No.

Ministry of Energy and Mines
Electricite du Laos
EDL-Generation Public Company
Lao People's Democratic Republic

LAO PEOPLE'S DEMOCRATIC REPUBLIC
PREPARATORY SURVEY ON
NAM NGUM 1 HYDROPOWER STATION EXPANSION (PHASE 2) IN
LAO PEOPLE'S DEMOCRATIC REPUBLIC

FINAL REPORT

OCTOBER 2012

JAPAN INTERNATIONAL COOPERATION AGENCY

NIPPON KOEI CO., LTD.
ELECTRIC POWER DEVELOPMENT CO., LTD.

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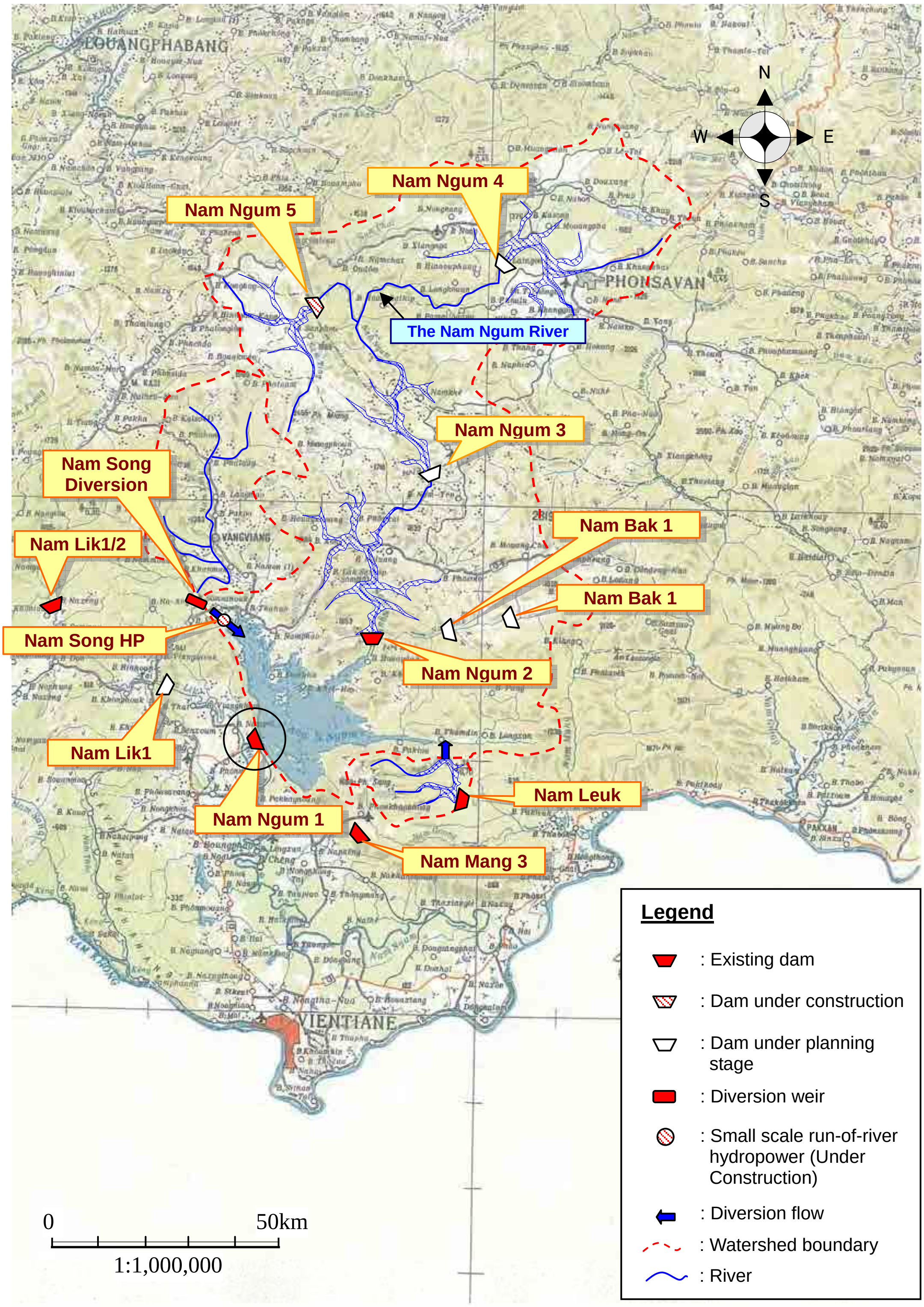

Location Map of the Project Area

PREPARATORY SURVEY ON NAM NGUM 1
HYDROPOWER STATION EXPANSION IN LAO PDR (PHASE 2)
INTERIM REPORT

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Terms

Abbreviations	English
Lao PDR agencies	**Lao PDR Agencies**
DMH	Department of Meteorology and Hydrology
CDEP	Committee for Development of Electric Power
CPC	Committee for Planning and Cooperation
DEB	Department of Energy Business, MEM
DEPP	Department of Energy Policy and Planning, MEM
DEM	Department of Energy Management, MEM
DOE	Former Department of Electricity, MEM
EDL	Electricite du Laos
EDL-Gen	EDL-Generation Public Company
FIMC	Foreign Investment Management Committee
GOL	Government of Lao PDR
LNCE	Lao National Committee for Energy
LWU	Lao Women's Union
MEM	Ministry of Energy & Mines
MONRE	Ministry of Natural Resources and Environment
STEA	Science, Technology & Environment Agency
WREA	Water Resources and Environment Agency
Foreign organizations	**Foreign Organizations**
ADB	Asian Development Bank
EGAT	Electricity Generation Authority of Thailand
EVN	Electricity of Vietnam
IMF	International Monetary Fund
IUCN	World Conservation Union (Switzerland)
JICA	Japan International Cooperation Agency (Japan)
MOI	Ministry of Industry of Vietnam
MPI	Ministry of Planning and Investment of Vietnam
NEPO	National Energy Policy Office of Thailand
NTEC	Nam Theun 2(NT2) Electricity Company
NTPC	Nam Theun 2(NT2) Power Company
PEA	Provincial Electricity Authority in Thailand
PRGF	Poverty Reduction and Growth Fund
UNDP	United Nations Development Program
WCD	World Commission on Dams
Others	**Others**
AAU	Assigned Amount Unit
B.	"Ban" Village in Laotian language
BOT	Built-Operate-Transfer
CA	Concession Agreement
CDM	Clean Development Mecah
CER	Certified Emission reduction
COD	Commercial Operation Date
ECA	Export Credit Agencies
EIA	Environmental Impact Assessment
EMMP	Environmental Management & Monitoring Plan
EPC	Engineering, Procurement and Construction
EPMs	Environmental Protection Measures
ERU	Emission Reduction Unit
ET	Emission Trading
FS	Feasibility Study
FARD	Focal Area for Rural Development
GHG	Green House Gas
GIS	Geographic Information System
GMS	Greater Mekong Sub-region
GPS	Global Positioning System
HEPP	Hydroelectric Power Project
ICB	International Competitive Bidding
IEE	Initial Environmental Examination
IPDP	Indigenous Peoples Development Plan
IPP	Independent Power Producer
IWRM	Integrated Water Resources Management
JI	Joint Implementation
LA	Loan Agreement
LEPTS	Lao Electric Power Technical Standard
LLDC	Least Less-Developed Countries
MOU	Memorandum of Understanding

Terms

Abbreviations	English
NBCA	National Biodiversity Conservation Area
NEM	New Economic Mechanism
NGOs	Non Governmental Organizations
NNRB	Nam Ngum River Basin
O&M	Operation and Maintenance
ODA	Official Development Assistance
PDA	Project Development Agreement
PDP	Power Development Plan
PPA	Power Purchase Agreement
S/W	Scope of Works
SIA	Social Impact Assessment
SPC	Special Purpose Company
SPP	Small Power Producer
TOR	Terms of Reference
Unit/Technical Terms	**Unit/Technical Terms**
B-C, B/C	B: Benefit and C: Cost
EIRR, FIRR	Economic/Financial Internal Rate of Return
EL.( ) m	Meters above Sea level
FSL.	Full Supply Level of Reservoir
GDP	Gross Domestic Product
GWh	Giga Watt Hour (one billion watt hour)
IRR	Internal Rates of Return
LWL	Low Water Level of Reservoir
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MCM	Million Cubic Meter
MOL.	Minimum Operation Level of Reservoir
MW	Mega Watt (one million watt)
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
US$	US Dollar

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

Current Status of Power Supply

In Lao PDR, the domestic power load and energy demand during year 2001 to year 2010 is rapidly increased for 13.4% and 15.0%, respectively. This increase in electricity demand is mainly due to the increase in electrification rate of the household which is lead by the Lao government's electrification policy. Other factors such as construction of speed railway and mining development of copper or Bauxite is also driven force to increases total electricity demand. This trend in electricity demand is expected to be continued.

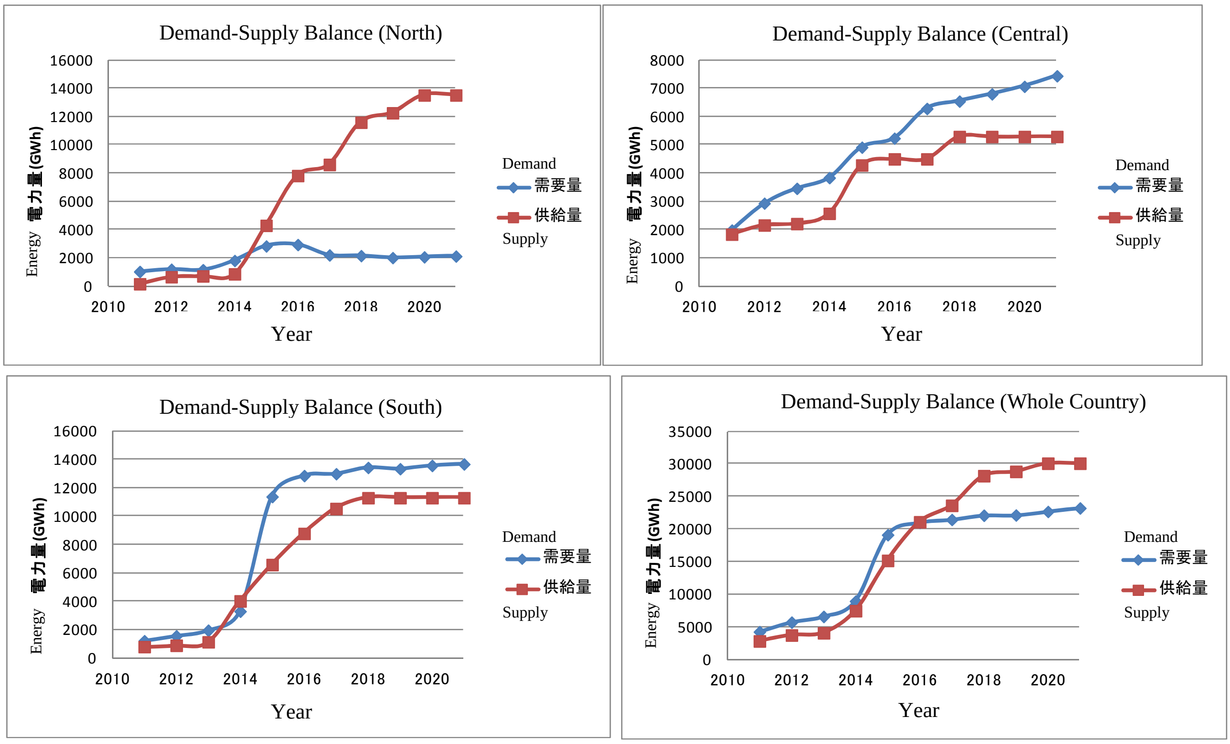
In the year 2010, the total installed capacity of powerplant with IPP projects in Lao PDR is accumulated to 2,557MW, and the installed capacity for domestic supply is 492MW. Within this installed capacity for domestic power supply, the installed capacity of Nam Ngum 1 hydropower station is 155MW and it shares 31.5% of the total capacity for domestic power supply. As most of domestic power supply facilities in Lao PDR are hydropower stations, power supply capacity against domestic demand drastically decreases during dry seasons due to less river flow, and this situation forces power import from neighboring countries.

The power export to the neighboring counties is one of the method to earn foreign exchange for Lao PDR. The power export and import balance, which excludes IPPs' power production, was positive until year 2005. However, due to increase in domestic power demand, the power import exceeded power export. In 2001, the import and export electricity energy were 183 GWh and 797 GWh respectively. In 2010, the import and export electricity energy became 796 GWh and 344 GWh, respectively. The unit price of import power is set to higher than that of export power and this induces in deficit in power exchange for the financial aspect. Therefore, it is necessary to develop new power plant to earn foreign exchange, and to extend the transmission line in the country to cover the domestic power demand.

Electric Power Policy and Hydropower Development Plan

In August 2010, Power Development Plan (PDP 2010: objective year from 2010 to 2020) was formulated to achieve the target to secure the social development through power supply and earn foreign exchange by the power export. After the formulation of the PDP, the changes in power demand forecast was recognized, and the PDP 2010 has been updated as Revision-1 (PDP 2010-R1) in August 2011 by the study among the relevant authorities. The revision of the demand forecast was made to electricity demand of the speed railway construction and operation, and mining development in southern area in the country.

PDP 2010-R1 estimated power supply and demand balance in Northern area, Central area, and Sothern area. In Northern area, the power demand for peak load and energy exceeds the power supply capacity until 2014, and the power supply is expected to exceed the power demand after 2015. The deficit in power supply until year 2014 is planned to be supplied by power import from China. The excess in power supply and demand balance after year 2015 is planned to be delivered to Central area. In Central area, the power demand for peak load and energy is not fulfilled until 2020. The deficit in power supply is to be covered by power import from Northern area, or import from EGAT. In Sothern area, the power demand is anticipated to exceed power supply due to mining development. Therefore it is necessary to import power to Sothern area to cover the power supply deficit.



Source：EDL　PDP 2010-2020 (Revision -1)

Figure 1.1.1　Power Supply and Demand Balance in Northern Area, Central Area, Southern Area and Whole Country

The power supply and demand balance in whole country of Lao PDR is expected to be negative until 2015, i.e. power demand exceeds power supply, and is necessity of import power from China, Vietnam and Thailand. Meanwhile, export of surplus energy is expected from 2016.

The PDP 2010-R1 describes that the power development potential exists in Northern area and large bulk demand exists in Sothern area for mining development. The PDP 2010-R1 describes the power supply plans as the counter measure to resolve demand and supply imbalance as follows.

1) The energy surplus in Northern area will be delivered to Central area
2) The imports power from Northern area passes through Central area is necessary.

If the above power supply plan is implemented, domestic power demand in whole country of Lao PDR will be covered by the domestic power supply after year 2016. This requires the timely reinforcement of the power system/grid of Northern area, Central area and Sothern area.

EDL also formulates the power development policy to secure the power supply capability to cover the power demand. The policy of EDL is as follows.

- EDL will put an investment on some new power plants,
- Purchase from Small Power Producers (SPP) and Domestic Independent Power producer, IPP(d) projects,
- Purchase from off-take from IPP(e) projects,
- Continue to imports power from neighboring counties to the area where no network accessed and,
- Continue to exchange (import/export) power from neighboring counties to increase reliability and security of power supply.

Past Studies on Nam Ngum 1 Hydropower Station Expansion

JICA conducted "Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion in Lao PDR" from January 2009 until January 2010. After this, relevant studies have been conducted as seen in below.

Name	Period	Purpose
Preparatory Survey on Nam Ngum 1Hydropower Station Expansion	January 2009～ January 2010	Preparatory survey for expansion of Nam Ngum 1 hydropower station to examine viability of expansion from technical, environmental and economic/financial aspects
Assistance to Reservoir Operation for the Nam Ngum 1 Hydropower Station	March 2010～ October 2010	Examination of reservoir operation for Nam Ngum 1 for the case during impounding of Nam Ngum 2which is located upstream, and after completion of Nam Ngum 2, and examination of environmental impact to downstream reach
Study on Power Supply and Demand in Central Region	May 2012～ July 2012	Review of power demand and supply for central area of Laos, and examination of optimum countermeasure to cope with peak load demand including a option of Nam Ngum 1expansion
Preparatory Survey on Nam Ngum 1Hydropower Station Expansion (Phase 2)	**July 2012～ October 2012**	**Preparatory survey required for appraisal of Nam Ngum 1 hydropower station expansion to be implemented as yen loan project**

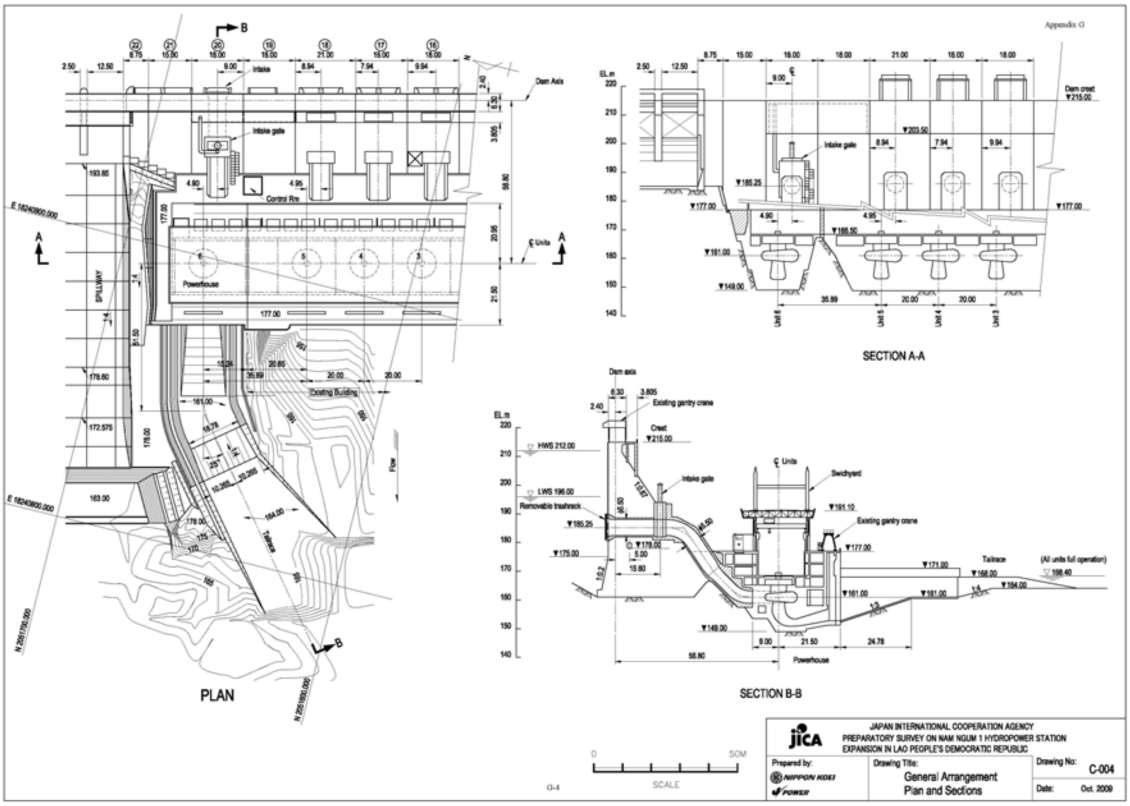
Review of Nam Ngum 1 Hydropower Expansion Plan

Nam Ngum 1 Hydropower Station

The power demand in Central and Northern area is met by coordinated operation between the Nam Ngum 1 (NN1) Hydropower Station (155 MW), Nam Leuk Hydropower Station (60 MW), Nam Mang 3 Hydropower Station (40 MW), and Nam Lik 1/2 Hydropower Station (100 MW) which commenced its operation in year 2010. In rainy season, the power supply capability exceeds the power demand of Central and Northern area and surplus of power supply is exported to Thailand. On the other hand, the total power output of the four power stations falls below the daily load in peak hours in the dry season due to less inflow into the each reservoir. In this case, the power shortage is supplemented with power import from Thailand.

In this circumstance, the Nam Ngum 1 hydropower station was studied in “Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion in Lao PDR” and its final report was submitted in January 2010. The purpose of the expansion is to increase the power output in peak hours from 18:00 to 22:00 by allocating reservoir water from off-peak hour, and to meet the increased power demand. The study results showed that the expansion of power plant enables to decrease the power import from Thailand during peak hours, and to increase the annual energy by utilizing the void release in flooding. The study considers the inflow regime changes due to the storage effect of the Nam Ngum 2 hydropower which aims to export power to Thailand.

As the result of comparative study for scale (40MW~120MW) and layout for waterway and powerhouse, the optimum expansion scale was selected to 40 MW. 40MW was selected for advantage in economic and financial index which is induced by the reasons; i) limited available water for power generation, and ii) maximization of usage of existing powerhouse facilities. The project was feasible with respect to the economic aspect with EIRR, but its FIRR was low. This low FIRR indicated that the project would be financially feasible only with low interest soft loan. EDL did not give any concrete decision on the project, and ODA yen loan was not available to Lao PDR at the preparatory survey stage, therefore, request of ODA yen loan was not made by Lao government at that time.



Source：Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion

Figure 1.1.2 Proposed Layout of NN1 Expansion Plan (40MW)

In March 2012, yen loan project resumed in Laos after two years passed following completion of "Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion". In April 2012, the government of Laos submitted request letter of yen loan for Nam Ngum 1 hydropower station expansion. Upon this request, JICA conducts "Study on Power Supply and Demand in Central Region" so as to identify issues to cope with peak power demand in Central Region and to examine countermeasure including Nam Ngum 1 hydropower station expansion. Final Report of the study will be submitted in August 2012.

Changes of external factors are recognized during the two years after completion of "Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion", such as power demand forecast, power development plan, transmission line extension plan, tariff of electricity, condition of power trade with EGAT, and interest of yen loan. It is also necessary to check daily peak load curve. Re-assessment of the expansion project based on the latest information is required.

JICA determined to conduct "Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion (Phase 2)" to obtain necessary information for appraisal of Nam Ngum 1 hydropower station expansion to be implemented with Japanese ODA Loan.

1.2 OBJECTIVE OF THE SURVEY

Objective of the Survey is to conduct necessary study for appraisal such as objective and effect, outline, cost, implementation schedule, construction and procurement plan, implementation system, operation and maintenance system, and environmental and social considerations of Nam Ngum 1 hydropower station expansion project so as to implement as yen loan project.

1.3 SURVEY AREA

Study area is the Nam Ngum 1 hydropower station in Vientiane Province and overall Nam Ngum River Basin.

1.4 COUNTERPART OF THE SURVEY

Counterparts of the Survey are the Department of Energy Policy and Planning (DEPP) of the Ministry of Energy and Mines (MEM), the Electricity du Laos (EDL) and EDL-Generation Public Company (EDL-Gen).

1.5 TEAM MEMBERS

In order to conduct various work items related to the Nam Ngum 1 expansion project, the team for the survey was organized with the corresponding members as shown in Table 1.5.1 below.

Table 1.5.1 Staff of Survey Team

Position	Name
1. Team Leader / Hydropower Development Planning	Masaki WADA
2. Power Demand and Supply Analysis・Power System Operation	Masahiro IWABUCHI
3. Hydrology・River System Operation	Sohei UEMATSU
4. Geology	Nobehiro TSUDA
5. Electric Power Civil Engineering A (Dam)	Shigeru TSUCHIDA
6. Electric Power Civil Engineering B (Powerhouse)	Yukio AZEGAMI
7. Electrical Equipment	Kiyoshi HASEGAWA
8. Mechanical Equipment	Kenji SETO
9. Construction and Procurement Planning・Cost Estimate	Tateki KAN
10. Economic and Financial Analysis	Takeshi YAMASHITA
11. Environmental and Social Consideration	Mayumi GOTO
12. Coordinator / Assistant for Hydrology・River System Operation	Kazuhiro YAMAKAWA

Prepared by JICA Survey Team

CHAPTER 2 SURROUNDING CONDITIONS

2.1 ECONOMIC AND SOCIAL CONDITIONS

Economic and social conditions in Vientiane Capital and Vientiane Province, which are the target area for power supply by this expansion project, are outlined in the following table.

Table 2.1.1 Economic and Social Indicators

Item	Unit	Whole Country	Vientiane Capital	Vientiane Province	Year
GDP					2010
GSP	mil. kip	56,522,565			
GDP per capita	US$	1,088			
Share of GDP	%	100			
Agriculture	%	28.4			
Industry	%	25.9			
Services	%	39.3			
Taxes	%	6.3			
Growth Rate of GDP	%	8.1			
Agriculture	%	3.0			
Industry	%	17.5			
Services	%	7.0			
Taxes	%	4.5			
Population					2010
Area	km2	236,800	3,920	22,554	
Capital and Provinces	no.	17	1	1	
Districts	no.	143	9	13	
Villages	no.	8,662	490	506	
Households	no.	1,027,468	132,542	81.693	
Population	no.	6,256,197	768,743	480,440	
Density	no./km2	26	196	21	
Agricultural Production					2010
Season Rice	ton	2,331,330	233,935	227,220	
Irrigated Rice	ton	512,430	101,725	32,920	
Upland Rice	ton	226,880	-	15,190	
Maize	ton	1,020,875	9,235	90,470	
Starchy Roots	ton	725,925	113,915	62,995	
Vegetable and Bean	ton	947,670	79,440	101,055	
Work Status & Poverty					2007/08
Work Status					
Paid Enployee	%	14	32	14	
Self Employed	%				
Non farm	%	20	40	25	
Self operated farm	%	66	27	61	
Poverty					
Poverty gap	%	6.5	3.4	6.2	
GINI Index	%	35.4	38.0	32.1	

Source: Statistical Yearbook 2010, Lao Department of Statistics

2.2 ISSUES IN POWER SECTOR

Issues of the power sector in Laos, especially power supply demand balance for peak load in Central Region, is outlined in the report of Study on Power Supply and Demand in Central Region (2012).

(1) Reduction of Actual Power Generation during Dry Season

Most of the power consumed in Laos is currently provided by hydropower plants and shortage is compensated by power import from neighboring countries. It is well known that the actual power output of hydropower plants is extremely lower than the rated output of generators during dry season. Power supply to the central area was assumed to have shortage during peak demand throughout 2017, whereas the north and south areas will have a surplus during wet season which will then be transferred to the central area. However, during dry season, even both northern and central areas will face shortage in power supply. The problem therefore will be the central area not receiving power from the northern or southern areas. During dry season, power import is the only way to compensate power shortage.

(2) Power Shortage for Peak Time Demand

It is observed in the demand/supply balance for 2017 that the expected 709 MW power shortage will be very sever during peak hours between 19:00 to 20:00 in April. EDL is required to secure a peak load power supply capacity against the peak demand during dry season.

(3) Over Reliance on Power Import in the Future from View of Power Supply Security

If the shortage of electricity in Lao PDR is fully compensated by importing, it is projected that in the future, the proportion of power import to the demand in central area will vary approximately from 20% to 60% during dry season (November to May) in 2017. 60% power supply during peak time must especially depend on the importation of power from Thailand. The power system operation in Lao PDR relies on the power system of EGAT in Thailand. The situation of overreliance on the EGAT system should be improved so as to reduce the proportion of power importation as much as possible from a viewpoint of power supply security.

(4) Low Proportion of Controllable Power Supply Capacity to the Whole Power Supply Capacity

The proportion of the installed generation capacity of EDL-owned power stations will reduce from 68% in 2010 to 17% in 2020.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Total Supply by EDL	385	391	391	398	500	640	845	885	969	969	969	969	969	969	969	969
Total Supply by IPP(d)	100	104	225	233	247	679	1,394	1,948	3,185	3,518	3,976	4,286	4,286	4,286	4,286	4,286
Total Supply by IPP(e)	85	85	170	170	492	592	592	592	704	704	764	811	811	811	1,075	1,075
Whole Country	570	579	786	802	1,240	1,911	2,831	3,425	4,858	5,191	5,709	6,066	6,066	6,066	6,330	6,330

Prepared by the Study Team, updating PDP

Figure 2.2.1 Installed Generation Capacity by Ownership

EDL, as owner of the power plants has produced 391 MW of the 579 MW (67% generation capacity) in 2011. Many IPP domestic power generation projects will be completed in 2017 to 2018, although EDL-owned generation capacity will be 885 MW, the occupancy rate will decrease to 25% out of the rapidly growing generation capacity in the whole country of 3425 MW. In 2020, the proportion will be further decreased to 17%.

Generally, the IPP’s daily generation pattern is regulated under the conditions mentioned in the PPA between EDL and IPP. The operation cannot flexibly be controlled by EDL due to its intension to increase or decrease the generation according to the power network which changes from time to time. EDL is recommended to secure more EDL-owned power stations for domestic supply in the future. At least the project of EDL power plants should be implemented on schedule as much as possible.

2.3 ACTIVITIES BY OTHER DONORS IN POWER SECTOR

World Bank (IBRD) and Asian Development Bank (ADB) has been supporting the power sector in Laos, in the fields of hydropower development, grid extension, rural electrification and capacity building.

(1) Hydropower Projects

The Nam Theun 2 hydropower plant (1,088MW) of which implementation was supported by IBRD and ADB started its operation in 2010.

ADB also supported implementation of Nam Song Diversion, Nam Leuk (60MW) and Theun-Hinboun (210MW) hydropower projects. ADB decided financing to Nam Ngum 3 (440MW) hydropower project in 2011, and now considering on Nam Ngiep 1 (289MW).

(2) Grid-Extension / Rural Electrification

IBRD conducted Rural Electrification Master Plan and Hydro Assessment Studies in Lao PDR in 2010.

In 2010, ADB provided financial support to transmission extension plan in northern area of Laos. (400km of 115kV).

ADB is also supporting cross-border transmission and power trade in GMS.

CHAPTER 3 ISSUES OF NN1 HYDROPOWER STATION

3.1 OPERATION AND MAINTENANCE OF NN1 HYDROPOWER STATION

3.1.1 OPERATION

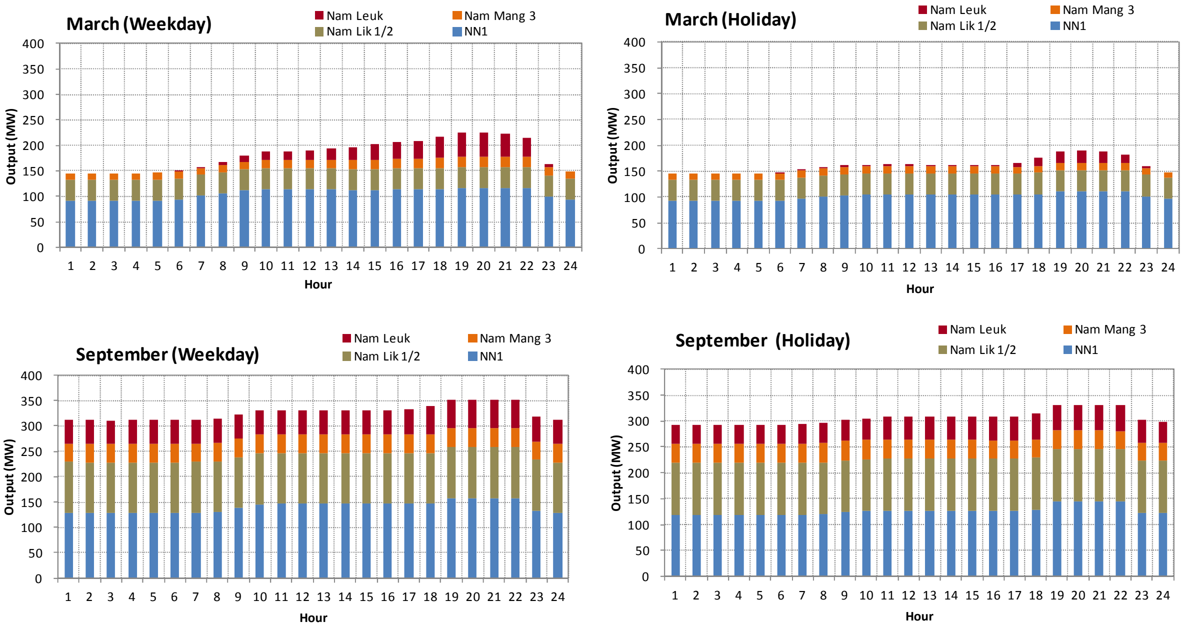
The NN1 hydropower station is being operated to meet the power demand in the central area through the coordination with EDL-Gen power station for the operation of the Nam Leuk hydropower station and Nam Mang 3 hydropower station. In 2010, the IPP(d) hydropower project of Nam Lik 1/2 started its operation aiming to supply electricity to the central area. During the dry season, NL1/2 supplies power for base load, while NM3 and NL supply power for peak load, and NN1 supplies power for both peak and base load. During the wet season, all of the power stations operate at full capacity for 24 hours as inflow into these reservoirs are abundant.

The principal feature of existing power stations of Nam Leuk, Nam Mang 3, and Nam Lik 1/2 hydropower stations is shown in Table 3.1.1. The typical operation pattern of these hydropower stations together with NN1 hydropower station is shown in Figure 3.1.1.1

Table 3.1.1.1 Principal Features of Existing Hydropower Station in Central Area

Item/project		Nam Leuk	Nam Mang 3	Nam Lik 1/2
Purpoose		Domestic	Domestic	IPP (Domestic)
Status		Existing	Existing	Existing
Main Developer		EDL	EDL	China International Water & Electric Corp.
Planened Commencement of Power Generation		2000	2004	2010
Principal Feature				
Catchment area	(km^2)	274	65	1993
Storage at FSL	(MCM)	154	45	1095
Average annual inflow	(MCM)	438	-	2690
Type of dam		Rockfill	RCC	CFRD
Dam hieght	(m)	46.5	22	101.4
Design flood of spillway	(m^3/s)	2100	57	2080
Powerhouse		Above ground	Above ground	Above ground
Rated output	(MW)	60	40	100
Max. plant discharge	(m^3/s)	63	9.1	160.6
Average annual energy	(GWh)	230	134	395

Prepared by the Study Team



Prepared by the Study Team

Figure 3.1.1.1 Power Generation Pattern of NN1 and Other Existing Hydropower Station

As shown in Figure 3.1.1, NN1 hydropower station operates for the base load power supply as well as peak load power supply during dry season. NN1 hydropower station supplies the majority of electricity in the central area especially during dry season.

3.1.2 MAINTENANCE

The NN1 has started power generation of Units No.1 and No.2 with installed capacity of 30 MW and has been expanded up to 155 MW after the stepwise development.

