Mekong River Commission
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Overview
of the Pak Beng Hydropower Project and its submitted documents

Prepared by the **Mekong River Commission Secretariat**
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This document provides an overview on the Pak Beng Hydropower Project and the submitted documents of the proposed project from Lao PDR. The document presents only some key information extracted from the submitted documents, except where stated otherwise. This document provides a short summary for key features of the supplied documents, to facilitate and direct concerned stakeholder, who might be interested in the PNPCA process to find essential information with respect to the principle of the project design, negative impact mitigation measures, monitoring programmes, social and environmental impact assessment.

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Introduction

On 4 November 2016, the Mekong River Commission (MRC) Secretariat received notification from the National Mekong Committee of the Lao PDR initiating the formal process of Prior Consultation for the Pak Beng Hydropower Project. The proposed Pak Beng Hydropower Project is located in the Lao PDR's northern province of Oudomxay. It is planned as a run-of-river project with an installed capacity of 912 megawatts (MW).

The proposed Pak Beng Hydropower Project is the third proposed use to be submitted for the Prior Consultation process under the MRC's Procedures for Notification, Prior Consultation, and Agreement (PNPCA). The earlier two Prior Consultation processes were for the Xayaburi and Don Sahong Hydropower Projects conducted in 2010-2011 and 2014-2015, respectively.

The PNPCA requires the three notified Member Countries (Cambodia, Thailand, and Viet Nam) to acknowledge and review the documents submitted for prior consultation and submit their replies to the MRC Joint Committee. The MRC Joint Committee may direct the MRC Secretariat to appoint a task team to assist in the evaluation of the proposed use by undertaking a technical review of the submitted documents. This may include an assessment of possible impacts on water uses; the ecological functioning of the river system; and any impingement on the rights of the Member Countries.

Purpose of this document

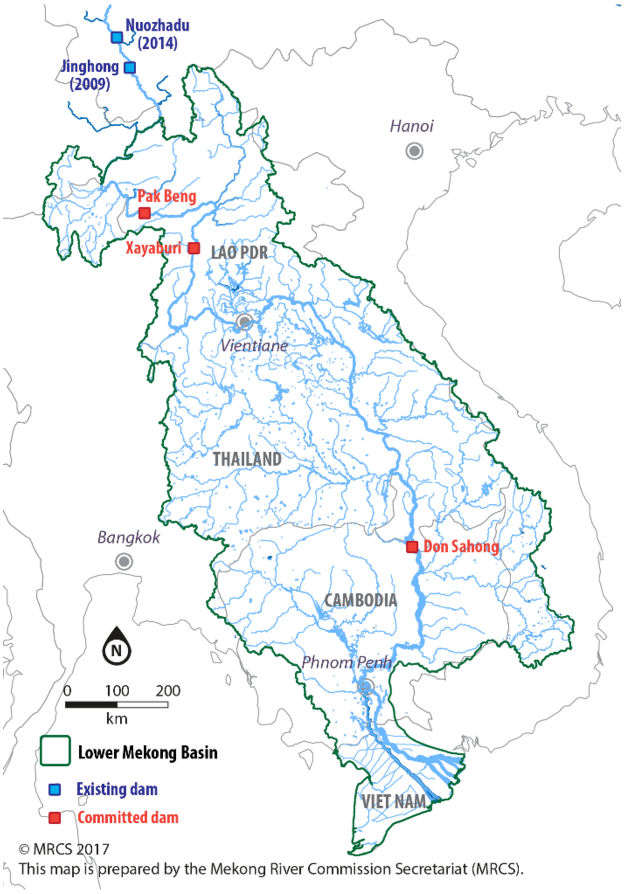
This document serves as a summary of the submitted documents by Lao PDR, and enabling stakeholders involved in the PNPCA process to access key information on the principles of the project design, likely social and environmental impacts, and proposed mitigation measures, and monitoring and hydrological and river forecasting scheme. The document presents only information extracted from the submitted documents, except where stated otherwise.

Summary of the Pak Beng Hydropower Project

The Pak Beng Hydropower Project is the first in the cascade of hydropower projects on the mainstream of the Lower Mekong River, located at 298 metres (m) above the mean sea level (masl) and 2,188 kilometres (km) distance from the sea. The dam site is in the Pak Beng District, Oudomxai Province, northern Lao PDR, about 530 km downstream from Jinghong Hydropower (the last hydropower station on the Lancang River or Upper Mekong River within China), 180 km from Chiang Saen (the first hydrological station on the Lower Mekong River), 174 km upstream of Luang Prabang, and 258 km from Xayaburi Hydropower. The project site is situated in the north part of the Lower Mekong Basin, where the landform is mostly hills and mountains covered by natural forests.

The developer has indicated that the Pak Beng Hydropower Project is designed and operated as a run-of-river hydropower project with a total storage capacity of 559 million cubic metres (m^3) at a normal water level of 340 masl, with daily regulation of capacity. This suggests that the outflow from the reservoir is equal to the inflow to the reservoir, meaning that the reservoir would not reserve water in the wet season for dry season power generation. Hence, the proposed project should not create a potential impact due to inter-seasonal flow distribution in the mainstream.

The Pak Beng Hydropower Project consists of 16 bulb turbines of 57 megawatts (MW), totalling an installed capacity of 912 MW. The annual average energy production is 4,765 gigawatts per hour (GWh) (or the annual utilisation time of 5,225 hours): 2,947 GWh in the wet season of June-November and 1,818 GWh in the dry season of December-May.



Location of the Pak Beng Hydropower Project.

Engineering structures of the proposed project

The complex structures of the project consist of water retaining structures, flood release structures, a powerhouse, a navigation ship lock and a fish passage.

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

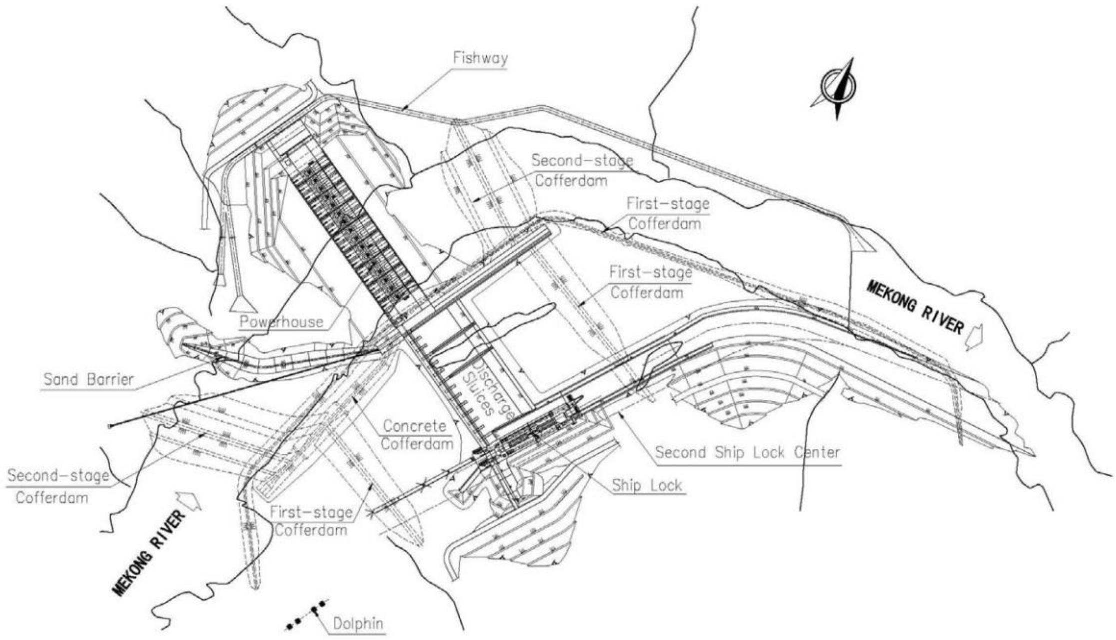
The **flood release structures** consist of discharging sluices and sand outlets. The discharging sluices are located on the right side with 14 sluices of 15 m wide × 23 m high. A stilling basin with energy dissipation is designed just behind the sluices. The sand outlets are within the powerhouse section, with an opening of 2.5 m wide × 5 m high, at 288.50 masl. They are constructed between every two generating units, with a total of 8 sand outlets.

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

The **navigation structure** is a one-way one-step ship lock for 500-ton ships, and a space for the ship lock for upgrading into a double-way lock is reserved. The maximum working head of the navigation lock is 32.38 m, and the size of the lock chamber is 120 m long × 12 m wide × 4 m deep. The one-line lock is being designed at the present time.

The **bypass fishway** is arranged on the left bank of the river, it is approximately 1.6 km long, 10 m bottom width and 17.2 m top width. The slope is about 1.85%. Several pools will be set along the fish passage and serve as rest pools. An observation room is set downstream of the service gate, and a counting, observing and trapping facility will be equipped in this room. The planned fish bypass channel entrance is some distance of about 1 km downstream of dam wall.

The dam and water transfer structure are designed based on a 500-year return period (26,800 m^3/s or 341.20 masl at reservoir) and checked based on a 2,000-year return period (30,200 m^3/s or 343.74 masl at reservoir). Additionally, structures for energy dissipation and protection are based on a 50-year return period.



