possibly downstream communities. The actual impact needs to be further assessed with consideration of the fact that the project plans to develop a fish migration system to mitigate the impact or creating a barrier for fish migration.

An overarching study of recent upstream and downstream projects such as Pak Beng HPP and Xayaburi HPP may shed further light on the cumulative projects induced impacts. The type and quantum of impacts can further clarify appropriate coping and mitigation mechanism or improvements of the existing mitigation measures. Nevertheless, the project developer is expected to be responsible to ensure that food and nutrition requirements of PAP are addressed during the transition period of resettlement and for longer period for the most vulnerable households.

7.6 Social Impacts

Cumulative impacts will be rather short-lived and mostly related to the current ongoing construction works of the Chinese Lao railway project. As an additional disruption in river traffic, the travel and transportation along the Mekong River will be further impeded.

The installation of navigation locks will serve to reduce these impacts. There will be a time loss to pass through the navigation lock but on the other hand, the resulting elevation of the water level and the reduced flow velocities upstream of the dam will simplify passage for boats transporting passengers and goods.

8 TRANSBOUNDARY IMPACTS ASSESSMENT

8.1 Hydrology

A transboundary impact from China to all the Mekong- downstream countries is given by the operation of the storage power plants in the Lancang cascade. The operation causes a flatter but wider hydrograph since peak flows are cut, but low flows increase. As a ROR- plant LP HPP is not affecting the hydrograph and has no further hydrological effect to the downstream countries. Accordingly there is no hydrological impact to the Tonle Sap great lake system from LP HPP.

However a positive transboundary effect to be mentioned here is given from the Lancang cascade to the Pak Beng-, Luang Prabang-, Xayaburi- cascade: Since the Lancang cascade changed the flow pattern more water is released during dry month whereas the spillway peaks are lower. Therefore more energy can be produce in the latter cascade in an average year.

8.2 Sediment Transport

The Lancang cascade causes a significant transboundary effect to all downstream countries concerning sediment transport as described in Feasibility Study Report Volume 5-TBIA/CIA-chapter 5.2.10. The Pak Beng, Luang Prabang, Xayaburi run-of-river cascade will, for some time slightly reduce sediment transport until new equilibriums in their backwater areas are reached.

As described in Feasibility Study Report Volume 5-TBIA/CIA-chapter 5.2.10 the reduction of sediment transport due to the impoundment of the Manwan reservoir has immediately impacted the following approx. 800 km downstream section. But further downstream (ca. 1,160 km), near Luang Prabang it took over 3 years to recognize this effect. It is assumed that the buffer volumes from sediments within the river compensated the impact during this time (CNR, 2013c).

The distance from LP HPP to Hueang confluence, where Mekong reaches the Thai border is approx. 330 km. It can be assumed that the phase with reduced sediment release from LP HPP can be recognized in Thailand quite early.

For other downstream countries like Cambodia (more than 1,000 km downstream) and Vietnam (more than 1,500 km downstream) the impact to sediment transport from this run-of-river cascade is rather low. Main reductions is caused by the Langcang cascade and the dams on the Mekong tributaries (e.g. Nam Ngiep 1 or Nam Theun 1).

8.3 Fish and Fishery

According to Poulsen et al [1] the upper fish migration system seems to be relatively isolated, with little exchange between it and the other more south located migration systems. It is therefore being expected that the transboundary impact concerning the fish migration is mainly affecting the upper migration system with migration towards China and can hardly be measured in the south towards Cambodia and Vietnam.[1]

[1] Poulsen, A.F., O. Poeu, S. Virvong, U. Suntornratana and N.T. Tung, 2002: Deep pools as dry season fish habitats in the Mekong River Basin, MRC Technical Paper No. 4, Mekong River Commission, Phnom Penh. 22 pp

9 SALIENT FEATURES

LOCATION	
Country	Lao PDR
Province	Luang Prabang
Nearest village	Ban Houaygno
Name of the river / river basin	Mekong River
Catchment and Hydrology	
Catchment Area	231,329 km^2
Average Annual Discharge	3,293 m^3/s
Construction Design Flood (HQ_{100})	23,800 m^3/s
Design Flood ($HQ_{10,000}$)	33,500 m^3/s
Safety Check Flood (PMF)	41,400 m^3/s
Reservoir	
Full Supply Level (FSL)	312.00 m asl
Maximum Flood Level ($HQ_{10,000}$)	313.60 m asl
Maximum Flood Level (PMF)	314.20 m asl
Surface Area	55 km^2
Reservoir Volume	1,256 million m^3
Length of Backwater Area	156 km
Barrage	
Location (WGS84)	N 20° 04' 22.39" E 102° 11' 14.13"
Dam type	Barrage type
Dam height (over deepest foundation)	79.0m
Foundation level	238.00 m asl
Crest elevation	317.00 m asl

