

Technical Description Nam Ngum 3 Hydropower Project

I. INTRODUCTION

1. **Overall situation.** The Nam Ngum 3 Hydropower Project (NN3) will be located on the Nam Ngum (or Ngum River) in Vientiane and Xieng Khouang Provinces of Lao PDR, upstream of the 151 MW Nam Ngum 1 (NN1) and 615 MW Nam Ngum 2 (NN2) hydropower plants, both of which are operational, downstream of the 120 MW Nam Ngum 5 (NN5, under construction), and downstream of Nam Ngum 4 (NN4, in the planning phase). The Project is 130 km north of Vientiane, about 4.5 km upstream of the confluence of the Nam Ngum with the Nam Pha.

2. **Schedule of construction.** Main construction activities of NN3 are scheduled to start in October 2011. The NN3 reservoir is planned to be filled during the rainy season of 2016. Electricity will be generated from August 2016, and commercially as from Commercial Operation Date (COD) in January 2017 for a concession period of 27 years.

3. **Project history.** The Government of Lao PDR (GOL) has signed several memoranda of understanding (MOU) with the government of Thailand in several occasions for the export of electric power from Lao PDR to Thailand: (i) on 4 June 1993 for development of 1,500 MW; (ii) 19 June 1996 for development of 3,000 MW of hydropower by 2006; (iii) on 18 December 2006 for development of 5,000 MW by 2015; and (iv) in 22 December 2007 for development of 7,000 MW within Lao PDR by 2020. The GOL incorporated the NN3 in the development plan to supply the Thai Grid in accordance with the 22 December 2007 MOU.

4. The Project was identified by the Mekong Secretariat in the 1970s. The Project vehicle was chosen through the MOU process adopted by GOL for its IPP development. This was the same process as for the Nam Theun 2 for which ADB provided financial assistance in 2005. GOL granted MDX Public Company Limited (MDX) of Thailand the right to develop the NN3 site under an MOU signed with GOL on 16 March 1994. The MOU provided the exclusive cooperation between MDX and GOL regarding (i) the formation of a limited liability company for the purpose of planning, designing, constructing, operating and implementation of NN3. In 1997, MDX Lao Company Limited (a successor to MDX) then entered into a project development agreement (PDA) with GOL on 15 November 1997, which superseded the 1994 MOU. MDX Lao later changed name to GMS Lao. The PDA has been regularly renewed and extended. It will be superseded by the Concession Agreement to be signed before the signing of the Power Purchase Agreement and the financing agreements.

5. In anticipation of the establishment and registration of the Nam Ngum 3 Power Company in Lao PDR for the purposes of investing, designing, building, commissioning and operating the Project, GMS Lao; Ratchaburi Electricity Generating Holding Public Company Limited of Thailand; Marubeni Corporation of Japan; and the Lao Holding State Enterprise (LHSE), an agency designated to be the Shareholder on behalf of the Government, executed a shareholders' agreement dated 13 May 2008 and articles of association in accordance with the requirements of the PDA to govern the management and activities of the Company and the implementation of the Project. Thereafter, GMS Lao, Ratchaburi Electricity Generating Public Holding Company Limited, Marubeni Corporation and the LHSE registered and established the Company. On 13 December 2010, the Shareholders re-executed and the Company executed the shareholders agreement first executed on 13 May 2008.

6. The feasibility study, including environmental studies, was finalized in 1995 by Snowy Mountains Engineering Corporation Limited of Australia and Southeast Asia Technology Company Limited of Thailand. Resource Management and Research of the United Kingdom was engaged in 1998 to carry out an impact analysis to provide the Developer with detailed social action and environmental management plans. These documents were used as a basis for two rounds of public workshops in 2002 and resulted in environmental approval by the Science, Technology and Environment Agency (STEA) allowing the Developer to start construction. However the Southeast Asia financial crisis interrupted the development until 2006. By that time, the environmental and social baseline situation had changed and required an update of the environmental and social documentation, which was undertaken from 2007 to 2009 by EcoLao of Lao PDR and Norplan of Norway.