Layout of the Pak Beng Hydropower Project which consists of water retaining structures, flood release structures, powerhouse, navigation ship lock and fish passage (not to scale).

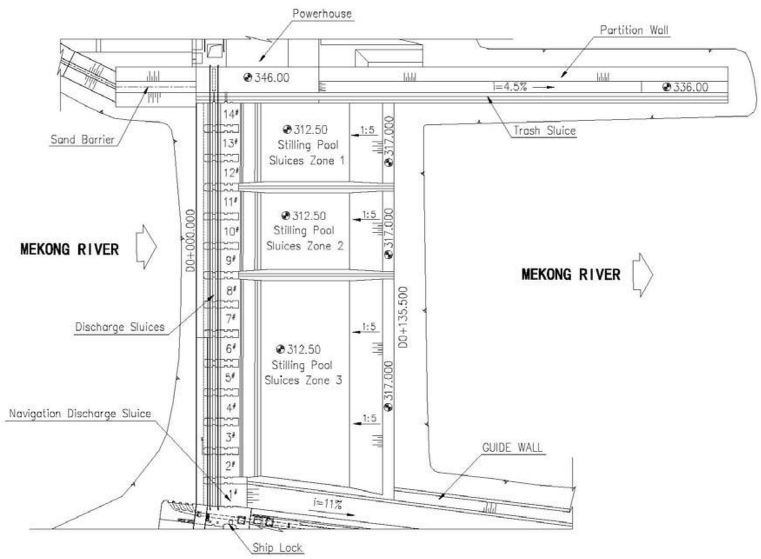
Water retaining structure

The **water retaining structures** include a gravity dam, a powerhouse, discharge sluices and a ship lock. The dam crest elevation is 346 masl, the maximum dam height is about 64 m, and the dam crest length is 896.70 m. Non-overflow dam sections with the length of 47 m are designed on the left bank, while 100m long non-overflow dam sections are set on the right bank. Additionally, ten powerhouse dam sections with a total length of 410 m are designed on the main river channel, and the maximum height of powerhouse is 64 m. Moreover, the discharging sluice sections consist of fourteen blocks with a total length of 299.5 m. The foundation of sluice sections ranges from 304 masl to 307.5 masl, and the maximum dam height is 42 m. Furthermore, the ship lock section is 42 m wide and the foundation plane of its upper head is located between 290 masl and 304 masl, and the maximum height is 56 m.

The dead water level of the hydropower project is 334 masl or 1 m lower than the operating water level of 335 m during low flow periods, corresponding dead storage of 363 million m^3. During low flow periods, the storage difference between operating water level (335 masl) and dead water level (334 masl) is 29 million m^3, while that between normal water level (340 masl) and dead water level (334 masl) is 196 million m^3. The reservoir is capable of daily regulation.

Flood release structure

The **flood release structures** consist of discharging sluices and sand outlets. The discharging sluices are located on the right side with 14 sluices of 15 m wide × 23 m high. To prevent sediment accumulation at the intake of the powerhouse, a sand barrier is arranged before the powerhouse section with a view to diverting sediment into the discharge sluices to bypass the dam and go downstream. Additionally, there are a total of 8 sand outlets at the powerhouse for discharging accumulated deposited sediment before the intakes. Each of them has an opening of 2.5 m wide × 5 m high for every two generating units, passing thought the bottom of the powerhouse. The bottom elevation of the inlet and outlet is 288.5 masl and 300 masl, respectively. Furthermore, a bulkhead gate is designed for the inlet and outlet, while a service gate is designed for the outlet only.

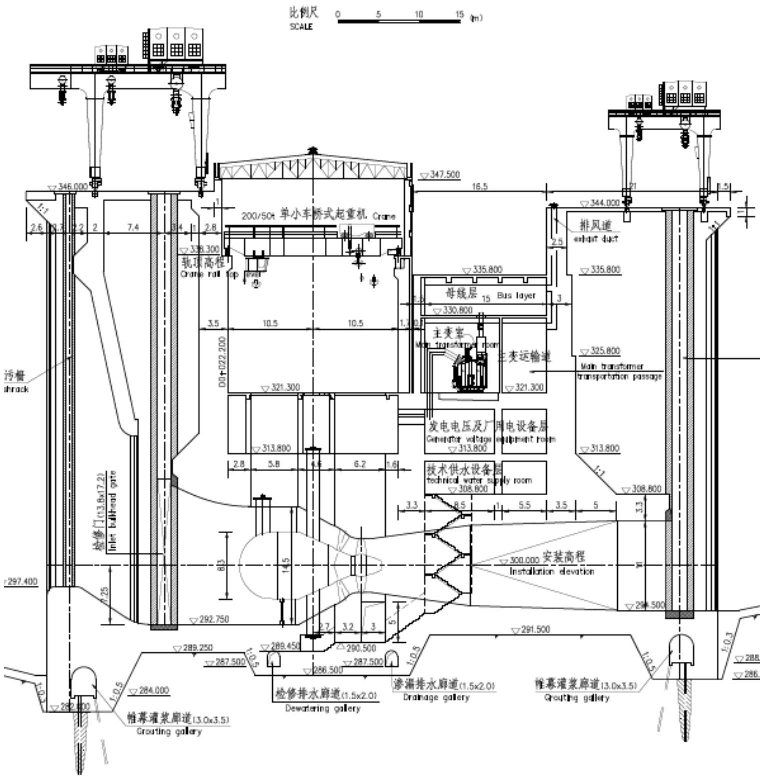


Fourteen discharge sluices are part of the flood release structures (not to scale).

Powerhouse

To prevent sediment from entering the power intakes, a debris barrier with a crest elevation 297.4 masl is proposed before the intakes, and 8.9 m higher than the inlet slab of sand outlets. A vertical trash rack is designed for the intake. A two-opening trash rack with 5.65 m wide × 38.6 m high and a 13.8 m wide × 17.2 m high bulkhead gate is applied to the power intake of each generating unit, while one emergency gate of 13.8 wide m × 11 m high is designed for the tailrace outlet. The elevation of the tailrace slab is 294.5 m, and a tailrace channel with a slope ratio of 1:5 is connected to the downstream river channel, and the bottom is protected with a concrete slab.

Sixteen bulb turbines are designed for the powerhouse. There are eight generator sections,



Structural layout of powerhouse. Sixteen bulb turbines are designed in powerhouse (not to scale).

which are 41 m long along dam axis, and each section has two generators. To facilitate installation and maintenance of the generating units, a 41-meter long erection bay is constructed on both ends of the generator section.

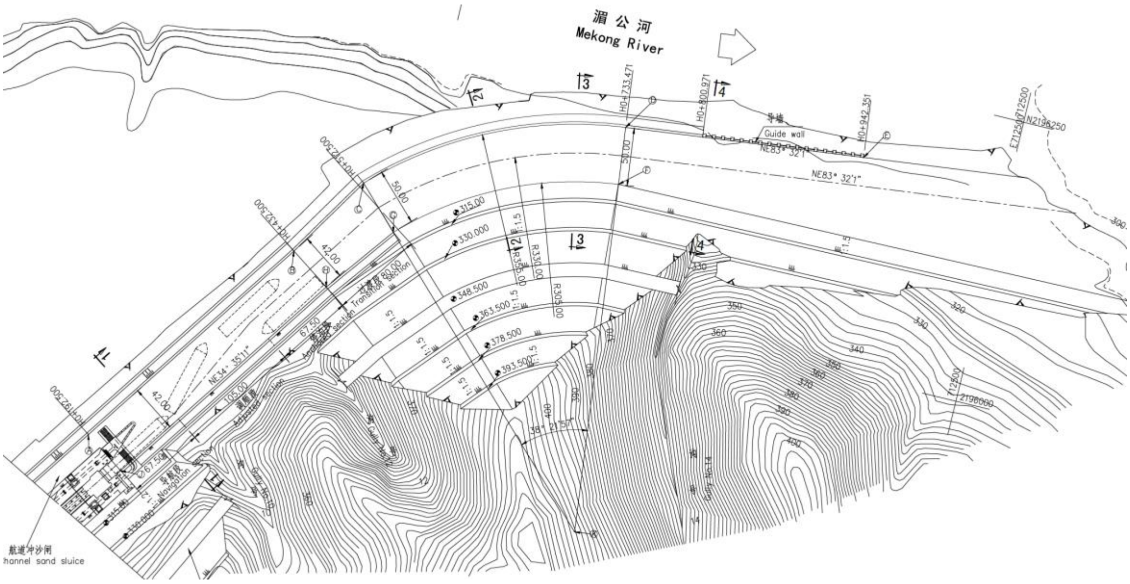
The span of main powerhouse is 21 m. The installation elevation of generating units is 300.0 masl while the elevation of generator floor is 321.3 masl, and the clear height of powerhouse above the generator floor is 26.2 m. The roof of the main powerhouse is constructed of light steel.

The auxiliary powerhouse is located downstream of the main powerhouse, and water supply equipment room, auxiliary power equipment room, main transformer chamber, cable layer are arranged in turn. The outgoing line platform is located on the top of the auxiliary powerhouse, and the tailrace platform. The outgoing line platform is used for laying out gantry cranes for hoisting the tailrace gate and bulkhead gate and roadway. The sump well for powerhouse drainage is located below the erection bay on the left of the powerhouse.