Table 3.1.2.1 History of Changes in Installed Capacity of Nam Ngum 1 Hydropower Station

Year	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Sum
1971	15.0 MW	15.0 MW	-	-	-	30.0 MW
1979	15.0 MW	15.0 MW	40 MW	40 MW	-	110.0 MW
1985	15.0 MW	15.0 MW	40 MW	40 MW	40 MW	150.0 MW
2003	17.5 MW	15.0 MW	40 MW	40 MW	40 MW	152.5 MW
2004	17.5 MW	17.5 MW	40 MW	40 MW	40 MW	155.0 MW

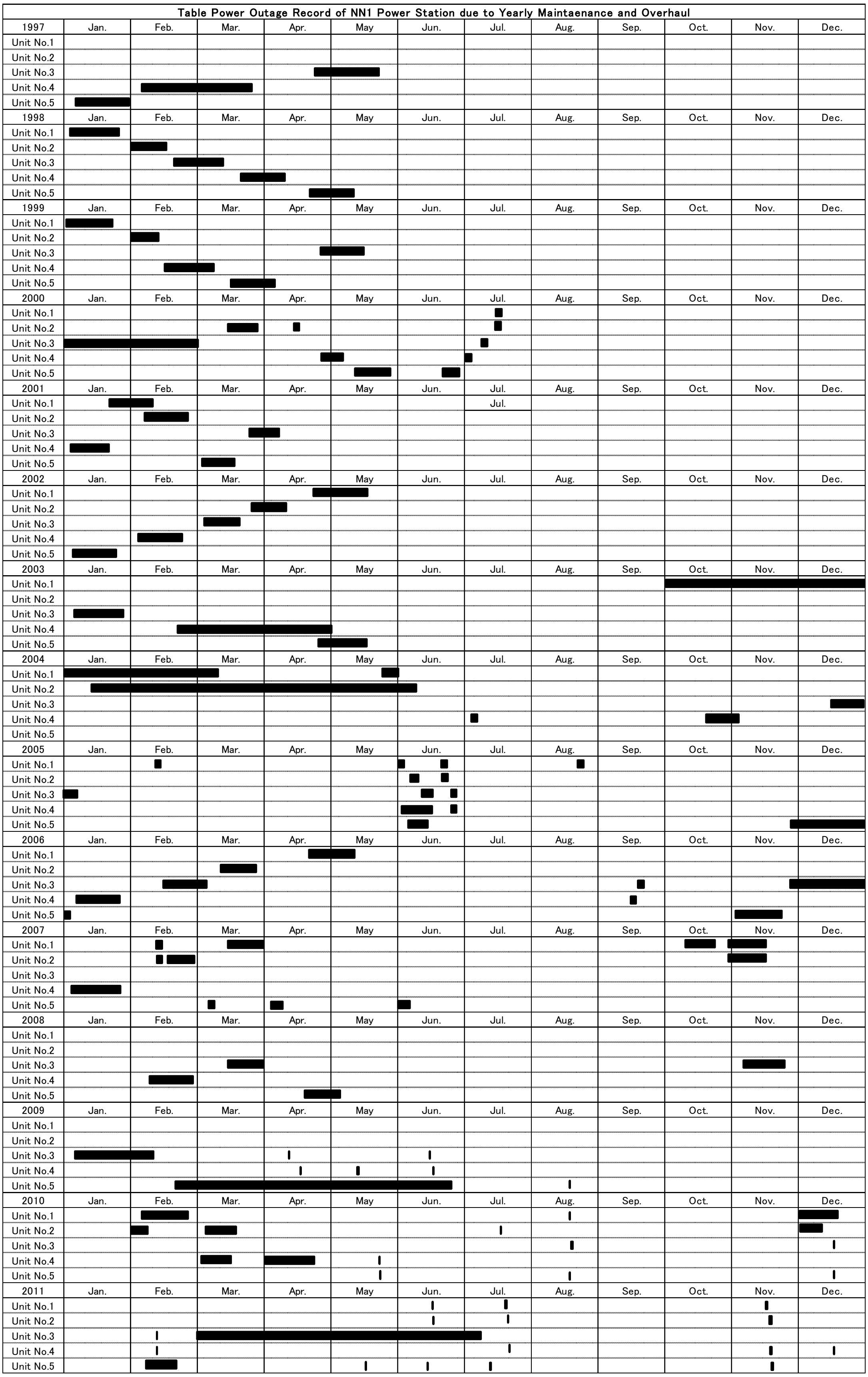
Source：Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion

The Units No.1 and No.2 were rehabilitated from 2003 and 2004 and presently operating in good condition. The regular maintenance of Units No.1 and No.2 is carried out once a year for 20 days. Unit No.5, which started power generation in 1985, was overhauled in mid-February to mid-June 2009. Unit No.3 was put into overhaul March 2011, while Unit No.4 is kept poised for overhaul in a dry season at appropriately soonest timing. Yearly maintenance for Units No.3, No.4 and No.5 are being carried out within 30 days in dry season. The generator unit No.3 has not been in operation since March 2012 due to an incident of control system and stator coil. This generator is expected to be repaired and resume the operation in December 2012.

According to the opinion of staff of NN1 Hydropower Station, the timing of maintenance is limited within the dry season and flexible adjustment of the maintenance schedule is difficult.

(1) Maintenance Record of Existing Power Generation Facilities

The power outage record of NN1 power station from 1997 to 2011 was obtained from NN1 Hydropower Station and plotted in Figure 3.1.2.1. The power outages occurred mainly due to yearly maintenance and rehabilitation of Unit No.1 and No.2, and these were recorded in a five-month period in 2003 and 2004, respectively. Basically, the annual maintenance is carried out in dry season to avoid inefficient spillage of water from reservoir. However, the inflow into NN1 reservoir will be well-regulated due to commencement of power generation of NN2 Hydropower Station in 2011. It is expected that the inflow into NN1 reservoir in dry season will increase and reservoir water level will be kept at relatively high elevation and the periodic maintenance, which has been based on the seasonal fluctuation of reservoir water level, is expected to be changed.



Source: NN1 Power Station

Figure 3.1.2.1 Power Outage Record of NN1 Power Station due to Yearly Maintenance and Overhaul

The operation hour ratios of each unit in recent years were obtained from NN1 Hydropower Station and summarized in Table 3.1.2.2. The operation hour ratio in 2003 and 2004 are not so high because of the implementation of the rehabilitation of Units No.1 and No.2. Likewise, the recorded operation hour ratio in 2007 is only 68% due to less inflow into NN1 reservoir in special dry year. In the case of year 2005, 2006 and 2008, the operation hour ratios range between 83% and 85%, which seems to be high for the reservoir-type hydropower station.

Table 3.1.2.2 Operation Ratio Recorded at NN1 Power Station

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Jan.	66.1	77.5	80.3	62.7	59.3	73.2	52.7	73.7
Feb.	65.2	85.6	83.3	68.5	61.2	78.9	56.0	71.2
Mar.	73.4	89.3	78.3	71.4	69.0	72.9	62.7	62.2
Apr.	73.0	77.7	73.9	71.7	71.5	67.6	59.3	60.7
May	62.1	47.1	68.2	63.7	76.5	61.6	63.1	58.9
Jun.	69.2	37.9	69.7	53.3	86.1	69.9	56.6	61.1
Jul.	76.6	84.5	74.6	66.0	100.0	94.9	42.7	100.0
Aug.	100.0	100.0	95.7	55.3	100.0	100.0	49.1	100.0
Sep.	100.0	100.0	71.3	52.3	100.0	93.2	70.3	100.0
Oct.	99.0	100.0	71.8	55.1	100.0	73.6	73.1	100.0
Nov.	75.3	92.3	65.8	71.9	78.6	51.1	63.8	100.0
Dec.	76.2	78.7	63.4	62.5	74.4	49.7	86.5	100.0
Ave.	78.0	80.9	74.7	62.9	81.4	73.9	61.3	82.3

Source: NN1 Power Station

Though all power generation units receive a yearly maintenance, the opportunity of overhaul or rehabilitation is quite limited. It is important to develop the adequate maintenance schedule for the power generation Unit No.1 to No.5 and prolong life of important infrastructure in Laos. If the NN1 Hydropower Station has additional power generation unit, the operation ratio of existing power generation units will be lowered and the flexible arrangement of maintenance for existing 5 units would be easier than present conditions. Further, due to reduction of operation ratio of existing power generation, the frequency of repair of consumable parts of power generation units will be decreased and yearly maintenance cost also will be reduced.

(2) Maintenance Plan of Power Generation Facilities

According to the information of staff in NN1 Hydropower Station, the period required for proper and adequate yearly maintenance is shown in Table 3.1.2.3. The maintenance period is scheduled in the dry season to avoid inefficient spillage of water from the reservoir. On the basis of this yearly maintenance period, the maximum operation hour ratio is calculated to be 92.6%, and it was found that the operation hour ratios recorded in recent years are not so far from this ratio. The period for yearly maintenance (days) shall be read as inclusive of inspection for turbine runner erosion.

Table 3.1.2.3 Power Outage for Yearly Maintenance

	Period required for yeary maintenance (days)	Preparation Period	Period of Power Outage
Unit No. 1	18	3	21
Unit No. 2	18	3	21
Unit No. 3	28	3	31
Unit No. 4	28	3	31
Unit No. 5	28	3	31
Total			135

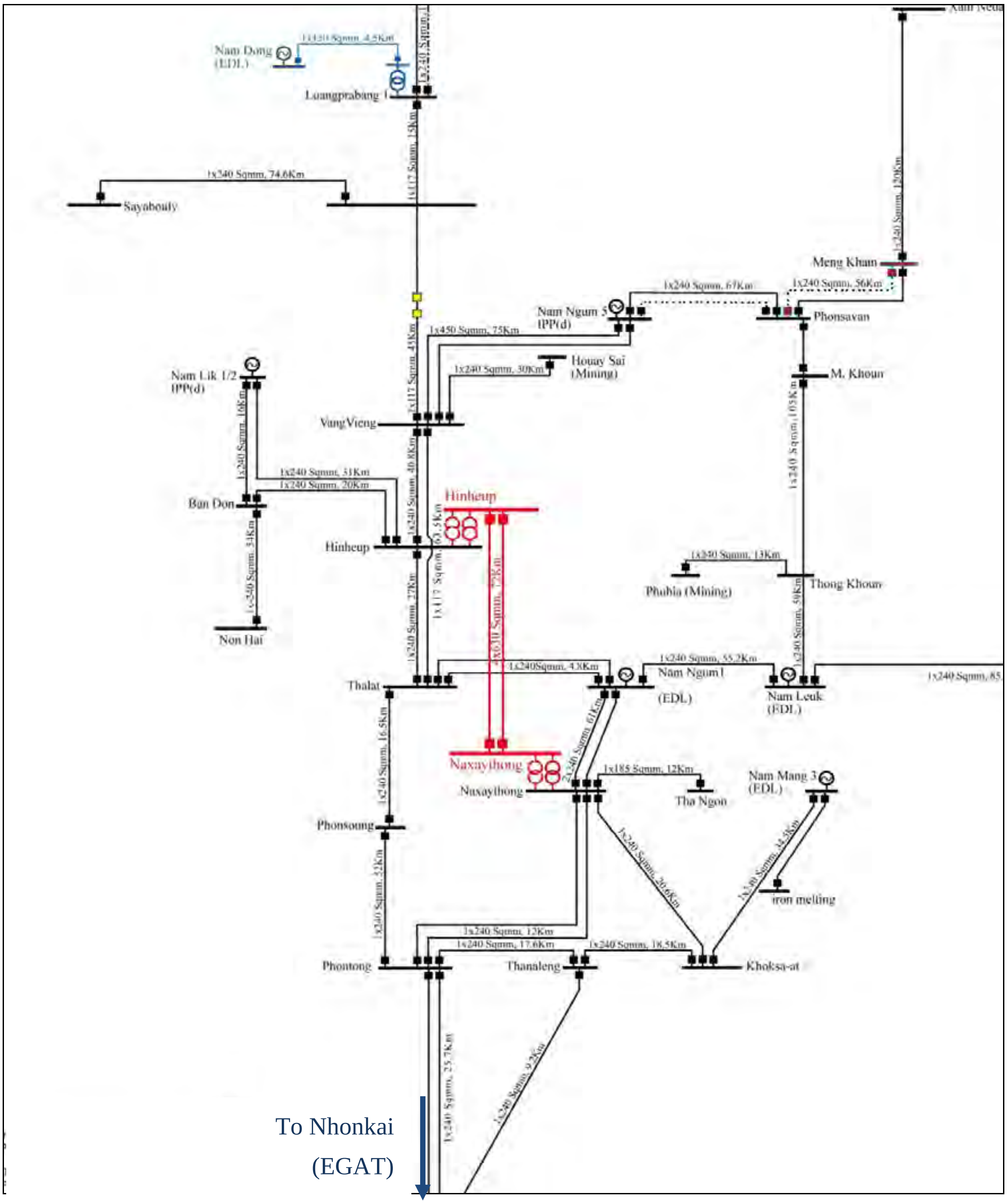
Sorce: NN1 Power Station

After commencement of NN2 power generation in 2011, the inflow into NN1 reservoir will be regulated and the difference of flow conditions in the rainy and dry seasons will be decreased. Therefore, the arrangement of timing of the periodic maintenance will be reconsidered.

3.2 TRANSMISSION LINE NETWORK AROUND NAM NGUM 1 HYDROPOWER STATION

3.2.1 CURRENT SITUATION OF TRANSMISSION LINE NETWORK

The current transmission line network near Nam Ngum 1 hydropower station is focused on Figure 3.2.1.1 from the PDP 2010-2020 Revision 1.



Source: System Planning Office, EdL

Figure 3.2.1.1 Present Transmission Line Network of Central Area (2012)

As shown in Figure 3.2.1.1, five circuits of 115 kV transmission line are connected to NN1 as of 2012. Four circuits out of the above lines are used for power supply to the Vientiane Municipality. Another remaining single circuit functions for interconnection between two hydropower stations of NN1 and Nam Leuk. In case either any of those generators is caused to stop at two power stations, this interconnection line will function to mutually make backup for power supply.

Two circuits from NN1 are connected to Naxaythong S/S which is located about 61km to south from NN1, and supply the power to Phontong S/S in the Vientiane capitol via Naxaythong S/S. Another two circuits from NN1 are connected to Thalat S/S which is located about 5 km to west from NN1 and also supply the power to Phontong S/S via Phon Soung S/S. Phontong S/S and Thanaleng S/S are interconnected with the EGAT power system. Surplus power in central area is exported from Phontong S/S and Thanaleng S/S to Thailand through the 115kV interconnection transmission lines.

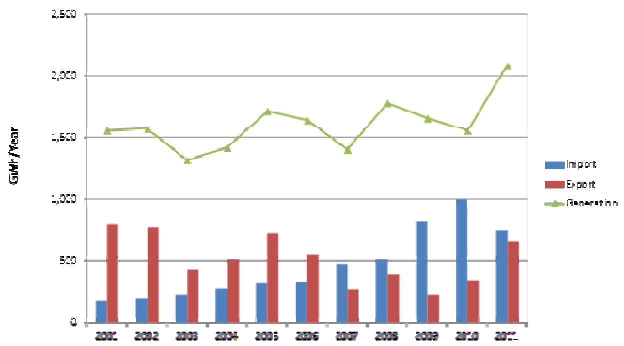
A single circuit of 115 kV transmission line located at Thalat S/S reaches to Luang Prabang S/S over 212 km via Vangvieng substation. The line located at the Xieng Ngen switching station is connected to the Xayaboury substation. The other single circuit line located at the Thalat substation is connected to the Non Hai substation via the Ban Dong substation.

Hinheup substation and Naxaythong substation are connected with 230kV double circuit transmission line, which only one 230kV transmission line is available for EDL's grid in Lao PDR for domestic power supply at present.

3.2.2 CURRENT SITUATION OF INTERNATIONAL POWER TRADE

Power trade is being carried out with Thailand, China and Vietnam. The power trade with Thailand is the main channel among the transactions.

In Lao PDR, power export is to be one of the significant means to earn foreign money. The annual amount of power export (except for IPP's export) had been larger than that of import until 2006. However, the annual import has exceeded the annual export since 2007. For instance, the power import drastically exceeded the export by 589 GWh and 653 GWh in 2009 and 2010, respectively, as shown in Figure 3.2.2.1.

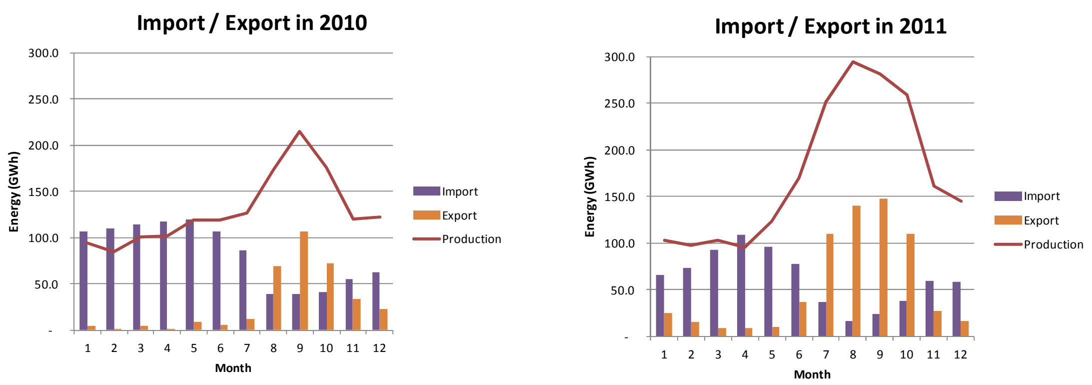


Source : PDP 2010-2020 revision-1

Figure 3.2.2.1 Past Record of Power Trade with Neighbor Country

The tariff for power trade with Thailand is set out, which the unit price for import from Thailand is higher than that for export to Thailand. In addition, the surcharge is required considering escalation of fuel cost in case that annual amount of import exceeds export. Therefore, overpower import from EGAT would become a financial predicament of EdL. Accordingly, new power stations for domestic supply be urgently developed to commence the commercial operation.

Figure 3.2.2.2 shows the seasonal variation of power import and export and energy generation in Lao PDR in 2010 and 2011. As indicated in graphs, the power export generally exceeds the import during rainy season. On the contrary, the power import exceeds the export during dry season. The volume of power export tends to follow the volume of energy production, which means depending on the rainfall variation. For example, the power export in 2011 relatively increased compared with 2010 because 2011 was a much wet year.



Prepared by Study Team

Figure 3.2.2.2 Seasonal Variation of Power Trade

Table 3.2.2.1 shows the list of existing international interconnection transmission lines, except 22 kV distribution lines for import at borders.

Currently, there are six 115 kV transmission lines internationally connecting the EGAT system in Thailand and the EdL domestic system in Lao PDR. The interconnection capacity connecting the power systems in Central area and EGAT is estimated at 400MW in total by four circuits without consideration of N-1 condition.

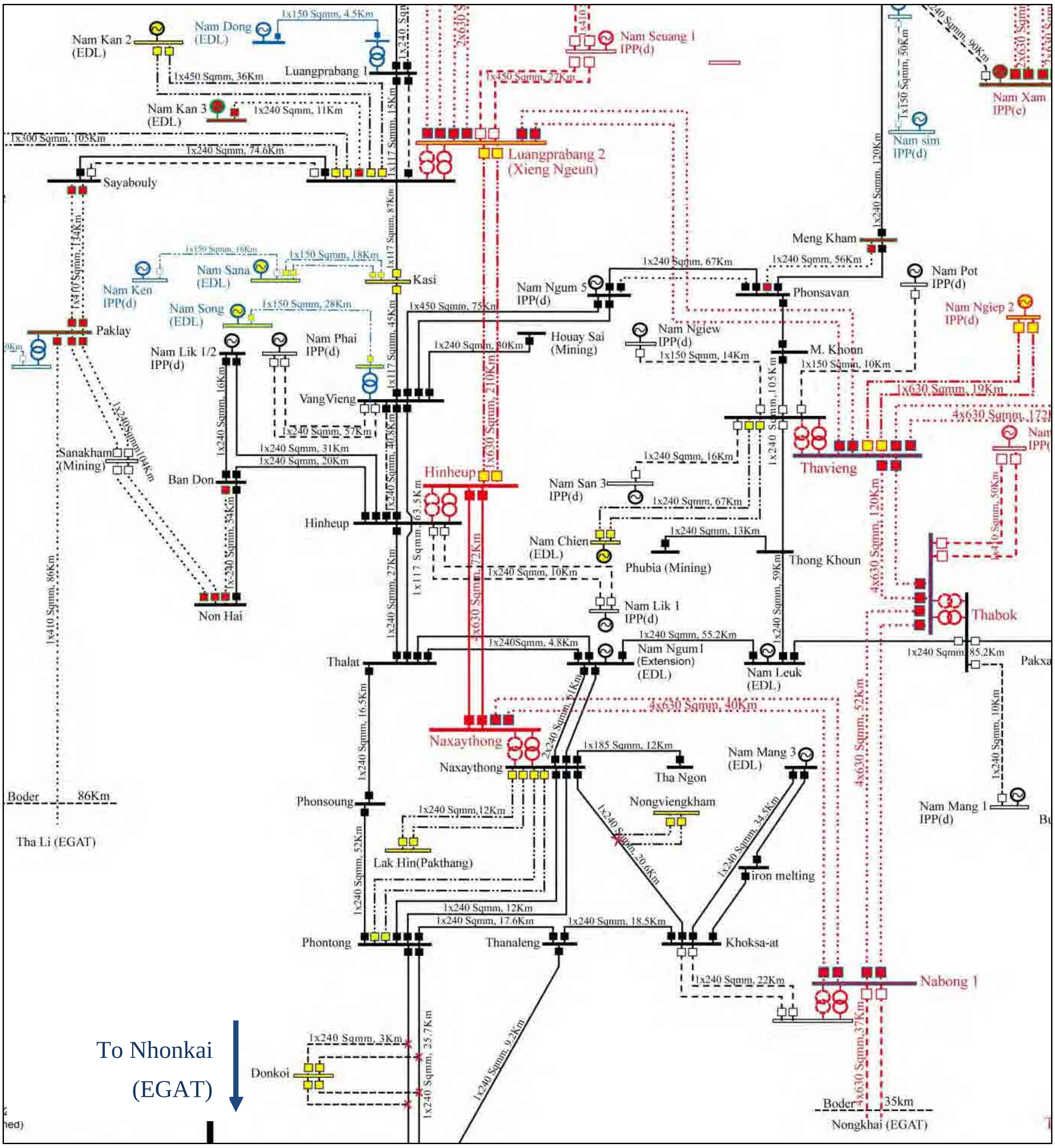
Table 3.2.2.1 Existing International Interconnection Transmission Lines

No.	Substations		Length	No. of Circuit		Voltage	Conductor	Capacity
	EDL (Area)	EGAT	(Km)	Existing	Futrue	(kV)	(Sq.mm)	(MW)
1	Phontong (Central)	Nongkhai	26	2	2	115	240	100 x 2
2	Thanaleng (Central)	Nongkhai	9	1	1	115	240	100
3	Paksan (Central)	Bungkan	11	1	2	115	240	100
4	Thakhek (South)	Nalhonphanom	10	2	2	115	240	100 x 2
5	PakBo (South)	Mukdahan 2	5	1	2	115	240	100
6	Bang Yo (South)	Sirinthon P/S	61	1	1	115	240	100

Prepared by Study Team based on PDP 2010-2020 Revision 1

3.2.3 TRANSMISSION LINE NETWORK IN FUTURE

The future transmission line network near NN1 hydropower station as of 2017 is focused on Figure 3.2.3.1. The year of 2017 is expected when the commercial operation of expanded NN1 hydropower station is started.



Source : PDP 2010-2020 revision-1

Figure 3.2.3.1 Transmission Line Network in the Central Area in 2017

It will be same situation that the five circuits of 115 kV transmission line are connected to NN1 in 2017.

In regard to the 115kV transmission lines around NN1, the existing 115 kV double circuit transmission line connecting Naxaythong and Phontong is planned to be reinforced with additional circuits. Some 115/22 kV substations such as Donkai, Nongviengkham, Lak Hin, etc will newly be established as shown in Figure 3.2.3.1, to increase the transformer capacities for distribution of electricity to end consumers in the Vientiane metropolitan area.

Under such EDL's development plan on 115kV transmission lines, there will not be significant change in future 115kV transmission system nearby NN1 as of 2017 other than the said augmentation.

Meanwhile, regarding 230kV transmission system in this stage, the 230 kV transmission lines will consist of a ring-line by double-circuit with grid substations, including Luangprabang 2–Hinheup–Naxaythong–Nabong 1–Thabok–Thavieng. The Nabong 1 Substation is expected to connect the 230 kV international interconnection transmission line for power trade with EGAT. The transmission line is designed as a double circuit with four conductors of ACSR 630 mm^2 per phase.

3.3 ISSUES OF NAM NGUM 1 HYDROPOWER STATION

Issues of Nam Ngum 1 Hydropower Station and roles of its expansion area summarized in below.

Table 3.3.1 Issues of NN1 Hydropower Station and its Expansion Plan

Issues		Role of Expansion
1	Increase of domestic peak demand during night-time	The power demand in Laos is increasing rapidly, and night peak demand is of particular note. As the countermeasure to ensure the source of power supply in short term period, the expansion of NN1, which has huge reservoir, is considered with concentration power generation in peak time of power demand instead of power generation in off-peak.
2	Regulated discharge due to hydropower development in upstream	NN2 power station was constructed with huge reservoir at just upstream of NN1 reservoir, and the inflow into NN1 reservoir is regulated through a year. Due to this change of inflow pattern, the power generation can be kept with relatively high reservoir water level and the invalid water release through the spillway can be minimized. As the results of that, the increase of annual power generation can be expected due to expansion.
3	Aging of existing power generation facilities	The existing power generation facilities have been installed since 1971 in series. Though the Unit No.1 and 2 have received rehabilitation, the all units are getting older. The yearly maintenance is carried out only within the dry season to minimize the invalid water release and there is no sufficient time space to adjust the timing of maintenance. The expansion of additional one unit would contribute not only the decrease of power generation time ratio and maintenance cost but also planning of maintenance with sufficient time period and safety power generation.
4	Transmission line development plan surrounding NN1	Five circuits of 115 kV transmission line are connected to NN1 as of 2012. Four circuits out of the above lines are used for power supply to the Vientiane Municipality. There may exist deficit of capacity in transmission line in case NN1 expansion is in large scale.

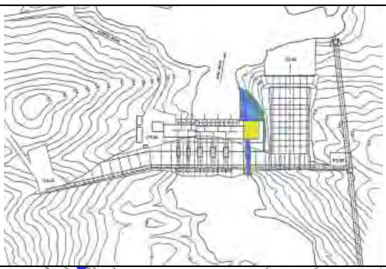
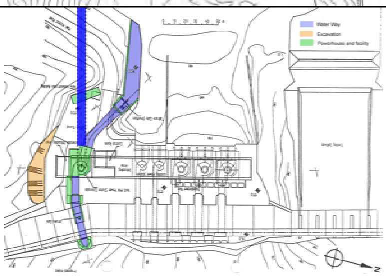
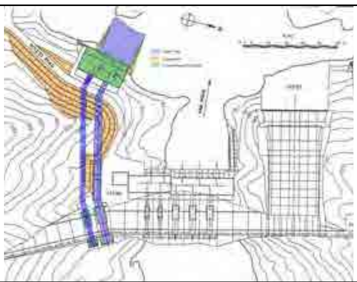
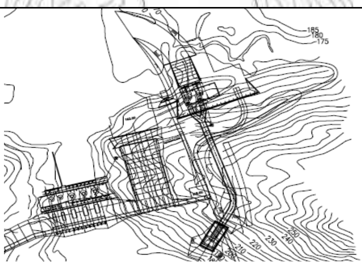
CHAPTER 4 SELECTION OF OPTIMUM EXPANSION PLAN

4.1 BASIC APPROACH

In the beginning of this Survey, twelve alternatives of the expansion plans were taken into account. In choosing them, the results of the Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion in Lao PDR in 2010 by JICA were referred to, and new layouts were additionally considered.

Those prospective alternatives were compared in detail by analyzing power generation efficiency, designing the powerhouse expansion layout, and estimating construction cost of respective alternatives. Final selection of the optimum expansion plan was made on the basis of technical, economic, financial and environmental assessment of the alternatives.

Table 4.1.1 Alternative Plans for Comparison

Alternatives group	Layout	Plan	Installed Capacity	Remarks
A1-A2		A1 A2	40 MW x 1 unit 60 MW x 1 unit	
A4		A4-1 A4-2	40 MW x 1 unit 60 MW x 1 unit	Short tailrace tunnel
		A4-3 A4-4	40 MW x 1 unit 60 MW x 1 unit	Long tailrace tunnel
B2’		B2’-1-1 B2’-2-1	40 MW x 1 unit 60 MW x 1 unit	Open penstock
		B2’-1 B2’-2	40 MW x 2 units = 80 MW 60 MW x 2 units = 120 MW	Open penstock Separate intake and open penstock are provided for each unit.
D2		D2-3 D2-4	40 MW x 2 units = 80 MW 60 MW x 2 units = 120 MW	

Prepared by the JICA Survey Team

Layout of each plan (alternative) was elaborated and the conceptual design was carried out for estimating respective construction costs. Basic conditions for the conceptual design are as follows:

Reservoir WL:	Max. flood WL	EL. 215.0 m
	Normal high WL	EL. 212.0 m
	Minimum operation WL	EL. 196.0 m
Tail WL:	Minimum WL	EL. 164.0 m (Q=0)
	Existing max operation WL	EL. 168.0 m (Q=465m3/s, Units 1 to 5)

4.2 SELECTION OF OPTIMUM EXPANSION PLAN

4.2.1 TOPOGRAPHY

The topography of the dam area, including both banks, is presented in a 1:1000 contour map prepared in the 1960s. However, since the topography around the dam was changed after the construction work carried out in 1968-1971, the 1:1000 map is partly not usable for the study of the expansion plan. The altered topography is shown in a 1:500 map prepared during the F/S stage (1995) and it covers the right bank area between the spillway and the tail bay, and the left bank hill area of the powerhouse. However, the 1:500 map does not cover the tail bay underwater.

In the present preparatory survey, therefore, topographic survey results obtained in the previous preparatory survey in 2010 were used. The survey work items in 2010 were as follows:

- Topographic survey of alternative expansion sites (1/500 map): 13.5 ha
- River cross section survey (along 23.5-km stretch): 25 sections
- Additional river cross section survey (along 1 km stretch): 15 sections

4.2.2 GEOLOGY

(1) Regional Geology

Details of the geology of the Indochina region is described in the report (IIDMG, 1989) prepared by a study group of Vietnam, Lao PDR and Cambodia. According to the report, the project area is situated in Kontum Savannakhet province, which had been subjected to the "Baicalian orogeny” in Proterozoic Era or to the "Caledonian orogeny” in early Paleozoic Era. A part of the Kontum Savannakhet province is covered with Mesozoic sedimentary rocks, and the project area is located in the area of this Mesozoic sedimentary rocks. Following four formations are mainly distributed in the area as shown in **Figure 4.2.2-1**.

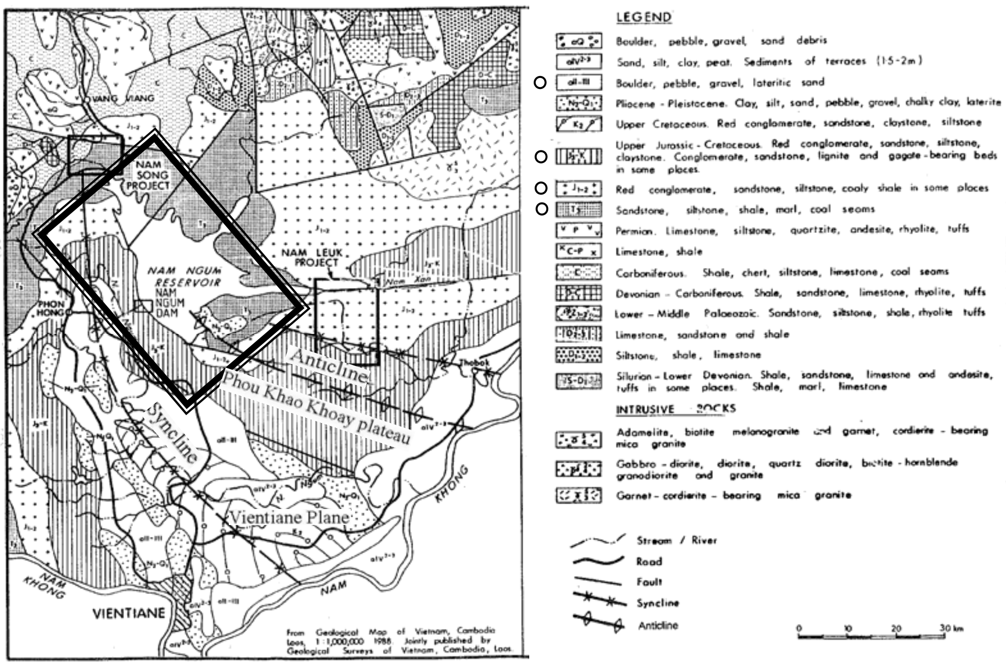
a. Quaternary system (all-III)
   Boulder, pebble, sand, silt and clay

b. Upper Jurassic to Cretaceous system (J3-K).
   Conglomerate, sandstone, siltstone, claystone

c. Jurassic system (J1-2)
   Conglomerate, sandstone, siltstone, coaly shale

d. Triassic system (T3)
   Siltstone, shale, rhyolite, tuff

These formations form a syncline structure of which axis strikes NW-SE to N-S and plunges southward in the west of the project area. As the Nam Ngum 1 dam and power station is situated in the east wing of this syncline structure, Jurassic to Cretaceous alternating bed of sandstone and mudstone is distributed with NW-SE strike and SW dipping.



Reference: Nam Ngum 1 Hydropower Station Extension Feasibility and Engineering Study (Lahmeyer, 1995); partly corrected (original geological map is from IIDMG, 1989)

Figure 4.2.2-1 Regional Geology

(2) Geological Investigation Works

1) Previous Geological Investigation

Geological investigation for the project site were carried out in the F/S of the Nam Ngum 1 hydropower Station Extension (1995, Lahmeyer) and the preparatory survey on Nam Ngum 1 hydropower expansion (2010, JICA). In addition, geological investigations were executed in the construction stage of the existing Nam Ngum 1 power station, and these investigation results were compiled in the contract drawings, completion report and as-built drawings. Although a lot of the investigation works has been carried out in the construction stage, the detailed data such as drilling logs or test records are not available at present. In this study, geotechnical evaluation of the expansion project is made based on the geological investigation results compiled in the following reports.

- NAM NGUM PROJECT LAOS GENERAL CONTRACT Volume III, DRAWINGS, Februay 1968, NIPPON KOEI CO., LTD

- Final Report on NAM NGUM HYDRO-ELECTRIC PROJECT, FIRAST STAGE, and As-Built Drawings, 1972, NIPPON KOEI CO., LTD

- Report on NAM NGUM 1 HYDROPOWER STATION EXTENSION FEASIBILITY AND ENGINEERING STUDY, August 1995, LAHMETER INTERNATIONAL

- Report on PREPARATORY SURVEY ON NAM NGUM 1 HYDROPOWER STATION EXPANSION, June 2010, JICA

2) Previous Geological Investigation Works

(a) Geological Mapping

Geological mapping of the project site was carried out in the D/D study for the Nam Ngum 1 power station, and the geological map including the information obtained during the construction works was made in the as-built drawings (1972). After that, new geological maps, which reflect the results of additional drilling and surface geological survey, were drawn up at the feasibility study in 1995 and at the preparatory study in 2010.

Table 4.2.2-1 Existing Geological Map

Geological Map	Scale	Area	Reference		
Geological Plan and sections	1/2,000	Dam & Powerhouse	General Contract, Voume III, Drawings	1968	Nippon Koei
Geological Plan and sections	1/2,000	Dam & Powerhouse	Completion Report and as-built Drawings	1972	Nippon Koei
Geological Plan and sections	1/2,000	Dam & Powerhouse	Report on Feasibility and Engineering Stu	1995	Lahmeyer
Geological Plan and sections	1/2,000	Dam & Powerhouse	Report on Preparatory Survey	2010	JICA

(b) Investigation Drillings

Investigation drillings were executed at the F/S in 1962, D/D in 1966-1967, F/S for the extension in 1995 and the preparatory study for the expansion in 2010. As for the investigation drillings at 1962 and 1966-1967, geologic logs and core photographs are not preserved, but some of them are utilized for the geological sections in the completion report and as-built drawings. **Table 4.2.2-2** and **Figure 4.2.2-2** show a list of investigation drillings and the location of drillings respectively.