Navigation Lock	
Type of Lock	2-step Navigation Lock
Design Vessel	2 x 500 DWT
Maximum Passage Time	50 min
Max. Total Lifting Height	35.50 m
Length of Lock Chamber (useable length)	120.00 m
Width of Lock Chamber	12.00 m
Depth under lowest WL	5.00 m
Upper Lock Chamber	
Maximum Water Level	312.50 m asl
Minimum Water Level	294.25 m asl
Maximum Flood Level (U/S)	312.50 m asl
Sill Level	289.25 m asl
Lower Lock Chamber	
Maximum Water Level	294.25 m asl
Minimum Water Level	276.50 m asl
Maximum Flood Level (D/S)	294.50 m asl
Sill Level	271.50 m asl
Feeding System	
Size of Main Feeding Conduit (width/ height)	3.0 x 4.5 m
No of Diffuser per conduit (per chamber)	7 with 5 openings each
Upstream Approach Channel	
Length	min 250 m
Mooring Posts	9
Downstream Approach Channel	
Length	min 250 m
Mooring Posts	9

Spillway	
Type	6 Surface Spillway Bays 3 Low Level Outlet Bays
Spillway Capacity (PMF)	41,400 m^3/s
Overall Width	195.00 m
Surface Spillway	
Number of Bays	6
Width	19.00 m
Sill Elevation	288.00 m asl
Size of Gate (width/ height)	19.00 m / 25.00 m
Low Level Outlet	
Number of Bays	3
Width	12.00 m
Sill Elevation	275.00 m asl
Size of Gate (width/ height)	12.00 m / 16.00 m
Powerhouse	
Number of units	7
Main dimensions	
Overall size of powerhouse (length/ width/ height)	275.00 / 97.00 / 80.00 m
Size of machine hall (length/ width/ height)	195.20 / 26.00 / 34.50 m
Number of erection bays	2
Size of erection bay(s) (length/ width)	80.00 / 26.00 m 50.00 / 26.00 m
Unit spacing	32.00 m
Powerhouse Crane	
Main Crane	2 x 380 ton
Auxiliary Crane	2 x 80 ton
Heaviest part (motor-generator)	650 ton
Installed rated capacity (total)	1,460 MW
Rated gross head	29.56 m
Closing Structure	
Dam Type	RCC Concrete Gravity
Height	50.20 m
Length	281.23 m
Crest Elevation	317.00 m asl

Main Equipment	
Kaplan Turbine	
Type	Vertical Kaplan turbine
Rated unit capacity	200 MW
Rated discharge per unit	765.0 m^3/s
Rated head	29.56 m
Speed (nominal / runaway)	83.3 / 235 rpm
Generator	
Type	Three phase synchronous generator
Rated output	220 MVA
Power factor	0.90 overexcited
Frequency	50 Hz
Transformer	
Type	Three phase, two windings, oil immersed
Numbers	7 + 1(spare unit)
Rating	240 MVA
Voltage reduction	16 / 550 kV
Frequency	50 Hz
Transport weight	650 ton
Transport dimensions (length/ width/ height)	7.0 x 3.0 x 4.0 m
Switchgear equipment	
Type	550 kV SF6 gas-insulated metal-enclosed switchgear (GIS)
Voltage level	500 kV
Max. operating voltage	550 kV
Energy Production	
Energy Output (at Powerhouse)	6,622 GWh/a
Energy Output (at EGAT Delivery Point)	6,424GWh/a
Energy Output (at EVN Delivery Point)	6,231 GWh/a

10 DRAWINGS

Project Location Overview Map

Project Area Topographic Map

Project Area Aerial Map

Project Area Plan view 1:2,000

Spillway Longitudinal Profile Low Level Outlet

Spillway Longitudinal Profile Surface Spillway

Powerhouse Longitudinal Profile