Both the upstream side and downstream side of the powerhouse are a water retaining structure. The power intake platform and tailrace platform are located on the elevation of 346 masl and 344 masl, respectively.

Navigation structure

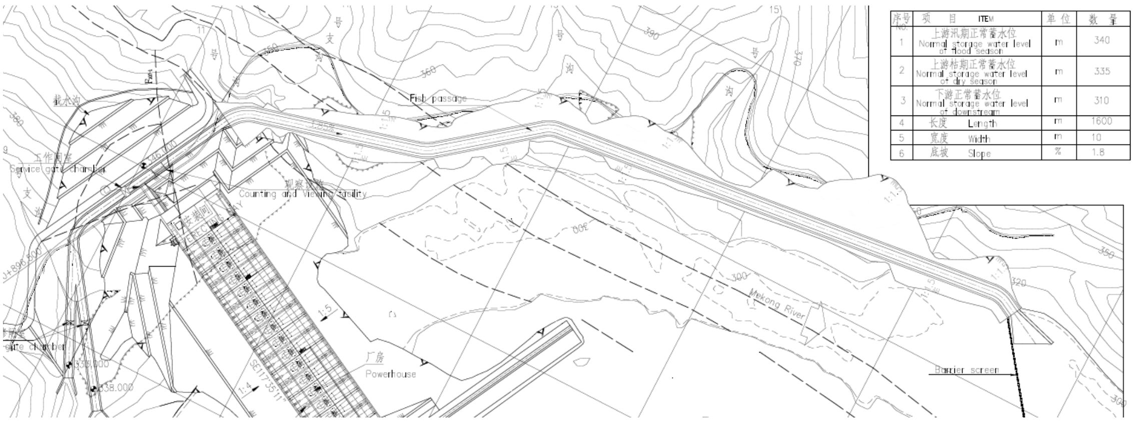
The navigation ship lock is composed with a head bay, a lock chamber, a tail bay and a water conveyance system. The maximum working head of the navigation lock is 32.38 m, effective size of the lock chamber is 120 m long × 12 m wide × 4 m deep. The head bay and lock chamber are integrated. It is designed to be a one way and a one-step lock, and the passing time of a ship can be guaranteed not to exceed 30 minutes (min). The access channel can generally govern two standard vessels of 500 tons, whose width is 10.8 m, so it’s designed to be two-way circulation.



Navigation channel with a maximum working head of 32.38 m and a chamber size of 120 m × 12 m × 4 m (not to scale).

Fishway structure

Building a hydropower dam across a river will undoubtedly affect the aquatic ecosystem and biodiversity, especially fish. The main impact of the Pak Beng Hydropower Project is the cutting off of the migration pathway of fish. According to the survey results, 54 species belonging to 14 families were found in the samples collected from 6 sampling sites during the wet and dry seasons. The survey also indicates that the fishing activities along the Mekong River at the Pak Beng area become more intense during the transition period of the dry season and rainy season (May to August depending on hydrological condition), which is the time of fish migrations in the mainstream and its tributaries.



Fish passage with a length of 1.6 km is designed for the left bank of the main river (not to scale).

The **bypass fishway** is proposed for the left bank of the river, it is approximately 1.6 km long, 10 m bottom wide and 17.2 m top width, with its entrance located at some distance downstream of the dam wall (about 1 km). The slope is approximately 1.85%. Several pools will be set along the fish passage and serve as the rest pools. Two exits are designed for the fish passage, it can thus operate at between 340 masl (normal operation water level of the wet season) and 335 masl (normal operation water level of the dry season). The fish outlet is set in an open area at least 200 m away from the dam. To guide the fish to find the entrance, barrier screens are proposed from the entrance side to the opposite bank.

The maintenance gate is arranged at the exit. The service gate is set on the left side of the gravity dam. When the upstream water level exceeds the normal storage level, the service gate will be closed, and the fish passage will not work. An observation room is set downstream of the service gate, and a counting, observing and trapping facility will be equipped in this room.

Dam safety

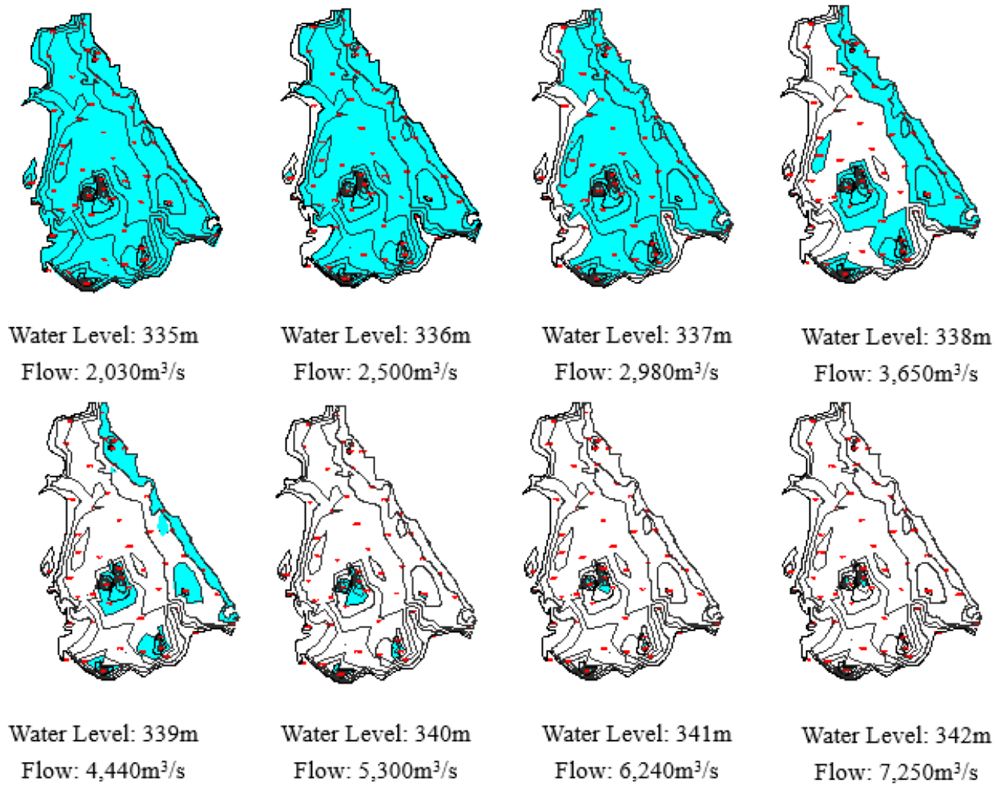
Two gravity dams are to be put in place to hold the main dams. The right gravity dam is at the side of the ship lock with a crest length of 100 m and crest elevation of 346 masl. The left gravity dam is located between the powerhouse and fish passage with a crest length of 48 m and crest elevation of 346 masl. In considering the shorter length of dam and the need for a road from the upstream gravity dam to the downstream tailrace platform, a concrete retaining wall is set on the left of the tailrace platform, and the space between the upstream gravity dam and downstream retaining wall will be backfilled with stone slag as a platform.

The Pak Beng Hydropower Project is capable of daily regulation but not control of flooding downstream to farmland and towns. Its flood control function is therefore mainly intended for the flood safety of its hydraulic structures.

The dam safety management issues considered in the proposed project includes emergency preparedness plan, dam safety monitoring and inspection, maintenance and management of hydraulic structure operation, management of defect of hydraulic structures and management of prohibited dam zone.

Operation

The main considerations of the operation of the proposed hydropower project focus not only on energy generation, but also on navigation requirements, the impact on natural reef of Keng Pha Dai and the requirement for sediment management. Located on a navigable stretch of the Mekong mainstream, the project includes a navigation structure, which enables the passage of ships up to 500 tons. Additionally, to avoid the significant impact on navigation, the proposed dam does not use peak load regulation by operating with a low head and large discharge, i.e. the dam will only generate power as per inflow. The reef of Keng Pha Dai is collectively recognised as a natural monument for demarcating national border between Thailand and Lao PDR. Considering this important landmark, the appearance of the natural reef is surveyed and water level is consequently maintained at 335 masl in the dry season and 340 masl in the wet season, to ensure visibility of the reef. Furthermore, the proposed dam is equipped with a sediment flushing facility such as discharge sluice gate and low bottom holes under the powerhouse to ensure settled sediment carrying downstream properly. Comprehensive hydrological and sediment monitoring, before and after construction and during operation, will also be undertaken.



Note: The blue in the figure represents exposure parts of reefs.

Exposure of the natural reef of Keng Pha Dai was considered in planning for the operation of the proposed project.

Overview of the submitted documents

There are total **20 reports** and relevant appendix submitted from the notifying country of Lao PDR. These documents contain primary and secondary hydrological data, design concept, methodology, and analysis results in format of photos, maps, tables and figures, and provide information and assessment of issues including: hydrology and hydraulics; sediment transport and river morphology; fish passage and fisheries ecology; water quality and aquatic ecology; navigation; dam safety; and transboundary socio-economic impacts. The following sections provide a summary of each submitted report.