Table-4.2.2-2 Existing Investigation Drillings

No.of Drillhole	Length (m)	Elevation (m)	Inclination (degree)	Location	Coordinates E	Coordinates N	Investigation Stage	Remarks
15 holes in total	397m in total	–	–	Project Area	–	–	F/S for NAM NGUM 1 Project 1962	Core Logs are not preserved.
94 holes in total	1,714 m in total	–	–	Project Area	–	–	D/D for NAM NGUM 1 Project 1966	Core Logs are not preserved.
XA1/1	30	178.192	90	A1 option	18,240,899	2,051,670	F/S for NAM NGUM 1 Extension (by Lahmeyer) 1995	WPT
XA1/2	25	177.498	90	A1 option	18,240,855	2,051,663	ditto	WPT
XA4/1	30	177.108	90	A4 option	18,240,930	2,051,522	ditto	WRT
XA4/2	25	177.169	90	A4 option	18,240,913	2,051,521	ditto	WPT
XA4/3	25	177.102	90	A4 option	18,240,894	2,051,527	ditto	
JCA-1	20	177.296	90	A1 option	18,240,872.7	2,051,663.3	Preparatory Survey for NAM NGUM 1 Expansion (by JICA) 2009	SPT and WPT
JCB-1	26	177.689	90	B2 option	18,240,810.6	2,051,466.8	ditto	SPT
JCB-2	25	204.893	90	B2 option	18,240,869.3	2,051,458.8	ditto	SPT
JCD-1	25	176.887	90	D2 option	18,240,736.2	2,051,800.3	ditto	SPT
JCD-2	55	224.777	90	D2 option	18,240,938.0	2,051,859.8	ditto	SPT and WPT

WPT: Water Pressure Test, SPT: Standard Penetration Test

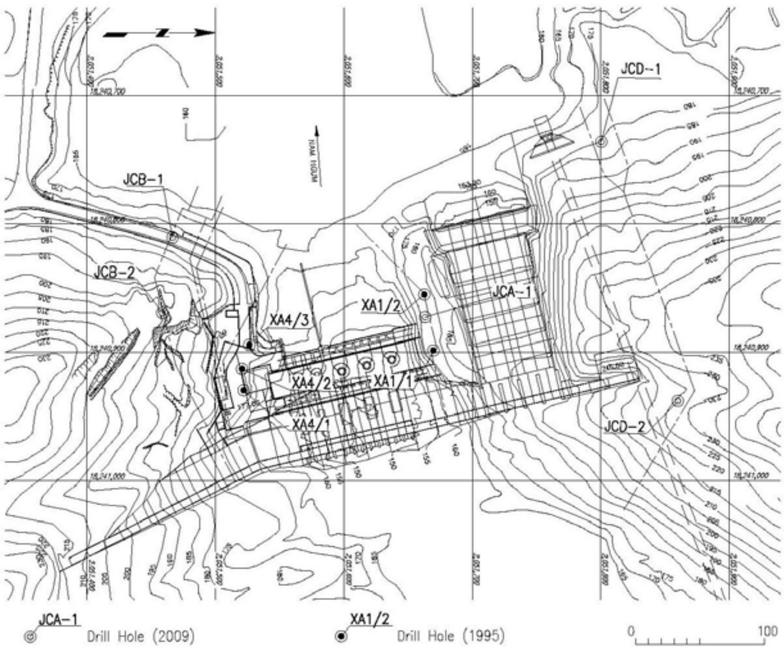


Figure 4.2.2-2 Location of Drill Holes

(c) Laboratory Test of Drilled Core

Physical property test and mechanical property test of rock using the drilled core are carried out at the construction stage of Nam Ngum 1 Power station, F/S of the extension project (1995) and the preparatory study of the extension project (2010). Content and quantity of the laboratory tests are shown in **Table 4.2.2-3.**

Table 4.2.2-3 Existing Laboratory Test of the Drilled Core

	Physical property Test		Mechnical Property Test	
	Specific Gravity	Toal Unite Weight	Unconfined Compression Test	Splitting Tensile strength Test
NAM NGUM 1 Construction Stage (1969-70)	*	*	29 samples	*
F/S for NAM NGUM 1 Extension (by Lahmeyer, 1995)	*	*	29 samples	*
Preparatory Survey for NAM NGUM 1 Expansion (by JICA, 2010)	12 samples	12 samples	6 samples	6 samples

*: No Information

(d) Other investigations

At the D/D study of Nam Ngum 1 dam, plate bearing tests were executed in the exploratory adits for determining the deformability of the dam foundation rock. Further, test pits for the construction materials were dug and the material test (particle size, water absorption, Los Angeles abrasion, alkali reactivity etc.) were carried out at the D/D study of Nam Ngum 1 dam and F/S of the extension project (1995).

Table 4.2.2-4 Existing Investigation Works for Concrete Aggregate

type	number	geology	place	reference	material
Drilling	30 holes	Nam Lik alluvium	a few kirometers upstream of the confluence	Completion Report (Nippon Koei,1972-1)	sand and gravel
Test Pit	13 pits	ditto	ditto	Completion Report (Nippon Koei,1972-1)	ditto
Test Pit	2 pits	ditto	ditto	FS report (Lahmeyer,1995)	ditto

(3) Geology of the Foundation Rock

1) Distributed Rock and geological structure

The project site consists of alternating beds of sandstone and mudstone in Jurassic to Cretaceous era, which strike N10 - 20W and dip 45 - 65W, namely parallel to the dam axis and dipping to the downstream direction. The alternating beds are composed of sandstone rich layer and mudstone rich layer of which thickness are 10 to 50m. The thickest sandstone layer is 45m in thickness, which comprises Nam Ngum 1 dam foundation.

Sandstone is hard to moderately hard and has higher resistance to weathering compared to mudstone. So, it tends to outcrop and form a ridge. Grain size of sandstone varies from fine to coarse and it is pebble size in some horizons. Sandstone is grayish white, blue-gray and purplish in color and it sometimes shows cross-laminations. As a thin or lenticular mudstone layer is sometimes intercalated in sandstone layer, it tends to exfoliate along bedding plane or thin mudstone layer in weathering condition. Low and high-angle joint, which cross the bedding planes at 45 to 90 degrees, are prominent in sandstone.

Fresh to slightly weathered mudstone is generally massive with few joint, but the strength and resistance to weathering are low compared with sandstone. Mudstone varies from clay to silt in grain size, and shows black to dark grey color in fresh part, brown to reddish brown color in weathered portion.

Mudstone in the project site has been described as shale in the completion report, mudstone or siltstone in the F/S report (1995) and mudstone in the preparatory study report (2010). Mudstone in the project site has not fissility like shale and the term of mudstone generally includes both of siltstone and claystone. Therefore, the name of mudstone is used in this report.

No major fault has been identified in the project area. The Nam Xan fault in the east of the project area is presumed to continue to the anticline axis around the Phou Khao Khoay plateau and not extend to the Nam Ngum 1 dam site (Lahmeyer, 1995). Based on the site reconnaissance, large landslides or unstable deposits are not found in the project area.

2) Weak rock

Mudstone has low strength even in the fresh portion and it tends to be deteriorated into the deep portion due to the low resistance to the weathering. Further, a crushed weak mudstone layer has been confirmed from the surface to around 24m depth in the drill hole XA4/3 which has been drilled on the left bank near the existing powerhouse. This weak mudstone layer is assumed to be sheared layer associated with the folding judging from the outcrops and drilled cores of the consolidated sheared portion (Prearatory Survey, 2010, JICA). In sandstone layer, thin clay material along the bedding plane and joints with slickenside are sometimes observed. These planes may cause the sliding of rock mass. Further, mudstone intercalation with maximum thickness of 1.5m and fine-grained sandstone may be weathered and deteriorated in local.

3) Rockmass Classification

As the physical and mechanical properties of the rockmass in the project area depend on the weathering degree, the rockmass has been classified by the weathering degree in the previous study (Preparatory Survey, 2010, JICA). In this study, rockmass classification is based on the previous study as shown in Table 4.2.2-5. The features of rockmass of sandstone and mudstone are as follows;

a) Sandstone

- Slightly Weatherd Sandstone

The rock is sound and hard, and the joint spacing is more than 30cm. The existing geological sections suggest the slightly weathered rock may appear deeper than 5 to 10m from the ground surface in general.

- Moderately Weathered Sandstone

The rock is weathered but still sufficiently hard, and the joint spacing is more than 10cm.

- Highly Weathered Sandstone

The rock is highly weathered and brittle. The joint spacing is less than 10cm. Generally, the rock zone is distributed at the top of the basement rock or sheared zones. Coarse-grained sandstone layers tend to maintain moderately weathered condition while the fine-grained sandstone is highly weathered. Hence, it is often observed that highly weathered sandstone is alternated with the moderately weathered sandstone.

b) Mudstone

- Slightly Weathered Mudstone

The rock is sound and massive with fewer joint immediately after excavation, but the deterioration is proceeding as the time passes. The existing geological sections suggest that the slightly weathered rock may appear deeper than 10 to 20m from the ground surface in general.

- Moderately Weathered Mudstone

The joint spacing is more than 10cm, but the rock is a little bit brittle. Degradation may arise just after exposure to air. The moderately weathered mudstone seems alternated with highly weathered mudstone

- Highly Weathered Mudstone

The maximum spacing of joints is 10cm and the rock is completely brittle or softened. Generally, the rock zone is distributed at the top of the basement rock or sheared zones, and sometimes lies between fresh sandstone strata. In addition, this class includes the mudstone layer sheared as a result of tectonic strain during folding.

Table 4.2.2-5 Rock Mass Classification based on the Weathering Degree

	Rock Mass Classification based on the Weathering Degree		
	Slightly Weathered (SW)	**Mederatory Weathered (MW)**	**Highly Weathered (HW)**
Sandstone	The rock is slightly dsicolored and discontinuities have slightly disocolored surfaces. The rock is still sufficiently hard. Joint spacing is generally lager than 30 centimeters. Several blows of hammer required to break sample.	The rock is discolored and discontinuities may be open and surfaces have greater discoloration. But, it's still sufficiently hard. Joint spacing is generarly larger than 10 centimeters. Several blows or few blows of hammer required to break sample.	The rock is discolored and brittle. Discontinuities are open and the rock is easily separated into the frgaments in many cases. Completely weatherd rock, which is externaly changed to a soil, is sporadically observed. One blow of hammer breaks sample. In some cases, broken by hand only with difficulty.
Mudstone	The rock may be slightly discolored and massive with less fissures. Several blows or few blows of hammer required to break sample.	The rock is discolored and discontinuities may be open and surfaces have greater discoloration. Joint spacing is generally larger than 10 cm, but it's a little bit brittle. Highly weatherd rock is sporadically observed. Few blows or one blow hammer breaks sample.	The rock is discolored and very brittle.Joint spacing is less than 10cm. Completely weatherd rock, which is externaly changed to a soil, is sporadically observed. One blow hammer breaks sample or broken by hand.

<Remarks> Modified the ckassification standard in the Report on Preparatory Survey on NAM NGUM 1 Hydropower Station Expansion, 2010, JICA

(4) Properties of the Foundation Rock

1) Physical Properties

Physical property tests (specific gravity, water absorption and unit weight) are carried out in the preparatory survey (2010, JICA). The tests are executed on the drilled cores of unweathered and slightly weathered sandstone. The result of the test shows that specific gravity is 2.56 and water absorption is 2.86% in average. Test results and the relationship between specific gravity and water absorption are shown in **Table 4.2.2-6** and **Figure 4.2.2-3** respectively.

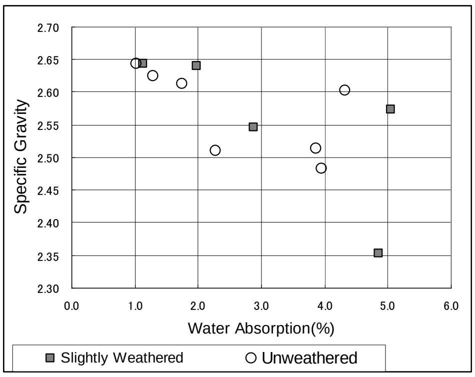


Figure 4.2.2-3 Specific Gravity and Water Absorption

Table 4.2.2-6 Result of the Physical property Tests

Drillhole (no.)	Sample (no.)	Depth (m)	～(m)	Material Type (geology)	(feature)	(weathering)	Specific Gravity % Water Absorption	Saturated Surface Dry	Total unit weight (kN/m^3)	Executed year	Remarks
JCA-1	sample 1	10.72	10.93	Sandstone	mudstone spot	SW	1.98	2.641	25.9	2009	
JCA-1	sample 2	17.72	17.87	Sandstone		UW	1.02	2.644	25.9	2009	
JCB-1	sample 3	17.73	18.00	Sandstone	grey,brown spot	SW	1.13	2.643	25.9	2009	
JCB-1	sample 4	18.12	18.29	Sandstone	dark grey	UW	4.32	2.602	25.5	2009	
JCB-2	sample 5	10.40	10.60	Sandstone	dark grey	UW	3.95	2.483	24.3	2009	
JCB-2	sample 6	22.00	22.19	Sandstone	grey,brown spot	SW	5.05	2.573	25.2	2009	
JCD-1	sample 7	9.85	10.00	Sandstone	grey,brown spot	SW	4.86	2.353	23.1	2009	
JCD-1	sample 8	22.77	23.00	Sandstone	grey,brown spot	SW	2.87	2.547	25.0	2009	
JCD-2	sample 9	5.50	5.66	Sandstone	dark grey	UW	3.86	2.513	24.6	2009	
JCD-2	sample 10	17.00	17.20	Sandstone	dark grey	UW	1.75	2.612	25.6	2009	
JCD-2	sample 11	41.64	41.89	Sandstone	dark grey	UW	2.28	2.510	24.6	2009	
JCD-2	sample 12	54.00	54.31	Sandstone	dark grey	UW	1.28	2.625	25.7	2009	
JCA-1	TT-1	10.10	10.14	Sandstone	grey,brown spot	SW	-	-	24.8	2009	naturally dry conditio
JCA-1	TT-2	10.14	10.18	Sandstone	grey,brown spot	SW	-	-	24.9	2009	naturally dry conditio
JCA-1	TT-3	10.18	10.22	Sandstone	grey,brown spot	SW	-	-	25.0	2009	naturally dry conditio
JCA-1	TT-4	16.49	16.53	Sandstone	dark grey	UW	-	-	25.5	2009	naturally dry conditio
JCA-1	TT-5	16.53	16.58	Sandstone	dark grey	UW	-	-	25.5	2009	naturally dry conditio
JCA-1	TT-6	16.58	16.62	Sandstone	dark grey	UW	-	-	25.6	2009	naturally dry conditio
JCA-1	UC-1	11.20	11.33	Sandstone		SW	-	-	25.4	2009	naturally dry conditio
JCA-1	UC-2	11.33	11.43	Sandstone		SW	-	-	25.3	2009	naturally dry conditio
JCA-1	UC-3	11.43	11.53	Sandstone		SW	-	-	25.7	2009	naturally dry conditio
JCA-1	UC-4	17.10	17.20	Sandstone		UW	-	-	25.5	2009	naturally dry conditio
JCA-1	UC-5	17.20	17.31	Sandstone		UW	-	-	25.6	2009	naturally dry conditio
JCA-1	UC-6	17.31	17.42	Sandstone		UW	-	-	25.7	2009	naturally dry conditio

Reference: Report on Preparatory Survey on NAM NGUM 1 Hydropower Station Expansion, 2010, JICA

2) Mechanical Properties

(a) Unconfined Compression Strength

Unconfined compression tests of rock are carried out for 64 samples in the construction stage of Nam Ngum 1 dam, F/S of the extension (1995, Lahmeyer) and the preparatory study of the expansion (2010, JICA). **Table 4.2.2-7** shows the test result and **Figure 4.2.2-4** shows the relationships between rock type/weathering degree and unconfined compression strength.

The average unconfined compression strength of sandstone is 82 MPa in unweathered condition, 50 MPa in slightly weathered condition and 33 MPa in moderately weathered condition. Although sandstone has high strength in general, some test results indicate extremely-low strength. This is assumed to be caused by the weak plane such as weathered bedding planes. On the other hand, the unconfined compression strength of mudstone is low in general, 22.4 Mpa in slightly weathered condition and 13.0 MPa in moderately condition.

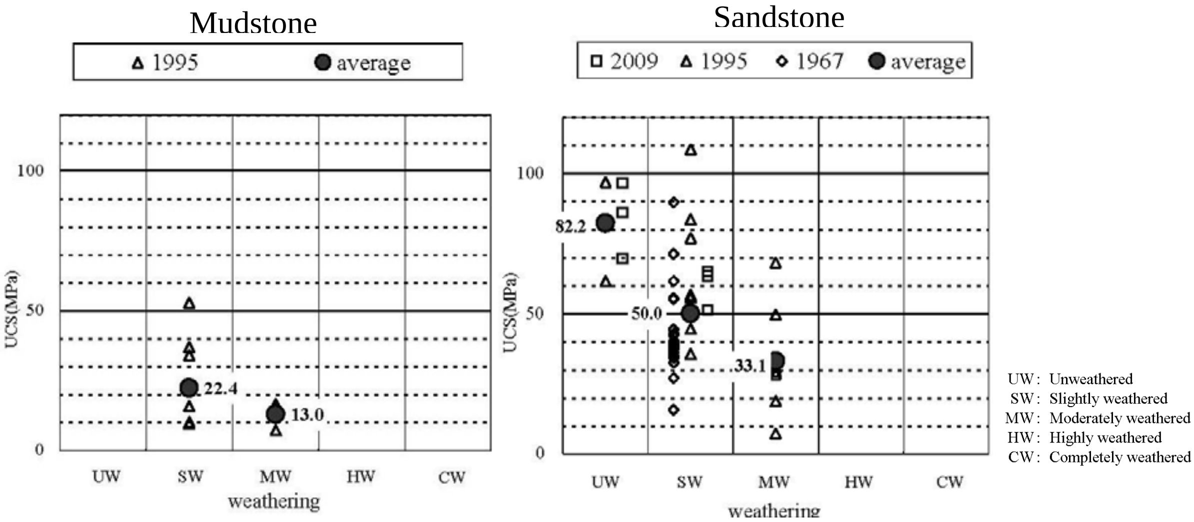
The unconfined compression strength tests of the dam concrete (No.20 block) are carried out in the F/S of the expansion (1995, Lahmeyer). Test results are shown in **Table 4.2.2-8.**

Table 4.2.2-7 Result of the Unconfined Compression Test

Drillhole	Sample	Depth		Geology			Diameter	Length	Unconfined Compressive Strength		Elasticity	Poisson ratio	Total unit weight	Executed year
(no.)	(no.)	(m)	～(m)	Rock Type		(weathering)	(cm)	(cm)	(kgf/cm2)	(MPa)	(MPa)		(kN/m^3)	
(dam foundation)	A-1	-	-	Sandstone	medium coarse	SW	49.00	98.00	265.00	26.01				Construc-tion Stage
(dam foundation)	A-2	-	-	Sandstone	medium coarse	SW	49.00	106.00	366.00	35.92				
(dam foundation)	A-3	-	-	Sandstone	medium coarse	SW	49.00	100.00	414.00	40.63				
(dam foundation)	A-4	-	-	Sandstone	medium coarse	SW	49.00	98.00	541.00	53.09				
(dam foundation)	A-5	-	-	Sandstone	medium coarse	SW	49.00	100.00	371.00	36.41				
(dam foundation)	B-1	-	-	Sandstone	coarse	SW	39.00	80.00	879.00	86.26				
(dam foundation)	B-2	-	-	Sandstone	coarse	SW	39.00	81.00	435.00	42.69				
(dam foundation)	B-3	-	-	Sandstone	coarse	SW	39.00	63.00	544.00	53.39				
(dam foundation)	B-4	-	-	Sandstone	coarse	SW	39.00	78.00	368.00	36.11				
(dam foundation)	B-5	-	-	Sandstone	coarse	SW	39.00	84.00	335.00	32.88				
(dam foundation)	C-1	-	-	Sandstone	fine medium	SW	49.00	93.00	604.00	59.27				
(dam foundation)	C-2	-	-	Sandstone	fine medium	SW	49.00	100.00	419.00	41.12				
(dam foundation)	C-3	-	-	Sandstone	fine medium	SW	49.00	97.00	700.00	68.69				
(dam foundation)	C-4	-	-	Sandstone	fine medium	SW	49.00	104.00	387.00	37.98				
(dam foundation)	D-1	-	-	Sandstone	medium	SW	49.00	100.00	153.00	15.01				
(dam foundation)	D-2	-	-	Sandstone	medium	SW	49.00	98.00	381.00	37.39				
(dam foundation)	D-3	-	-	Sandstone	medium	SW	49.00	86.00	435.00	42.69				
(dam foundation)	D-4	-	-	Sandstone	medium	SW	49.00	80.00	318.00	31.21				
(dam foundation)	E-1	-	-	Sandstone	very coarse	SW	49.00	90.00	355.00	34.84				
(dam foundation)	E-2	-	-	Sandstone	very coarse	SW	49.00	100.00	392.00	38.47				
(dam foundation)	F-1	-	-	Sandstone	medium	SW	39.00	80.00	335.00	32.88				
(dam foundation)	F-2	-	-	Sandstone	medium	SW	39.00	80.00	544.00	53.39				
(dam foundation)	F-3	-	-	Sandstone	medium	SW	39.00	90.00	343.00	33.66				
(dam foundation)	A'-1	-	-	Sandstone	coarse	SW	58.00	116.00	190.00	18.65				
(dam foundation)	B'-1	-	-	Sandstone	coarse	SW	58.00	95.00	152.00	14.92				
(dam foundation)	B'-2	-	-	Sandstone	coarse	SW	58.00	116.00	284.00	27.87				
(dam foundation)	B'-3	-	-	Sandstone	coarse	SW	58.00	85.00	190.00	18.65				
(dam foundation)	C'-1	-	-	Sandstone	medium coarse	SW	39.00	80.00	167.00	16.39				
(dam foundation)	D'-1	-	-	Sandstone	medium	SW	39.00	75.00	335.00	32.88				
XA1/1	1	2.82	2.95	Sandstone		MW	5.20	10.40	314.29	30.8				1995
XA1/1	2	6.70	6.90	Sandstone		MW	5.50	11,00	333.67	32.7				
XA1/1	3	12.00	12.15	Sandstone		SW	5.20	10.40	853.06	83.6				
XA1/1	4	15.00	15.15	Sandstone		SW	5.20	10.40	568.37	55.7				
XA1/1	5	18.75	19.00	Siltstone		MW	5.20	10.40	169.39	16.6				
XA1/1	6	20.00	20.20	Siltstone		MW	5.10	10.20	153.06	15.0				
XA1/1	7	22.05	22.30	Siltstone		SW	5.20	10.40	539.80	52.9				
XA1/1	8	26.15	26.30	Siltstone		SW	5.20	10.40	97.96	9.6				
XA1/1	9	28.50	28.65	Siltstone		SW	5.20	10.40	97.96	9.6				
XA1/2	2	4.40	4.60	Sandstone	fine grained	MW	5.20	10.40	507.14	49.7				
XA1/2	3	5.75	5.90	Sandstone		MW	5.20	10.40	73.47	7.2				
XA1/2	5	10.75	11.00	Siltstone	dark purple	SW	5.10	10.20	104.08	10.2				
XA1/2	7	17.50	17.70	Siltstone	dark purple	SW	5.20	10.40	97.96	9.6				
XA1/2	8	21.75	22.80	Siltstone	sandy	SW	5.20	10.40	347.96	34.1				
XA1/2	9	24.45	24.65	Sandstone		SW	5.20	10.40	578.57	56.7				
XA4/1	1	3.50	3.70	Sandstone		MW	5.40	10.80	190.82	18.7				
XA4/1	2	6.30	6.50	Sandstone		SW	5.20	10.40	363.27	35.6				
XA4/1	3	10.75	10.90	Sandstone		UW	5.20	10.40	989.80	97.0				
XA4/1	4	16.85	17.00	Sandstone		UW	5.20	10.40	627.55	61.5				
XA4/1	5	19.70	19.90	Mudstone		MW	5.00	10.00	74.49	7.3				
XA4/1	6	24.00	24.15	Mudstone		SW	5.20	10.40	377.55	37.0				
XA4/1	7	27.65	27.80	Mudstone		SW	5.00	10.00	162.24	15.9				
XA4/2	1	7.00	7.18	Sandstone	fine medium	MW	5.20	10.40	695.92	68.2				
XA4/2	2	9.35	9.55	Sandstone	conglomeratic	MW	5.20	10.40	298.98	29.3				
XA4/2	3	13.10	13.30	Sandstone	fine coarse	MW	5.20	10.40	288.78	28.3				
XA4/2	4	18.55	18.70	Sandstone	fine coarse	SW	5.40	10.80	455.10	44.6				
XA4/2	5	22.25	22.50	Sandstone	fine coarse	SW	5.40	10.80	786.73	77.1				
XA4/2	6	24.40	24.60	Sandstone	fine medium	SW	5.40	10.80	1109.18	108.7				
XA4/3	3	9.80	10.00	Mudstone		CW	5.00	10.00	58.16	5.7				
JCA-1	UC-1	11.20	11.33	Sandstone		SW	5.38	10.18	662.87	64.961	12,847	0.33	25.4	2009
JCA-1	UC-2	11.33	11.43	Sandstone		SW	5.40	10.10	522.46	51.201	12,002	0.27	25.3	
JCA-1	UC-3	11.43	11.53	Sandstone		SW	5.38	10.23	647.04	63.410	19,664	0.23	25.7	
JCA-1	UC-4	17.10	17.20	Sandstone		UW	5.40	10.48	985.99	96.627	17,532	0.30	25.5	
JCA-1	UC-5	17.20	17.31	Sandstone		UW	5.40	10.51	710.19	69.599	14,362	0.21	25.6	
JCA-1	UC-6	17.31	17.42	Sandstone		UW	5.40	10.55	878.13	86.057	16,251	0.24	25.7	

Reference: Report on Preparatory Survey on NAM NGUM 1 Hydropower Station Expansion, 2010, JICA

UW Unweathered
SW Slightly weathered
MW Moderately weathered
HW Highly weathered
CW Completely weathered



Reference: Report on Preparatory Survey on NAM NGUM 1 Hydroelectric Power Station Expansion, 2010 JICA

Figure 4.2.2-4 Unconfined Compression Strength and the Weathering Degree of Rock

Table 4.2.2-8 Result of the Unconfined Compression Test of Dam Concrete

Drillhole	Sample (no.)	Material Type	Diameter (cm)	Length (cm)	UCS (kgf/cm2)	UCS (MPa)
Dam	1	concrete	11.2	12.6	377.0	37
Dam	2	concrete	11.1	22.4	214.0	21
Dam	3	concrete	11.1	22.4	234.4	23
Dam	4	concrete	11.2	12.3	305.7	30
Dam	5	concrete	11.2	13.7	254.8	25
Dam	7	concrete	11.2	14.3	254.8	25
Dam	7	concrete	11.2	16.2	224.2	22
Dam	9	concrete	11.1	17.9	315.9	31
Dam	9	concrete	11.2	12.6	214.0	21
Dam	10	concrete	11.4	14.3	244.6	24

The cores were drilled normal to the dam face at an elevation of about 178m at 2 to 3m centres along Block 20

<Data sorce> Feasibility and Prelominary Design Report, 1995, LAHMEYER

(b) Tensile Strength

Results of the splitting tensile strength test executed in the preparatory study of the extension (2010, JICA) are shown in **Table 4.2.2-9** and the relationship between the weathering degree and tensile strength is shown in **Figure 4.2.2-5**. The average tensile strength is 20Mpa in unweathered condition and 5.8 MPa in slightly weathered condition. Although the test is executed only 6 sandstone samples, the tensile strength is obviously affected by weathering.

Table 4.2.2-9 Result of Splitting Tensile Strength Test

Drillhole	Sample	Depth		Geology			Diameter of sample	Length of sample	Tensile Strength		Total unit weight
(No.)	(No.)	(m)	～(m)	(Rock Type)		Weathering	(cm)	(cm)	(kgf/cm2)	(MPa)	(kN/m^3)
JCA-1	TT-1	10.10	10.14	Sandstone	grey,brown spot	SW	5.23	4.02	12.24	1.2	24.8
JCA-1	TT-2	10.14	10.18	Sandstone	grey,brown spot	SW	5.15	3.93	88.78	8.7	24.9
JCA-1	TT-3	10.18	10.22	Sandstone	grey,brown spot	SW	5.19	4.03	76.53	7.5	25.0
JCA-1	TT-4	16.49	16.53	Sandstone	dark grey	UW	5.39	4.49	179.59	17.6	25.5
JCA-1	TT-5	16.53	16.58	Sandstone	dark grey	UW	5.40	4.28	215.31	21.1	25.5
JCA-1	TT-6	16.58	16.62	Sandstone	dark grey	UW	5.39	4.41	219.39	21.5	25.6

Reference: Report on Preparatory Survey on NAM NGUM 1 Hydropower Station Expansion, 2010, JICA

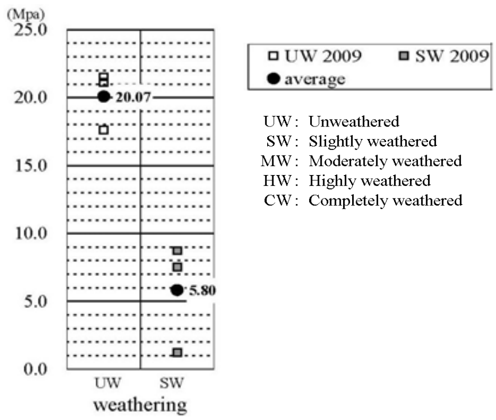


Figure 4.2.2-5 Tensile Strength and Weathering degree

(c) Deformability

As for the deformability of the rock foundation, the results of the plate bearing tests carried out in the exploratory adits are described in the completion report of Nam Ngum 1 Power station (1972, Nippon Koei). **Table 4.2.2-10** and **Figure 4.2.2-6** show the test results.

Table 4.2.2-10 Plate Bearing Test Result of dam Foundation Rock

Rock condition			Diameter	Max load	Creep under Max load		Total testing time	Total settlement	Load of failure	Young's moduls	
(geology)	(feature)	(weathering)	(cm)	(kgf/cm2)	(mm)	(hr)	(hr)	(mm)	(kgf/cm2)	(kgf/cm2)	(Mpa)
Sandstone	fresh	SW	350	104.1	0.214	22:58	26:35	1,320	no failure	41,000	4,024
Sandstone	weathered	MW	350	72.9	0.210	22:31	25:42	1,450	no failure	21,000	2,061
Sandstone	weathered	MW	350	83.3	0.343	23:10	26:35	2,912	no failure	19,000	1,865
Sandstone	weathered	MW	350	83.3	0.307	46:00	49:25	3,185	no failure	15,000	1,472
Sandstone	seriously weathered	HW	350	83.3	0.641	22:10	25:35	7,610	no failure	9,000	883
Mudstone	fresh, shale	SW	350	78.1	0.349	20:20	117:05	3,381	no failure	12,000	1,178
Mudstone	decomposed, stiff clay	CW	350	23.9	-	-	141:10	50.8	16.7	-	-

Reference: Final Report on NAM NGUM Hydro-Electric Project, 1972 NIPPON KOEI CO., LTD

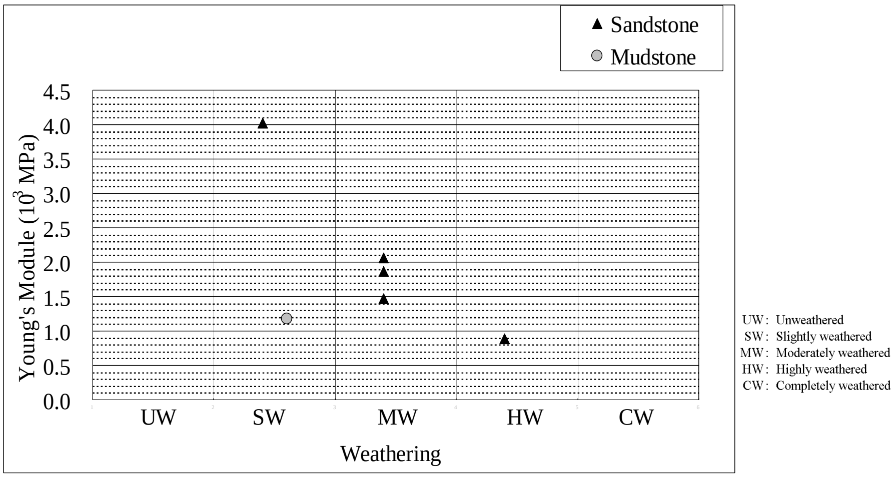


Figure 4.2.2-6 Deformability of the Dam foundation rock and Weathering degree

(d) N-Value

Standard penetration tests (SPTs) are carried out at the filling-up ground and completely or highly weathered zone. **Table 4.2.2-11** shows the test results. N-Value of the filling-up ground is N=36 at the surface and N>50 at the portion deeper than 3m from the ground surface according to the results of SPT in XA4/2 and XA4/3 holes at the existing powerhouse site on the left bank. Most of N-Values of the completely or highly weathered zone at the existing powerhouse site is N>50 except for the shallow portion of XA4/3 hole where the sheared mudstone layer associated with the folding movement is distributed in. N-Value in XA4/3 hole is N=5 to 14 from the ground surface to the depth of 4m, and N-Value is larger than 50 in deeper portion.

Table 4.2.2-11 List of Standard Penetration Tests

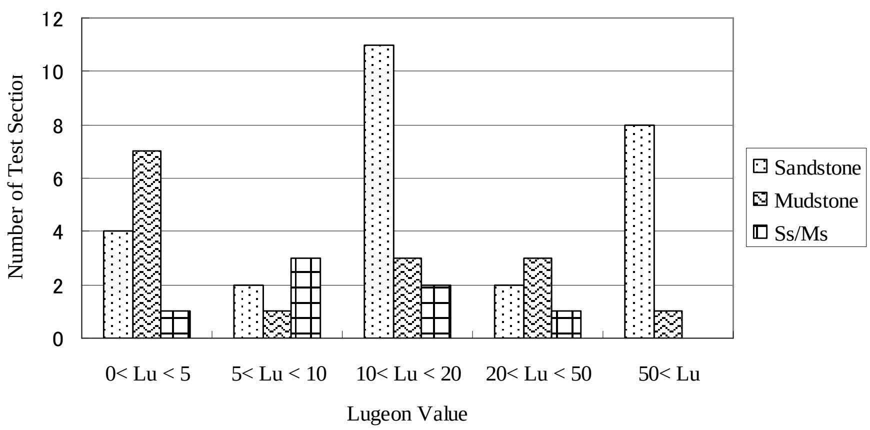
Drillhole (no.)	Stage (no.)	Depth (m)	~(m)	Material Type (geology)	(weathering)	Diameter (cm)	N (15-45)	penetrate (cm)	Number of Blows (0-10)	(10-20)	(20-30)	(30-40)	(40-50)	-	total penetrate (cm)	total blows	executed year
XA4/2	1	1.50	2.00	fill materiai A	-	9.90	36	30	14	17	10	11	13	-	50	65	1995
	2	3.00	3.26	fill materiai A	-	9.90	>50	6	19	30	50	-	-	-	26	99	1995
	3	5.20	5.27	Mudstone	CW	9.90	>50	7	50	-	-	-	-	-	27	50	1995
XA4/3	1	1.00	1.50	Sandstone	CW	9.90	5	30	1	1	2	2	1	-	50	7	1995
	2	3.45	3.95	Mudstone	CW	9.90	14	30	2	3	4	5	8	-	50	22	1995
	3	5.00	5.50	Mudstone	CW	9.90	46	30	6	11	12	18	22	-	50	69	1995
	4	7.05	7.19	Mudstone	CW	9.90	>50	14	37	50	-	-	-	-	34	87	1995
									(0-7.5)	(7.5-15)	(15-22.5)	(22.5-30)	(30-37.5)	(37.5-45)			
JCA-1	SS1	1.00	1.45	Sandstone	CW	10.0	15	30	4		5		10		45	19	2009
	SS2	2.00	2.45	Sandstone	CW	10.0	20	30	17		13		7		45	37	2009
	SS3	3.00	3.45	Sandstone	CW	10.0	56	30	15		26		30		45	71	2009
	SS4	4.00	4.45	Sandstone	CW	10.0	43	30	15		20		23		45	58	2009
	SS5	5.00	5.45	Sandstone	CW	10.0	61	30	12		29		32		45	73	2009
	SS6	6.00	6.05	Sandstone	CW	10.0	>50	5	unknown	unknown	50	-	-	-	20	>50	2009
	SS7	7.00	7.05	Sandstone	HW	10.0	>50	5	unknown	unknown	50	-	-	-	20	>50	2009
	SS8	8.00	8.08	Sandstone	HW	10.0	>50	7.5	unknown	unknown	50	-	-	-	23	>50	2009
JCB-1	SS1	1.00	1.45	fill materiai	-	10.0	13	30	3	3	3	4	3	3	45	19	2009
	SS2	2.00	2.45	fill materiai	-	10.0	11	30	3	3	3	3	2	3	45	17	2009
JCB-2	SS1	1.00	1.45	fill materiai	-	10.0	16	30	16	6	3	6	3	4	45	38	2009
	SS2	2.00	2.45	fill materiai	-	10.0	>50	3	24	45	50	-	-	-	18	119	2009
JCD-1	SS1	1.00	1.45	Mudstone	CW	10.0	26	30	4	6	5	8	6	7	45	36	2009
	SS2	2.00	2.45	Mudstone	CW	10.0	30	30	5	7	6	8	7	9	45	42	2009
	SS3	3.00	3.45	Mudstone	CW	10.0	36	30	8	6	7	9	9	11	45	50	2009
	SS4	4.00	4.30	Mudstone	CW	10.0	>50	30	15	15	20	32	-	-	45	82	2009
JCD-2	SS1	1.00	1.45	Sandstone	CW	10.0	>50	30	6	8	9	10	18	21	45	72	2009

Reference: Report on Preparatory Survey on NAM NGUM 1 Hydroelectric Power Station Expansion, 2010 JICA

3) Characteristics of Permeability

(a) Permeability

Results of the Lugeon test conducted in the project site are shown in **Table 4.2.2-12**, and the Lugeon values of sandstone and mudstone are shown in **Figure 4.2.2-7**. Permeability of sandstone is large in general; it ranges from 10 Lu to several tens Lu in many cases. On the other hand, permeability of mudstone is relatively low; it is less than 5 Lu in many cases. High permeability of sandstone is presumed to be caused by joints parallel or oblique to the bedding plane in sandstone.