II. ENVIRONMENTAL BACKGROUND

7. **Climate.** Lao PDR has a tropical monsoon climate. At elevations of the NN3 reservoir area three main seasons prevail. The rainy season lasts from May to October. From November to February it is cool and dry and from March to April it is hot and dry. The southwest monsoon arrives in Laos between May and July and lasts into October. The mean annual rainfall in the NN3 catchment varies from about 1,200 mm in the northeast of the catchment to about 2,700 mm at the dam site. High daily rainfall occurs generally during the months of September and October when typhoons from the South China Sea hit the coast at Vietnam and peter out in Lao PDR.

8. **Topography.** The NN3 catchment area consists of deeply incised valleys and step-sided ridges. The altitudes vary between 280 meters above seal level (masl) and 1,500 masl. The main channel of the Nam Ngum drains the northern part of the catchment, flowing in a south-westerly direction to the confluence with the Nam Ting. The NN5 hydropower dam is under construction in the Nam Ting. Downstream of the confluence with the Nam Ting, the Nam Ngum flows in southern direction to the dam site. Downstream of the dam site, the river continues through mountainous terrain with no settlements before it reaches the NN2 reservoir.

9. **Geology and Soil.** The project is located in an area dominated by sediment rocks of Jurassic-Cretaceous age to the west of the reservoir. In the east, the geology is dominated by Devonian, Carboniferous and Silurian rocks. Mining concessions have been granted at both sides of the Nam Ngum draining into the lower and the mid part of NN3 reservoir, including the large Phou Bia mining concession area.

10. The Developer has carried out extensive geological investigation. In addition to giving a general idea of the project area geological characteristics, the investigations confirmed that leakages are unlikely to occur from the reservoir, that the reservoir slope stability is not a cause of concern, and that the Project is located in an area of low to moderate seismicity. The Lenders' Technical, Environmental and Social Advisors (LTESA) agreed with the conclusion in the feasibility study that no effect in the project area in excess of the Maximum Credible Earthquake (MCE) amplitude is expected because of reservoir induced earthquake (RIS) event of the size equivalent of the largest RIS earthquake so far recorded world wide (M=6.5). A RIS earthquake of this or smaller size at NN3 reservoir is considered more likely than MCE. The dam is designed to withstand an MCE.

11. **Hydrology.** The Nam Ngum discharges depend on the pronounced differences in rainfall during the wet and dry seasons. High discharges occur towards the end of the wet season with

the highest daily rainfalls. Low Nam Ngum discharges occur at the end of the dry season. Average monthly inflow to the Nam Ngum reservoir range from 22.4 m³/s (April) to 286.9 m³/s. (August). Based on 35 years of records (1972-2006), the average flow at the dam site is 96.5 m³/s.

12. The choice to design the spillway for NN3 for the 10,000-year flood for n-1 gates (i.e. two gates in operation), as the design flood, and to apply the probable maximum flood (PMF) as the safety check flood for concrete-faced rockfill dams follows international accepted standard. The adopted 10,000-year flood magnitude is 6,320 m³/s and the PMF is 12,100 m³/s.

13. **Sedimentation.** The rate of sediment transport of the Nam Ngum allows for a lifetime of the NN3 reservoir of at least 70 years. When the NN5 and NN4 hydropower projects are operational, the sediment inflow to the NN3 reservoir will be significantly reduced, causing an increase of the lifetime of the reservoir.

14. **Water Quality.** In general the water quality in the Nam Ngum is very good, with a low content of nutrients, indicating oligotrophic conditions. In the rainy season the quality declines as a result of sediment loads increasing turbidity. Nitrate and phosphate concentrations are low throughout the year. The iron content and the concentrations of coliform bacteria indicate that seasonally the Nam Ngum water quality does not meet the water quality standards for drinking water.

15. **Unexploded Ordinance (UXOs).** The main project construction sites (dam and power station) are considered to have a relatively low risk of UXOs. It is however a serious concern at other locations, in particular in project impacted villages that used to have an airstrip during the 1970s, such as at the villages of Long Cheng, Ban Xiengdet, Nam Sam, and Xam Thong.