Engineering Status Report

The Engineering Status Report (and its appendix) is the major document of the proposed project. It covers many engineering aspects of the project including geology and geotechnical investigation, topography and mapping, hydrology and sediment, project planning and layout, components of infrastructure, dam safety, fish passage, mechanical and electrical equipment, construction plan and scheduling and total cost of the project. The document also presents the principles of the structure design and operation mode of the project. The essence of this report is presented in the summary section of this overview. Furthermore, the compliance of the proposed project with the MRC Preliminary Design Guidance, which was prepared by the developer is analysed in the appendix to the Engineering Status Report.

Drawings of Engineering Status Report

The drawings, prepared as a companion to all submitted documents, visually represent the engineering design of the Pak Beng Hydropower Project, providing detailed maps and plans of all features of the project: (1) geological engineering of the project sites, (2) detailed structural layout, (3) drawings of electromechanical equipment and steel structure, and (4) drawings of the construction plan and site preparation.

Hydrological Data and Sediment Sampling

This report documents data used in the study and design of the proposed project. It contains primary and secondary hydrological data including water level, discharge and sediment data. The monthly average discharge at Chiang Saen, Luang Prabang and Pak Beng dam site is presented and historical water level observation at Pak Beng for 1976-1978 is tabulated. New information on water levels and results of flow measurement using Workhorse Rio Grande ADCP at Pak Beng for 2008-2014 are also presented. Furthermore, different methods of sampling suspended sediment were adopted in the survey of 2008 (one-point sampling for three vertical lines on left bank, right bank and centre lines) and 2015 (three-point sampling of equal distance of 20%, 60% and 80% water depth).

Reservoir Sedimentation and Backwater

The sedimentation and backwater effect of the Pak Beng Hydropower Project was studied using SUSBED-2 developed by Wuhan University. The study covers the upstream river stretch of the proposed dam site to confluence of Nam Ing River, confluence of Nam Ngao River and area of the natural reef of Keng Pha Dai.

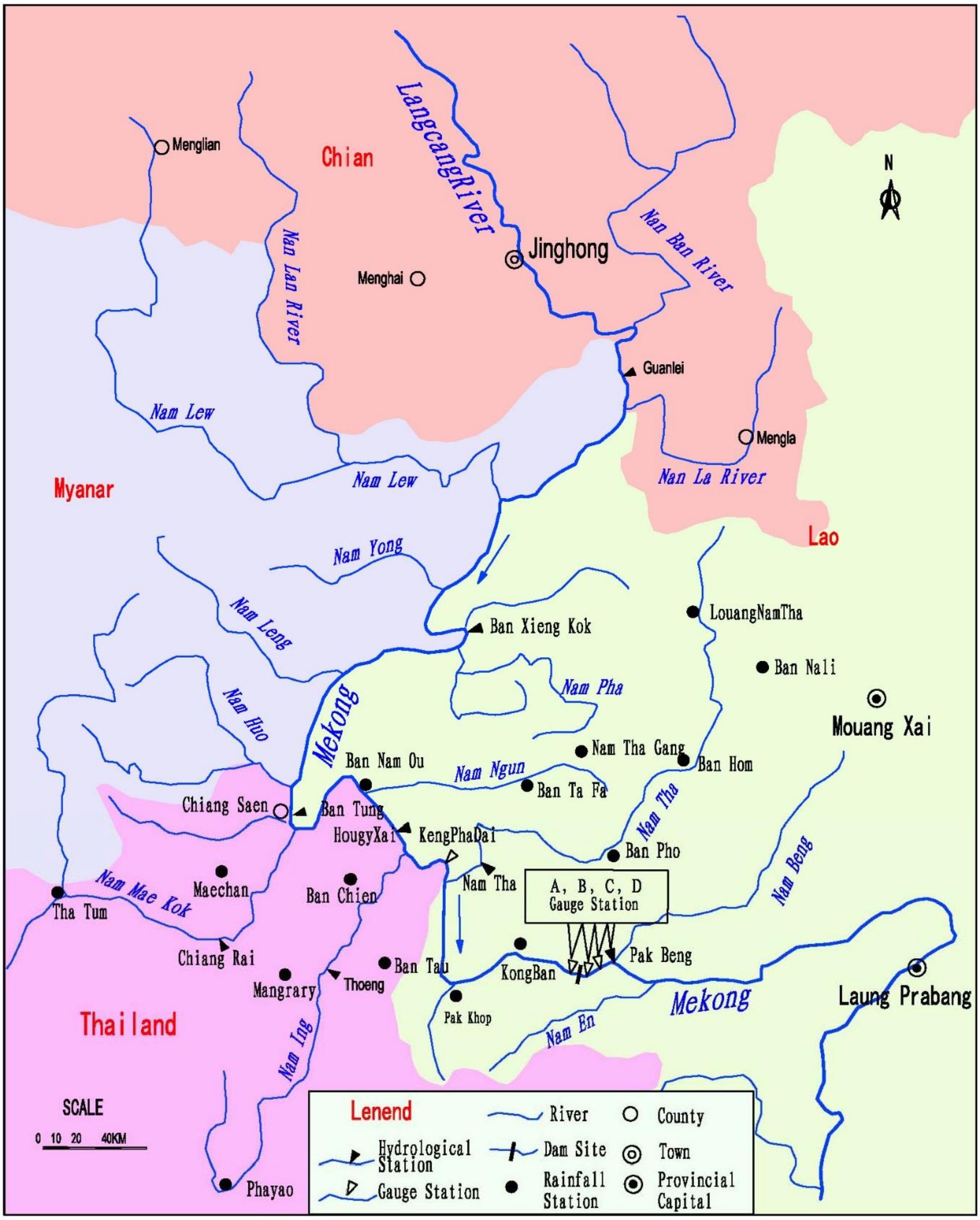
The loss of reservoir storage and effective reservoir storage at normal water level due to siltation is about 29% and 7%, respectively, after operation of 50 years. After operation of 100 years, these figures increase to 35% and 10%, respectively. Sediment is primarily accumulated downstream of Keng Pha Dai.

The corresponding water level due to hydropower development (335 masl in the dry season and 340 masl in the flood season) somewhat rises the water level at Keng Pha Dai compared with the natural conditions, but it does **not basically change the characteristics of exposure of the natural reef**.

Furthermore, water level at the confluence of the Nam Ing and Nam Ngao Rivers rises about 1-2.5 m in the flood season, however, overbank flows would not take place since the river banks are relatively high. Rising of water level at these locations is not remarkably observable during the dry season: about +0.10 m for the confluence of Nam Ing River and about +0.55 m for the confluence of Nam Ngao River. In addition, reservoir backwater does not influence the water level at Chiang Khong.

Overall Design Report of Automatic System of Hydrologic Data Collection and Transmission

Automatic water level and rainfall data collection were considered during construction and operation of the project. The report covered preliminary design of hydrological stations, location, communication, equipment configuration, power supply, lightning protection, civil engineering structure and way of operation/management and usage of collected data for forecasting purposes. The report stated that, since no specification and standard of automatic system of hydrological data connection and transmission in Lao PDR, regulation and standard of the design of China were suggested. It is proposed to additionally install **27 telemetry stations**: 12 hydrological stations (water level and discharge) and 9 rainfall stations in Lao PDR and 6 rainfall stations in Thailand. Two communication channels were suggested: GSM and Beidou satellite.



Location of 27 newly proposed telemetry stations: 12 hydrological stations (water level and discharge) and 9 rainfall stations in Lao PDR and 6 rainfall stations in Thailand.

Data collected from the telemetry stations is used for hydrological forecasting (rainfall-runoff forecasting and river system forecasting) during the construction and operation. Two methods of rainfall-runoff forecasting were proposed: empirical correlation of precipitation, antecedent precipitation and runoff or **Antecedent Precipitation Index (API)** and **Xin'anjian model**. The Xin'anjiang model is a conceptual rainfall-runoff model of 'three water sources of surface water, interflow and groundwater'. On the other hand, river system forecasting considered is a **lumped hydrological model**, calculated as a function of time and governed by continuity equation and flow/storage relationship.

Overall Design Report of Sediment Monitoring System

A comprehensive sediment-related monitoring system was proposed in Overall Design Report of Sediment Monitoring System. It covers the following aspects of (1) monitoring sediment in/out the reservoir, (2) monitoring of water surface line in the reservoir and tail section of the reservoir, (3) sediment deposition in the reservoir, (4) monitoring of sediment deposition in the project area, (5) monitoring of downstream river reach, and (6) monitoring bank deformation.

- **Monitoring sediment in/out the reservoir (sediment concentration and grain size distribution)**: LISST-100X automatic suspended sediment grain size distribution probe is planned to install in a controlled environment to monitor inflow and outflow sediment in the reservoir. The incoming sediment monitoring station is proposed opposite Chiang Saen hydrological station, on river bank of Lao PDR. Additionally, the outgoing sediment monitoring station is at Pak Beng hydrological station.
- **Monitoring of water surface line in the reservoir and tail section of the reservoir**: part of the installed hydrological network is used for monitoring water surface and tail section of the reservoir.
- **Sediment deposition in the reservoir**: Sixty cross-sections of the reservoir were surveyed during the design phase. The sections underwater were acquired by digital navigation fathometer and section above the water surface obtained by the total station equipped with GPS. For monitoring purpose, when the hydropower is in operation, the monitoring cross-sections would overlap with the cross-sections of the pre-dam conditions. The reservoir shoreline, river course and terrace should be monitored using high resolution satellite imagery.
- **Monitoring of sediment deposition in the project area**: detailed topographic and bathymetric surveys of 1-km upstream and 2-km downstream river sections from the project site would be conducted every year before and after the flood season.
- **Monitoring of downstream river reach**: high resolution satellite imagery of 50-km downstream of the project site would be purchased every year and then the topographic map of the interest area could be generated.
- **Monitoring bank deformation**: before reservoir impoundment, it is proposed to investigate the stability of the reservoir banks and identify the potential position of landslide deformation. The monitoring of bank deformation would include: a displacement, a displacement velocity, an acceleration, and a displacement vector map.