Data Source: Report on Preparatory Survey on NAM NGUM 1 Hydroelectric Power Station Expansion, 2010 JICA

Figure 4.2.2-7 Rock Type and Lugeon Value

Table 4.2.2-12 Results of Lugeon Test

Drillhole	stage	Depth		section	Material Type			Lugeon		(break	(max	executed
(no.)	(no.)	(m)	~(m)	(m)	(geology)	(feature)	(weathering)	(original)	(JICA '09)	pressure)	pressure)	(year)
D-1	-	6.90	9.30	2.40	mud stone	weak		5.0				1966
D-16	-	4.30	9.30	5.00	mud stone	decomposed		5.0				1966
D-16	-	9.30	14.30	5.00	sand stone, mud stone	jointed		10.0				1966
D-16	-	14.30	19.30	5.00	sand stone, mud stone	jointed		5.0				1966
D-16	-	19.30	24.30	5.00	mud stone	jointed		19.0				1966
D-16	-	24.30	27.30	3.00	sand stone	jointed		6.0				1966
D-28	-	7.50	12.50	5.00	sand stone, mud stone		weathered	20.0				1966
D-28	-	12.50	17.50	5.00	sand stone, mud stone	jointed		12.0				1966
D-28	-	17.50	20.50	3.00	sand stone, mud stone			6.0				1966
D-29-1	-	5.00	10.00	5.00	sand stone		weathered	28.0				1966
D-29-1	-	15.00	21.00	6.00	sand stone		weathered	16.0				1966
D-29-3	-	6.80	11.80	5.00	sand stone		weathered	93.0				1966
D-29-3	-	11.80	16.80	5.00	sand stone		weathered	93.0				1966
D-29-3	-	16.80	20.00	3.20	sand stone	hard		1.0				1966
D-33	-	4.50	9.50	5.00	sand stone		weathered	20.0				1966
D-33	-	15.00	20.50	5.50	sand stone	hard		80.0				1966
D-34	-	10.00	15.00	5.00	sand stone	hard		80.0				1966
D-18	-	9.60	15.00	5.40	sand stone	cracks		9.0				1966
D-25	-	11.60	15.40	3.80	sand stone	jointed		11.0				1966
D-25	-	15.50	20.50	5.00	mud stone	jointed		8.0				1966
D-24	-	6.10	11.00	4.90	mud stone	decomposed		102.0				1966
D-24	-	16.00	20.00	4.00	sand stone	hard		25.0				1966
D-30	-	6.00	11.00	5.00	mud stone	jointed		22.0				1966
D-30	-	11.00	16.00	5.00	mud stone	jointed		20.0				1966
D-30	-	16.00	20.00	4.00	sand stone	jointed		11.0				1966
DX-2	-	11.00	17.00	6.00	sand stone	jointed		47.0				1966
DX-2	-	5.00	10.00	5.00	sand stone	decomposed		20.0				1966
XA1/1	1	8.65	14.20	5.55	sand stone	conglomrate	MW	62.0	25.4	-	2.20	1995
XA1/1	2	14.00	18.50	4.50	sand stone, mud stone	breaken	SW-MW	20.0	33.3	-	2.11	1995
XA1/1	3	19.00	23.60	4.60	mud stone	crack	SW-MW	101.0	24.4	1.81	1.81	1995
XA1/1	4	24.00	29.00	5.00	mud stone		UW-SW	30.0	1.3	2.15	2.65	1995
XA1/2	1	5.00	9.75	4.75	mud stone	core loss	MW	42.0	30.1	-	1.92	1995
XA1/2	2	9.75	15.15	5.40	mud stone		SW	0.4	0.4	-	2.15	1995
XA1/2	3	16.00	20.80	4.80	mud stone	crushed	CW	0.4	0.3	1.67	2.17	1995
XA1/2	4	19.00	25.00	6.00	mud stone		SW	0.1	0.043	-	2.19	1995
XA4/1	1	6.00	11.00	5.00	sand stone	core loss	SW, CW	133.0	104.2	-	2.45	1995
XA4/1	2	10.00	15.00	5.00	sand stone		UW	1.0	0.7	-	2.66	1995
XA4/1	3	15.00	20.00	5.00	sand stone, mud stone	core loss	MW, CW	17.0	5.4	1.48	2.44	1995
XA4/1	4	20.00	25.05	5.05	mud stone	core loss	SW, CW	19.0	10.9	-	2.44	1995
XA4/1	5	25.00	30.00	5.00	mud stone		SW, HW	1.0	1.4	-	2.32	1995
XA4/2	1	6.90	12.15	5.25	sand stone	core loss	MW, CW	47.0	32.7	1.26	1.65	1995
XA4/2	2	12.80	17.30	4.50	sand stone	core loss	MW, CW	3.0	0.3	-	2.34	1995
XA4/2	3	17.00	22.30	5.30	sand stone		SW	62.0	107.4	-	1.33	1995
XA4/2	4	20.00	25.00	5.00	sand stone		SW	28.0	180.0	-	1.00	1995
JCA-1	1	14.50	20.00	5.50	sand stone		UW		61.6	-	3.55	2009
JCD-2	1	10.00	15.00	5.00	sand stone		SW		12.6	-	5.33	2009
JCD-2	2	15.00	20.00	5.00	sand stone		UW		2.2	-	5.48	2009
JCD-2	3	41.00	46.00	5.00	sand stone	core loss	MW		11.2	-	5.09	2009
JCD-2	4	50.00	55.00	5.00	sand stone		UW		10.1	-	5.33	2009

Reference: Report on Preparatory Survey on NAM NGUM 1 Hydroelectric Power Station Expansion, 2010 JICA

(b) Groutability

According to the record of the curtain grouting at the existing Nam Ngum 1 dam, the average distance between injection holes is 80cm and average injected cement volume is 1 to 2 kg/m.

In the extension project, the sandstone layers and the weathered zone of the foundation rock may need to be grouted in order to prevent seepage through the foundation. As the injected cement volume for the curtain grouting at the existing dam is the results in the fresh sandstone, the necessary cement volume is estimated to increase in the weathered zone, and the cement volume will be little in the low permeable mudstone.

(5) Geological Evaluation of the Alternative Options

The geological plan of the project area is shown in **Figure 4.2.2-8**. The project area is composed of alternating beds of sandstone and mudstone in Jurassic to Cretaceous era, which strike parallel to the dam axis. Therefore, geology of each alternative option, which is planned in right bank, downstream of the dam and in the left bank, is basically similar. Sandstone is hard in general, but mudstone is somewhat weak and tends to be deteriorated by weathering. However, both of them have no serious problem for the foundation of the structure planned in each option. Further, large fault or landslide, which may obstruct the expansion works, has not been found in the project area.

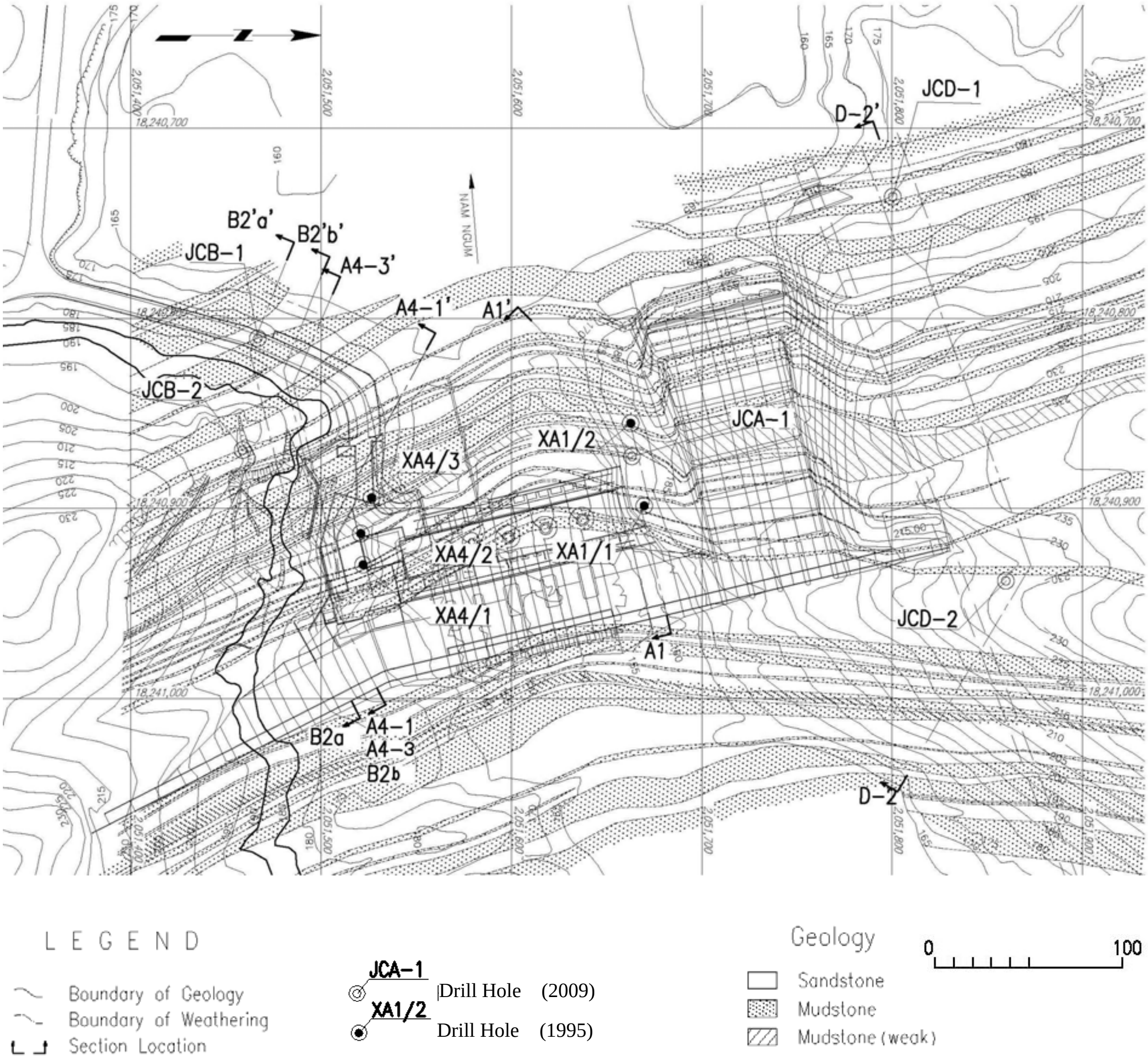


Figure 4.2.2-8 Geological Plan of the Project Site

1) Option A1 (40MW) [Option A2 (60MW)]

In this option, a new powerhouse is planned to be constructed between the existing powerhouse and the spillway, and the existing tail bay will be shared by a new unit. Option A1 and A2 are same layout, but option A1 is 40MW upgrading and option A2 is 60MW upgrading.

The space for the new powerhouse is so narrow that a steep excavated slope will be formed at the spillway side (north side). Further, the temporary enclosure in the tail bay will be necessary to secure the generation of existing power station during the construction works. The longitudinal profile of the waterway alignment is shown in **Figure 4.2.2-9**.

Excavated slope consists of alternating bed of sandstone and mudstone. The direction of bedding plane, which crosses the slope face perpendicularly, is favorable for the slope stability. However, an appropriate reinforcement of the slope and protection of the slope surface are necessary because of the following reasons; a) some part of the slope is composed of deteriorated weak mudstone, b) the height of the slope is 30 to 40m, c) the slope is very steep, d) the top of slope is near to the spillway. Especially, considerable attention is required in A2 option because the top of slope is very near to the spillway. The slope at upstream side (east side) will be excavated parallel to the bedding plane of sandstone which forms the dam foundation. Therefore, a suitable reinforcement of slope is required preventing the slope failure along the bedding plane.

As the basement rock of the tail bay consists mainly of mudstone, the permeability of the foundation rock is relatively low in general. However, permeable sandstone layers are intercalated in mudstone, hence, the grouting may be necessary to prevent the seepage under the temporal closure.

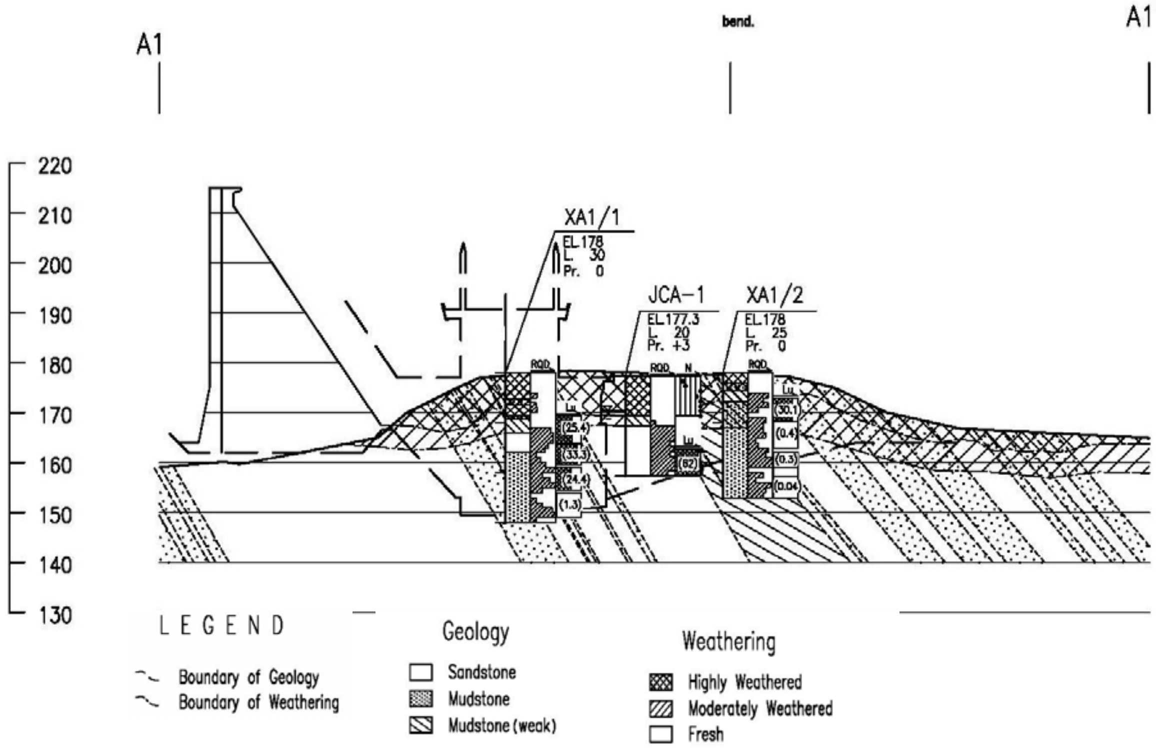


Figure 4.2.2-9 Geological Profile (A1 & A2)

2) Option A4 [A4-1(40MW), A4-2(60MW), A4-3(40MW), A4-4(60MW)]

In this option, a new powerhouse is planned to be constructed at the immediately downstream of the existing dam on the left bank, and the tailrace tunnel will be excavated to the downstream. Although this option is divided into 4 options (A4-1 to A4-4) according to the location of the outlet and upgrading scale, the geological condition and the geotechnical important points are same in each option.

The foundation rock of the powerhouse is alternating bed of sandstone and mudstone same as A1 option. And the same attention to the slope stability as A1 option is required. Further, as large excavated slope is formed on the left bank composed of highly or completely weathered rock, the countermeasure for the surface sliding of the slope is required.

Tailrace tunnel passes the highly weathered mudstone layer, which is also sheared due to the folding immediate downstream of the planned powerhouse. The length of this section is 20 to 30m and the earth covering is thin in this section. Therefore, careful excavation and proper supporting are required especially in this section.

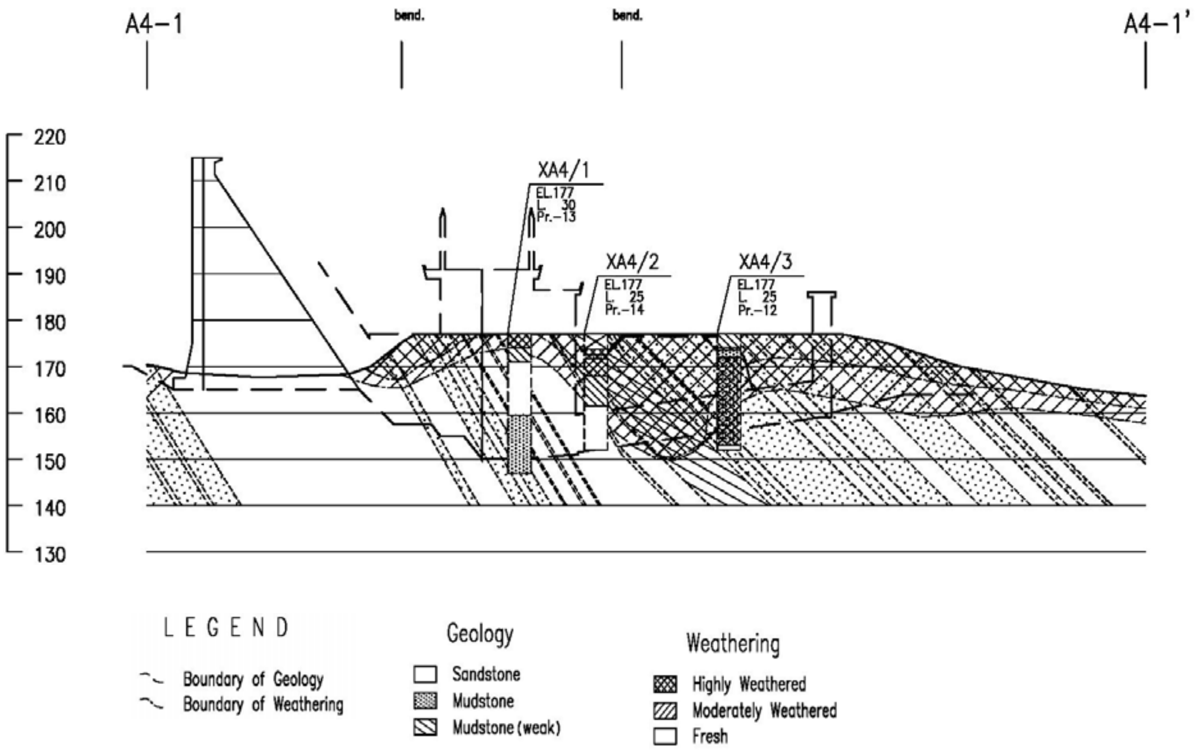


Figure 4.2.2-10 Geological Profile (A4)

3) Option B2 [B2-1(80MW), B2-2(120MW)]

In this option, two headrace tunnels are excavated in the left bank, one is 150m length and the other is 60m length, and a powerhouse is constructed in the downstream area.

The tunnel route is composed of alternating bed of sandstone and mudstone, these rocks are fairly fresh, slightly weathered, except for the mouth of tunnel. However, as the south (mountain side) tunnel crosses the detorirated mudstone layer and higly weathered zone with thin earth covering, careful excavation and proper supporting are required in this section. Groundwater level in the left bank is confirmed at high elevation of EL.200 in the investigation drilling, JCB-2. So, the attention should be paid to the deterioration of mudstone caused by the spring water. As for the north (near the riverside) headrace, the first 90m section is open cut and creates a large excavated slope the left bank composed of highly or completely weathered rock. Therefore, the countermeasure for the surface sliding of the slope is required.

Foundation rock of the powerhouse is presumed to be slightly or moderately weathered sandstone and mudstone.

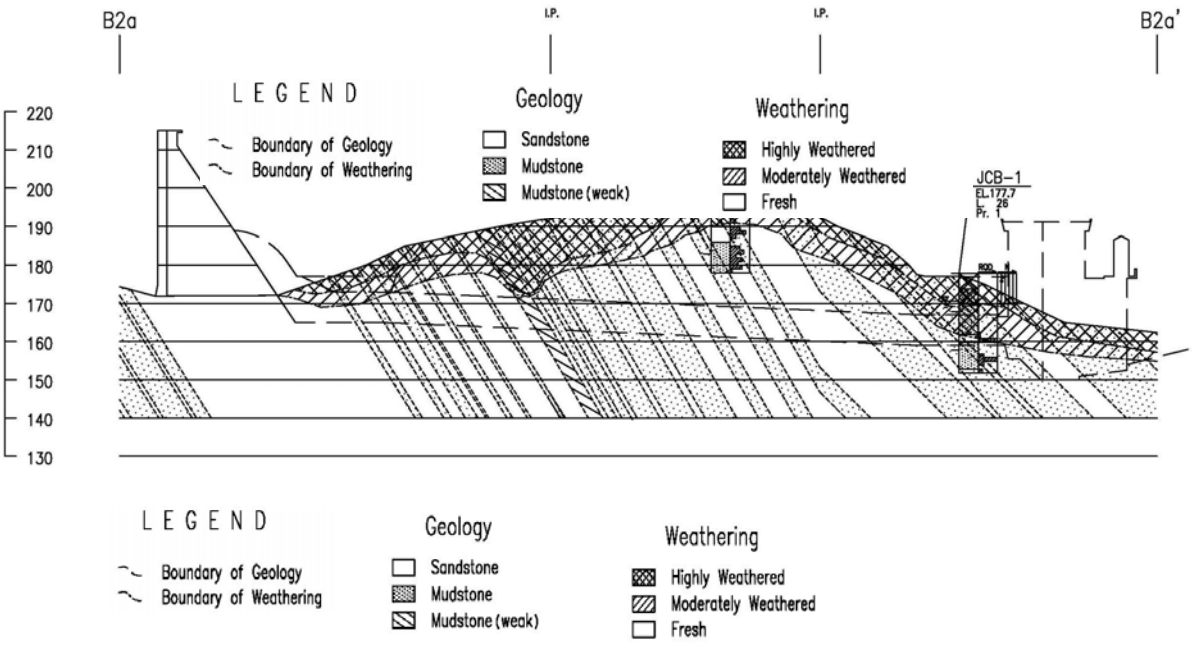


Figure 4.2.2-11 Geological Profile (B2)

4) Option B2' [B2'-1(80MW), B2'-2(120MW), B2'-1-1(40MW), B2'-2-1(60MW)]

The alignment of the headrace in this option is same as one in option B-2, but the whole headrace route is open excavated and the elevation of the headrace is EL.177 equal to the ground level of the existing powerhouse site. Two headraces are constructed in option B2'-1 and B2'-2, and one hedrace is constructed in north side(near the riverside) in option B2'-1-1 and B2'-2-1.

The excavated slope will be formed on the left bank in this option. In case of two headraces option (B2’-1 and B2’-2), a large excavated slope is formed in the left bank composed of highly weathered rock. So, the adequate countermeasures for the surface slope collapses are required in this case. On the other hand, the excavated slope is small and composed mainly of the moderatory weathered rock in case of one headrace tunnel option (B2’-1-1 and B2’-2-1) because the headrace route is situated at near the riverside. This is an adavantage to the slope stability.

Foundation rock of the powerhouse is same as B2 option, and serious geotechnical problem is not confirmed.

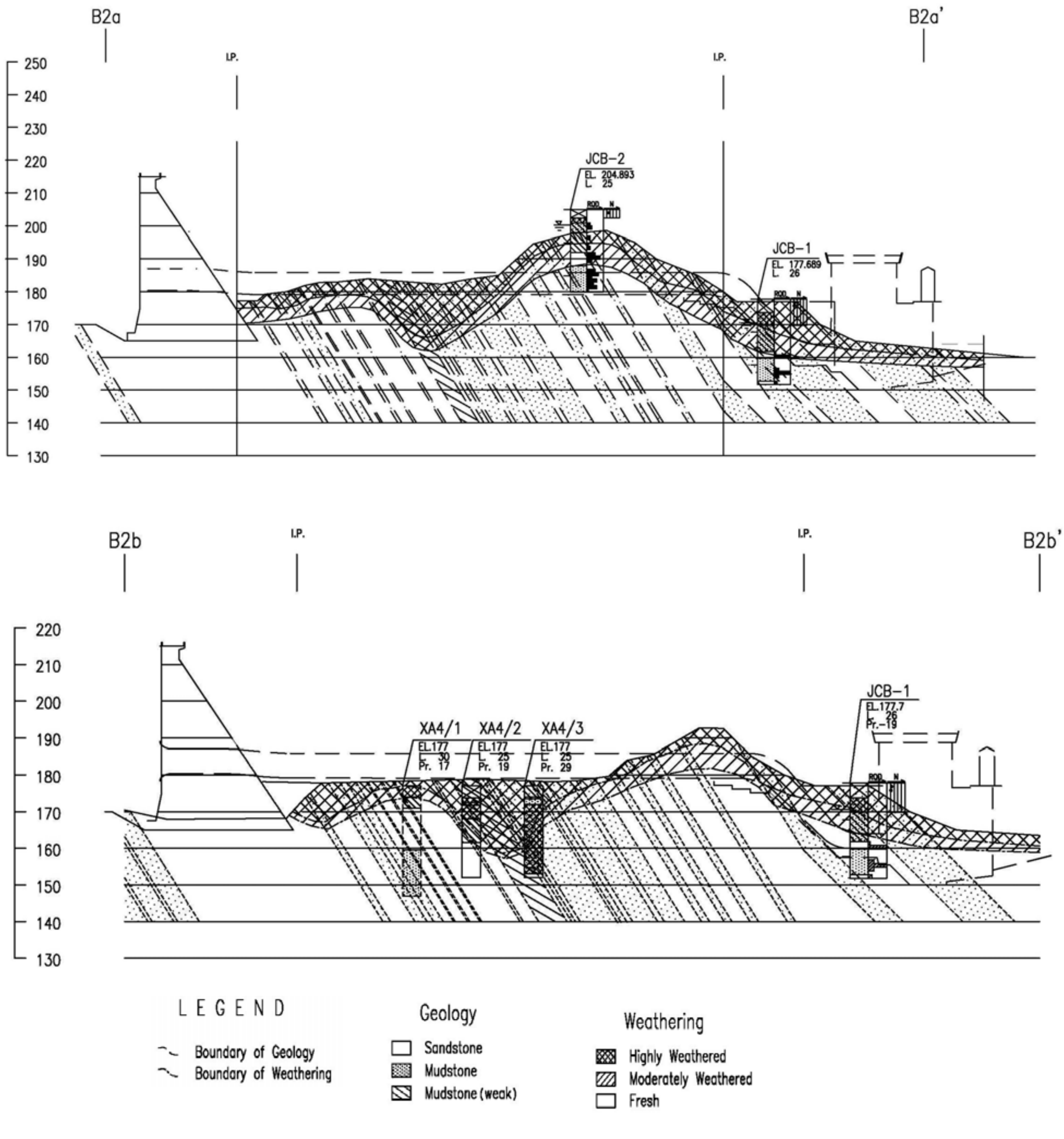


Figure 4.2.2-12 Geological Profile (B2’)

5) Option D2 [D2-3(80MW), D2-4(120MW)]

In this option, an intake is constructed in the upstream of the right abutment of dam and a headrace tunnel is excavated in the right bank. Although the headrace tunnel route is consists mainly of slightly weathered alternating bed of sandstone and mudstone, some deteriorated mudstone layers are distributed in several portions of the tunnel route. According to the completion report, collapse of tunnel wall and deterioration of mudstone (changing to clay) due to spring water occur in the tunnel section of mudstone during the excavation of the diversion tunnel. So, the countermeasures for these phenomenon are required.

In this option, the temporary enclosure is also located in the inlet portal. The basement rock consists dominantly of permeable sandstone, thus grouting at the sandstone parts may be necessary.

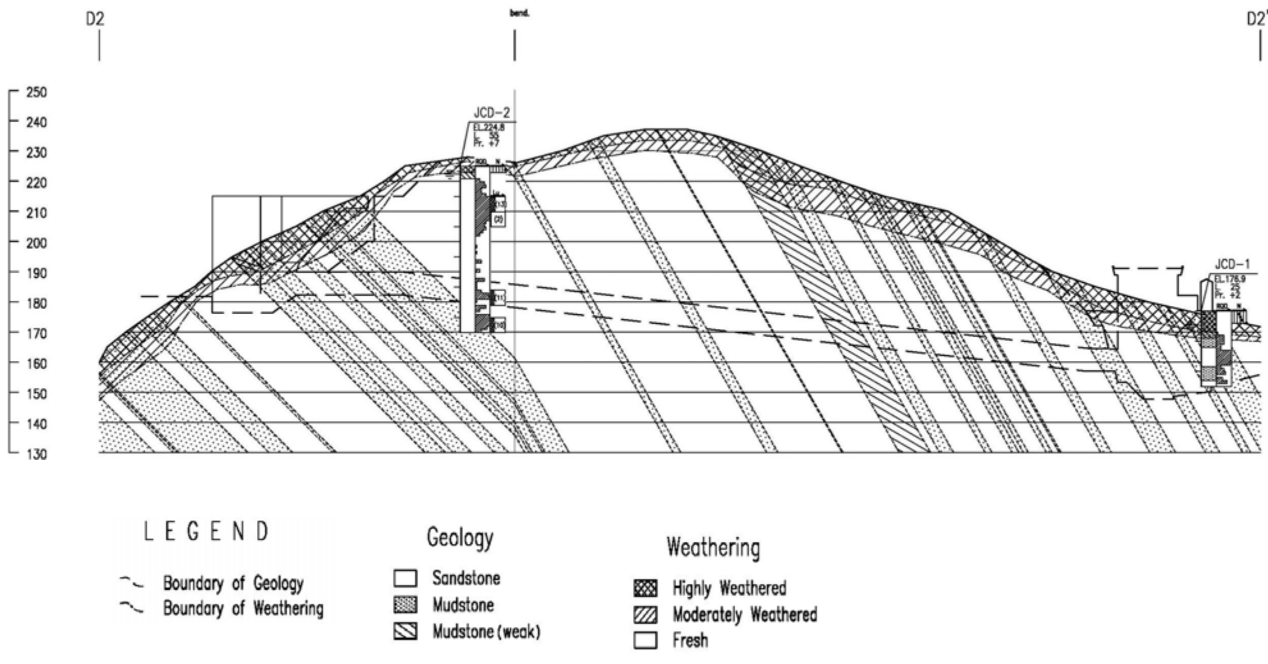


Figure 4.2.2-13 Geological Profile (D2)

(6) Construction Materials

According to the F/S of extension (1995) and Preparatory survey of expansion (2010), sand and gravel of the Nam Lik River is promising for the concrete aggregates. The candidate site is located in the riverbed 3 to 4 km upstream of the confluence of Nam Lik River with the Nam Ngum River. A company named “VATSANA PONGPANYA ABORBROCK BEACH COMPANY” runs the quarrying there. The materials of Nam Lik River have been used for the construction of the existing

Nam Ngum 1 powerhouse.

At the F/S of the extension (1995), concrete aggregate tests are carried out using sand and gravel collected from the candidate site. Test results show that specific gravity is 2.53 -2.66, water absorption is 0.35 -1.21% and abrasion loss is 28.0 -32.97% as indicated in **Table 4.2.2-13.** These results satisfy the ASTM standard and JIS standard. The result of Alkali-Silica reaction test (chemical method) shows that Sc=28.08-32.97 mmol/L and Rc=41.83-68.61 mmol/L. This result means that materials from the candidate site of Nam Lik River have no Alkali-Silica reactivity.

Table 4.2.2-13 Test Result of the Concrete Aggregate

Type of Material	% Passing Sieve													F.M	Los Angeles Abration %	Specific Gravity g/cm3	Water Absorption %
	50.0 mm	38.1 mm	25.0 mm	19.0 mm	12.50 mm	9.50 mm	4.75 mm	2.36 mm	1.18 mm	0.600 mm	0.300 mm	0.150 mm	0.075 mm				
Sand	-	-	-	-	100	99.3	97.72	95.09	91.32	41.23	8.42	1.42	0.18	2.65	-	2.54	1.21
Sand & gravel	-	-	100	85.66	76.97	70.83	57.66	44.28	28.97	17.66	5.52	0.97	0.28	4.86	-	2.53	0.83
Gravel	-	-	100	64.43	52.59	38.58	1.12	-	-	-	-	-	-	6.95	31.40	2.66	0.79
Gravel	100	65.4	56.73	42.56	25.73	15.26	2.89	0.24	0.19	0.14	0.09	-	-	7.73	28.00	2.64	0.35

Reference: Report on NAM NGUM 1 HYDROPOWER STATION EXTENSION FEASIBILITYAND ENGINEERING STUDY, August 1995, LAHMETER

Table 4.2.2-14 Result of the Alkali-Silica Reaction Test

Sample No.	Dissolved Silica mmol/L	Reduction in Alkalinity mmol/L
Sand No.1 Ban kail ko	29.42	68.61
Sand No.2 Had Xay Ngam 1	28.08	66.93
Gravel No.1 Ban kail ko	32.97	41.83

Reference: Report on NAM NGUM 1 HYDROPOWER STATION EXTENSION FEASIBILITYAND ENGINEERING STUDY, August 1995, LAHMETER

4.2.3 INTAKE AND WATERWAY

(1) Intake

As to alternatives A (A1, A2, A4-1, A4-1, A4-3, A4-4) and B (B2’-1, B2’-2, B2’-1-1, B-2’-2-1) among 12 alternatives in total, an intake is installed after the construction of temporary steel enclosure at the upstream surface of the dam and piercing dam. As to Alternatives D (D3, D4), an intake is installed after the construction of steel pipe sheet pile enclosure, which is located in the upstream right bank of the dam. As to alternatives B2’-1 and B2’-2 having capacity of 80MW and 120MW respectively, piercings are not made at a single but neighboring No. 10 and 11 blocks in order to reduce the piercing diameter to the dam block width of 15m.

Penstock diameter is determined so that the velocity should be about 5 m/s in alternative A and B in which the waterway lengths are relatively short, while it is determined larger to reduce head loss in alternative D of which waterway length is longer than other alternatives.

Principal features of the intake for each generating capacity in each waterway are shown in **Table 4.2.3.1**.

Table 4.2.3.1 Principal Features of Intake

	Alternative-A,B		Alternative-D			
	40MW	60MW	40MW	60MW	80MW	120MW
Penstock Diameter	5.50m	6.70m	6.00m	7.40m	8.50m	10.50m
Penstock Center Level	185.25	183.70	186.00	184.60	183.25	180.25
Maximum Discharge	$118m^3/s$	$177m^3/s$	$118m^3/s$	$177m^3/s$	$236m^3/s$	$354m^3/s$

Prepared by JICA Survey Team

(2) Headrace tunnel

As to Alternatives D, a pressure headrace tunnel is constructed between the intake and power station.

Diameter of the headrace tunnel is the same as of the intake. Steel liner is installed where the rock coverage is small to the expected inner pressure in the headrace tunnel, and the gap between the liner and rock surface is filled with concrete.

(3) Penstock

Penstock is lined until the powerhouse from the intake gate in alternatives A and B, and from the end of the headrace in alternative D, while the upstream section is lined with concrete.

Diameter of the penstock in the upstream end is the same as of the intake.

(4) Tailrace tunnel

As to Alternatives A4-1, A4-1, A4-3, A4-4, a tailrace tunnel is constructed between the power station and outlet. For a successive operation of the Nam Ngum 1 power station, temporary enclosure is constructed during the construction work of outlet structure. Diameter of the tailrace tunnel is the same as the headrace tunnel, and lining concrete is placed.

(5) Temporary enclosure

As a temporary enclosure in Alternatives D, a steel pipe sheet pile enclosure is proposed to resist a high water pressure. The steel pipe sheet pile is installed from the steel pier.

As a temporary enclosure for piercing dam in Alternatives A and B, the enclosure method was recommended best in the previous feasibility study to be channel shaped placed from the piercing elevation to the dam crest along the upstream surface and fixed with brackets and anchorages conducted underwater because of a plenty of experiences in Japan. Although this channel type of enclosing method provides a construction space to water surface for easiness of piercing and settling metal structures as well as high reliability, comes expensive to the total project cost in case of the closing depth is as large as over 30 m. It was also pointed in the previous feasibility report that restriction of reservoir level would bring cost reduction, however it is still uncertain to realize.