III. DESCRIPTION OF THE PROJECT

16. **Design and Location Alternatives.** The present dam site and power station location were confirmed in the original Feasibility Study on the basis of technical, financial, and economic considerations for electricity generation and subsequent export to Thailand. Subsequent detailed design ensured that basic safety standards for high hazard dams were applied to guarantee that no uncontrolled release of water will take place by: (i) enabling the passage of the maximum probable flood, and (ii) ensuring that the structure can withstand loads applied for the maximum credible earthquake. Initially, the consultants had recommended a roller-compacted concrete (RCC) dam, but in 2009 it was decided that bids would be asked for both RCC and concrete-faced rockfill (CFR) dams. Bids for CFR dams came in at lower costs.

17. **Dam and Reservoir.** NN3PC will build a 220 m high CFR dam located in the Nam Ngum about 10 km due west of Ban Long Cheng. The dam will be one of the highest of its type in the world, and the highest in Lao PDR.

18. To allow for the construction of the dam without overtopping during the rainy season the contractor will construct two cofferdams, and one diversion tunnel. The upstream cofferdam will be built to withstand a 500-year flood in combination with the diversion tunnel. The horse-shoe shaped diversion tunnel will have an internal diameter of 11.6 m and a flat bottom. The LTESA have provided various design recommendations for the detail design and construction of the diversion tunnel in view of the very high water velocities that are expected in the event of extreme floods.

19. The foundation of the dam will require excavation of about 1.7 million m³ of soil and 0.12 million m³ of rock. The depth of excavation will vary, but generally between 5 m and 10 m. The total volume of the rockfill dam will be about 13.2 million m³. NN3PC has identified several quarries, and the contractor will decide which ones to use.

20. The LTESA have endorsed the layout and design of the chosen dam type, which follow recent practice and trends for this type of dam. The LTESA considers the proposed dam to be safe if built in accordance with the tender drawings and technical specification.

21. The spillway is located on the left slope of the valley, directly aside of the dam. The spillway consists of a crest structure with three radial gates, a 327 m long chute, a flip-bucket structure and a pre-excavated plunge pool. The LTESA deems the spillway layout and the design of the structure as satisfactory. Due to the very steep cuts, there will be a special need monitor the excavated slopes against deformation and slippage. The geological conditions along the spillway structure can vary, and additional investigations will be required for the detail design.

22. The NN3 catchment is 3,769 km² at the dam site. NN3 reservoir will be narrow, long and deep. The reservoir storage capacity will be 1,407 million m³ at Full Supply Level (FSL, 723 masl) and its active storage, 1,070 million m³. At this level the total surface area of the reservoir will be 27.1 km². The Minimum Operation Level (MOL) will be at 660 masl at which level the reservoir will cover an area of 9.4 km². The total length of the reservoir at FSL will be about 55 km. The FSL is about 14 m below the NN5 power plant tail water, which discharges into the NN3 reservoir.

23. Reservoir will normally fill in three months during the rainy season and the average water retention is 4.2 months. Filling of the reservoir is scheduled to commence on 15 April 2016 when the diversion tunnel will be closed. By July, the reservoir level will be sufficient to fill the waterways and start testing the generating equipment. By 1 January 2017, the reservoir level should have reached FSL.

24. **Waterways.** Water will be withdrawn from the reservoir hypolimnion.¹ The invert level of the reservoir water off take is 645 masl. Water from the reservoir intake will be channelled through a 10.6 km headrace tunnel to the power station, from where it will be returned to the Nam Ngum. Each year, from August to October spills over the dam will occur.

25. The power intake is located on the right hand side of the river about 400 m upstream of the dam crest. The power intake is a concrete structure with a bell mouth opening 6.0 x 7.5 m. The design flow for the intake is 165 m³/s. There will be a trash rack at the entrance of the intake. The steepness of the valley side means that special precautions will need to be taken during construction to avoid landslides. The LTESA finds the design appropriate.

26. The 10.6 km long headrace tunnel will have slight slope from upstream to downstream. It will operate under a pressure of up to about 140 m. There will be three adits for construction: at the intake, about half way and at the location of the surge shaft. Both Drill and Blast Method (DBM) and tunnel Boring Machine (TBM) were considered during design. Due to the lack of detailed geological knowledge along the whole length of the tunnel, it was decided to use DBM.