Sediment Management

Sediment management of the Pak Beng Hydropower Project will be facilitated by a water retaining structure, a sluice gate, bottom holes under the powerhouse, a navigation structure and a fish passage, with operations of different incoming flows patterns. Sediment management proposed for the Pak Beng Hydropower Project include the following:

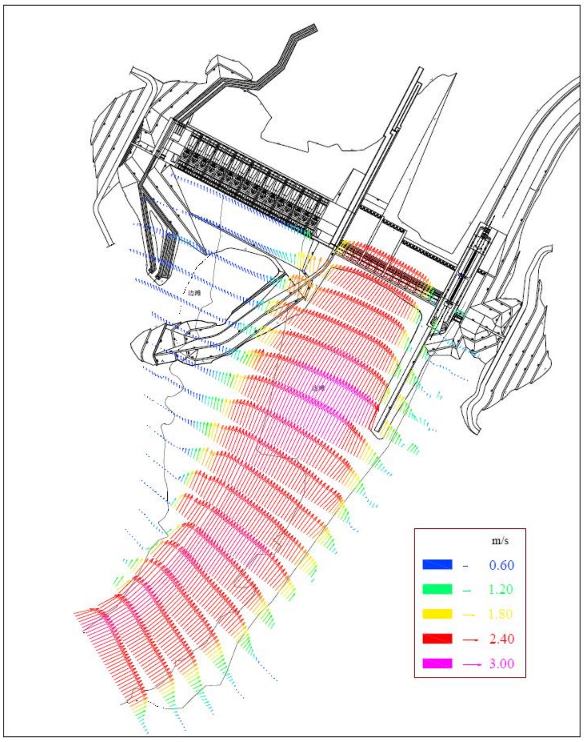
- **Sediment deposit in the reservoir area**: it is claimed that the effective storage capacity of the reservoir reduced about 7% after 50-year operation and about 10% after 100-year operation.
- **Sediment control of water intake**: coarse particles of suspended sediment and bed load are supposed to be intercepted with sediment barrier and carried to sluice gates. Fine particles would deposit in front of the powerhouse and discharge downstream through bottom holes under the powerhouse. Once this proposed mechanism is found ineffective, artificial or mechanical dredging measures shall be taken.
- **Sediment control at the approach channel**: sediment that enters the approach channel would be flushed by sand-sluicing gate, adjacent to the navigation channel. Similar to the above, if it is not found effective, artificial or mechanical dredging measures shall be taken.
- **River bank scouring**: it is recognised that water level fluctuation caused by reservoir impoundment and operation scheduling would impact on the bank stability of the reservoir and downstream channel. The monitoring of bank stability was proposed. When it is found instable, engineering measures, i.e. block or gabion protection, shall be taken.
- **Eco-friendly sediment flushing**: fish spawning period between March and June shall be avoided when flushing sediment. Additionally, gates shall be gradually opened to allow well-mixed sediment concentration for a certain period of time.

Two-dimensional Sediment Numerical Simulation of Pak Beng Hydropower Station

A two-dimensional flow and sediment mathematical model was established by Wuhan University for studying sediment transport through the Pak Beng Hydropower and the variation of scouring-deposition of river reach of the dam area. In considering reservoir operation mode and characteristic discharges, the sediment movement was studied with a fixed number of years in operation (5-year, 10-year, 15-year, 20-year, 25-year and 30-year). The time series of flow and sediment used for this study is 1984-1988 (5 years). The study covers the following aspects:

- **Silting situation of the sand barrier**: it is found that, after 25-year operation, without artificial or mechanical dredging of sediment deposit, the sand barrier would not play an effective role in intercepting coming bed load. The sediment flushing would only draw the deposited sediment near the dam section.
- **Silting situation before the powerhouse**: after 30-year operation, the silting situation of the left bank of the powerhouse (non-overflowing section) is more serious than that of the right bank.

- **Sediment concentration and grain distribution**: the annual average sediment concentration through the powerhouse slightly increases from 0.325 kg/m^3 after 5-year operation to 0.342 kg/m^3 after 30-year operation. Similarly, the sediment volume of grain size greater than 0.062 mm increase from 1.32% after 5-year operation to 2.95% after 30-year operation.
- **Silting situation in the entrance area of upstream approach channel**: after 20-year operation, water depth in the entrance area of the upstream approach channel could not satisfy year-round navigation. Artificial or mechanical dredging would need to be considered.
- **Silting situation in the entrance area of downstream approach channel**: after 5-year operation, the sediment deposit predicted to be 5 m. Navigation during low flow is still operational, but attention would be focused to (reduced) width of the channel and backflow near the entrance of downstream approach channel.



Two-dimensional flow and sediment mathematical model: Flow velocity of 13,272 m^3/s after 20-year operation (not to scale).

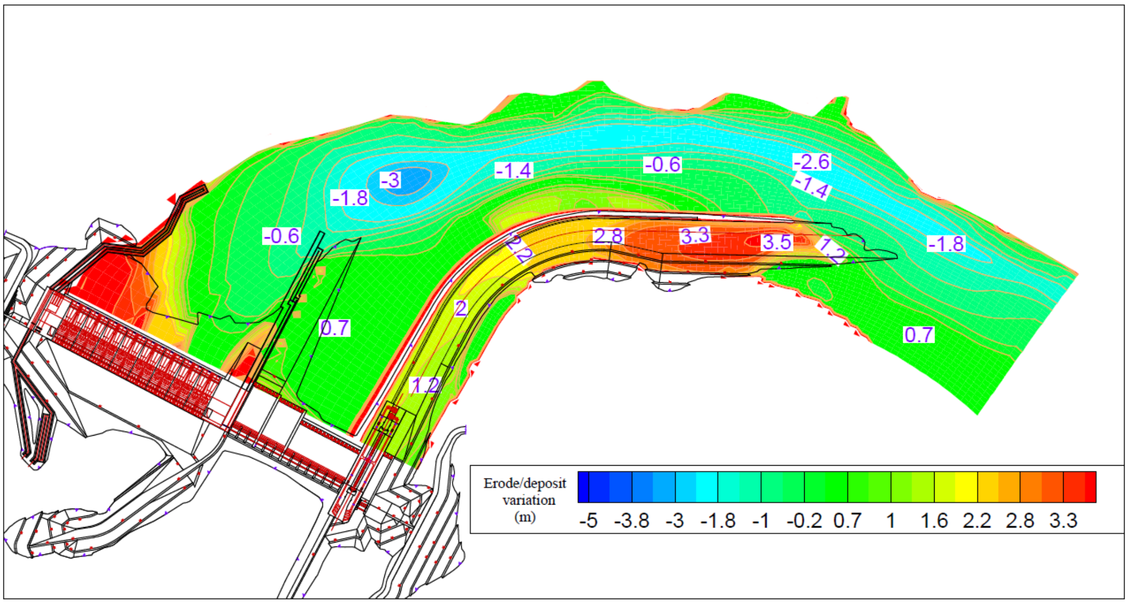
The report also suggests that the study would be further verified using a dataset of recent years since the current simulation scenarios of 5-year, 10-year, 15-year, 20-year, 25-year and 30-year was generated from available data of 1984-1988.

Numerical Simulation of Sediment Movement in the Ship Channel of Pak Beng Hydropower Station Downstream

The stability of the approach channel is indispensable for successful operation of ship lock structure. The design of the approach channel and the ship lock structure used a three-dimension mathematical model of flow and sediment. The report presents research findings on sediment deposit in the approach channel and analysis results of the scouring effect in the river channel.

- **Velocity distribution in the approach channel**: there is no adverse effects on navigation in the approach channel when the maximum horizontal velocity is less than 0.3 m/s, which is the case that flow is lower than 2-year return period.
- **Erosion and deposition variation in the downstream river channel of the hydropower project**: the river channel downstream of the reservoir is eroded in different degrees along the talweg when the hydropower project become operational. Cross-sectional erosion decreased from the talweg towards banks. The average erosion depth on the talweg ranges from 1.4 m to 2.0 m and could be 3.0 m at certain location.

- **Erosion and deposition variation in downstream approach channel**: the thickness of sediment deposition has a descending trend from the entrance to the main channel of the downstream approach channel. After 5-year operation, the deposition at the entrance is 3.6 m and gradually reduces to 1.0 m along the main channel.
- **Flood discharge and sediment erosion in the downstream approach channel**: erosion effect is apparent when the flow rate exceeds 3,160 m^3/s. Additionally, it is found that the sediment deposit in the downstream approach channel after 5-year operation could be cleaned up within a 24-hour period with a flow rate of 3,160 m3/s.