On the other hand another alternative is proposed on this report in addition to the previous method, that is, the minimum working area is enclosed with a bulkhead to conduct breaking through of the dam-body and installing the screen jigs. This method had been estimated in Japan as an inexpensive alternative to the traditional channel-shaped and has been realized under 26 m depth in Naruko dam in 2006. Therefore it is also considered sufficiently reliable.

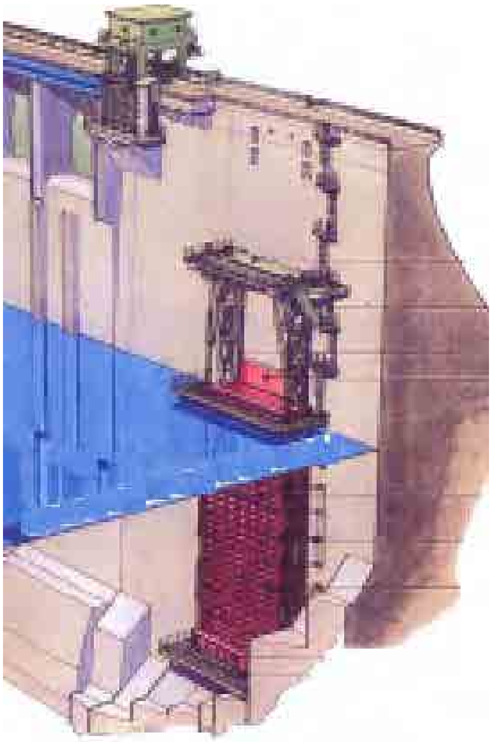
As to alternatives A and B, general features and cost in each method are shown in **Table 4.2.3.2**. The images of the both methods are also exhibited in **Figure 4.2.3.1**. The results show us that bulkhead method can reduce steel weight to a third, and accordingly cost to a half of the channel-shaped. Therefore hereinafter the bulkhead method is adopted for enclosing the Nam Ngum dam.

Table 4.2.3.2 Principal Features of Steel Enclosure

Closure Type		Channel-Shaped		Bulkhead	
Installed Output		40MW	60MW	40MW	60MW
Inner Dimension	Width	12m	13m	10m	11m
	Length	4m	4m	2m	2m
	Height	32m	32.7m	12m	13m
Weight of Steel		580t	660t	160t	200t

Prepared by JICA Survey Team

In accordance with revision of enclosing method, some of the steel structures in the intake shall be revised because, different from in the existing units, with the method the rails for exchanging screen and stop logs cannot be attached to the dam upstream surface. The inlet screen shall be of fixed type and the inspection gate shall be shifted just upstream of the main gate. Since the inspection gate leaf is advisable to be repaired and inspected above the reservoir level, the inspection gate should be installed in the gate tower at the downstream end of the dam section, and accordingly the main gate type should not be of a high-pressure slide gate but a roller gate.



Channel-Shaped

Bulkhead

Figure 4.2.3.1 Two Types of Steel Enclosure

Prepared by JICA Survey Team

(6) Piercing dam

Diameter of piercing dam is 6.7 m for 40 MW expansion and 7.9 m for 60 MW expansion. Clearance between the penstock and dam body is set to 0.6 m as a necessary space for installing the penstock. It is determined from similar precedents of installing penstock. In this study the dam piercing method is expected excavation with a giant breaker after isolation in every 1.2 m along the whole circumference of the excavated area with slot drilling.

Principal features of piercing dam is shown in Table 4.2.3.3.

Table 4.2.3.3 Principal Features of Piercing Dam

	40MW	60MW
Penstock Diameter	5.50m	6.70m
Piercing Diameter	6.70m	7.90m
Piercing Length	22.4m	23.4m
Center Level of Piercing	185.25	183.7

Prepared by JICA Survey Team

4.2.4 POWER HOUSE

As presented in Section 4.1, there are 12 alternative plans determined based on the location of power stations and the installed capacity.

Major features of such alternatives are summarized below.

Table 4.2.4.1 Major Features of Powerhouse and Tailrace for Each Alternative Plan

No.	Alternative Plans	Major Features	
1	**A1** (40MWx1 unit)	Powerhouse	• Above ground powerhouse is extended adjacent to the existing powerhouse and spillway. • No turbine inlet valve is installed. • No additional overhead traveling (OHT) crane is installed.
		Tailrace	• Tailrace type is open channel. • The existing tailrace gate & gantry crane are used.
2	**A2** (60MW x 1 unit)	Powerhouse	• Above ground powerhouse is extended adjacent to the existing powerhouse and spillway. • No turbine inlet valve is installed. • New OHT crane (250 tons) is installed.
		Tailrace	• Tailrace type is open channel. • New tailrace gate (80 tons) & gantry crane is installed.
3	**A4-1** (40MW x 1 unit)	Powerhouse	• Above ground powerhouse is independently constructed adjacent to the existing control room. • No turbine inlet valve is installed. • New OHT crane (170 tons) is installed.
		Tailrace	• Tailrace type is short tunnel with 6.0 m dia. and approximately 40 m length. • New tailrace gate (56 tons) & gantry crane is installed.
4	**A4-2** (60MW x 1 unit)	Powerhouse	• Above ground powerhouse is independently constructed adjacent to the existing control room. • No turbine inlet valve is installed. • New OHT crane (250 tons) is installed.
		Tailrace	• Tailrace type is short tunnel with 7.4m diameter and approximately 40 m length. • New tailrace gate (80 tons) & gantry crane is installed.
5	**A4-3** (40MW x 1 unit)	Powerhouse	• Above ground powerhouse is independently constructed adjacent to the existing control room. • No turbine inlet valve is installed. • New OHT crane (170 tons) is installed.
		Tailrace	• Tailrace type is long tunnel with 6.0 m diameter and approximately 100 m length. • New tailrace gate (56 tons) & gantry crane is installed.
6	**A4-4** (60MW x 1 unit)	Powerhouse	• Above ground powerhouse is independently constructed adjacent to the existing control room. • No turbine inlet valve is installed. • New OHT crane (250 tons) is installed.
		Tailrace	• Tailrace type is long tunnel with 7.4 m diameter and approximately 100 m length. • New tailrace gate (56 tons) & gantry crane is installed.

No.	Alternative Plans		Major Features
7	**B2'-1** (40MW x 2 units = 80MW)	Powerhouse	• Above ground powerhouse is independently constructed at left bank of approx. 160 m downstream from the existing power station. • No turbine inlet valve is installed. • New OHT crane (170 tons) is installed.
		Tailrace	• Tailrace type is open channel. • New tailrace gate (56 tons) & gantry crane is installed.
8	**B2'-2** (60MW x 2 units = 120MW)	Powerhouse	• Above ground powerhouse is independently constructed at left bank of approximately 160 m downstream from the existing power station. • No turbine inlet valve is installed. • New OHT crane (250 tons) is installed.
		Tailrace	• Tailrace type is open channel. • New tailrace gate (80 tons) & gantry crane is installed.
9	**B2'-1-1** (40MW x 1 unit)	Powerhouse	• Above ground powerhouse is independently constructed at left bank of approximately 160 m downstream from the existing power station. • No turbine inlet valve is installed. • New OHT crane (170 tons) is installed.
		Tailrace	• Tailrace type is open channel. • New tailrace gate (56 tons) & gantry crane is installed.
10	**B2'-2-1** (60MW x 1 unit)	Powerhouse	• Above ground powerhouse is independently constructed at left bank of approximately 160 m downstream from the existing power station. • No turbine inlet valve is installed. • New OHT crane (250 tons) is installed.
		Tailrace	• Tailrace type is open channel. • New tailrace gate (80 tons) & gantry crane is installed.
11	**D2-3** (40MW x 1 unit)	Powerhouse	• Above ground powerhouse is independently constructed at right bank of the existing spillway stilling basin. • New turbine inlet valve (2 sets9 is installed. • New OHT crane (170 tons) is installed.
		Tailrace	• Tailrace type is open channel. • New tailrace gate (56 tons) & gantry crane is installed.
12	**D2-4** (60MW x 2 units = 120MW)	Powerhouse	• Above ground powerhouse is independently constructed at right bank of the existing spillway stilling basin. • New turbine inlet valve (2 sets) is installed. • New OHT crane (250 tons) is installed.
		Tailrace	• Tailrace type is open channel. • New tailrace gate (80 tons) & gantry crane is installed.

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The drawings of plan, profile and sections for plans A1 (40 MW), A2 (60 MW), A4-1 (40 MW), A4-2 (60 MW), A4-3 (40 MW), B2'-2(120MW), B2'-2-1(60MW), D2-3 (80 MW) are attached in Appendix A-1.

4.2.5 EXCAVATION OF RIVERBED OUTCROP

Excavation of riverbed outcrop for lowering the tailrace water level is not counted in this comparative study, meanwhile such excavation is considered in the basic design.

4.2.6 ELECTROMECHANICAL EQUIPMENT

(1) Principal Features of Existing Electromechanical Equipment

Types, ratings, layouts and present operating status of the existing electromechanical equipment are outlined as follows:

a) Turbines (Unit 3, 4, 5)

The existing turbine for each unit consists of vertical-shaft, Francis turbine and has no inlet valve. The existing cooling water supply system for each unit is arranged for closed-circuit water circulation system with water-to-water heat exchangers.

The exiting turbines for units 3, 4, and 5 are rated as follows:

1) Rated head:	37.0 m
2) Rated unit discharge:	117.1 m^3/s
3) Rated output:	40,000 kW
4) Rated rotational speed:	136.4 rpm
5) Turbine centerline elevation:	EL. 161.0 m

As of August, 2012, operation of unit 3 turbine is stopped due to repair of unit 3 generator.

b) Generators (Units 3 to 5)

The existing generator for each unit is of three-phase, vertical-shaft synchronous alternator with umbrella-type construction. Each generator for units 3 to 5 is arranged for a special construction to support the thrust bearing from the turbine head cover. Each generator is provided with a water spray-type firefighting system.

The existing generators for units 3 to 5 are rated as follows:

1) Rated output:	50,000 kVA
2) Rated voltage:	11 kV
3) Rated frequency:	50 Hz
4) Rated rotational speed:	136.4 rpm
5) Rated power factor:	0.8

As of August, 2012, operation of unit 3 generator is stopped due to its repair.

c) Main Transformers (Unit 3 to 5)

The existing main transformer for each unit consists of three single-phase transformers. The method of cooling is through the natural-oil-circulation forced-air-cooling (ONAF). Each single-phase transformer is provided with independent water mist-type firefighting system. One single-phase transformer is provided as a spare for common use to the main transformers for units 3 to 5.

The main transformers are rated as follows:

a) Rated power: 50,000 kVA for three-phase connection
b) Rated voltage ratio: 115/11 kV
c) Transformer connection: YNd1
d) Short-circuit impedance: 8.5 % for three-phase connection

The main transformer unit 5 has risen in temperature at its R phase, which has been made normal by adding fan.

d) Powerhouse Overhead Traveling Cranes

There are two overhead traveling cranes in the existing powerhouse; one is a 100-ton crane and the other is 80-ton crane. The synchronous tandem operation of two cranes is not conducted, instead, two cranes are individually operated for their combined capacity. The overhead traveling cranes are designed for the following conditions:

a) Lifting capacity (main hoist/auxiliary hoist)
 · No. 1 crane: 100/20 tons
 · No. 2 crane: 80/10 tons
b) Span of runway crane rails: 16.2 m
c) Boundary to powerhouse structure
 · Upper space over crane rail: 3.8 m
 · Side space: 0.6 m
d) Lifting beam for tandem operation
 · Rated load: 170 ton
 · Lifting beam own weight: 9.9 ton

e) 115 kV Outdoor Switchyard

The existing outdoor switchyard is of conventional, outdoor open type bus-and-switch arrangement for 115 kV switchgear, and is located on the roof of the powerhouse. The 115 kV switchyard is connected to five generating units and five 115 kV transmission line feeders. The electric power generated by the five generating units is supplied to the C1 area through the five transmission line feeders. The existing outdoor switchyard and 115 kV switchgear are designed as follows:

1) Bus arrangement: Main and transfer bus scheme in which a transfer bus is added to the single-bus scheme
2) Bus conductors
 · Main bus for No. 1 TL side: ACSR 240 mm^2
 (ACSR: Aluminium Conductor Steel Reinforced)
 · Transfer bus for No. 1 TL side: ACSR 240 mm^2
 · Common bus for Units 1 and 2: HDCC 150 mm^2
 (HDCC: Hard-drawn Copper Stranded Conductor)
 · Main bus for Units 3 to 5: HDCC 325 mm^2

· Transfer bus for Units 3 to 5: HDCC 200 mm^2

3) Insulator strings
   · Type and color of insulator disc: Porcelain, brown color
   · Number of insulator discs: Nine pieces/string
4) 115 kV circuit breakers for Units 3 to 5
   · Operating method: Stored energy operation with motor charged spring
   · Rated voltage: 123 kV
   · Rated normal current: 3,150 A
   · Rated short-circuit breaking current: 40 kA
5) 115 kV disconnectors for Units 3 to 5
   · Operating method: Manual operating
   · Rated voltage: 121 kV
   · Rated normal current: 800 A
   · Rated short-time withstand current: 26 kA for 4 s
6) 115 kV current transformers for Units 3 to 5
   · Rated voltage : 121 kV
   · Rated current ratio : 500-250//5/5 A
   · Rated short-time withstand current : 26 kA for 1 s

f) 115 kV GIS (Gas Insulated Switchgear)

The 115 kV GIS is installed for interconnection between the NN1 Hydropower Station and the Nam Leuk Hydropower Station. For this purpose, the 115 kV GIS is connected to the conventional outdoor switchyard by two circuits of 115 kV, 400 mm^2 XLPE power cable, each of which has a current carrying capacity of 450 A or a power transmission capacity of 90 MVA. Recently, the 115 kV GIS was extended for one circuit to connect an additional 115 kV transmission line between the NN1 Hydropower Station and the Thalat Substation.

The 115 kV GIS is designed as follows:

1) Bus arrangement : Main and transfer bus scheme in which a transfer bus is added to the single-bus scheme
2) Number of circuits
   · Nam Leuk line feeder: 1 circuit
   · Thalat line feeder: 1 circuit
   · Nam Ngum 1 switchyard main bus: 1 circuit
   · Nam Ngum 1 switchyard transfer bus: 1 circuit
3) Rated voltage: 123 kV
4) Rated normal current: 1250 A
5) Rated short-time withstand current: 25 kA for 1 s

All the existing 115kV GIS will be replaced by new ones.

g) AC Station-Service Power Supply Equipment

An AC power supply to the auxiliary equipment for all the five units and the station’s common facilities is generated by two station-service transformers. One of these transformers is connected to the generator bus for either unit 1 or unit 2, while the other is connected to the 115/22 kV transformer through a 22 kV cubicle. The two station-service transformers are arranged for normal/standby operation duty, so that either transformer is normally used for supplying power to the whole power station. Judging from its actual load current, each station-service transformer has sufficient extra capacity to serve for additional equipment/facilities.

Based on the above, it was reported that the station-service power supply from the 22 kV circuit is often unstable because the 115/22 kV transformer is also connected to the 22 kV distribution lines for supplying power to local consumers living in the vicinity.

On the other hand, the existing low voltage switchgear has no spare circuit breakers for supplying power to additional equipment/facilities. Judging from the circuit configurations and cable connections, it seems difficult to make modifications for installing additional circuit breaker to the existing low voltage switchgear. The existing station-service power supply system is designed for the following:

1) Nominal AC voltage: 380 - 220 V AC for three-phase and four-wire system
2) Rated frequency: 50 Hz
3) No. 1 station-service transformer (power source: unit 1 generator or unit 2 generator)
   · Rated power: 1,000 kVA
   · Rated voltage ratio: 11/0.38 kV
4) No. 2 station-service transformer (Power source: 22 kV bus)
   · Rated power: 1,000 kVA
   · Rated voltage ratio: 22/0.38 kV

h) DC Power Supply Equipment

The existing DC power supply system consists of two sets of stationary batteries and battery chargers. In normal operation, one set is used for DC power to supply unit 1, unit 2 and station-common loads while the other set is used for DC power to supply units 3, 4, 5. However, each set of DC equipment has sufficient capacity to supply DC power to the whole power station, in case of emergency.

The DC distribution panels for units 1 and 2 have a few spare circuit breakers for additional equipment/facilities. However, no spare circuit breakers will be available in the DC distribution panels for units 3, 4 and 5. The DC power supply equipment is designed as follows:

1) Normal DC voltage: 110 V DC
2) Stationary batteries
   · Quantity: 2 sets
   · Type: Valve regulated type lead acid batteries
   · Capacity: 300 AH at 10-hour discharge rate
   · Number of cells: 53 cells/set
3) Battery charger
   · Quantity: 2 sets
   · AC input voltage: 380 V AC, three-phase, 50 Hz
   · DC output current: 60 A DC
   · Floating charge voltage: 114 - 122 V DC

i) Control and Protection Equipment

The control and relay boards for units 1 and 2 are all arranged in the control room. These were refurbished in 2004 under the Project for Rehabilitation of the NN1 Hydro Power Station through Japan's Grant Aid Scheme, and are still operating in good condition.

Concerning units 3, 4 and 5, their local control and relay boards are arranged in a relay room located at the side of the machine bay for each unit. In addition, their remote control boards are arranged in the control room, aligned with the local control boards for units 1 and 2. The existing control room has space remaining for the installation of just one duplex-type control board for the additional units.

It is noted that the control boards for unit 5 were refurbished in July 2009, and for unit 3 were thereafter refurbished as well. However, the control and relay boards for unit 4 are still being used since 1978 even if these have already deteriorated due to aging. Therefore, Edl plans to refurbish the control and relay boards for unit 4 in the near future. Also, the control system for unit 3 which is currently under repair of generator will be rehabilitated all together.

The national control center is under construction for aiming at effective use of hydropower stations including NN1 hydropower station and power grid in Lao PDR.

j) 115 kV Transmission Line

A total of five 115 kV transmission line feeders are connected to the NN1 Hydropower Station. Three feeders are connected directly to the outdoor switchyard, but the remaining two feeders are connected to the outdoor switchyard through the 115 kV GIS.

Each conductor of the 115 kV transmission lines is made up of ACSR 240 mm^2 which has current carrying capacity of 590 A at continuous allowable temperature of 90 °C, and could possibly carry electric power of 117 MVA.

The 115 kV transmission line systems around the NN1 Hydropower Station are shown in Figure 4.2.6.1.

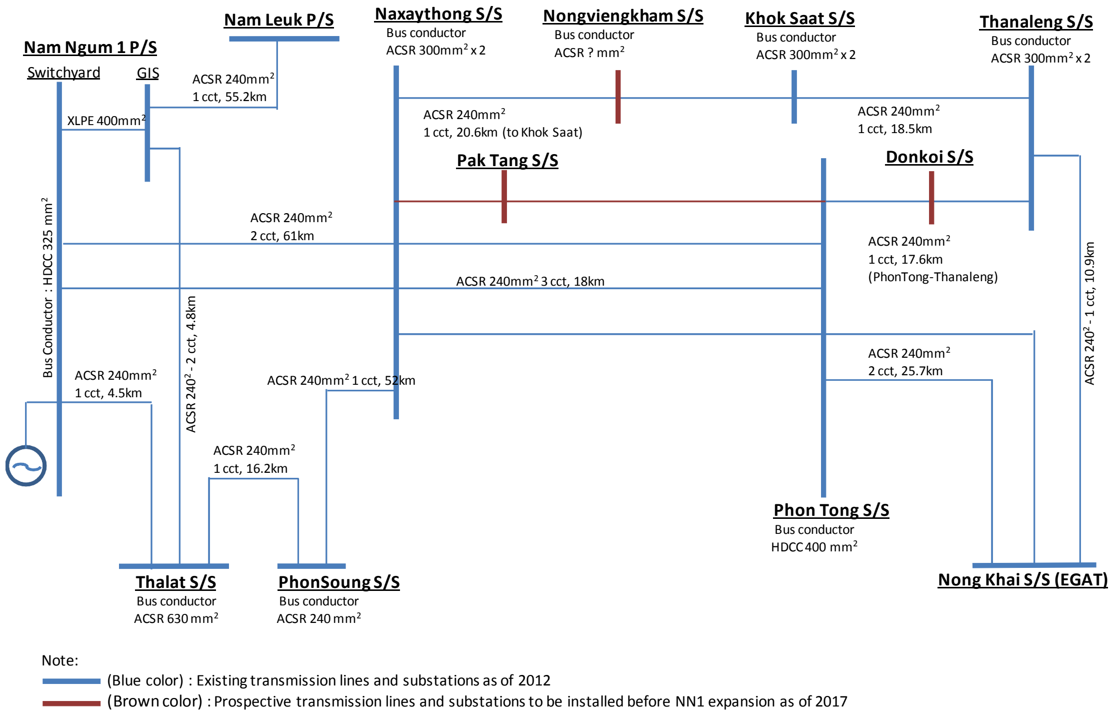

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Figure 4.2.6.1 115 kV Transmission Line Connection Diagram for NN1

k) 115 kV Thalat Substation

The Thalat Substation is located at a distance of about 4.8 km from the NN1 Hydropower Station. Recently, the main and transfer bus has been added and the concern about current carrying capacity due to expansion project is solved for the time being. The Thalat Substation is designed as follows:

1) Bus arrangement: Main and transfer bus scheme in which a transfer bus is added to the single-bus scheme

2) Bus conductors:
- · Main bus: ACSR 600 mm^2 (changed from 240 mm^2)
- · Transfer bus: ACSR 600 mm^2 (changed from 240 mm^2)

3) Number of circuits
- · Transmission line feeders: 5 circuits
- · Transformer: 1 circuit
- · Bus coupler: 1 circuit

(2) Study Items for Electrical and Electromechanical Equipment for Expansion Plans

a) Net Head for Additional Turbine

Each of the existing turbine units 1 to 5 is designed for a rated net head of 37 m.

After completion of the NN2 Hydropower Station, which is now under construction, inflow to the NN1 reservoir will be regulated by the operation of NN2. As a result, it is expected that yearly average water level of the NN1 reservoir will increase considerably due to the regulated inflow from NN2. On the other hand, after completion of this NN1 Expansion Project, the water level at the NN1 tailrace will also increase due to the additional turbine discharge from the additional unit.

Therefore, it is required to review the rated net head for the additional turbine.

The turbine rated net head will be determined through further study at the basic design stage. For the purpose of comparative studies of alternative plans, however, the turbine rated net head was tentatively assumed at 38.0 m, on the assumption that the rated net head will increase by at least 1.0 m from the present condition.

b) Turbine Output

For convenience of comparative studies, the unit output for each alternative plan was considered as 40 MW or 60 MW at the generator terminal. Accordingly, taking the generator efficiency into consideration, the turbine rated output for each alternative plan was determined at 40.9 MW or 61.3 MW.

c) Type of Turbine

Referring to the existing turbines for units 3 to 5, Francis turbine was selected as the type of turbine for each alternative plan.

d) Turbine Rotational Speed

The turbine rotational speed was selected referring to the specific speed which is calculated by the following equation:

$$Ns = N \times \sqrt{Pt}/Hn^{1.25}$$

where,
- Ns: Specific speed (m-kW)
- N: Rotational speed (rpm)
- Pt: Turbine output (kW)
- Hn: Net head (m)

In case of the Francis turbine with a net head of lower than 40 m and a turbine output of higher than 40 MW, the specific speed will become very high. If the specific speed exceeds 300 m-kW, it is expected that the operating performance of Francis turbine will worsen remarkably. Therefore, in the selection of the turbine rotational speed, the specific speed for Francis turbine is practically limited to 300 m-kW. Relationship between the applicable turbine speed and calculated specific speed is shown in Table 4.2.6.1 below:

Table 4.2.6.1 Selection in Turbine Speed for Alternative Plans

Turbine Output Pt	Net Head Hn	Speed N	Specific Speed; Ns	Ns Upper Limit	Judgment
(kW)	(m)	(rpm)	(m-kW)	(m-kW)	
40,900	38.0	125.0	267.9	300	○
		136.4	292.4		◎
		142.9	306.3		×
61,300	38.0	107.1	281.1	300	○
		111.1	291.6		◎
		115.4	302.8		×
Existing Units 3 to 5 (for reference)					
40,000	37.0	136.4	298.9	-	-

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The higher the turbine speed, the smaller the machine size required. This will consequently be economical. Therefore, the turbine speed was chosen at 136.4 rpm for the 40.9 MW turbine and 111.1 rpm for the 61.3 MW turbine, which are the maximum values within the upper limit of specific speed.

e) Inlet Valve

For all the alternative plans, except for D2-3 (40 MW x 2) and D2-4 (60 MW x 2), each turbine was designed to directly connect with an individual steel penstock without an inlet valve, in the same manner as the existing turbines for units 1 to 5.

For the alternative plans D2-3 and D2-4, one steel penstock was arranged for common use of two units of turbines. In this arrangement, each turbine was provided with an inlet valve for convenience of operation and maintenance. Each inlet valve was designed for through-flow type butterfly valve and its internal diameter was estimated at 5.0 m for alternative plan D3 and 6.0 m for alternative plan D4.

f) Generator Output

The rated power factor of each generator was selected as 0.8, which is the same as the existing generator units 3, 4 and 5, and the rated generator output was determined as either 50 MVA (40 MW) or 75 MVA (60 MW).

g) Type of Generator

Each generator was designed for three-phase, vertical-shaft, synchronous alternator with umbrella-type construction, which is the same as the existing generators for units 3, 4 and 5.

h) Powerhouse Overhead Traveling Crane for Additional Units

The rotor weights for the generators with rated output of 50 MVA (40 MW) and 75 MVA (60 MW) were estimated at 164 ton and 246 ton respectively.

1) Alternative plan A1 (40 MW x 1)

   Two (2) existing overhead traveling cranes (100 ton and 80 ton) can be used as they are.

2) Alternative plan A2 (60 MW x 1)

   The existing overhead traveling cranes cannot be utilized for lifting the 75 MVA generator because its rotor weight exceeds the total lifting capacity (180 tons) of said cranes. Moreover, the required crane rail span is wider than the existing one.

   Therefore, other than the existing cranes, one new 250-ton crane is required for handling the additional generator.

3) Other Alternative Plans

   The existing overhead traveling cranes cannot be utilized for the other alternative plans either.

   Therefore, one new overhead traveling crane is required in the additional building for each alternative plan. The required lifting capacity of the new crane is estimated at 170 ton for the 50 MVA generator, and 250 ton for the 75 MVA generator.

i) Main Transformer Rated Power

The rated power of the main transformer selected is either 50 MVA or 75 MVA, which is equal to the generator rated output.

j) Type of Main Transformer

The main transformer is the heaviest item during shipping and transportation. Due to transporting restrictions on the access roads, it is preferable that the shipping weight be limited to 30 tons. However, the shipping weight of a 50 MVA three-phase transformer will be no less than 50 tons. In order to reduce the shipping weight, single-phase type or special three-phase type was applied to the main transformer as described below:

1) The existing main transformers for units 3 to 5 are rated for 50 MVA each and of single-phase type. One spare single-phase transformer is provided for common use to units 3 to 5.

   In case of the alternative plans A1 and A4-1, a new 50 MVA main transformer was arranged near the existing powerhouse, similar to the existing main transformers. Therefore, a single-phase type transformer was selected for the alternative plans A1 and A4-1 along with the design policy for the existing main transformers for units 3 to 5.

2) Special-three phase type was selected for the main transformer to be installed at a place far from the existing powerhouse or have rated power other than 50 MVA. This was adopted since the special three-phase type transformer will have a practical advantage not only for a required installation place but also for connection with the generator main bus.

k) Relocation of Existing 115 kV GIS

The existing 115 kV GIS is located in the area to be excavated under alternative plans A4-1 (40 MW x 1), A4-2 (60 MW x 1), B2'-1 (40 MW x 2) and B2'-2 (60 MW x 2). In case of these alternative plans, it is required to relocate the existing 115 kV GIS to another place where it is convenient for connecting with the existing 115 kV transmission lines. The candidate site for this relocation is the left bank of the dam, which is about 150 m away from the present location. This relocation work includes disassembling and reassembling of the existing GIS, construction of a new GIS building, replacement of two 115 kV transmission towers, replacement of 115 kV power cables between the 115 kV GIS and the outdoor switchyard.

l) Connection of Additional Units to 115 kV Transmission Lines

The existing 115 kV outdoor switchyard is located on the roof of the powerhouse and are connected with five 115 kV transmission line feeders as shown in Figure 4.2.6.1. Referring to the results of power flow analysis, in case the additional output is 60 MW or less, it is practical to connect the additional units to the existing 115 kV transmission lines through the existing outdoor switchyard.

On the other hand, in case the additional output is 80 MW, the current exceeds the allowable current carrying capacity of the existing 115 kV transmission lines. In this case, construction of a new 115 kV transmission line is required to connect the additional units to the 115 kV network system. Taking these conditions into consideration, connection of the additional units to the 115 kV transmission line was planned as follows:

1) Alternative Plans A1 (40 MW x 1) and A2 (60 MW x 1)

The existing outdoor switchyard should be extended to the roof of the additional powerhouse building to connect the additional unit to the existing 115 kV bus.

2) Alternative Plans A4-1 (40 MW x 1) and A4-2 (60 MW x 1)

Since there are three circuits of the existing 115 kV transmission lines over the planned construction site for the additional powerhouse building, new 115 kV switchgear for the additional unit cannot be installed on the roof, in similar way to the existing outdoor switchyard. No sufficient space for installation of new 115 kV switchgear is available either in the expansion area. Therefore, it was planned to connect the additional unit to the existing outdoor switchyard through the 115 kV GIS to be relocated under Sub-Paragraph k) above. The new main transformer for the additional unit should be connected to the relocated 115 kV GIS by 115 kV XLPE power cables. This will require extension of the 115 kV GIS for one more circuit for the 115 kV power cable connection to the new main transformer.

3) Alternative Plan B2’-1-1 (40 MW x 1) and B2’-2-1 (60MW x1)

It is difficult to arrange a route for direct cable connections between the additional powerhouse and the existing outdoor switchyard. Therefore, there seems to be no choice but to connect the additional units to the existing outdoor switchyard through the 115 kV GIS to be relocated under Sub-Paragraph k) above, in the same manner as the Alternative Plan A4-1. The new main transformers for the additional units should be connected to the relocated 115 kV GIS by 115 kV XLPE power cables. This will require extension of the 115 kV GIS for one more circuits for 115 kV power cable connections to the new main transformers.

4) Alternative Plans B2’-1 (40MW x 2), B2’-2 (60 MW x 2), D2-3 (40MW x2) and D2-4 (60 MW x 2)

The existing 115 kV transmission lines have no sufficient capacity to carry the additional output of 80 MW without overloading. Therefore, the additional units for these alternative plans cannot be connected to the existing outdoor switchyard. As a result, construction of a new 115 kV double-circuit transmission line is required to connect the additional units to the 115 kV network system. For this purpose, it is necessary to construct a new 115 kV outdoor switchyard near the additional powerhouse. The new outdoor switchyard will be of conventional, outdoor open type with a conventional type 115 kV switchgear. The 115 kV bus will be arranged for the main and transfer bus scheme in the same manner as the existing outdoor switchyard.

The existing Thalat Substation and Phon Soung Substation, which are the nearest substations from the NN1 Hydropower Station, do not have sufficient space for the necessary extension to introduce additional 115 kV double-circuit transmission lines. Therefore, the new 115 kV double-circuit transmission line was planned to be connected to the existing Naxaythong Substation at a distance of 61 km from the NN1, or to the Hin Heup Substation at a distance of 54 km.

m) Conductor Size of 115 kV Bus for Existing Outdoor Switchyard

Each conductor of the existing 115 kV main bus is HDCC 325 mm^2 of which the continuous current carrying capacity is 875 A at the maximum allowable temperature of 90 °C. The required conductor size of the 115 kV main bus for each alternative plan was examined under the following conditions and assumptions:

1) All the generators, including additional units, are operated with their rated outputs.
2) The outdoor switchyard is receiving incoming power of as much as 20 MVA from the Nam Leuk Hydropower Station.
3) The kind of conductor for the 115 kV main bus is assumed as hard-drawn copper conductor (HDCC), which is similar to that of the existing conductor.
4) The continuous allowable temperature of the 115 kV bus conductor is assumed at 90 °C.

The current carrying capacity and required conductor size of the 115 kV bus are summarized in table below.

Table 4.2.6.2 Required Conductor Size for 115 kV Main Bus for Alternative Plans

Plan	Generator Output [MVA]			Max. Current in 115 kV Bus	Required Conductor Size
	Additional	Existing	Total	[A]	[mm^2]
A1	50	190 + 20 (*1)	260	1,305	HDCC 725
A4-1					
D1					
A2	75		285	1,431	HDCC 850
A4-2					
D2					
B2-1	0		210	1,054	HDCC 500
D3					
B2-2	0		210	1,054	HDCC 500
D4					

Note (*1): Including power received from the Nam Leuk Hydro Power Station (20 MVA)
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It is noted that the maximum current in the 115 kV main bus during operation of the existing five units has already reached 954 A, which exceeds the current carrying capacity of the existing conductor HDCC 325 mm^2 (875 A). In the case of the alternative plans B2’-1 (40MW x 2), B2’-2 (60 MW x 2) and D2-3 (40MW x 2) and D2-4 (60 MW x 2), the additional units are not connected to the existing 115 kV bus. Even in such case, it is preferable that the existing conductors be replaced with new ones in the appropriate size to solve the shortage of current carrying capacity of 115 kV bus. As a result, replacement of the existing conductors for the 115 kV main bus is required for all the alternative plans.

n) AC Station-Service Power Supply System for Additional Equipment/Facilities

AC station-service power supply system for each alternative plan was examined as follows:

1) Alternative Plans A1 (40MW x 1), A2 (60MW x 1), A4-1 (40MW x 1), A4-2 (60MW x 1), B2’-1-1 (40MW x1) and B2’-2-1 (60MW x 1)

   Each of the two existing station-service transformers has sufficient extra capacity to serve for the additional equipment/facilities. Therefore, it was planned to use the two existing station-service transformers as they are, for supplying AC power to the additional equipment/facilities.

   On the other hand, the existing low voltage switchgear has no spare circuit breakers for power distribution to the additional equipment/facilities. Therefore, it was planned to add one set of low voltage switchgear for the additional equipment/facilities.

2) Alternative Plans B2’-1 (40 MW x 2) and B2’-2 (60 MW x 2)

It was planned to provide one set of the station-service power supply equipment in the additional powerhouse, separately from the existing power supply system for the reason that the construction site for the additional powerhouse is located at some distance from the existing powerhouse and each of these alternative plans is provided with two additional units. The new station-service power supply system was designed to consist of two station-service transformers and low voltage switchgear. The power sources for the new power supply system will be one unit of the additional generators as well as the existing 22 kV bus. The new station-service power supply system was designed to be interconnected with the existing power supply system by a 22 kV power cable between the existing and new powerhouses.

3) Alternative Plans D2-3 (40 MW x 2) and D2-4 (60 MW x 2)

The construction site for the additional powerhouse is located at some distance from the existing powerhouse. Therefore, it was planned to provide one set of the station-service power supply equipment in the additional powerhouse. The new station-service power supply system was designed to be interconnected with the existing power supply system by constructing a 22 kV overhead distribution line between the existing and new powerhouses.

o) DC Power Supply Equipment for Additional Equipment/Facilities

DC power supply equipment for each alternative plan was examined as follows:

1) Alternative Plans A1 (40MW x 1), A2 (60MW x 1), A4-1 (40MW x 1) and A4-2 (60MW x 1)

The existing DC power supply system consists of two sets of stationary batteries and battery chargers. Each set of the DC supply equipment has sufficient extra capacity to serve for the additional equipment/facilities. Therefore, it was planned to use the existing DC supply equipment to supply DC power to the additional equipment/facilities.

On the other hand, the existing DC distribution panels have insufficient number of spare circuit breakers for distributing DC power to the additional equipment/facilities. Therefore, it was planned to add one DC distribution panel for the additional equipment/facilities.