¹ The hypolimnion is the dense, bottom layer of water in thermally-stratified reservoirs. It is the layer that lies below the thermocline.

Should a TBM get stuck, it could cause severe construction delays, especially in a remote location like NN3. The tunnel will be concrete-lined and the design of the lining will depend on the characteristics of the rock as excavation proceeds.

27. The surge shaft at the end of the headrace tunnel will dampen the pressure variations in the power waterways. It will have an internal diameter of 14 m, and an orifice with a diameter of 2.9 m.

28. The vertical high-pressure shaft connecting the headrace tunnel with the penstock will be 213 m high with a diameter of 7.5 m.

29. The 192 m long penstock connecting the pressure shaft to the power plant will be steel-lined with a diameter of 5.6 m. As it enters the power cavern it will be split into a bifurcation with a diameter of 3.2 m.

30. **Power Station.** An underground power station will be sited on the right bank of the Nam Ngum 15.5 km downstream of the dam along the river. The power station will have two vertical axis Francis generating units with a rated installed capacity of 220 MW each. The average annual energy production is estimated to be 2,114 GWh. The cavern housing the power generating facilities will be 26 m wide, 95 m long and 48 m high. It will be accessed along a 725 m long access tunnel. In addition, a second cavern 20.5 m wide, 70 m long and 13.5 m high will house the transformers. The 500 kV power cables will be conveyed to a surface switchyard along a 328 m long cable tunnel.

31. While the rated capacity is 440 MW, the power plant maximum output will depend on the reservoir surface level, and will vary between 357.4 MW at MOL and 464 MW at FSL. Minimum safe operation will be 179 MW with one unit.

32. Before discharging into the river, the water will be conveyed through a 14.5 x 46.5 x 39.0 m downstream surge arrangement, and a 909 m long concrete-lined circular tailrace tunnel. The elevation of the tailrace is about 8 m above NN2's FSL.

33. **Transmission Line.** A 99 km long, 500 kV double-circuit transmission line, will connect the 120 m x 170 m switchyard close to the power station to the Nabong substation. For a large part of its alignment, the NN3 transmission line will run in parallel with the NN2 transmission line as it crosses the Phou Khao Khouay National park. At Nabong substation the power from initially NN3 and NN2 (and later, other hydropower plants in the central region of Laos) will be evacuated to Thailand along an existing 27 km long 500 kV double circuit transmission line.

34. **Construction.** The Project may be considered a large undertaking. NN3PC intends to award three main construction contracts. The general topographical features of the Project Area, and along the Nam Ngum, are steep terrain and absence of flat land in the vicinity of the river; the river stretch involved is relatively steep. This can be favourable for facilitating a high-head power development, but is challenging with respect to access to construction sites, establishing work areas, provision of suitable temporary roads for construction works, and transportation of large and heavy equipment. Bids have been received for these contracts already and negotiations are on-going for the civil works contract and the electro-mechanical equipment contract. The transmission line contract will be awarded later. About 3,000 to 4,000 workers will be engaged in construction work over five years. There will be two workers' camps: close to the dam site and one close to the power station site.

35. **Operation.** The COD is presently planned on 1 January 2017. The power station will operate on a daily basis in an intermittent mode. The exact production mode will depend on the actual availability of water in NN3 reservoir and dispatches by EGAT.

36. NN3PC is however, under the Power Purchase Agreement with EGAT obliged to declare and make available guaranteed monthly and annual primary energy. From Monday through Saturday, NN3 must provide a guaranteed monthly minimum of 8 hours per day and maximum of 16 hours per day of primary energy. For secondary energy the monthly maximum is 5.35 hours per day. On Sundays, the monthly maximum is 21.35 hours/day. Primary and Secondary Energy have different tariffs. The annual supply target is 1,929 GWh/year of Primary Energy and 151 GWh/year of Secondary Energy. For excess energy over and above Primary and Secondary Energy will be declared, but EGAT has no obligation to dispatch.