Erosion and deposition distribution over 5-year operation of the proposed hydropower (not to scale).

Hydraulic Physical Model Investigation of Filling and Emptying System

The research presented in this submitted report aims to (1) determine hydraulic characteristics of the filling and emptying process in lock chamber, e.g. filling/emptying times, discharge, rise/descend velocity of water level, head loss coefficient, etc; (2) observe the hydraulic phenomenon at intake, outlet, lock chamber and approach channel; (3) determine hawser forces of tows in the lock chamber; (4) determine and calculate overtravel during lock filling and emptying; (5) determine hydraulic pressures in lock culverts for different valve openings; (6) determine mooring conditions of tows in downstream lock approach and analyse flow conditions. The following are the main findings from the research:

- The experimental results of the **filling and emptying system for the navigation lock** confirmed and optimised the design of the lock system: the two-section dynamically balanced lock filling system with wall culvert and vertical bifurcation at the midpoint of the chamber, and longitudinal manifolds with the energy dissipation ditch.
- Comprehensive consideration of the **filling and emptying times** was proposed. The valve opening/closing times were recommended as 6 min. The filling and emptying times for discharge of 146 m^3/s and 140 m^3/s were 10.60 min and 11.16 min, respectively, or the maximum average velocities were 10.1 m/s and 9.6 m/s in valve culvert cross section, and 7.2 m/s and 6.9 m/s in the bifurcation of the cross section.

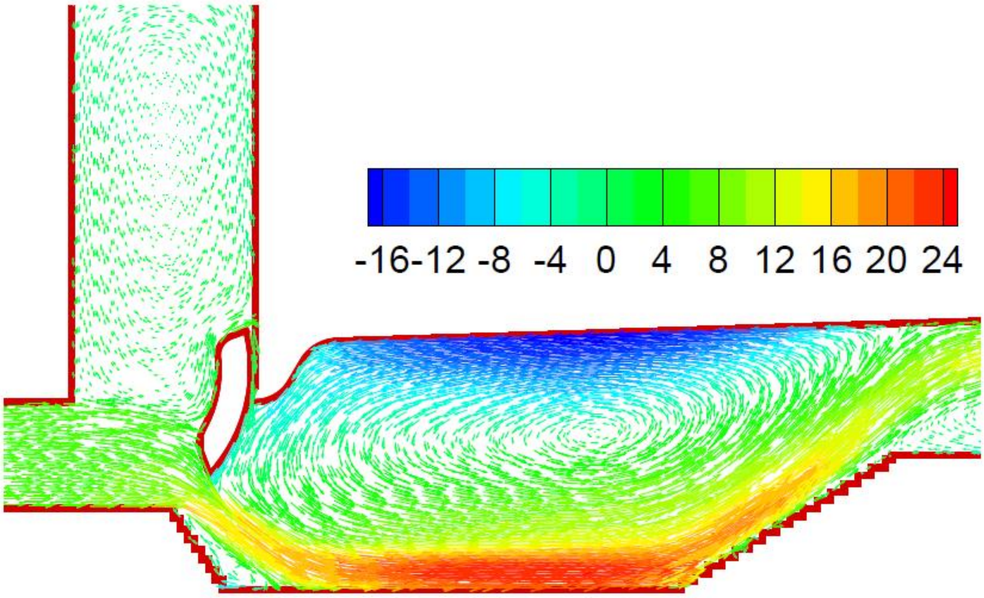
- The **maximum longitudinal and transverse hawser forces** of 500-ton vessel in chamber were 16.5 kilonewtons (kN) and 5.6 kN for lock filling with two-valves operation (opening time of 6 min), and were 17.6 kN and 6.0 kN with one-valve operation (opening time of 6min).
- The **vessel free drifting experiment** showed that free parked vessel (not-moored) at center of the chamber was raised with the chamber water level and almost no drift in the lock filling process. The water surface in the chamber was smooth. The discharge of chamber manifold and the main culvert divided into branch culverts were symmetrical.
- Except the valve culvert section, the **pressures at other locations of emptying system**, were all positive in the culvert system under various hydraulic heads with one or two-valve operation.
- The overall **lock coefficient for filling and emptying** for two-valves operation were 0.816 and 0.743, and 0.928 and 0.743 for one valve operation.

In the upstream approach channel, the bottom elevation of intake manifolds was raised to 322.00 masl with the eddy-eliminating beams. Additionally, no vortices were formed or observed at various hydraulic heads under all operating conditions. In the downstream approach channel, the left guide wall with hollow-out and the outlet culverts in two side wall were connected to the energy dissipation chamber.

Hydrodynamic Characteristics Research on Valve and Culvert at Valve Section for Pak Beng Ship Lock

The ship lock of the Pak Beng Hydropower is the throat of navigation main line on the Mekong River. The effective size of the lock chamber is 120 m × 12 m × 4 m. The cross-section size of recommended culvert at the valve section of the filling and emptying system is 2.2 m × 2.6 m and the maximal water head is 32.38 m. This water level variation requires complex hydraulic features and is **one of the highest level of built ship locks in the world**. Among which the valve hydraulic problem is one of the key technical problems in this ship lock hydraulic design. The research covers the unsteady hydraulic model tests and steady pressure-reduction model tests with a scale of 1:10 (at present stage), hydrodynamic pressure on the culvert at the back of the valve, hoist load characteristics, hydrodynamic load on culvert at back of valve during period of closing valve, effect of valve operation speed and water head on hydrodynamic pressure and hoist load. The cavitation characteristics at valve lip, upward slope and downward slope were thoroughly examined. The report put forward effective measures of automatic aeration at the top sealing sill to suppress cavitation at top sealing sill and valve lip, forced aeration at the downward slope to suppress cavitation at the upward slope and downward slope, which are verified by a pressure-reduction model test. Characteristics of hydrodynamic pressure on the culvert at the back of the valve under the condition of raising its elevation of 5 m and the feasibility were discussed. The cavitation factors were also estimated while culvert's elevation was raised 2 m.

Considering importance of the navigation on this international river and hydraulic complexity of the ship lock, the report **highly recommended that international best practice** and experience of similar high water head ship lock and its existing technology would be engaged. This would optimise operation parameter of specific hydraulic features and provide a basis for operation management of the lock to ensure secured navigation and its benefit of cross-border trade.



Velocity distribution in the culvert at valve section of navigation channel of the Pak Beng Hydropower (not to scale).

Overall Hydraulic Physical Model Investigation of Pak Beng Hydropower Project

The report of Overall Hydraulic Physical Model Investigation of Pak Beng Hydropower claimed that a physical model was built to study hydraulic characteristics of the project: (1) discharge capacity of the sluices; (2) flow condition in the entrance of the approaching channel both upstream and downstream; (3) energy dissipation efficiency of the stilling pool of sluices; (4) pattern of sediment deposit at upstream and downstream area of the dam; (5) sediment flushing efficiency of discharge sluices and navigation discharge sluice; (6) optimize the layout of hydraulic complex by experiment. The physical model includes all structures of the hydropower project and is made according to gravity similarity, covering actual upstream length of 4,200 m and downstream length of 2,000 m.

The experiment suggests that the release of flood discharge was divided in **three different zones of 14 discharge sluices**, ranging discharge from 5,000 m^3/s to 30,200 m^3/s. Alternative operation modes of discharge sluices were also investigated.

The sluices would be **uniformly opened to ensure a smooth flow pattern and less pressure** on downstream river channel. Additionally, for flows less than 3-year return period flood, flow pattern and velocity in the entrance area of navigation channel was relatively smooth.

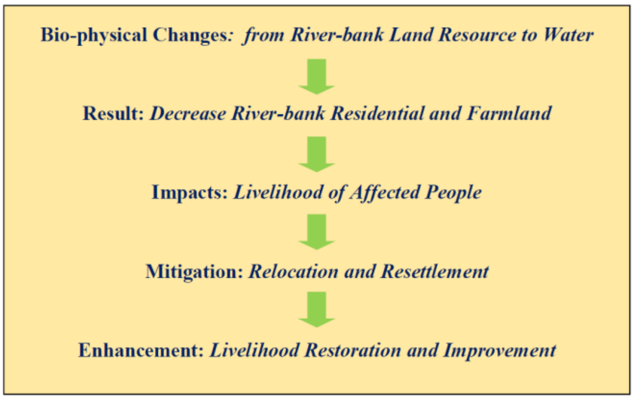
With proper sluice operation, the sediment deposition was observed to be far from the entrance area of the downstream approach channel. Moreover, there was **no obvious sediment accumulation in immediate upstream area** of the sluices. Furthermore, sediment deposits could be cleaned up at a distance of 150-200 m upstream when the sluices were fully opened for 2-year or 5-year return period flood. This subsequently reduces sediment build-up in the reservoir.

Due to the natural meander of the upstream channel, the sediment did not accumulate much near the sand barrier, however, deposit on the upstream right side of the sand barrier formed longitudinal dunes.