2) Alternative Plans B2’-1 (40MW x 2), B2’-2 (60MW x 2), B2’-1-1 (40MW x 1), B2’-2-1 (60MW x 1), D2-3 (40 MW x2) and D2-4 (60 MW x 2)

Since the construction site for the additional powerhouse is located at some distance from the existing powerhouse, the existing DC power supply equipment can not be utilized for the additional equipment/facilities. Therefore, it was planned to provide one set of the DC power supply equipment in the additional powerhouse. The new DC power supply equipment was designed to consist of one set of stationary batteries, one battery charger and two DC distribution panels.

p) Control and Protection Equipment

The existing control room has space to install just one duplex-type control board for the additional units. For each alternative plan, however, the control and protection equipment was examined to achieve remote control of the additional units from the existing control room as follows:

1) Alternative Plans A1 (40MW x 1), A2 (60MW x 1), A4-1 (40MW x 1) and A4-2 (60MW x 1)

It was planned to install one local control board, one relay board and one automatic control board in the machine bay for each additional unit, in the same manner as the existing system for units 3 to 5. It was also planned to install a remote control board for the additional unit in the existing control room.

2) Alternative Plans B2'-1-1 (40MW x 1) and B2'-2-1 (60MW x 1)

It was planned to install the following control and relay boards in the new local room to be provided in the additional powerhouse:

- One local control board, one relay board and automatic control board for the additional units.
- One local control board and one relay board for the additional station-service power supply system.

It was also planned to install remote control boards for the additional units and station-service supply system.

3) Alternative Plans B2'-1 (40 MW x 2), B2'-2 (60MW x 2), D2-3 (40MW x2) and D2-4 (60 MW x 2)

It was planned to install the following control and relay boards in the new local room to be provided in the additional powerhouse:

- One local control board, one relay board and automatic control board for each additional unit
- One local control board and one relay board for the additional station-service power supply system.
- One local control board and one relay board for the additional 115 kV switchgear and bus
- Two relay boards for the additional 115 kV double-circuit transmission line

It was also planned to install remote control boards for the additional units, station-service supply system and 115 kV switchgear.

q) Necessity of Renewal of Existing Control System

As described in Sub-Clause 8.3.4 (1) i), the present status of the existing control system is summarized below:

1) The control and relay boards for units 1 and 2 were refurbished in 2004 under the Project for Rehabilitation of the NNI Hydro Power Station through Japan's Grant Aid Scheme and are still operating in good condition.
2) The control and relay boards were refurbished in July 2009 for unit 5, and thereafter for unit 3.
3) The control and relay boards for unit 4 are still used since 1978 and have already been deteriorated due to aging. Therefore, Edl intends to carry out refurbishment of the control and relay boards for unit 4 in the near future.
4) Parts of the control and relay boards for unit 3 are planned to be rehabilitated during the period of repairing the generator unit 3 by end of December 2012.

Judging from the present station, renewal of the existing control and protection systems will not be required for this expansion project.

Besides, the national load dispatch center is currently under construction. The operation of NN1 hydropower station may also be monitored and supervised by a regional load dispatch center in future.

4.2.7 HYDROMECHANICAL EQUIPMENT

(1) Intake Facilities

1) Arrangement of facilities

The following intake facilities are considered in the study of the optimum expansion plan:

i) Intake trashracks

ii) Intake stoplogs

iii) Intake gate

The existing intake facilities of NN1 power station have the characteristics mentioned below as the function of intake for 15 MW and 40 MW units.

a) The existing intake trashracks, which consists of the removable type of screen, is adopted. When the intake stoplogs are installed, the trashracks are removed from the guide frames and the stoplogs are inserted into the same guide frames. Since the guide frames are shared for trashracks and stoplogs, the intake structures are simple and compact.

b) The intake of 15 MW has a 5 m width. As for the 40 MW intake, two-barrel intake of 5 m width each is provided for sufficient flow area. Since the barrel width is 5 m in inlets of both 15 MW and 40 MW, stoplogs with clear span of 5 m are commonly used for both 15 MW and 40 MW units.

c) As the stoplogs and trashracks of same clear span are adopted for 15 MW and 40 MW units, the stoplogs and trashracks are operated by a common gantry crane.

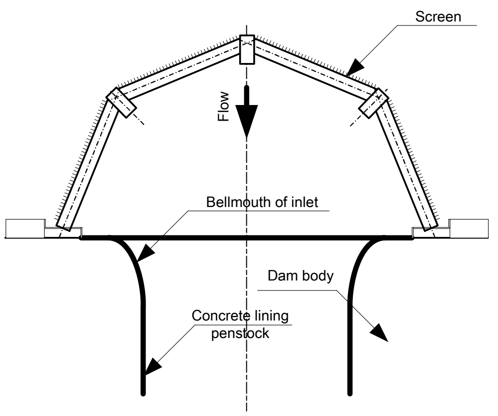
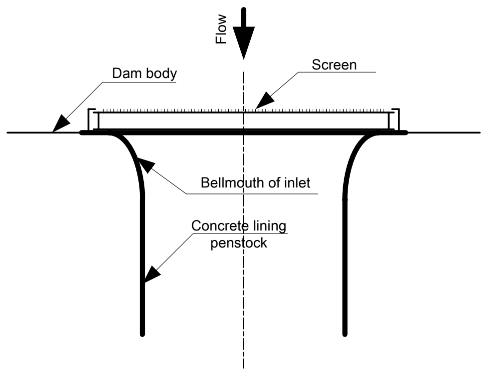
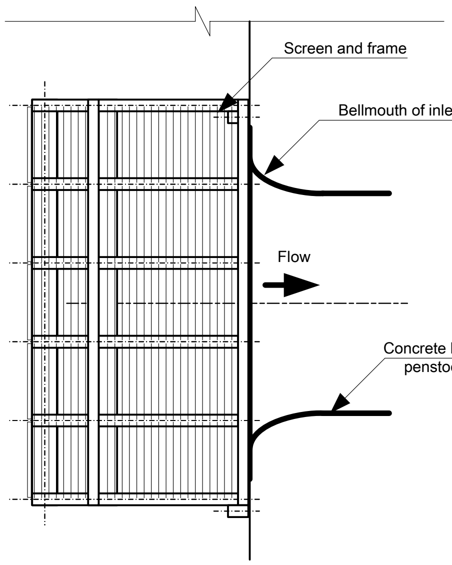
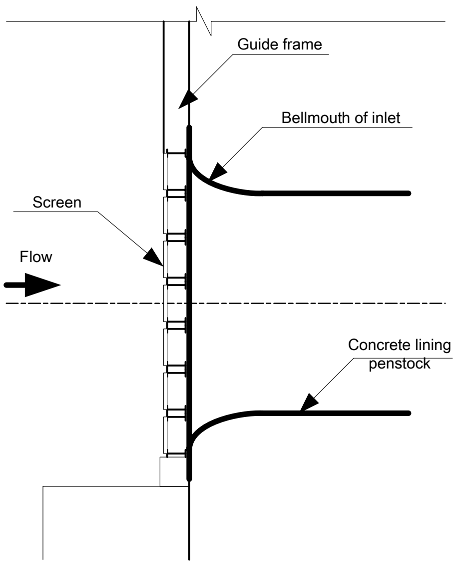
2) Intake trashracks

It was planned in the study of 2009 that the temporary water stop structure of channel shape was extended from the inlet up to the level above water surface. The method of temporary water stop is reviewed in the study of this time and the method of bulkhead structures is newly adopted instead of the channel structures. Although the cost of temporary water stop is decreased drastically due to the method of bulkhead, the space of dry condition for construction of inlet is limited to width 9.6m, height 11.6m and depth 2m under water. Because of the limited space for construction of inlet structure, there is no working space to provide two-barrel intake of 5 m width each as the existing intake.

The breakthrough of dam piercing will be made under dry condition inside the bulkhead. As the inlet will be shaped and constructed within the limited space inside the bulkhead, the shape of inlet will be a simply bellmouth added to the intake waterway. The inlet bellmouth will be covered with intake trashracks.

As for the alternatives of intake trashracks, two plans are considered, namely Plan I: Fixed type of trashracks, and Plan II: Removable type of trashracks, as shown in Table 4.2.7.1.

Table 4.2.7.1 Comparison of Screen for Alternative Plans

	Plan I. Fixed Type of Trashracks	Plan II. Removable Type of Trashracks
Plan		
Profile		
Structure	The screens are fixed on the dam to cover the inlet with an area so as to keep flow velocity around 1m/sec. The frame of screen is installed on the position by diving operation.	The removable type of trashrack is operated through the guide frames. The guide frames for trashrack are installed on the dam body from the inlet up to the dam crest by diving operation.
Issue	Because of the fixed type of screen, the diving operation will be required for cleaning the screen. Though the installation of trashrack is made by diving operation, the foundation and anchor for the frame of trashrack will be prepared under the dry condition covered with the bulkhead.	The temporary bulkhead cover stops water just around the inlet of intake. The foundation and installation of guide frames must be executed by diving operation from the inlet up to the dam crest. The accuracy of flatness and alignment of guide frames is required to be sufficient enough to pass the removable trashrack, however it is hard to gain such accuracy by the diving operation. Accordingly, the operation of trashrack is at high risk of jamming with the guide frames likely as temporary structures.

Conclusion	In case of the immersed intake, the cleaning will not be considered. It seems the serious clogging will not occur to the screen of immersed intake from the past records. Plan I should be adopted according to the construction method of the temporary water stop by bulkhead.	The installation of guide frames by diving operation is practically unrealistic because the accuracy will not be gained for the foundation of anchor for guide frame under water. Taking the safety operation into consideration, Plan II should not be adopted.

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Plan II: Removable type of trashracks should not be adopted because the installation of guide frames for removable trashracks is difficult under water by diving operation. Even though Plan I is also executed by diving operation for fixing the frames to the foundation, the foundation and anchor installed on the dam body will be constructed under dry condition inside the bulkhead. The work under dry condition of Plan I will realize the required accuracy of foundation flatness and alignment.

3) Intake gate

The existing intake gate has the function of shutting down the flow if the guide vane of the water turbine is not closed due to malfunctioning or any accident.

In case of the power station located just behind the dam like NN1, generally the individual waterways are provided to the respective units. However, the inlet valve for water turbine is sometimes not installed due to economical reasons. Accordingly, the intake gate, instead of inlet valve, is required to have a function of shutdown. In the expansion plan, though the possibility of inlet valve installation is preliminarily examined, the inlet valve is finally excluded from the study of optimum expansion plan, because the required space to install the inlet valve is not available as shown in the arrangement of existing turbine.

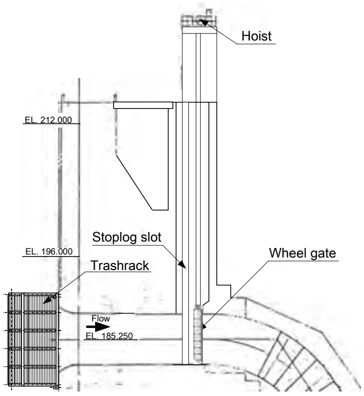
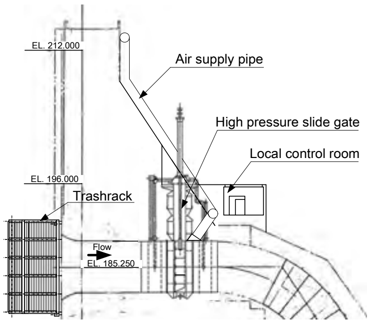
As for the alternative plan of the intake gate for piercing dam body with the temporary water stop by the method of bulkhead, the following two alternatives are considered for the arrangement of intake gate.

Plan I Fixed wheel gate on the downstream of dam with stoplogs

Plan II High pressure slide gate on the downstream of dam without stoplogs

The comparison is shown in Table 4.2.7.2 below.

Table 4.2.7.2 Comparison of Intake Gate Layout Plan

	Plan I Fixed wheel gate on the downstream of dam with stoplogs	Plan II High pressure slide gate on the downstream of dam without stoplogs
Outline		
Construction	A fixed wheel gate and stoplogs are provided on the downstream of the dam. Fixed trashracks are provided on the upstream surface of dam. All the guide frames for gate and stoplog are made of stainless steel from the sill of the intake to the dam crest. Hoist will be installed after completion of piercing work of dam.	A bonnet type of high pressure slide gate is provided on the downstream of the dam with hydraulic hoist. Fixed trashracks are provided on the upstream surface of dam. The stoplogs cannot be provided to this alternative plan.
Operation and Maintenance	The operation of gate is almost same as the case of the other unit. The gate is kept at the intermediate position for the operation of shutdown of guide vane in emergency cases. Usually, the gate will be operated under balanced condition. The gate is closed when the generator and/or turbine are maintained. When the maintenance of the gate leaf is required, the stoplog is installed and the gate leaf is raised above water level for maintenance work.	The slide gate is usually operated under balanced condition, except in the case of shutdown operation for failure of guide vane closure. The gate will be closed when the generator and/or turbine are maintained. Because stoplogs will not be provided, the maintenance of the gate cannot be made except the adjustment and replacement of packing for cylinder shaft.

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Because the space of dry condition is limited under the method of bulkhead, the installation work of guide frames must be executed under water by diving operation including the preparation of foundation and anchor for guide frames. The installation work under water should not be applied to the facilities requesting the accurate flatness and alignment. Taking account of the required accuracy of guide frames, the stoplogs shall not be provided on the upstream surface of dam as the maintenance gate for the intake gate facilities. Accordingly, in the case of Plan I, the stoplogs will be provided at the just upstream of intake gate.

As for Plan II: the bonnet type of high pressure slide gate, there is no space to provide the vertical shaft of stoplog at the just upstream of slide gate.

In the case of Plan II, the combination of slide gate and vertical shaft with stoplogs is unnatural arrangement of intake facilities even if there is enough space to provide the vertical shaft. Accordingly, the stoplog as the maintenance gate will be omitted for the intake.

Without stoplogs, only maintenance of packing for cylinder shaft can be made and the gate leaf including the lifting equipment such as the cylinder, shaft, piston, etc. cannot be maintained. The facilities without consideration of maintenance should not be adopted to the intake. From such circumstances, Plan I is adopted as the intake facilities, namely the wheel gate as intake gate is provided just upstream of penstock bend with stoplogs as the maintenance gate for the intake facilities.

4) Intake stoplogs

The existing intake of 40,000 kW unit is comprised of two barrels having a clear span of 5.0 m and a clear height of 12.0 m. For maintenance of the intake gate and waterway, twelve segments of stoplogs are provided for stopping water. Each segment of stoplogs has a clear span of 5.0 m and height of 2.05 m, and is operated using a gantry crane for installing and removing. The existing structure of stoplogs is shown in Figure 4.2.7.1.

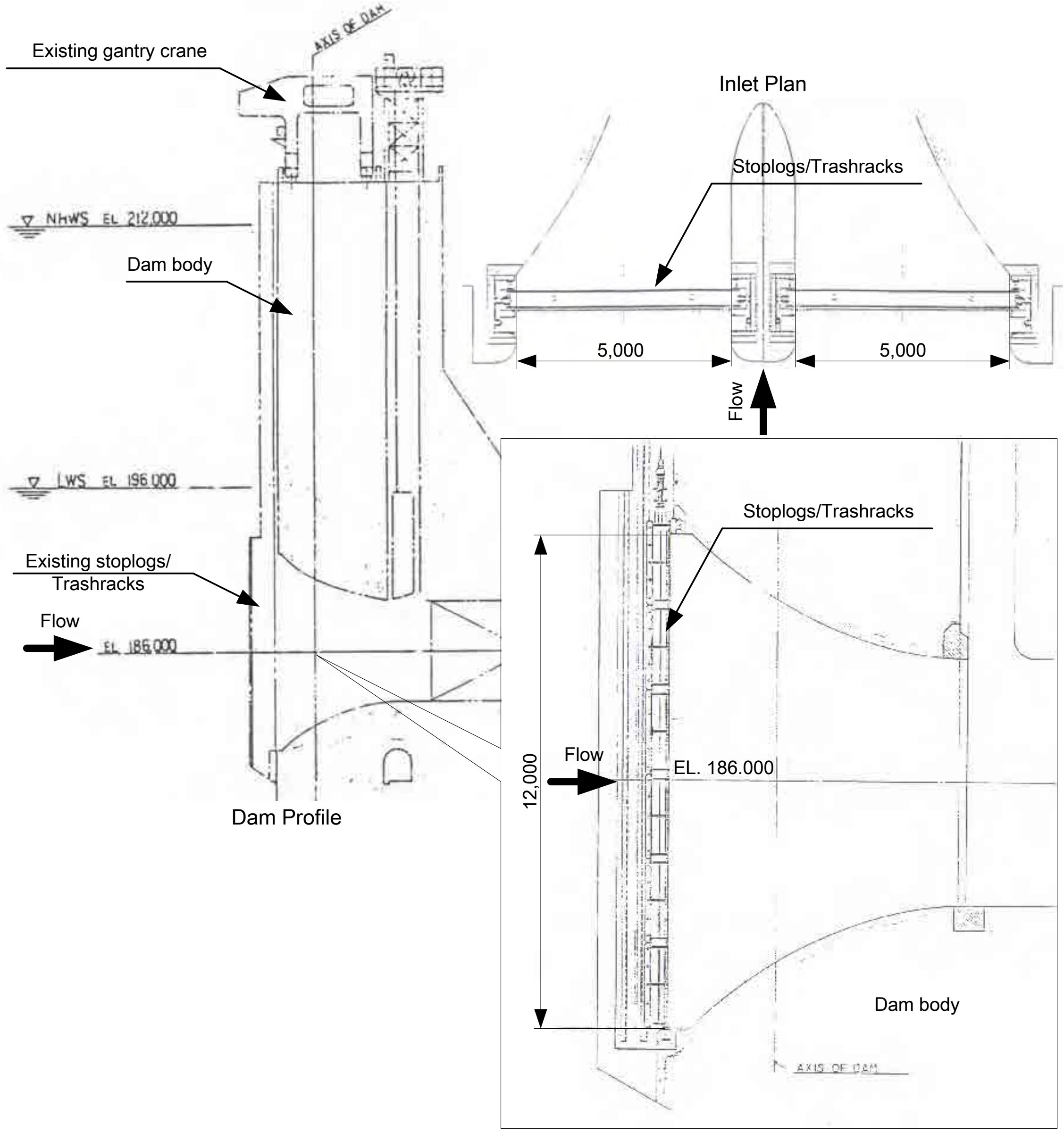

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Figure 4.2.7.1 Existing Stoplogs

The stoplogs are required to be installed for maintaining the intake gate and waterway in the expansion plan. Because the clear span in case of the expansion plan of 40,000 kW is shorter than that of the existing, the existing stoplog segments can be commonly used for the intake of expansion plan, if the dimensions of guide frames in the expansion plan are adjusted so as to suit the dimension of the existing stoplog segments. In the case of the expansion Plan of 60,000 kW, stoplog segments are also newly provided. As for the existing gantry crane, it cannot be utilized for operating the stoplogs for the intake of expansion plan, because the lifting center of existing crane cannot be shifted to the lifting center of stoplogs for the expansion plan located at the downstream of dam. It is necessary to provide new lifting equipment for the extension plan instead of the existing gantry crane.

In this preparation survey, it is confirmed the existing gantry crane will not interfere with the access/transportation of equipment and materials in the case of piercing the dam body. Accordingly it is unnecessary to recess the existing gantry crane during the construction period.

(2) Steel Penstock

In the expansion plan, the concrete lining is provided from bellmouth to the intake gate and the steel penstock is provided from the intake gate to inlet of spiral casing. The steel penstock of the embedded type is adopted in reference to the existing units.

Plate thickness of the penstock shell is decided to be the minimum plate thickness, study of static pressure and water hammer, and study of external pressure due to the seepage of reservoir water head. As for the existing steel penstock, the penstock shell is designed against external pressure with the strength of only the plate thickness without stiffener rings. The design of the existing penstock is judged to be reasonable considering the elimination of the processes of stiffener welded to the outer face of the large diameter pipe. In the expansion plan, the same concept of the existing design is applied for the design against external pressure, namely, that the penstock shell is designed without stiffener against external pressure, although thrust collars will be provided as referred to in the existing design of the steel penstock.

The following two sections of the work site are considered for the installation of steel penstock.

	Location	Access - Direction of installation
Section 1:	From embedded guide frames for intake gate to the end of upper bend	From the temporary steel stage constructed at the downstream of the dam for the work of piercing dam body, the unit pipe of steel penstock is transported to the respective location in the dam. The steel penstock is erected from the upstream side.
Section 2:	From the end of upper bend to the inlet of spiral casing	After removal of the temporary steel stage, the unit pipe of steel penstock is lifted down from EL. 177.0 m to the respective location. The steel penstock is erected from the spiral casing to upstream side.

The site workshop will be constructed near from the NN1 power station. The access and installation schedule are studied based on the plan of unit pipe manufactured at the site workshop.

(3) Draft Tube Gate Facilities

The draft tube gates are provided for the maintenance of water turbine. If the capacity of the expansion unit is the same as the existing, there is a possibility to adopt the same dimensions of the existing draft tube gate. In such case, the existing draft tube gate and gantry crane are commonly used for the expansion unit provided that the rail and power supply cables will be extended. Because the lifting capacity of the existing gantry crane is 7.6 tons, the weight of the new draft tube gate shall be adjusted to match said capacity. The existing gantry crane is commonly used for new gate having dimensions different from the existing gate.

Since the existing gantry crane is located at the interference to the access during construction period, the crane is required to be recessed to the downstream side wall of the power house. For removal of gantry crane, the use of jack-up equipment is considered.

4.2.8 TRANSMISSION LINE

(1) 115kV Transmission Line near NN1 Hydropower Station

A total of five 115 kV transmission line feeders are connected to the NN1 Hydropower Station. Three feeders are connected directly to the outdoor switchyard, but the remaining two feeders are connected to the outdoor switchyard through the 115 kV GIS.

Each conductor of the 115 kV transmission lines is made up of ACSR 240 mm^2 which has current carrying capacity of 590 A at continuous allowable temperature of 90 °C, and could possibly carry electric power of 120 MVA.

The 115 kV transmission line systems around the NN1 Hydropower Station are shown in below.

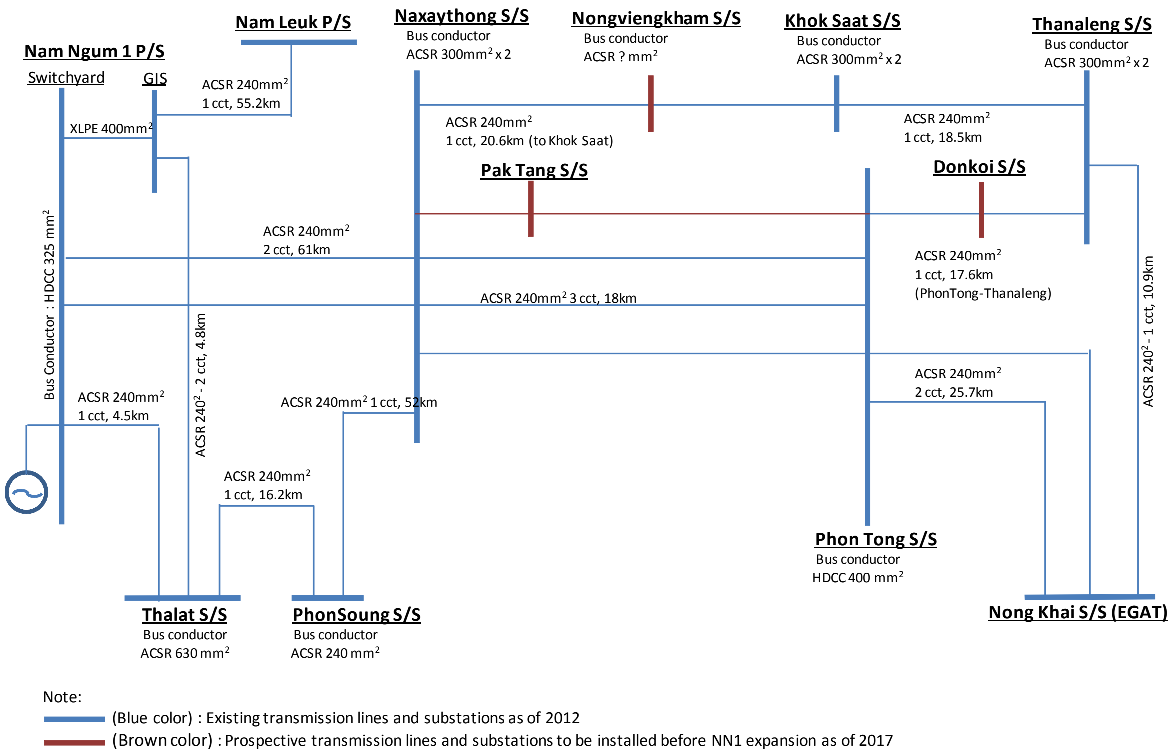

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Figure 4.2.8.1 115 kV Transmission Line Connection Diagram near Nam Ngum 1

(2) Load Flow Analysis

Power flow calculation and voltage analysis, as of wet season in 2017, were conducted. The calculation/analysis assumes that load capacities become the highest after the completion of the expansion of NN1 power station.

For the power flow analysis, software of PSS/E version 3.1 was used. The Study Team utilized the latest analysis model prepared by EDL for the whole transmission system with consideration of expanded generation capacities of NN1.

Basically, the power system of EDL is to be planned so as to maintain appropriate system voltage and fault current level, without causing power outage for Laos domestic power demand. The following technical criteria are applied for review and judgment of calculated load flow and voltage.

1) Load Flow

- Under normal operation, loads of transmission lines and transformers shall be within their rated capacities.
- In case of a single circuit fault for the section with more than double circuits, the power flow of the remaining facilities shall be within the rated capacities.
- Power transmission from the generators with single circuit transmission line is allowed when the generator rejection is not significant in case of a single circuit fault.
- In case of a single fault of a 115/22 kV transformer, the loads of the remaining transformers shall be within 110% of the rated capacities.

2) System Voltage

- Under normal operation condition, the bus voltage in the transmission system shall be within the range from 95% to 105% of the nominal voltage. In case of a single contingency, bus voltage shall be within the range from 92% to 108% of the nominal voltage.
- The power factors of the generators shall be within the range from 90% (leading) to 85% (lagging).

3) Transmission Line and Main Bus of Substations

The allowable current carrying capacity of the transmission line and the main bus of substations and the transmission capacity of transmission lines in case of normal conditions and N-1 contingency are shown in Table 4.2.8.1. In addition, the temperature within the ( ) indicates the allowable maximum temperature rise of conductors.

Table 4.2.8.1 Allowable Current and Transmission Capacity of Standard Conductors

Location	Conductor	Normal Condition (80)		N-1 Contingency (90)	
		A	MVA	A	MVA
Transmission Line	ACSR240	480	96	590	120
Main Bus of Substations	ACSR240			590	120
	ACSR300x2			1394	278
	HDCC325			875	174
	HDCC400			950	189

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4) N-1 Contingency Condition

- Single Circuit Fault of 115 kV Transmission Line between Nam Ngum power station and Thalat Substation

- Single Circuit Fault of 115 kV Transmission Line between Nam Ngum power station and Naxaythong Substation

Under the above conditions, the analyzed load flows of 115 kV transmission lines around the NN1 power station in each expansion capacity are summarized in Table 4.2.8.2(1). Overload of transmission line is indicated in red figures in the table. As explained above, the maximum allowable capacity of conductor for the transmission line is 96 MVA under normal condition, and 120MVA under N-1 contingency condition.

Table 4.2.8.2 (1) Results of Load Flow of Transmission Lines (around Nam Ngum 1 P/S)

(Unit: MVA)

NN1	T/L	NN1-NXA		NN1-NLE	NN1-TLA		TLA-PSO	PSO-NAX
Expansion	Line No.	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
Without Expansion	Norma	61.4	61.4	12.4	21.9	21.9	80.8	59.1
	N-1 (TLA fault)	61.6	61.6	12.6	39.5	-	80.4	58.8
	N-1 (NAX fault)	80.6	-	23.7	29.5	29.5	100.3	78.3
40MW	Norma	69.0	69.0	21.2	24.6	24.6	88.4	66.6
	N-1 (TLA fault)	69.5	69.5	21.6	45.2	-	87.6	65.8
	N-1 (NAX fault)	90.6	-	33.8	37.3	37.3	110.3	88.0
60MW	Norma	72.8	72.8	25.5	26.9	26.9	92.2	70.3
	N-1 (TLA fault)	73.5	73.5	26.1	49.8	-	91.2	69.4
	N-1 (NAX fault)	95.6	-	38.9	41.6	41.6	115.2	92.9
80MW	Norma	76.7	76.7	29.9	29.6	29.6	96.0	74.1
	N-1 (TLA fault)	77.4	77.4	30.5	55.3	-	94.8	72.9
	N-1 (NAX fault)	100.5	-	46.1	46.1	46.1	120.2	97.7
120MW	Norma	84.3	84.3	38.6	36.0	36.0	103.6	83.0
	N-1 (TLA fault)	85.3	85.3	39.4	67.9	-	101.9	79.9
	N-1 (NAX fault)	110.5	-	54.1	55.5	55.5	130.1	107.4

Note) NN1: Nam Ngum 1 P/S, NLE: Nam Leuk P/S, TLA:: Thalat S/S, PSO:: Phon Soung S/S, NXA: Naxaithong S/S

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Besides, the estimated maximum loads on transmission lines in Vientiane, which may be affected by NN1 expansion, are summarized below.

Table 4.2.8.2 (2) Results of Load Flow of Transmission Lines (around Nam Ngum 1 P/S)

(Unit: MVA)

NN1 Expansion	T/L Line No.	NXA-PTO (viii)	NXA-PTO (ix)	NXA-PTO (x)	PTO-NK (xi)	PTO-NK (xii)	TNA-NK (xiv)
Without Expansion	Norma	51.5	51.5	51.5	50.9	50.9	91
	N-1 (TLA fault)	51.6	51.6	51.6	51.1	51.1	91
	N-1 (NAX fault)	47.1	47.1	47.1	49.6	49.6	91
40MW	Norma	57.2	57.2	57.2	55.9	55.9	91
	N-1 (TLA fault)	52.2	52.2	52.2	53.2	53.2	91
	N-1 (NAX fault)	52.2	52.2	52.2	53.2	53.2	91
60MW	Norma	60.1	60.1	60.1	56.6	56.6	91
	N-1 (TLA fault)	60.1	60.1	60.1	58.8	58.8	91
	N-1 (NAX fault)	54.7	54.7	54.7	55.3	55.3	91
80MW	Norma	62.9	62.9	62.9	61.5	61.5	91
	N-1 (TLA fault)	62.9	62.9	62.9	61.7	61.7	91
	N-1 (NAX fault)	57.2	57.2	57.2	57.5	57.5	91
120MW	Norma	68.5	68.5	68.5	67.6	67.6	91
	N-1 (TLA fault)	68.5	68.5	68.5	67.8	67.8	91
	N-1 (NAX fault)	62.1	62.1	62.1	62.3	62.3	91

Note) TNA: Thanaleng S/S, PTO: Phonthong S/S, NK: Nongkhai S/S (in Thailand), NXA: Naxaithong S/S, PTO: Phontong S/S

In addition to the above, the estimated maximum loads of main bus in major 115kV substations near NN1 are shown in Table 4.2.8.3. Overload of bus conductor is indicated in red figures.

Table 4.2.8.3 Estimated Maximum Load of Main Bus in Substations

(Unit:MVA)

NN1 Expansion	Substation	NN1 P/S	TLA S/S	PSO S/S	NXA S/S	PTO S/S	KSA S/S	TNA S/S
	Conductor size	HDCC325	ACSR630	ACSR240	ACSR300x2	HDCC400	ACSR300x2	ACSR300x2
	Max current capacity per phase (A)	875	1078	590	1394	950	1394	1394
	for three phase (MVA)	174	214	120	278	189	278	278
Without Expansion	N-1 (TLA fault)	210.0	130.3	80.4	239.2	154.8	60.9	91.0
	N-1 (NAX fault)	210.0	138.8	100.3	225.4	141.3	60.9	91.0
40MW	N-1 (TLA fault)	260.0	127.2	87.0	256.4	171.6	60.9	91.0
	N-1 (NAX fault)	260.0	144.2	110.3	240.6	156.3	60.9	91.0
60MW	N-1 (TLA fault)	285.0	127.5	91.2	264.9	180.0	60.9	91.0
	N-1 (NAX fault)	285.0	147.9	115.2	248.2	163.8	60.9	91.0
80MW	N-1 (TLA fault)	310.0	128.7	94.8	273.4	188.7	60.9	91.0
	N-1 (NAX fault)	310.0	152.3	120.2	255.4	171.6	60.9	91.0
120MW	N-1 (TLA fault)	210.0	133.0	101.9	336.0	205.5	60.9	91.0
	N-1 (NAX fault)	210.0	158.3	130.1	271.1	186.3	60.9	91.0

Note) NN1: Nam Ngum 1 P/S, TLA:: Thalat S/S, PSO:: Phon Soung S/S, NXA: Naxaithong S/S, KSA: Khoksaat S/S, TNA: Thanaleng S/S, PTO: Phonthong S/S

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(3) Recommended countermeasures for prospective overload at transmission lines and substations

Based on the results of analysis indicated in Table 4.2.8.2 and Table 4.2.8.3, it is recommended for each NN1 expansion capacity that the following countermeasures on transmission lines or substations be taken by EDL before completion of NN1 expansion.

1) 115kV Transmission Lines

a) In case of 40MW and 60MWexpansion of NN1 hydropower station, there will not be overload of transmission lines. Therefore, construction of new substation nor a transmission line will not be required.

b) For 80MW expansion case, Thalat-PhonSoung transmission line will be in overload under N-1 condition. For countermeasure against this situation, it is recommended that one circuit of Thalat-PhonSoung transmission line or NN1-Naxaithong transmission line be additionally installed in order to reduce the load on Thalat-Phon Soung.

c) For 120MW expansion case, Thalat-PhonSoung transmission line will be in overload under normal condition and N-1 condition. For countermeasure, it is also recommended that one circuit of Thalat-PhonSoung transmission line or NN1-Naxaithong transmission line be additionally installed in order to reduce the load on Thalat-Phon Soung.

2) Bus Conductors in Substations

a) In case of 40MW and 60MW expansion of NN1, since the conductors of 115kV main bus in NN1 switchyard are in overload, these conductors will be required to be replaced for increasing the capacity.

b) For 80MW expansion, the replacement of bus conductors in NN1 115kV switchyard is also required. In addition, the 115kV bus conductor in Phon Soung substation will be in overload. It is recommended that the 115kV bus conductors in Phon Soung substation be replaced with upper-sized conductors.

c) In 120MW expansion case, the 115kV bus conductors in Phonthong substation and Naxaithong substation will be in overload. It is further required that the 115kV main bus conductors in these substations be replaced with upper-sized conductors for increasing the capacity.

4.2.9 TECHNICAL ASSESSMENT

Technical studies on each alternative were made in detail in the foregoing Sections 4.2.1 to 4.2.8. Conceptual design drawings (plans and sections) elaborated for major alternatives are shown in Appendix D-1.

The assessment of the alternatives from technical points of view is made as summarized in the following table. The assessment results are reflected in the final selection of the optimum plan to be made in the succeeding section.