Social Impact Assessment

Social Impact Assessment (SIA) is one of the six volume reports of the feasibility study on Environmental and Social Impact Assessment (ESIA). The other five volumes are Environmental Impact Assessment (EIA), Environmental Management and Monitoring Plan (EMMP), Social Management and Monitoring plan (SMMP), Resettlement Action Plan (RAP), and Ethnic Group Development Plan (EGDP). The SIA aims to address the social consequences, both positive and negative, of the project development. It analyses potentially significant socio-economic and cultural impacts arising from the design, construction and operation of the project including mitigation measures to minimize negative impacts. Methodology used includes desk review, meeting, interview, survey, consultation, census, and rapid rural appraisal.

The report discusses environmental and engineering features of the project, social policy and legislation framework, social baseline information at macro level, social baseline information at project level, analyses of social aspects in project area, assessment of social impact, and public involvement.



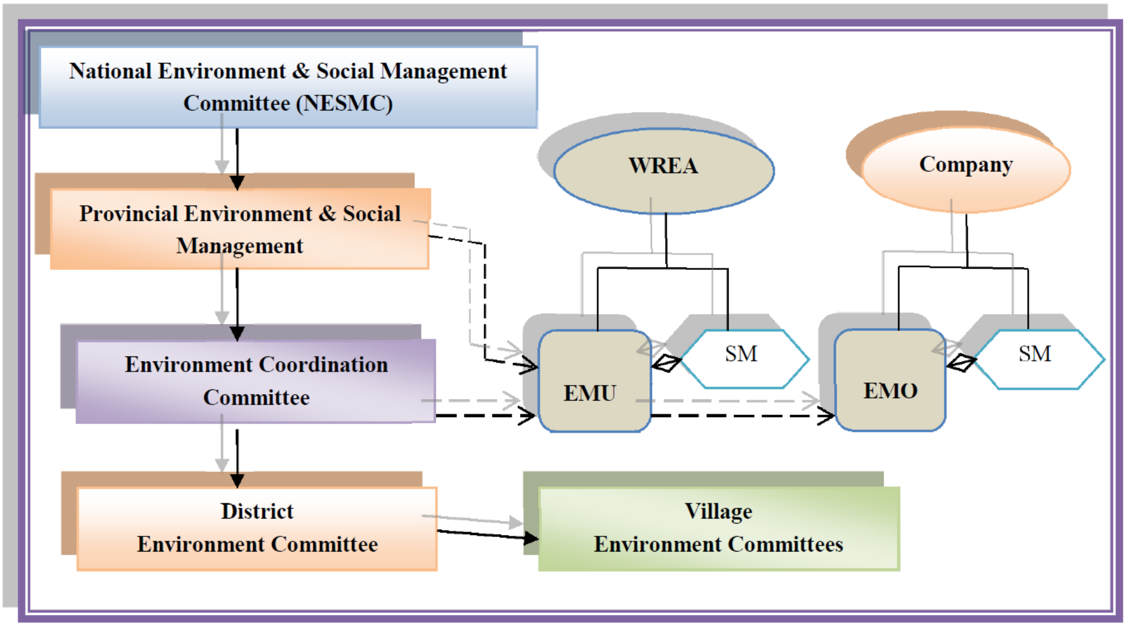
Social Consequence of Bio-physical Changes.

The SIA provides conclusion and recommendation in regards to macro social development issues, compensation issues, relocation and resettlement, livelihood and income restoration, impact equity, health impact assessment, education, culture and archaeology and benefit sharing.

The SIA identified 26 villages in three provinces of Oudomxay, Xayabury, and Bokeo in Lao PDR to be **directly impacted** by the project with the **total family of 923** or **population of 4,726**. Additionally, 151.5 ha of community land, and 176.2 of low-land paddy will be acquired on condition of compensation through land for **land or cash compensation** and/or a combination. Furthermore, Housing of **203 units** with associated structures such as rice storage and animal cages will be affected and require compensation or replacement. Some public structures such as primary schools and monastery temples will require reconstruction in the relocation/resettlement sites.

Social Management and Monitoring Plan

The report on Social Management and Monitoring Plan (SMMP) was developed from the Social Impact Assessment report. The overall objective of the SMMP is to improve the welfare of the people living in the project area who will be adversely affected by the proposed project. It aims to ensure that appropriate and sufficient mitigation measures as well as management plans are in place and taking into consideration of all anticipated or unforeseen impacts. The report describes the policy framework for the SMMP, identification of social impacts and analysis, compensation principles, institutional arrangement for the SMMP, consultation and grievance redress, SMMP implementation monitoring and evaluation, estimated budget for the SMMP, implementation schedule and reporting programme.



Institutional Arrangement for the Social Management and Monitoring Plan.

The total budget for SMMP is estimated at about **USD 10 million**. The SMMP cost covers two main programmes of (1) Social Management Plan (agricultural and forestry extension, fisheries programme, health and education programme, social development fund, archaeology and cultural heritage, and resettlement and compensation budget) and (2) Social Monitoring Plan (internal monitoring and independent monitoring).

Agricultural and forestry extension: Slash and burn is the only rice production system used in the area which is considered non-sustainable agriculture, and a forestry extension program will be introduced.

Fisheries programme: To compensate for the loss of fish, a fishery extension program will be introduced to the local people by building a fish pond or by some other related aquatic development, such as frog aquaculture, or some other enterprise which could be agreed upon with local villagers during consultation.

Health and education outreach programme: Health, nutrition, and education standards are inadequate in these remote areas and these are directly linked to the continuation of poverty in the area. The programme will include both the construction phase and some years of the project operation phase.

A **Social Development Fund** is proposed to help villagers with more a sustainable social programme. Provincial Environment and Social Management Committee supports local affected communities and provide direction in the use of funds for development in the area.

Archaeology and Culture Heritage programme will identify the sensitive sites and make a recommendation for the project to preserve them. Budget is allocated in the case of the ceremony cost for the cemetery, spirit and temple site.

Ethnic Group Development Plan

The Ethnic Group Development Plan (EGDP) is to ensure that the project adequately considers and addresses the concerns of indigenous people's groups in a culturally sensitive manner. It also aims to **avoid adverse impacts through fair and effective resettlement and/or compensation**. The methodology used includes: a literature review, a rapid rural appraisal, village consultation and field observation. The report contains an ethnic policy and institutional framework, existing condition of ethnic groups, ethnic impacts and mitigation/development activities, institutional arrangements, monitoring and evaluation, EGDP schedule, and suggestions on ethnic group development.

There are three main ethnic groups of the affected people in the project area including: Lao-Tai speaking group, Mon-Khmer speaking group, and Hmong-Eumien speaking group, which are collectively referred to as former Lao Soung. The majority of the residents in the project area is the Lao-Tai (accounting for 59%), followed by the Mon-Khmer (accounting for 34%) and the rest are the Hmong-Eumien.

Resettlement Action Plan

The resettlement action plan (RAP) aims to enhance the quality of life for people affected by the project; prevent and minimise adverse social impacts that may cause by resettlement or relocation: and mitigate possible social impacts by the compensation of land and assets and the re-establishment of infrastructure or supporting facilities including livelihood restoration.

The report explains: project features, policy framework relevant to resettlement, census and socio-economic survey results, housing, categories of affected people by type and degree of impacts, compensation entitlement criteria, economic rehabilitation, relocation scheme, resettlement scheme, livelihood development measures, public participation and grievance procedures, organization set-up, monitoring and supervision, and implementing schedule.

There are seven villages that will be directly affected by the Pak Beng Hydropower Project. One of these villages namely Luangtong (with 68 families or 292 inhabitants), will be severely impacted and required to move to the new selected land settlement area. The other six villages (140 families or 789 inhabitants) will be partially submerged and required relocation by shifting houses to higher ground to keep them safe from the risk of flooding and bank erosion.

Recommendations were made on employment, an implementation schedule and key milestones, appropriate budget for compensation costs of resettlement, the quality of production land, benefit sharing and equity issues and micro financing.

Environmental Management and Monitoring Plan

Three main objectives of the Environmental Management and Monitoring Plan (EMMP) are (1) to restore the environmental conditions of the affected environmental resources/values to be the same as or improved upon as compared to their previous conditions; (2) to ensure effective implementation of mitigation, management and monitoring measures during the construction and operation of the project; and (3) to integrate the EMMP of the Pak Beng Hydropower Project into the Lao government's environmental management policy, particularly those of watershed management, poverty reduction and environmental sustainability.

Environmental flow assessment and studies were suggested to conduct based on the agreement between the developer and provincial authorities in consultation with local communities who are dependent upon the river to support the implementation of mitigation measures of the environmental impacts during construction (including pre- and first two years) and operation phases. Findings of these assessment and studies would be expected to be useful to develop **hydrological models for filling the reservoir** and **appropriate flow regimes**

necessary to maintain the health of the river. Additionally, the report highlighted that a **fisheries research station** and a **fish transport mobile unit,** with a large container and an aeration system, were suggested to establish during construction phase. Furthermore, this report proposed to establish a viable population **of the fisheries resources** upstream of the dam. The detailed planning of resettlement and implementation of watershed management plans were also presented. The work schedule of Environmental Management and Monitoring Plan and specific environmental monitoring activities are described in the report.