Table 4.2.9.1 Technical Assessment of Each Alternative

Alternative	Capacity	Advantage	Disadvantage
A1	40 MW	• Although a large temporary enclosure is required on the upstream face of the dam for intake construction, there are precedents in Japan and its construction is easier than that for independent intake tower standing in the reservoir. • Head loss in waterway is minimal because of shortest length of waterway	• Land space is narrow and main construction works are in a deep pit. As vehicle access to deep work area is not possible, it is necessary to rely on mobile or fixed cranes in construction work. • An access way to the existing transformers at the toe of the dam is blocked by a temporary ramp bridge to

Alternative	Capacity	Advantage	Disadvantage
		among all alternatives considered. This is advantageous for power generation. Layout is most compact and it makes this plan economical. • Scale of 40 MW is identical to the existing units 3 to 5. The existing OHT crane can be utilized for new unit by only extending the crane runway.	work platform for dam piercing work. Large-scale repair of the transformers is not possible during that time (10 months or so).
A2	60 MW	• Intake is larger than that in A1 and consequently temporary intake enclosure becomes larger. However, it is still easier in construction than coffer for independently standing tower structure to be built in deep reservoir. • Length of waterway from intake to turbine is short and thus head loss is less. Layout becomes compact.	• Land space is tightly narrow as for 60 MW expansion and it makes construction difficult. Powerhouse width is larger than 40 MW plan. Rock foundation of the spillway chute wall is almost undermined due to new powerhouse. Special slope stabilization measures are required. • 60 MW turbine cannot be housed in the size of existing powerhouse since it is larger than the existing 40MW turbine. Width of new powerhouse has to be 2 m wider than the existing building. • 60 MW generator rotor is heavier than the existing 40 MW rotor. Further, crane rail span in new 60 MW bay is wider than the existing span. Thus, existing OHT crane cannot be utilized. • Machine bay floor on spillway side of existing unit 5 has to be used as erection floor for new unit 6. To operate a large new crane within the unit-5 bay, roof of the bay has to be demolished and raised. During the roof raising work of 3 months, switchyard equipment on roof is not operable and consequently unit-5 generation is stopped for 3 months.
A4-1 A4-3	40 MW	• Land space for expansion is ensured by excavation of left bank hill. • Tailrace outlet for Plan A4-3 is located apart from the existing units 1 and 2 tail bay. This arrangement does not disturb operation of units 1 and 2. • Intake is similar to Plan A1. Temporary intake enclosure is easier in construction than independent tower type. • Additional powerhouse is built nearby the existing powerhouse. Operation control of new unit is easy.	• Tailrace outlet of Alternative A4-1 is located just beside the existing units 1 and 2 tail bay. Temporary coffer dike for construction of new tailrace outlet partly blocks the existing tail bay and consequently tail bay WL goes up. The operation of units 1 and 2 is affected. • If crane runway is extended from the existing powerhouse, the existing two OHT cranes can conveniently be utilized for additional unit. However, the crane runway extension requires complete demolition of the roof and upper floor rooms of the existing control building and addition of new concrete columns penetrating from bottom floor in the existing control building in order to support new crane runway. These works are more costly than provision of an additional new crane. Therefore, the plan to utilize the existing cranes is abandoned. Erection bay is additionally

Alternative	Capacity	Advantage	Disadvantage
			needed in a new unit building. • Additional unit building is located just below the existing 115 kV transmission lines. Switchyard for additional unit cannot be located on roof of new powerhouse because of lack of safety clearance below the transmission line. Insulated high voltage cables have to be extended from the main transformer of additional unit to GIS building on left abutment of dam to connect them to the existing transmission line.
A4-2 A4-4	60 MW	• There are advantages similar to alternative A4-1. • As tailrace outlet of alternative A4-4 is located apart from the exiting tail bay, operation of units 1 and 2 is not disturbed.	• Because of the large turbine size, new powerhouse building has to be 2 m wider than A4-1. • Existing 115 kV transmission lines pass over the new powerhouse. Switchyard cannot be located on new powerhouse roof due to lack of safety clearance below the transmission lines. Insulated high voltage cables have to be extended from the main transformer of additional unit to GIS building on left abutment of dam to connect them to the existing transmission line.
B2'-1 B2'-2	80 MW 120 MW	• Intake configuration is similar to Alternative A1. Temporary intake enclosure is easier in construction than independent type. • Additional powerhouse is located apart from the existing powerhouse. Sufficient land space can be ensured. New powerhouse does not disturb the operation of the existing powerhouse in and after construction. • B2-1 and B2-2 originally planned have problems of thin cover and worse geological conditions for tunneling. By changing layout to open works, those risks are mitigated.	• Two lanes of waterway in open structure will cause rather high cut slope. • Existing transmission lines are not enough in capacity. New transmission line of 54 km long is required for new unit. • Temporary coffering for construction of powerhouse is required.
B2'-1-1 B2'-2-1	40 MW 60 MW	• Same as B2'-1. • Open excavation can be limited to the minimum degree.	• Insulated high voltage cables have to be extended from the main transformer of additional unit to GIS building on left abutment of dam to connect them to the existing transmission line. • Temporary coffering for construction of powerhouse is required.
D2-3 D2-4	80 MW 120 MW	• There are no obstructive structures in expansion site on the right bank. Sufficient land space can be ensured. • Existing 115 kV transmission lines are usable for transmission of power up to 80 MW. Power generated by new powerhouse can be fed to the existing roof switchyard through new overhead	• Independent intake structure has to be constructed in deep reservoir. Special coffer structure (pipe piles, etc.) is necessary for construction of the intake without lowering reservoir WL. The coffer has to withstand high water pressure more than 30 m. Its construction is not easy and results in high cost and

Alternative	Capacity	Advantage	Disadvantage
		transmission line.	long construction period. • It is necessary to add new switchyard and new 54 km long transmission line.

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In case of 40 MW expansion, Alternative A1 is technically superior to the other alternatives since it can achieve compact arrangement of waterway and powerhouse and can effectively utilize the existing facilities such as OHT cranes and draft tube stoplogs.

In case of 60 MW, Alternative A2 has the most compact layout. However, it threatens stability of adjoining spillway chute wall foundation and there is no possibility of using the existing OHT cranes. Thus, the left bank Alternative B2’-2-1, for which land space is sufficient, is technically superior to other 60 MW cases.

In cases of 80 MW and 120 MW expansions, the left bank alternative (B2’) which utilizes the existing dam body for new intake is superior to the right bank alternatives (D2), since the latter requires independent intake tower of which construction in deep reservoir is difficult and costly.

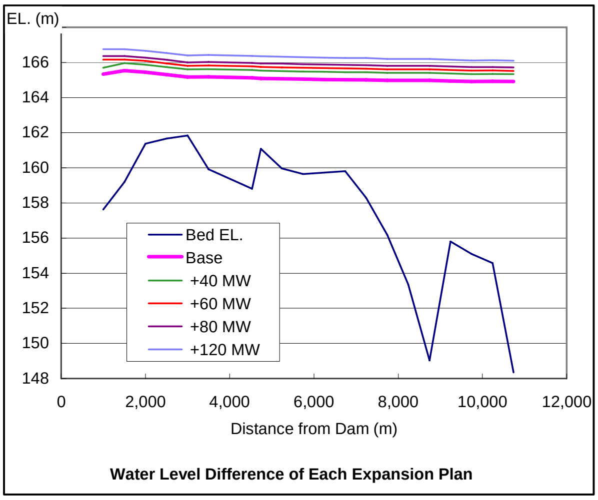
4.2.10 ENVIRONMENTAL ASSESSMENT

Construction activities for the power station expansion are limited within the existing dam and powerhouse area. The construction activities will not cause serious change of the present environmental situation. Although new intake and powerhouse of Alternative D2 are located apart from the existing powerhouse premises, their sites are still within the area used for original dam construction in the 1960s.

Most conspicuous environmental change caused by operation of the expanded power station will be an increased fluctuation of downstream river water level.

(1) Environmental Impact Due to the Water Level Rise in Dry Season

Figure 4.2.10.1 shows un-uniform flow analysis result and difference of water level between before and after expansion at the peak load time for 40MW, 60MW, 80MW and 120MW options. Taking account of the water level in case of 155MW before expansion as the basis, differences of the water levels are almost the same for respective positions at the downstream. In case of 40MW expansion, variation of water level increases 0.4m-0.5m. This becomes 0.6m-0.7m for 60MW expansion, 0.8m-0.9m for 80MW, and 1.1m-1.3m for 120MW, respectively.



Unit (m)			Increase from Base Level (m)			
Distance	Bed EL.	Base WL	+40 MW	+60 MW	+80 MW	+120 MW
10,740	148.35	164.91	0.42	0.62	0.81	1.19
10,240	154.57	164.92	0.42	0.62	0.82	1.20
9,740	155.09	164.92	0.42	0.62	0.81	1.19
9,240	155.81	164.94	0.42	0.63	0.83	1.21
8,740	149.03	164.97	0.43	0.64	0.84	1.23
8,240	153.35	164.98	0.43	0.64	0.84	1.23
7,740	156.17	164.97	0.43	0.63	0.83	1.22
7,240	158.29	165.00	0.44	0.64	0.85	1.24
6,740	159.81	165.01	0.44	0.65	0.85	1.24
6,240	159.73	165.03	0.44	0.65	0.85	1.25
5,740	159.65	165.05	0.44	0.65	0.85	1.25
5,240	159.97	165.07	0.44	0.65	0.86	1.26
4,740	161.09	165.10	0.44	0.65	0.86	1.25
4,530	158.81	165.13	0.44	0.65	0.84	1.24
3,500	159.92	165.17	0.44	0.65	0.85	1.25
3,000	161.84	165.16	0.44	0.65	0.84	1.23
2,500	161.66	165.30	0.43	0.64	0.84	1.24
2,000	161.38	165.45	0.43	0.63	0.83	1.22
1,500	159.20	165.53	0.43	0.64	0.83	1.23
1,000	157.62	165.33	0.36	0.83	1.03	1.42

Source: Preparatory Survey for Nam Ngum 1 Hydropower Station Expansion (2010)

Figure 4.2.10.1 Result of Non-uniform Flow Calculation: Output Increase at Peak Time

Figure 4.2.10.2 shows result of hearing survey on affected riverside users of gardening. Relationship between the ratios of affected users versus the discharges at Pakkagnoung gauging station which is located at 10km downstream of Nam Ngum and Nam Lik river conjunction is presented. This figure shows that 40% of riverside users of gardening will be affected if the discharge at Pakkagnoung exceeds 1,000 m^3/s.

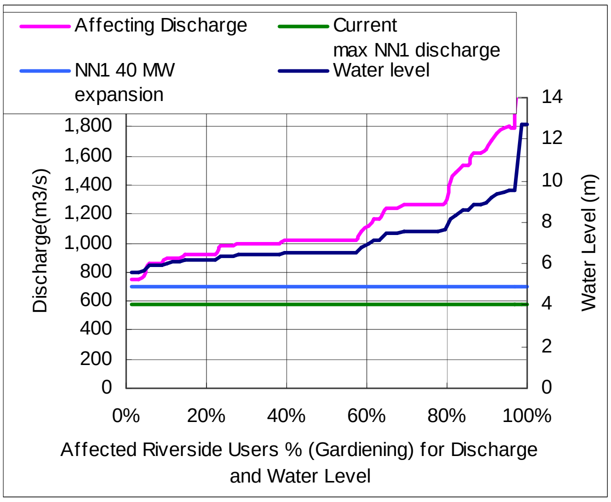


Figure 4.2.10.2 Affected Riverside Users

On the other hand, the Nam Lik 1/2 hydropower plant already started its operation. Installed capacity and maximum plant discharge of the plant are 100MW and 160 m^3/s, respectively. Operational pattern in 2011 of the plant is seen in Figure 4.2.10.3.

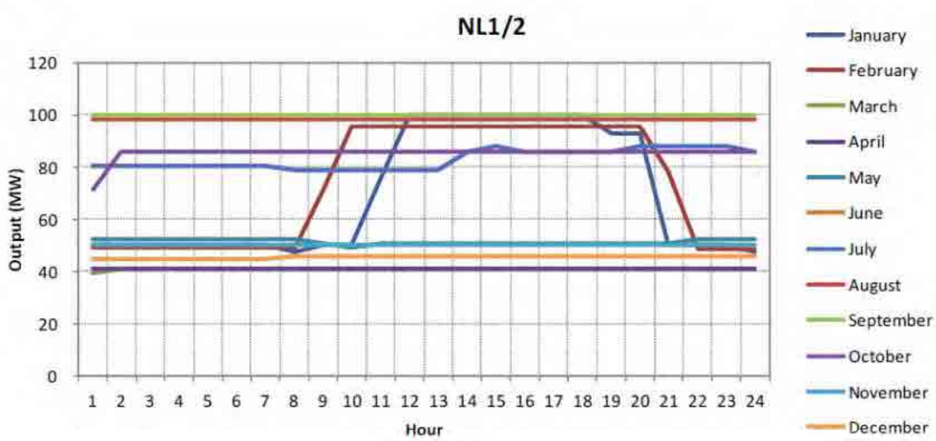


Figure 4.2.10.3 Operation Pattern of Nam Lik 1/2

As seen in the above, during the dry season the Nam Lik 1/2 hydropower plant is operated in both modes as peak load plant and base load power plant. In this comparative study, it is assumed that the Nam Lik 1/2 hydropower plant will discharge 160 m3/s

Meanwhile, the maximum mean monthly discharge of 10 years from the residual catchment area between the Nam Lik 1/2 hydropower plant and the conjunction with the Nam Ngum River is estimated at 84 m^3/s. As the result, the sum of the released discharge from the Nam Lik 1/2 and the residual catchment becomes 244 m^3/s/

Discharge at Pakkagnoung is obtained as the sum of discharges from the Nam Ngum 1 hydropower plant and the Nam Lik River. Discharges at respective scales and ratio of affected river users of gardening are therefore estimated as seen in the table below.

Table 4.2.10.1 Discharge and Affected Riverside User's Ratio

Expansion Scale	Nam Ngum	Nam Lik	Total	Affected Ratio
Existing	465	244	709	0%
40MW	582	244	826	≒0%
60MW	641	244	885	10%
80MW	699	244	943	23%
120MW	816	244	1,060	58%

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It is reasonablly assumed that operation of Nam Ngum 1 and Nam Lik 1/2 will be adjusted in the dry season to minimize the affect to downstream. However, such adjustment is not taken into account in this comparative study.

Environmental impact due to the water level rise in dry season are studied for each option taking into account of the result above. The number of affected households and negative impact for each option are shown in Table 4.2.10.2 Environmental Impact and Compensation Cost. In the Table, compensation cost is also presented for each option.

In the case of 40MW capacity expansion, households which practice river bank gardening would be not affected from the water level rise. Accordingly, no compensation cost is expected. However, in the case of other options, the number of affected households is expected to rise with increase of expansion capacity.

Table 4.2.10.2 Environmental Impact and Compensation Cost

Expansion Capacity (MW)	Water Level Rise in Dry Season (m)	Affected Households (of Total Households %)	Environmental Impact	Estimation of Compensation Cost (US$ 1,000)
40	0.5	0	No negative impact is expected due to the increase of water level during dry season	0
60	0.8	85 (10 %)	About 10 % of the households or 85 households, which practice riverbank, gardening will be affected due to the increase of water level during dry season Further study such as census survey, inventory of affected assets and socio-economic survey shall be conducted in order to clarify the real scale of affected area.	33.8
80	1.0	194 (23%)	About 23 % of the households or 194 households that practice riverbank gardening will be affected due to the increase of water level during dry season Further study such as census survey, inventory of affected assets and socio-economic survey shall be conducted in order to clarify the real scale of affected area.	77.1

120	1.4	490 (58%)	About 58 % of the households or 490 households which practice riverbank gardening will be affected due to the increase of water level during dry season Further study such as census survey, inventory of affected assets and socio-economic survey shall be conducted in order to clarify the real scale of affected area.	194.8

Note)
- Compensation cost here is for the cost of affected riverbank land only. In the cases of 80 MW and 120 MW option, additional cost for installing transmission line (115kv) is necessary. However, the related cost is not clear at this time, thus it is not included in the table.
-Cost was estimated based on the information of riverbank land price from the village head of Boungphao Village, which is one of the villages, locates in the downstream of the Nam Ngum Hydropower Station and expected to be affected by the increase of water level during dry season. In the Boungphao Village, average price for riverbank gardening area is 750 USD/ha . Meanwhile, average riverbank gardening area / household is 0.53ha.
- The cost was estimated as the riverbank gardening land would be affected 100 % from the increase of water level, which is at maximum effect. In reality, the effect is expected to be a part of the land and the cost would be lower than the figure represented in the Table.
Prepared by JICA Survey Team

The above figures are estimated based on the assumption that the total number of household which engage gardening at the river bank is 845 HH.

(2) Approval Process on Environmental and Social Requirements for Each Option

It is stipulated in the Decree on Environmental Assessment (No.112/PM Feb2010) that the project developer shall obtain Environmental Compliance Certificate (ECC) as environmental and social requirement in Lao PDR[1]. In order to obtain the ECC, Initial Environmental Examination (IEE) or Environmental Impact Assessment (EIA) shall be carried out and the result of IEE or EIA shall be reviewed and approved by MoNRE. Approval process on environmental and social requirements for each option is shown in Table 4.2.10.3 Approval Process (Required by MoNRE).

In the case of 40MW capacity expansion, conducing IEE was required for obtaining ECC in 2009. After conducting the IEE, the result was reviewed by MoNRE and the ECC was issued in May 2010 and extended[2] in July 2012. In the case of other options, no IEE or EIA is required. Instead, EDL needs to update the information in the certified IEE with renewed expansion capacity. In addition, social survey needs to be carried out for clarify the degree of impact from renewed expansion capacity and prepare Land Acquisition and Compensation Report. The updated IEE and Compensation Report shall be submitted to MoNRE for approval.

[1] It is stipulated in the Article 4 of the Decree on Environmental Assessment (No.112/PM Feb 2010) that ECC must be obtained by project developer before starting construction works.
[2] The ECC will automatically expire and cannot be used if the project does not start to operate within two years from the date of issuance. Accordingly, EDL made a request to MoNRE of expanding the validity. The request was accepted and the ECC was expanded for another 2 years.

Table 4.2.10.3 Approval Process (Required by MoNRE)

Expansion Capacity (MW)	Approval Process (Required by MoNRE)
40	ECC was issued in May 2010 and extended on 9 July 2012.
60 80 120	**- Update existing IEE (no IEE or EIA required)** •Update IEE report and conduct social survey to prepare Land Acquisition and Compensation Report (3 months) •Submit the report to the ESIA Dept., MoNRE for review (1～several months) •Obtain an approval letter assuring the validity of issued ECC with renewed expansion capacity

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4.2.11 PRELIMINARY COST ESTIMATE

Construction cost of civil works and electrical/mechanical works are estimated for each alternative based on the conceptual designs elaborated as mentioned above.

Civil work costs are estimated by multiplying the unit price and work quantity relevant to various works. Unit prices applied are calculated based on process cost; i.e., the prices of labor, equipment and material with their production rates.

Costs of gates and penstocks and of generating equipment and transmission facilities are referred to the prices in Preparatory Survey for Nam Ngum 1 Hydropower Station Expansion in Lao PDR (2010). Those prices in 2009 level are updated to 2012 level by applying escalation rates as follows.

- F/C (USD) : 3.88%
- L/C (LAK) : 11.42%

Other costs are estimated in the following manner.

- Engineering Cost: 15% of Direct Construction Cost (DCC)
- Physical Contingency: 10% of (DCC) and Engineering Cost
- Administration Cost: 5% of DCC, Engineering Cost and Physical Contingency
- Price Contingency, Land Acquisition, Tax, Interest during Construction: Exluded

The cost estimate calculations are detailed in Appendix D-2 and summary of the estimated costs is shown in the table below.

Table 4.2.11.1 Summary of Estimated Construction Costs of Alternatives

Nam Ngum 1 Expansion: Summary of Estimated Base Costs of Alternative Plans

Rev. 2012.08.05

	Description	Unit	40 MW Expansion				60MW Expansion				80 MW Expansion		120 MW Expansion	
			A1	A4-1	A4-3	B2'-1-1	A2	A4-2	A4-4	B2'-2-1	B2-1	D2-3	B2-2	D2-4
1	Construction Cost													
	a) Civil Works	M US$	21.5	26.8	27.1	22.2	26.8	34.4	34.8	25.0	40.5	64.5	46.3	83.2
	b) Hydraulic Steel Works	M US$	1.8	2.3	2.3	4.5	3.4	3.4	3.4	6.5	8.4	5.7	12.5	8.4
	c) Electrical/ Mechanical Eq.	M US$	20.7	24.4	24.4	24.4	34.1*	32.9	32.9	32.9	46.2	47.0	62.7	66.4
	d) Transmission Line	M US$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.6	5.6	5.6	5.6
	Sub-total	M US$	44.0	53.5	53.8	51.1	64.3	70.7	71.1	64.4	100.7	122.8	127.1	163.6
2	Engineering	M US$	6.6	8.0	8.1	7.7	9.1	10.6	10.7	9.7	15.1	18.4	19.1	24.6
	TOTAL (Base Price)		**50.6**	**61.5**	**61.9**	**58.8**	**73.4**	**81.3**	**81.8**	**74.1**	**115.8**	**141.2**	**146.2**	**188.2**
		Ratio	1.00	1.22	1.22	1.16	1.00	1.11	1.11	1.01	1.00	1.22	1.00	1.29

* : Reduction of energy production (US$ 3.9 M) due to 3-month shutdown of unit-5 during powerhouse roof renewal over Unit 5 is included.

(Note) : Costs of land acquisition, administration and contingency are not included

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In case of the 40 MW expansion, Alternative A1 (US$50.6 million) is the lowest in the base cost.

In case of the 60 MW expansion, Alternative A2 (US$73.4 million) is the least costly because the waterway layout is most compact among the four plans. However, this option is technically risky due to its high excavation beneath the spillway. Alternative B2'-2-1 (US$ 74.1 million) is superior as its technical risk is small.

In case of the 80 MW - 120 MW expansion, Alternative B2' in which the additional powerhouse is located on downstream left bank is lower in cost than Alternative D2 of which powerhouse is located on the right bank. The independent intake tower to be built in the reservoir for Alternative D2 is the main reason for the higher cost.

4.2.12 RESERVOIR OPERATION AND POWER GENERATION

(1) Reservoir Operation Rule

In Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion (2010), the consultant developed the reservoir operation rule considering the minimization of import energy from EGAT. The reservoir operation rule was developed for each option in the preparatory survey, then the power generation simulation was conducted for all options using the simulated inflow series from 1972 to 2007.

Since the purpose of the expansion of NN 1hydropower station is to increase the peak energy by shifting from the off-peak energy, thus to reduce the power import from EGAT, layout and component of the options are almost the same, therefore, this Study applies the reservoir operation rules for options developed in the previous preparatory survey for power generation simulation.

(2) Calculation of Inflow to NN1 Reservoir

The inflow to the NN1 reservoir from 1972 to 2011 is applied for power generation simulation. The previous preparatory survey applied the inflow series upto 2007 considering the storage effect of NN2 reservoir. In this Study, the inflow series from 2008 to 2011 was provided by the NN1 hydropower station to the Study Team. Then the inflow series to the NN1 reservoir was modified by the Study Team through the simulation of reservoir operation of NN2. The model developed in the previous preraratory survey was applied to simulate the NN2 reservoir routine in this Survey. In this way, the inflow series from 2008 to 2011 which are considered NN2 reservoir storage effect is appended.

(3) Power Generation of Alternative Options

Based on the conditions described above, the power generation simulation was conducted for the all options. The result of the power generation simulation is shown in Table 4.2.12.1

Table 4.2.12.1 Result of Annual Energy and Dependable Capacity

Option	Expansion Scale	Annual Energy (GWh)	Dependable Capacity (95%)
Existing (w/o Expansion)	0	1,078	110.89
A1	40	1,134	144.45
A2	60	1,138	161.72
A4-1	40	1,133	144.25
A4-2	60	1,136	161.41
A4-3	40	1,132	144.17
A4-4	60	1,135	161.31
B2’-1	80	1,150	188.79
B2’-2	120	1,160	227.82
B2’-1-1	40	1,134	144.39
B2’-2-1	60	1,138	161.74
D2-3	80	1,146	187.83
D2-4	120	1,153	225.78

Prepared by the Study Team

4.2.13 ECONOMIC AND FINANCIAL ANALYSIS

(1) Benefit of Expansion

The benefit of the power station expansion comes from both increments of dependable output capacity (MW) and energy production amount (GWh/year) resulting from the expansion. The increased dependable capacity and energy amount of each alternative option are obtained by the reservoir operation simulations performed in the foregoing section. The results are listed in Table 4.2.13.1 below.

Table 4.2.13.1 Increment of Annual Energy and Dependable Capacity

Expansion Scale	Alternative	Capacity Increment (MW)	Energy Increment (GWh/yr.)
40MW	A1	33.55	56.24
	A4-1	33.35	55.04
	A4-3	33.27	54.57
	B2'-1-1	33.49	55.87
60MW	A2	50.82	60.01
	A4-2	50.51	58.00
	A4-4	50.41	57.35
	B2'-2-1	50.85	60.15
80MW	B2'-1	77.90	72.12
	D2-3	76.94	67.90
120MW	B2'-2	116.93	81.86
	D2-4	114.88	75.46
Reference:	NN1 generation status before expansion (with NN2)		
	Dependable capacity:		110.89 MW
	Energy Production:		1,077.89 GWh/yr.

Prepared by the Survey Team

Economic Benefit

Economic values of increased peak capacity and energy production are estimated from the construction cost and O&M cost of the least-cost expansion alternative. Diesel plant of 5MW was selected as the least costly alternative for the NN1 expansion.

Unit construction cost of diesel power plant is set at US$ 657.8/kW, based on IBRD's paper (ESMAP Technical Paper 122/09) with adjustment of transportation cost and price escalation. Meanwhile, fuel cost is set at US$ 0.6376/L based on quotation from Lao Fuel Company.

The capacity value (kW value) and energy value (kWh value) estimated are US$ 113.11/kW and US$ 0.1457/kWh, respectively. Annual economic benefits calculated from these kW and kWh values are shown in the table below.

Table 4.2.13.2 Annual Economic Benefits of Alternatives

Expansion Scale	Alternative	Incremental capacity and energy (*)		Annual economic benefit (M US$/ year)		
		Capacity increment (MW)	Energy increment (GWh/year)	Capacity benefit	Energy benefit	Total
40 MW	A1	33.55	56.24	3.79	8.19	11.99
	A4-1	33.35	55.04	3.77	8.02	11.79
	A4-3	33.27	54.57	3.76	7.95	11.71
	B2'-1-1	33.49	55.87	3.79	8.14	11.93
60 MW	A2	50.82	60.01	5.75	8.74	14.49
	A4-2	50.51	58.00	5.71	8.45	14.16
	A4-4	50.41	57.35	5.70	8.36	14.06

	B2’-2-1	50.85	60.15	5.75	8.76	14.52
80 MW	B2’-1	77.90	72.12	8.81	10.51	19.32
	D2-3	76.94	67.90	8.70	9.89	18.60
120 MW	B2’-2	116.93	81.86	13.23	11.93	25.15
	D2-4	114.88	75.46	12.99	10.99	23.99

Reference (*): Generation status before expansion (with NN2):
Dependable capacity: 110.89 MW
Energy production: 1,077.89 GWh/year

Prepared by the JICA Survey Team

Financial Benefit

In the expansion plan optimization study, financial benefit of the expansion is identified as the increased revenue gained by selling the increased electricity to the domestic market. Average tariff rate planned in 2017 which is adjusted into 2012 price level is 9.39 US cents per kWh. This rate is applied to calculate the financial benefits of each expansion alternative. Table 4.2.13.3 below shows the calculated annual financial benefits.

Table 4.2.13.3 Annual Financial Benefits of Alternatives

Expansion Scale	Alternative	Incremental energy (GWh/year)		Annual financial benefit (M US$ / year)
		Generated energy	Sold energy after loss (*)	
40 MW	A1	56.24	52.34	4.92
	A4-1	55.04	51.23	4.81
	A4-3	54.57	50.78	4.77
	B2’-1-1	55.87	51.99	4.88
60 MW	A2	60.01	55.85	5.24
	A4-2	58.00	53.99	5.07
	A4-4	57.35	53.37	5.01
	B2’-2-1	60.15	55.99	5.26
80 MW	B2’-1	72.12	67.12	6.30
	D2-3	67.90	63.19	5.93
120 MW	B2’-2	81.86	76.18	7.15
	D2-4	75.46	70.23	6.60

(*): Loss: Transmission 6.0%, Internal consumption 0.5%, Forced outage 0.5%
Loss factor = (1-0.06) x (1-0.005) x (1-0.005) = 0.9306

Prepared by the JICA Survey Team

(2) Cost

Base costs of alternatives are listed in Table 4.2.11.1 above. To express the project cost, the amount of physical contingency equivalent to 10% of the base cost and administration equivalent to 5% of the sum of the base cost and physical contingencies are added as shown in the table below. Price escalation, land acquisition, tax, and interest during construction are excluded from this estimation.

Table 4.2.13.4 Project Costs of Alternatives

Expansion Scale	Alternative	Base cost (M US$)	Contingency and Administration (M US$)	Project cost (M US$)
40 MW	A1	50.60	7.84	58.44
	A4-1	61.50	9.53	71.03
	A4-3	61.90	9.59	71.49
	B2’-1-1	58.80	9.11	67.91
60 MW	A2	73.40	11.38	84.78
	A4-2	81.30	12.60	93.90
	A4-4	81.80	12.68	94.48
	B2’-2-1	74.10	11.49	85.59
80 MW	B2’-1	115.80	17.95	133.75
	D2-3	141.20	21.89	163.09
120 MW	B2’-2	146.20	22.66	168.86
	D2-4	188.20	29.17	217.37

Prepared by the JICA Survey Team

The project cost is disbursed during construction. Construction period, including bidding and contract process, is assumed to be five years. Disbursement of the cost is assumed to be made at 2 % in the 1st year, 3 % in the 2nd year, 20 % in the 3rd year, 40 % in the 4th year and 35 % in the 5th year.

(3) Economic and Financial Comparisons

Based on the calculated benefits and costs, ranking of economic and financial viabilities of the alternatives are analyzed.

Economic viability is analyzed for a project life of 50 years applying a nominal discount rate of 10 %. Financial viability is also analyzed for a 50-year project life applying a discount rate of WACC calculated on the basis of the assumed ODA soft loan (i=0.7 % p.a.) for the 85% portion of the total cost. WACC is calculated at 3.562% in case the Minimum Rate Test is not considered, and 4.615% in case the Minimum Rate Test is considered.

Table 4.2.13.5 Calculation of WACC

WACC Calculation			ODA Loan		Own Fund		Total
WACC Excluding Minimum Rate Test		3.431%					
Weight			0.85		0.15		1.00
Nominal Cost			0.550%	* General Condition	10.000%	* Estimation USD Base	
Tax Rate			-	* Not considered in Preliminar	-	* Not considered in Preliminary Analysis	
Tax Adjusted Nominal Cost			0.550%		10.000%		
Inflation Rate	* (Inflation Gap between Japan - G7:)		-2.005%	* Foreign Loan	1.756%	* Major Advanced Econlmies (G7)	
Real Cost	(1+NC)/(1+I)-1		2.607%		8.102%		
Minimum Rate Test			-	* Not considered	8.102%		
Weighted Component of WACC			2.216%		1.215%		3.431%
WACC with Minimum Rate Test		4.615%					
Weight			0.85		0.15		1.00
Nominal Cost			0.550%	* General Condition	10.000%	* Estimation	
Tax Rate			-	* Not considered in Preliminar	-	* Not considered in Preliminary Analysis	
Tax Adjusted Nominal Cost			0.550%		10.000%		
Inflation Rate			-2.005%	* Foreign Loan	1.756%	* USA	
Real Cost	(1+NC)/(1+I)-1		2.607%		8.102%		
Minimum Rate Test			4.000%		8.102%		
Weighted Component of WACC			3.400%		1.215%		4.615%

Prepared by the JICA Survey Team

Result of economic and financial analysis is as seen in Table 4.2.13.6.

Table 4.2.13.6 Result of Benefit-Cost Analysis

Capacity Exp.	Alternative Plan	Base Cost ($ mn)	Project Cost ($ mn)	Economic Benefit-Cost Analysis			Financial Benefit-Cost Analysis				
				Alternative Thermal Power			FIRR	WACC =	3.431%	WACC (MRT)=	4.615%
				EIRR	NPV ($ mn)	B/C		NPV ($ mn)	B/C	NPV ($ mn)	B/C
40 MW Expansion	A1	50.60	58.44	17.21%	32.99	1.81	7.00%	39.31	1.72	21.09	1.41
	A4-1	61.50	71.03	14.27%	22.99	1.46	5.44%	25.52	1.38	8.46	1.14
	A4-3	61.90	71.49	14.10%	22.18	1.44	5.34%	24.29	1.36	7.44	1.12
	B2'-1-1	58.80	67.91	15.01%	26.00	1.55	5.85%	29.82	1.47	12.27	1.21
60 MW Expansion	A2	73.40	84.78	14.65%	30.00	1.51	4.85%	20.94	1.26	2.76	1.04
	A4-2	81.30	93.90	13.08%	21.62	1.33	4.00%	9.04	1.10	-7.87	0.90
	A4-4	81.80	94.48	12.92%	20.55	1.31	3.90%	7.40	1.08	-9.23	0.89
	B2'-2-1	74.10	85.59	14.55%	29.59	1.49	4.80%	20.43	1.25	2.24	1.03
80 MW Expansion	B2-1	115.80	133.75	12.57%	25.51	1.27	3.22%	-4.70	0.96	-24.77	0.79
	D2-3	141.20	163.09	10.05%	0.56	1.00	1.84%	-39.25	0.74	-56.07	0.61
120 MW Expansion	B2-2	146.20	168.86	12.93%	36.89	1.31	2.63%	-21.31	0.87	-43.13	0.71
	D2-4	188.20	217.37	9.73%	-4.16	0.97	0.95%	-77.46	0.62	-94.13	0.51

Prepared by the JICA Survey Team

Result of economic analysis shows that all alternatives except D2-4 plan have EIRR which exceed 10%. A1 (40MW) has the highest IRR and B/C, and those economic indicators become worse in accordance with the increase of expansion scale. NPV is more or less US$20~30 mil. for all alternatives except D2 plans.

Result of financial analysis shows that 40MW plans and a part of 60MW plans (A2 and B2'-2-1) have FIRR which exceed WACC of 4.615% which considers the Minimum Rate Test. A1 (40MW) has the highest IRR, B/C and NPV, and those economic indicators become worse in accordance with the increase of expansion scale. FIRRs of 80MW and 120MW plans are less than WACC of 3.431% which does not consider the Minimum Rate Test.

4.2.14 SELECTED OPTIMUM PLAN

As analyzed in the above section, Alternative A1 (40 MW) is judged to be highest in cost performance among 12 alternative options considered. Alternative A1 aims to build a new unit bay building for 40MW plant in the space between the existing powerhouse and the spillway. The existing OHT cranes and draft tube gates can be utilized for the additional unit. Layout of the new powerhouse is most compact and economical among all the options. As the length of penstock and tailrace is short and waterway head loss is less, available water head can be most effectively utilized for power generation. Environmental impact is also less compared to the 60MW~120MW options.

By comprehensively judging from the technical, economical, financial and environmental viewpoints, Alternative A1 (40MW) is selected as the optimum expansion plan for the NN1 power station.

A part of 60MW plan (A2 and B2’-2-1) still clears the hurdle rate of WACC, although the indicators are worse compared with A1. Environmental impact by those plans are smaller compared to 80MW~120MW plan. Among them, A2 plan is not preferable for; i) affect to existing spillway for excavation at the immediate side, and ii) affect to the existing Unit 5 for modification of powerhouse building. Therefore, in case of seeking larger expansion scale than 40MW, B2’-2-1 is the plan which is conceivable, nevertheless this is not the optimum from viewpoint of cost performance.

Both A1 (40MW) and B2’-2-1 (60MW) adopt dam piercing. This method was developed in Japan through 30 past experiences in these 30 years, and thus its credibility is high. Furthermore, layout of B2’-2-1 (60MW) is duly examined so as to avoid any influence by the existing slopes nearby. From technical viewpoints, both plans can be implemented without any serious difficulties.

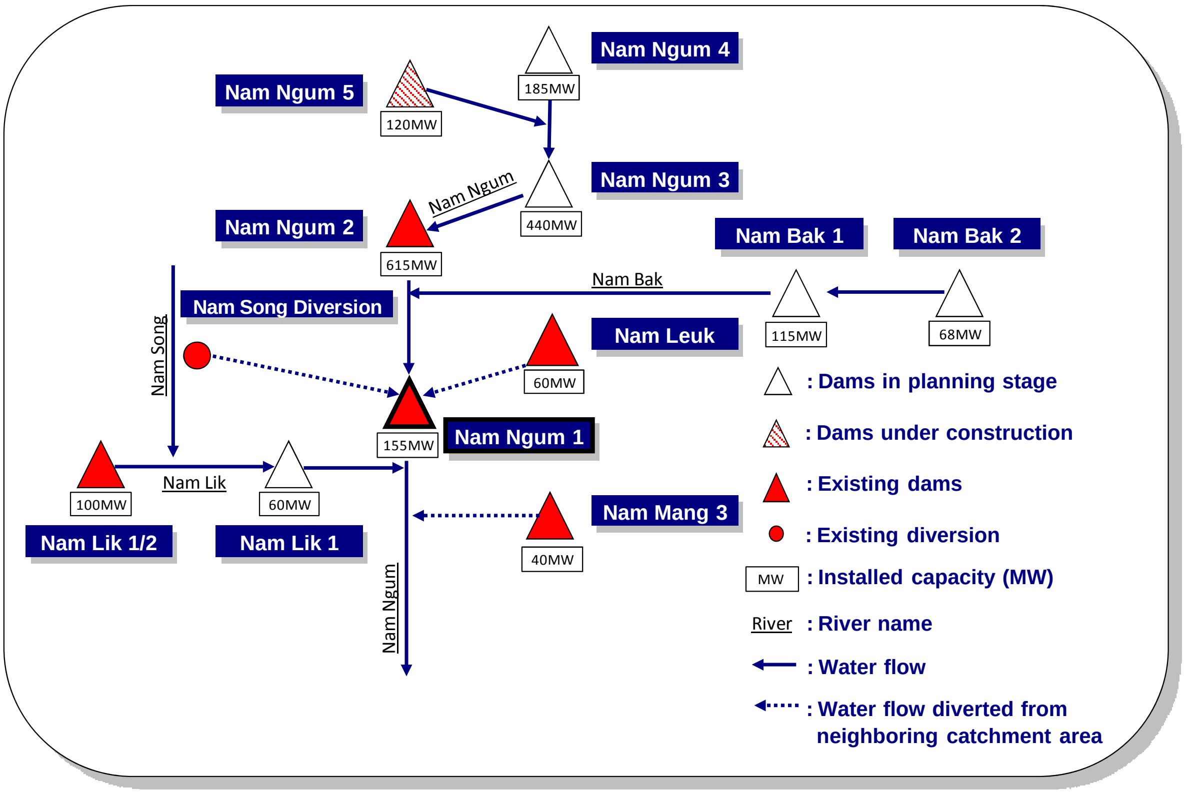
80MW and 120MW plans do not satisfy the hurdle rates of financial analysis, thus are not recommended for implementation.