Environmental Impact Assessment

Objectives of the Environmental Impact Assessment (EIA) are to (1) examine the existing information on the proposed project; (2) identify and review existing environmental and social information related to the potential effects of the project; (3) identify and outline the existing national and international legal framework and guidelines related to the project and its environmental and social impacts; (4) identify information gaps and an appropriate study area; (5) acquire additional project information and conduct baseline field studies to fill data gaps; (6) report the existing environmental and social context in the project area; (7) assess the significance of project-related, physical, biological, and social issues; (8) identify additional mitigation measures not included in the project design; and (9) prepare an environmental and social mitigation and monitoring plan.

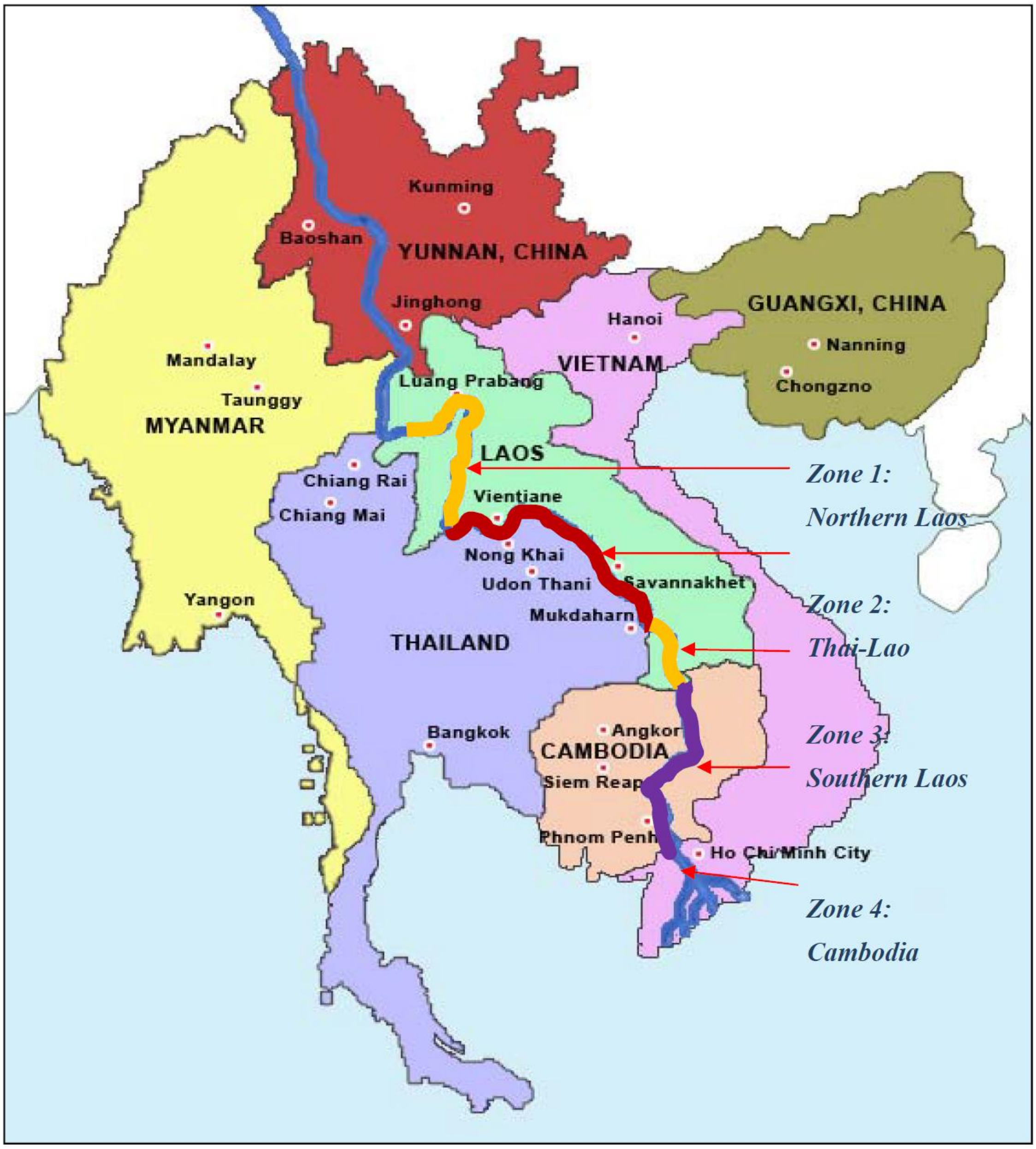
The report also provides the details of the impact area and potential environmental and social impacts, the assessment methodology, results of the assessment and general recommendations for each environmental aspect.

Public involvement in the EIA process was described. The key stakeholder groups were identified and the results of consultation with provincial and district authorities, the villages and local communities and other stakeholders was also presented in the report.

Seven key priority significant impacts were described from the Project's activities during both construction and operation phases, as follows: resettlement and relocation; hydrology and sediment; fishery; country economy (foreign direct investment, employment and income and agricultural output); benefit sharing, cumulative impact and trans-boundary impact. The report provided **recommendations for mitigation and enhancement** including monitoring and management of the seven key impacts. The formulation of an Environmental Management and Monitoring Plan (EMMP), with the participation of discipline experts, was also recommended.

Transboundary Environmental and Social Impact Assessment and Cumulative Impact Assessment

The overall purpose of the proposed Transboundary Environmental and Social Impact Assessment and Cumulative Impact Assessment was to provide decision makers with timely information on the potential transboundary, and cumulative environmental and social consequences, of the proposed project. The report includes key biophysical and social conditions (before the project), hydrology and sediment changes (after the project), transboundary and cumulative impacts, and mitigation and management interventions. The assessment considered both the context and intensity factors, and was conducted in 5 different zones along the Mekong mainstream. The assessment indicates that Pak Beng Hydropower Project:



Identification of transboundary impacted zones of the Pak Beng Hydropower Project (not to scale).

- Would likely be responsible for **transboundary sediment**, **morphology** and **nutrient impacts** leading to environmental impacts;
- Would **impact the fish population** and **various aquatic organisms** due to the change of water level and river flows, especially in downstream section, leading to a decline in biodiversity and abundance of fish species and aquatic organisms. However, the impact level cannot be distinctly assessed since the data of fish migration is not sufficiently available. In addition, the report indicated that the Mekong giant catfish (*Pangasianodon gigas*) is likely to be seriously and negatively impacted by the Pak Beng Hydropower Project and other downstream hydropower projects (e.g. Xayaburi and Don Sahong) eventually or possibly leading to extinction.
- Might also **decrease the water quantity in rapids and deep pools** to a level that is not

adequate for fish and other aquatic organisms to survive during the dry season (December-beginning of April).

- Would **not create significant transboundary and cumulative impacts on flows** of the Mekong River, **fish migration**, or **fisheries**.
- Would enhance the capability of **transhipping in upstream** due to the increase of water levels upstream in the dry season and insignificantly impact on navigation in downstream due to the navigation route from Vientiane to Viet Nam is separated by Khone Falls;
- Would **decrease** the country (Lao PDR) **production land for rice** and **food crops** that may consequence to the country food supply due to bio-physical changes of land use from river-bank farming area into water inundation area;
- May affect water quality due to **erosion/sedimentation**, **solid waste**, **wastewater** discharge, degradation of **biomass residue**, **agriculture** and **aquaculture**, navigation, and oil spills; and
- Would **not create significant impacts** on the **climate change**.

All impacts mentioned can be mitigated by monitoring, management, and engineering measures.

Design Report of Fish Passage Facilities

The fisheries data was collected through both secondary and primary data collection. The field survey – focused on fish, plankton, benthic invertebrate and aquatic plants – was done in both wet and dry seasons at six sampling sites. Based on the survey result, **fifty-four species belonging to 14 families** were found in the samples collected from the six sites during the wet and dry seasons. Sixteen fish species were found at the Pak Beng morning market and they were caught in Mekong River. Of which, one species caught from the Beng River was *Pa Mood* (*Gyrinocheilus aymonier*). During the dry season, there were very few fishermen along the Mekong River at Pak Beng town. Fishing in the area is only a part time job. Fishing areas were at rapid and riffle areas (Keng Lae and Ban Luang Tong), and at the confluence with the Mekong River (Ban Pakbang, Houay Kan). Also, the fishermen mainly use floating gill nets (for Cyprinids), hooks (for catfishes), nylon bag-nets, and nylon and scoop-nets as well as the illegal electrocution. The report stated that there is **no current management and protection programmes for fisheries resources in this area**. Fishermen reported that **fish catches and average sizes are declining**. The construction of a dam on a river can block or delay upstream fish migration and thus contribute to the decline and even the extinction of some species that depend on longitudinal movement along the stream continuum during certain phases of their life cycle. To maintain the diversity of aquatic organisms and the resources in the Mekong River, the report suggested that it is necessary to **comprehensively and systematically study the fish passage facilities and to compare and to select the suitable fish passage schemes** (e.g. vertical-slot fish passage, bypass the fish passage, fish lock, fish hoister, and fish collection and transport system). For fish passage design, the report mentioned that the fish passage object is not applicable to the biggest individual, because the fish passage is not designed to allow all fish to pass, but to ensure most existing individuals of sexual maturity (e.g. 50-60 cm in length) to pass, to address issues of reproduction. Also, about 3.5 ton of fish were considered to be able to annually pass through the proposed fish passage.

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

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