CHAPTER 5 OPERATION OF NAM NGUM RIVER BASIN AND NN1 HYDROPOWER STATION

5.1 OPERATION OF NAM NGUM RIVER BASIN

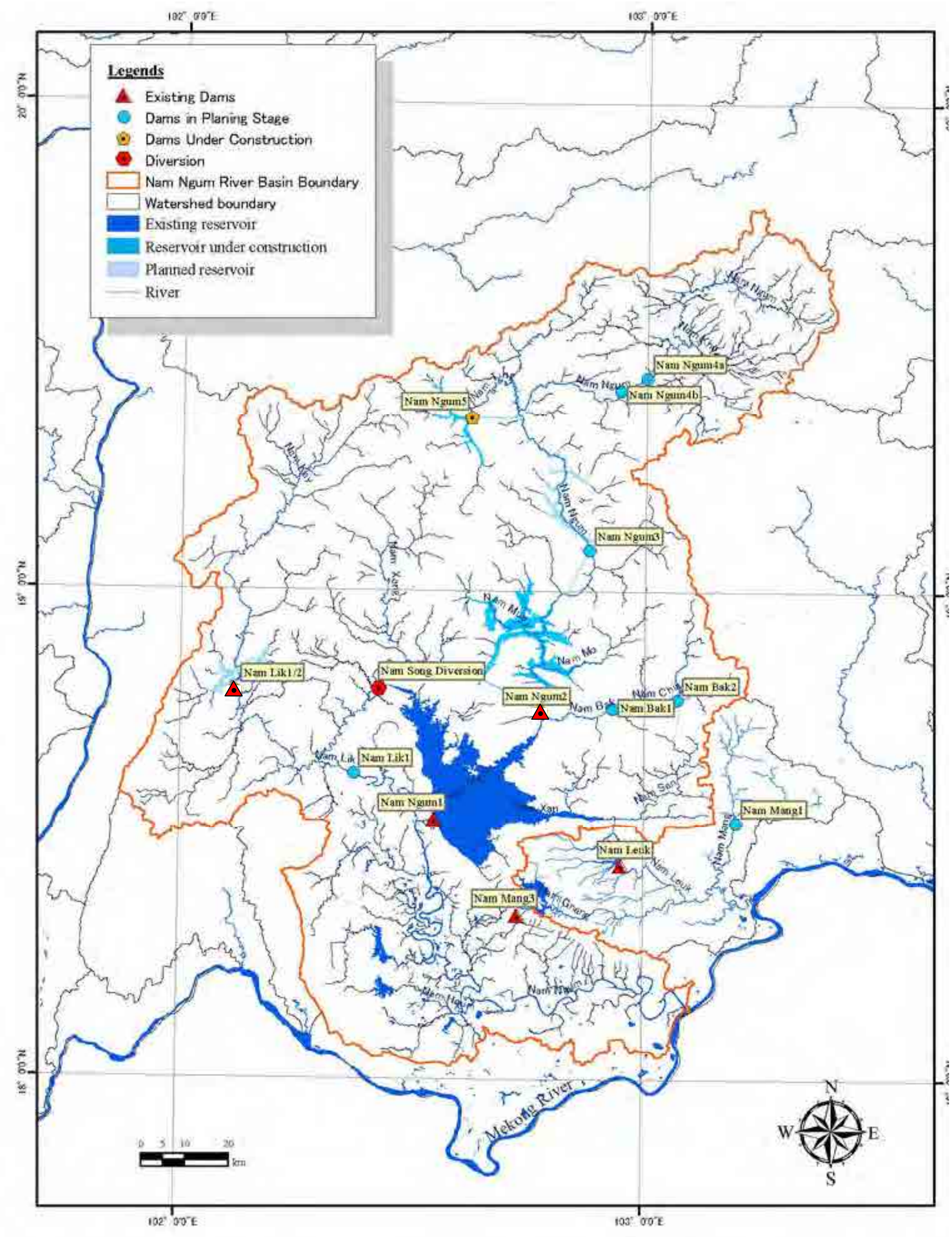
5.1.1 Development Upstream of NN1

The upstream of NN1 dam is intensively developed and is used mainly for hydropower project. The hydropower development in the Nam Ngum River basin is shown in Figure 5.1.1. The location map of the planned and existing hydropower stations in the Nam Ngum River Basin is shown in Figure 5.1.2.



Prepared by the Survey Team

Figure 5.1.1 Hydropower Development in the Nam Ngum River Basin



Source：Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion

Figure 5.1.2 Location Map of Hydropower Stations in NNRB

In 2010, the Nam Ngum 2 (NN2) Hydropower declared its initial operation day (IOD) and started operation for hydropower generation. So far, NN2 has not declared a commercial operation day (COD), therefore, NN2 operation does not meet operation requirements stipulated in the PPA. It is expected that the operation of NN2 will be changed after the COD which is expected by the end of 2012 or January 2013. The actual operation of the NN2 in compliance with the PPA is still unknown during this study unless NN2 states COD.

The principal feature of the planned/existing hydropower development in the upstream of NN1 is shown in Table 5.1.1.

Table 5.1.1 Principal Features of Planned Hydropower Station in Upstream of NN1

Items \ Project	Nam Ngum 2	Nam Ngum 3	Nam Ngum 4	Nam Ngum 5	Nam Bak 1	Nam Bak 2
Purpose	IPP (Export)	IPP (Export)	IPP (Export)	IPP (Domestic)	IPP (Export)	IPP (Domestic)
Status	Existing	PPA Signed	Pre-F/S	Under construction	Pre-F/S	Pre-F/S
Main Developer	Southeast Asia Energy Limited (Thailand)	GMS Power	Saigon Invest Group	NN5PC	Southeast Asia Energy Limited (Thailand)	Southeast Asia Energy Limited (Thailand)
Planned Commencement of Power Generation	December 2010	-	-	2012	-	2015
Principal Feature						
Catchment area (km_2)	5,640	3,888		483	597	320
Storage at FSL (MCM)	2,617	1,407		314	250	190
Average annual inflow (MCM)	6,270	3,090		719	750	400
Type of dam	CFRD	RCC		RCC	RCC	RCC
Dam Height (m)	181	220	125	99	83	85
Design flood of spillway (m^3/s)	10,855	7,900		3,231	1800	963
Powerhouse	Above ground	Underground		Semi-ground	Semi-ground	Semi-ground
Rated output (MW)	615	440	185	120	115	68
Average annual energy (GWh)	2,310	1,919	748	400	600	357

Prepared by the Study Team

5.1.2 IMPACT TO NN1 BY UPSTREAM DEVELOPMENT

In the upstream of the NN1 reservoir, NN2 hydropower station started its operation, and NN3 signed power purchase agreement (PPA) with EGAT. Thus it is very likely that NN3 project will be implemented. It is necessary to estimate the impact of upstream development to NN1 reservoir operation, although it is difficult to collect the information such IPP projects.

(1) Expected Operation of NN2

NN2 is contracted PPA with EGAT and 100% of its power output is sent to Thailand. NN2 will generate electricity from 6:00AM to 10:00PM except on Sunday, and the eletric energy generated during this period is regarded as primary energy which is rewarded by rather high price tariff. According to hearing from NN2 Engineer, NN2 will generate eletricity at least 8 hours during primary hours and the annual average should be greater than 10 hours/day. PPA describes minimum operation values which NN2 must comply to, and if NN2 can not comply such requirements, NN2 have to pay penalty to EGAT as liquidate damage.

Therefore, it is considered that, in every year, NN2 will operate the power plant following the operation rule stipulated in PPA so as to avoid from paying penalty.

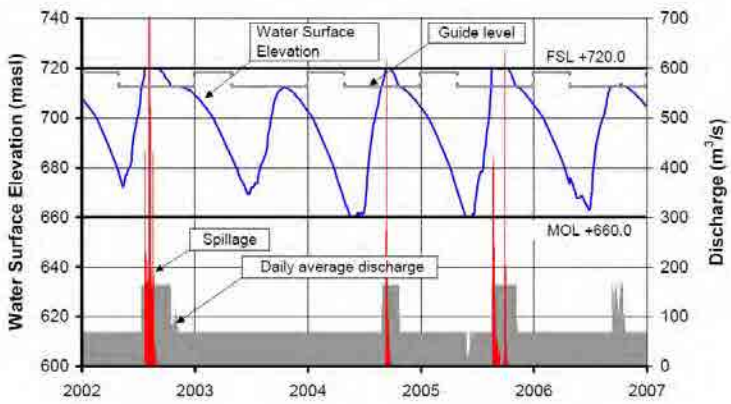
(2) The Impact of NN3 Development to Downstream Hydropower Stations

In 2008, NN3 hydropower project carried out the cumlative impact assessment of NN3 under financed by ADB[1]. This assessment includes asseement of the impact to the downstream hydropower station

[1] Vattenfall Power Consultant AB, “Preparing the Cumulative Impact Assessment for the Nam Ngum 3 Hydropower Project”, February 2008, ADB

operation by NN3 hydropower development through the simulation study. Since the information about NN3 is limited for the Study, the result of impact assessment is introduced.

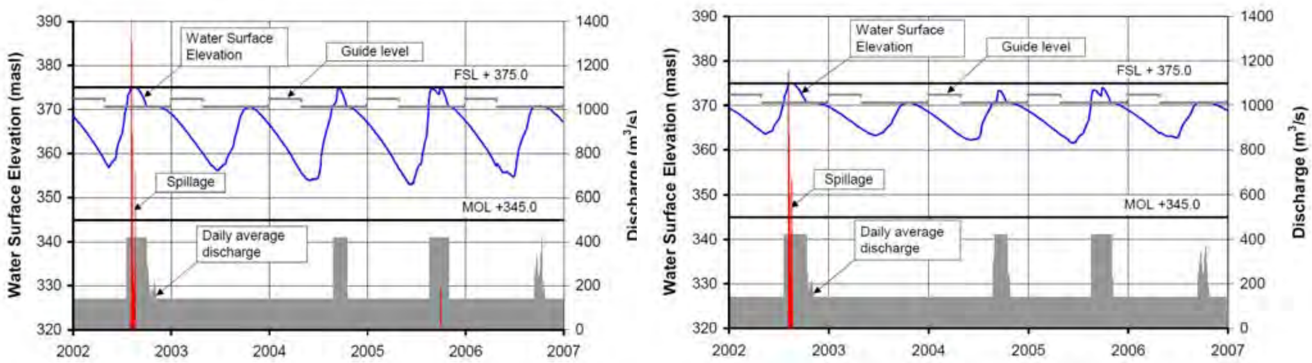
In the cumulative impact assessment(CIA) report, the consultant carried out the reservoir operation simulation study from 2002 to 2005. The result of the simulation of NN3 reservoir is shown in Figure 5.1.3.



Source; " Preparing the Cumulative Impact Assessment for the Nam Ngum 3 Hydropower Project", February 2008, ADB

Figure 5.1.3 Nam Ngum 3 Reservoir Operation Simulation from 2002 to 2007

The development of the NN3 hydropower may regulate the seasonal flow fluctuation to NN2 reservoir, therefore it will result in increasing in inflow, and rising reservoir water level during dry season. The reservoir water level fluctuation of NN2 reservoir for "with" and "without" NN3 hydropower is shown in Figure 5.1.4.



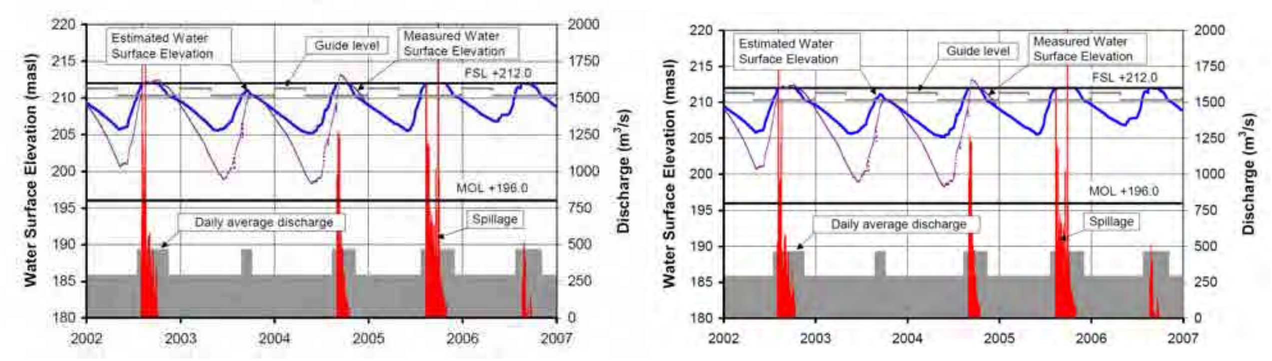
<u>Without NN3</u> **<u>With NN3</u>**

Source; " Preparing the Cumulative Impact Assessment for the Nam Ngum 3 Hydropower Project", February 2008, ADB

Figure 5.1.4 Nam Ngum 2 Reservoir Operation Simulation from 2002 to 2007

As shown in the figure, "with NN3" case rise the water level of NN2 during dry season. Meanwhile, the daily average discharge of "without NN3" does not differ to "with NN3" case as shown in the figure. This means that NN3 development does not change the release/generation pattern of NN2. However, according to the CIA report, rising reservoir water level during the dry season expects the augmentation of annual energy of NN2 to 36GWh/year.

The simulation study is further undertaken for the NN1 reservoir in the CIA report. The simulation result of the NN1 reservoir for “with NN3” and “without NN3” cases are shown in Figure 5.1.5.



<u>Without NN3</u> **<u>With NN3</u>**

Source; “ Preparing the Cumulative Impact Assessment for the Nam Ngum 3 Hydropower Project”, February 2008, ADB

Figure 5.1.5 Nam Ngum 1 Reservoir Operation Simulation from 2002 to 2007

As shown in Figure 5.1.5, NN3 development does not give impact to reservoir operation nor the release from NN1 hydropower station. This study result shows that the impact of NN3 development to NN1 hydropower operation is negligible.

This series of simulation study in the CIA report presumed that the NN2 operation would not be changed althoug NN3 would be developed. This assumption is reasonable since it is hard to consider that the NN2 hydropower will change its operation pattern that is stipulated in PPA. This may be the true even though the NN3 is constructed right upstream of the NN2 reservoir.

Therefore, in summary, it can be concluded that according to the CIA report of NN3, NN3 development will not affect to the NN1 reservoir operation, thus power output of NN1 hydropower station would not be changed after NN3 development.

5.1.3 River Basin Management by the Other Donors

Currently, World Bank (WB) promotes Integrated Water Resources Management (IWRM) for the Mekong River basin, and Asian Development Bank (ADB) together with Austrarian Government and Spanish Cooperation Fund undetake to promote IWRM to the major river basins in Lao PDR. The WB’s scheme targeted for Lower Mekong River Basin (LMB), whereas the ADB’s scheme targeted for the river basin management in Lao PDR. The general description of both schemes are described as below.

(1) Mekong Integrated Water Resources Managament: World Bank

According to the project information document of WB[2], WB consider the Mekong River Basin as a

[2] World Bank Project Information Document Appraisal Stage, “Mekong Integrated Resources Management” February 2012.

precious resource of significant socio-economic, environmental and cultural value, and the basin needs sustainable development involving the flood and drought issues as well as challenging to climate change. Meanwhile, pressure on increasing utilization of water resources of the Mekong River is increasing as China built five large-scale hydropower plants along the Mekong River, and the LMB has 11 hydropower projects at the planning or inception stages. These facts necessitate effective planning on water resources management with a holistic approach.

From these view points, WB committed to adoption of IWRM concept proactively to LMB, however, WB recognized that careful coordination of interests in LMB countries was needed, and WB considered that upgrading hydro-meteorological network was needed for sharing information among riparian countries. WB plans to implement Mekong Integrated Water Resources Management (MIWRM) for Thailand, Laos, Cambodia, Vietnam to promote IWRM in the Mekong River basin.

The MIWRM project is composed of following three components;

Component 1 : Regional Water Resources Management,

Component 2 : National Water Resources Management, and

Component 3 : Improved Floodplain and Aquatic Resources Management in Regionally Significant Areas

During the survey period of NN1 expansion phase 2, the MIWRM project was in the stage of selecting consultants, therefore, the project was still in the preparation stage.

(2) National Integrated Water Resources Managerment Support Project: ADB, Government of Australia and the Spanish Cooperation Fund for Technical Assistance

In 2007, Lao PDR established Water Resources and Environment Administration (AREA) by unifying fragmented water-related agencies and functions. According to the ADB report[3], the establishment of WREA was a significant step in strengthening capacity for IWRM in Lao PDR, however, it still lacked the capacity to effectively implement IWRM against rapid development in water sector in the country.

The function of WREA was transferred to Ministry of Natural Resources and Environment (MONRE) in 2011. ADB together with Austrarian Government and Spanish Cooperation Fund planned the project for further IWRM promotion to strengthen the capacity of MONRE to (i) manage its own water resources strategically against rapid development of water-related projects, (ii) be an informed and equal partner to Mekong River Commission, (iii) regulate cocessions of use of water as well as enforcing environmental management, and (iv) support river basin committee.

The project is called National Integrated Water Resources Managerment Support Project and the duration of the project is planned to four years.

[3] ADB Technical Assistance Report, "Lao People's Democratic Republic: National Integrated Water Resources Management Support Project" (Cofinanced by the Government of Australia and the Spanish Cooperation Fund for Technical Assistance) January 2011.

The project expected the following four principal outputs.

Output 1 : National capacity built in integrated water resources management,

Output 2 : River basin management developed,

Output 3 : National groundwater management action plan prepared, and

Output 4 : Integrated water resources management education strengthened at the National University of Laos

During the survey period of NN1 expansion phase 2, the project has already selected consultants and already undertaken by them. The reports of the projects are not obtained during the survey.

(3) Impact to Water Use in Nam Ngum River Basin

The activities of MIWRM by WB is mainly composed of (i) facilitate trans-boundary dialogue on critical water resources management issues among LMB, (ii) establishing a regional approah on environental and disaster risk assessment, (iii) development of a new Water Resources Law in the riparian countries in LMB, and (iv) improving floodplaing and aquatic resources management. The ADB's national IWRM mainly carries out (i) building capacity of Project Management Unit in MONRE, (ii) supporting river basin committee, (iii) support Nam Ngum River Basin committee as a pilot scheme, and (iv) national groundwater management.

As WB's MIWRM project targeted for promotion of IWRM to LMB raparian countries, therefore the impact to regional river basin operation such as of Nam Ngum river basin is considered minimal. ADB supported for the Nam Ngum river basin committee and its activities. Accordring to hearing to MONRE, the detailed role and commitment of the committee, which includes water allocation and development of rule of water use, are not yet determined or maybe determined in future. The flood control is not involved in the committee responsibility.

From these view points, the impact to Nam Ngum river basin operation by ADB's national IWRM is considered to be minimal, unless the committee determines the water allocation and water use affect to Nam Ngum river basin operation in future.

5.2 OPERATION OF NAM NGUM 1 HYDROPOWER STATION AFTER EXPANSION

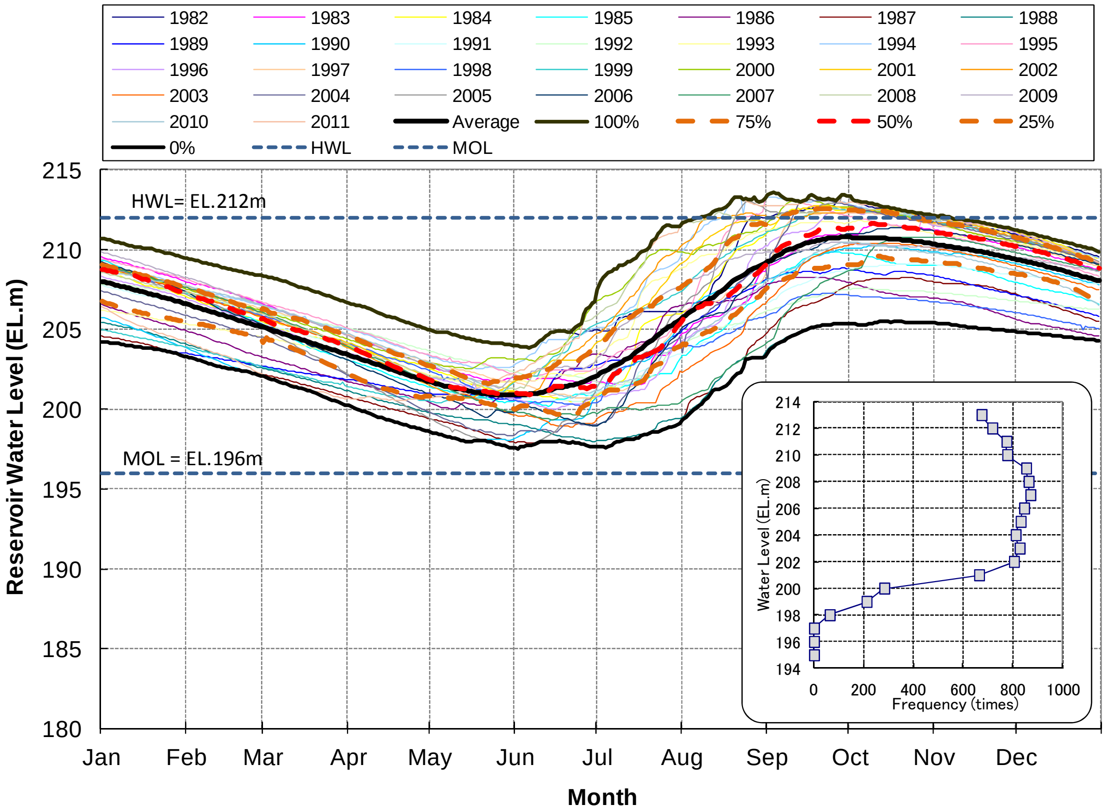
5.2.1 Nam Ngum 1 Reservoir Operation Record

The principal feature of the Nam Ngum 1 (NN1) reservoir is shown in Table 5.2.1.

Table 5.2.1 Principal Feature of NN1 Reservoir

Items		
Catchment area	:	8,460 km^2
Annual average inflow	:	382 m^3/s
Plant capacity	:	155 MW
Effective storage	:	7030 MCM
Storage area	:	370 km^2
Dam height	:	75 m
Dam crest length	:	468 m
Dam volume	:	360,000 m^3

The daily water level fluctuation of the NN1 reservoir from 1982 to 2011 received from the NN1 hydropower station is shown in Figure 5.2.1.



Data source; Nam Ngum 1 Hydropower Station, and Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion (2010)

Figure 5.2.1 Nam Ngum 1 Reservoir Water Level Record

Table 5.2.2 Statistic of Monthly Water Level

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MEAN	207.3	205.9	204.2	202.5	201.1	201.4	203.9	207.6	210.3	210.6	209.9	208.7
MAX	210.7	209.5	208.3	206.6	204.9	207.5	211.7	213.5	213.6	213.1	212.2	211.2
MIN	203.3	202.1	200.2	198.5	197.6	197.5	197.6	199.5	203.7	205.3	204.9	204.3
Exceedance WL												
25%	208.5	207.0	205.4	203.6	202.1	202.6	206.1	210.4	212.4	212.3	211.3	210.1
50%	207.9	206.4	204.6	202.6	201.2	201.0	203.6	207.4	210.9	211.4	210.6	209.3
75%	206.1	204.8	203.0	201.2	200.5	200.0	201.6	205.4	208.4	209.1	208.9	207.7
95%	204.1	202.7	201.3	199.7	198.2	198.1	198.8	202.1	206.1	206.9	206.2	205.0

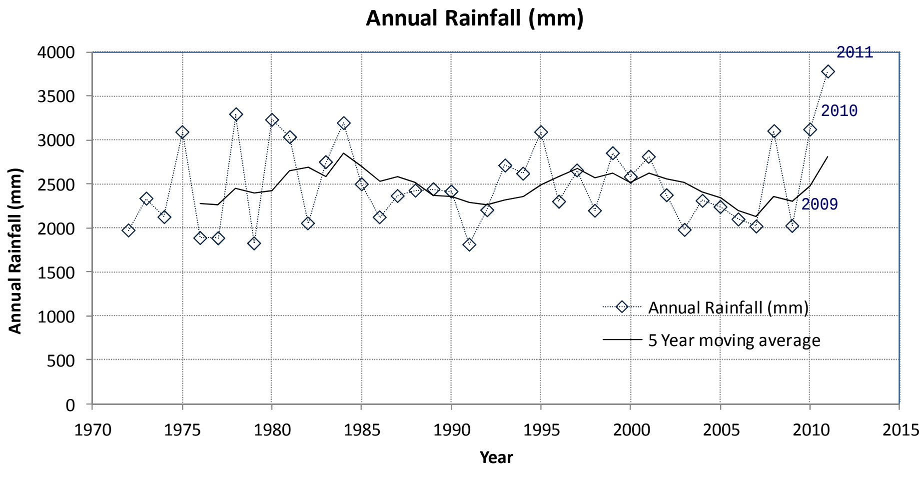
According to the water level record from the year 1982 to 2011, the frequency of water level is peaked in the range between 206 m to 207 m. This water level range occurs 869 days in 30 years which is equivalent to 8.0% of total duration.

The water level records show that the water level of the NN1 reservoir goes down to around EL.200 m at the end of May, then the water level rises until October.

5.2.2 Reservoir Operation in Recent Five Years

(1) Annual Precipitation

The annual rainfall observed in the NN 1 hydropower station is shown in Figure 5.2.2.



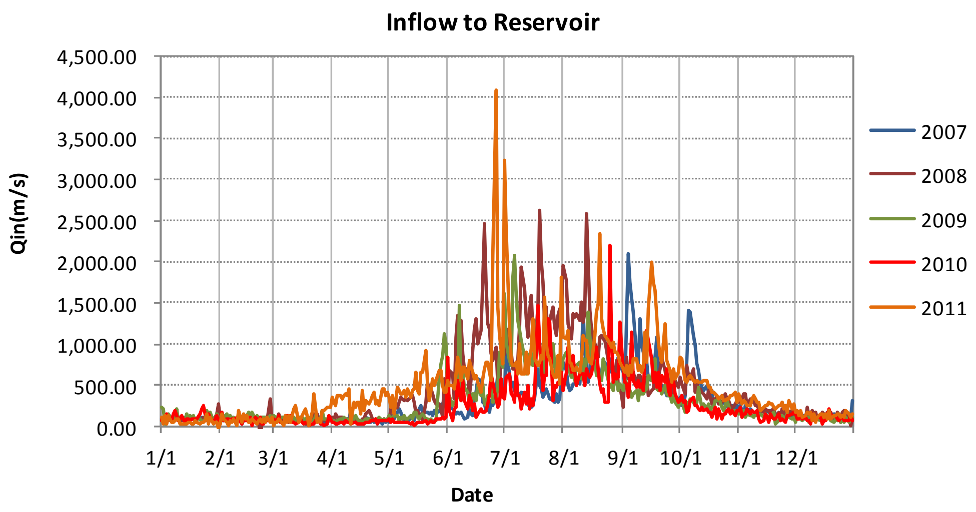
Prepared by the Study Team

Figure 5.2.2 Observed Annual Rainfall in NN1

It is noted that the annual rainfall observed in 2011 recorded the highest amount since NN1 commenced its operation in 1972. The annual rainfall in 2010 and 2011 were higher than the average of 2500 mm a year.

(2) Reservoir Operation

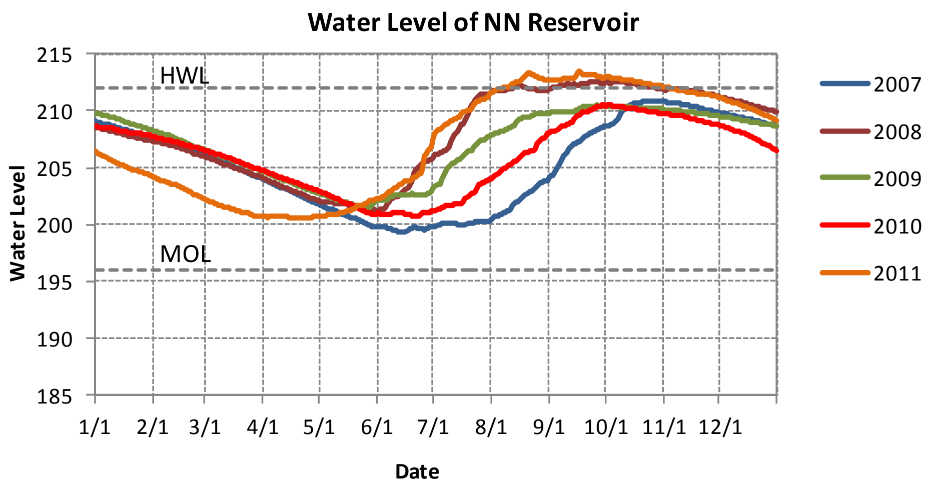
The inflow data is received from the NN1 power station. The inflow collected into the NN1 reservoir for the past five years is shown in Figure 5.2.3.



Prepared by the Study Team

Figure 5.2.3 Observed Inflow into NN1 Reservoir

The reservoir operation record of NN1 is shown in Figure 5.2.4.



Prepared by the Study Team

Figure 5.2.4 Reservoir Operation Record of NN1 Reservoir

It is noted that the water level in wet season in 2010 was relatively lower than those of the other years due to the impounding done at NN2 reservoir. In 2011, the starting water level is lower than other years since the water level could not be recovered during the year 2010 due to impounding of NN2. However, the water level was quickly recovered to HWL in 2011, due to the largest rainfall ever recorded that year.

5.2.3 Current Nam Ngum 1 Reservoir Operation Rule

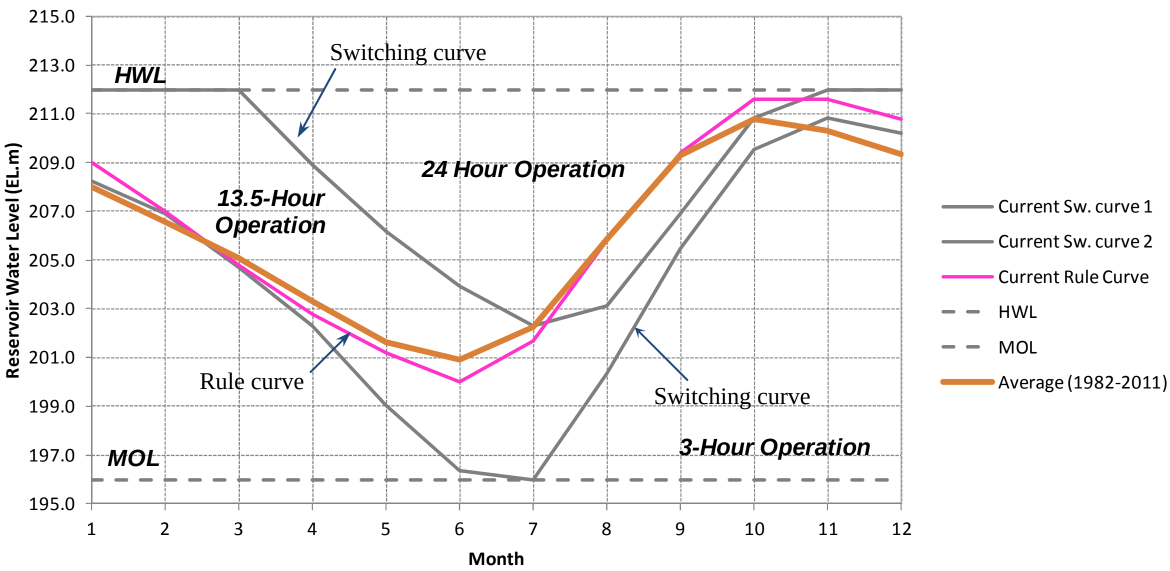
(1) Reservoir Operation Plan of Existing Hydropower Stations

The reservoir operation plan of the hydropower stations in the Nam Ngum river basin was studied by the European consultants in 1990s. Germany consultant of Lahmeyer International (LI) studied the reservoir operation plan of Nam Ngum 1 hydropower station and Nam Mang 3 hydropower station by applying optimization technique. The reservoir operation plan was developed and presented for both hydropower stations. The reservoir operation plan of Nam Leuk hydropower station was studied and proposed by French consultant of Sogreah.

(2) Reservoir Operation Plan by LITHO

LI studied the reservoir operation rule of the NN1 reservoir in the "Study to Improve Operation of the Nam Ngum Hydropower Station Laos" in 1990. The reservoir operation was further studied in "Nam Ngum 1 Hydropower Station Extension Feasibility and Engineering Study" in 1995 by LI. Both studies applied the generalized stochastic dynamic programming software developed by LI named LITHO (Lahmeyer International Hydro-Thermal Optimization). LITHO is a hydropower operation optimization tool for the hydro-thermal power system. The optimization is carried out so as to minimize the total system cost. The output of the optimum reservoir operation plan was monthly reservoir rule curve and the hydropower plant operation hours corresponding to the reservoir operation level so as called "Switching Curve."

The switching curve developed by LI for the Nam Ngum 1 Reservoir and the reservoir operation rule curve is shown in Figure 5.2.5.



Data Source; Nam Ngum 1 Hydropower Station Extension Feasibility and Engineering Study (1995), and Nam Ngum 1 Hydropower Station

Figure 5.2.5 Reservoir Operation Rule of NN1 Reservoir

Figure 5.2.5 also shows the average water level at the beginning of the month between 1982 to 2011 which noted as "Average (1982-2011)." As shown in the figure, the average water level coincides to the reservoir operation rule curve which was proposed by LI.

NN1 hydropower station used to updating the switching curve by running LITHO program with updated reservoir inflow prediction. However, as LITHO program does not run on the current windows operating system, therefore the program is no longer used to seek the optimum reservoir operation plan. On the other hand, EDF (Electricite du France) has provide reservoir operation optimization program, which is called PARSIFAL, and ADB funded NNRBDSP project. Currently the Nam Ngum 1 hydropower station tries to use the tool to seek the reservoir operation plan.

(3) Nam Ngum River Basin Development Sector Project (NNRBDSP)

In 2009, Nam Ngum River Basin Development Sector Project (NNRBDSP) was implemented by cofounding by ADB and ADF. The project aimed to introduce the Integrated Water Resources Management to Nam Ngum river basin, to supply river basin model and reservoir operation optimization tool as well as capacity building. Under this scheme, a reservoir operation optimization program which was called PARSIFAL was supplied to Lao government.

PARSIFAL applies stochastic dynamic programming with linear programming function. Therefore, PARSIFAL is a kind of hybrid optimization method. The program searches the optimum operation policy of the Hydro-Thermal combination system by maximizing the revenue. The mainframe of the program was developed using stochastic dynamic programming. The linear programming is used in searching the best value in the recursive cost function from stage t to $t-1$ or $t+1$ in forward type DP for each discretized water volume. The random variables considered in the program are hydrological data, system breakdown, variables influenced by hydrologic conditions such as electricity demand, and etc.[4]

PARSIFAL is a generalized software packages for hydro-thermal mix power source system. The formulation of reservoir operation plan by PARSIFAL is rather complicated and it requires two hours for calculation. Therefore, the program has not been fully utilized by EDL to develop reservoir operation planning.

(4) Current Reservoir Operation

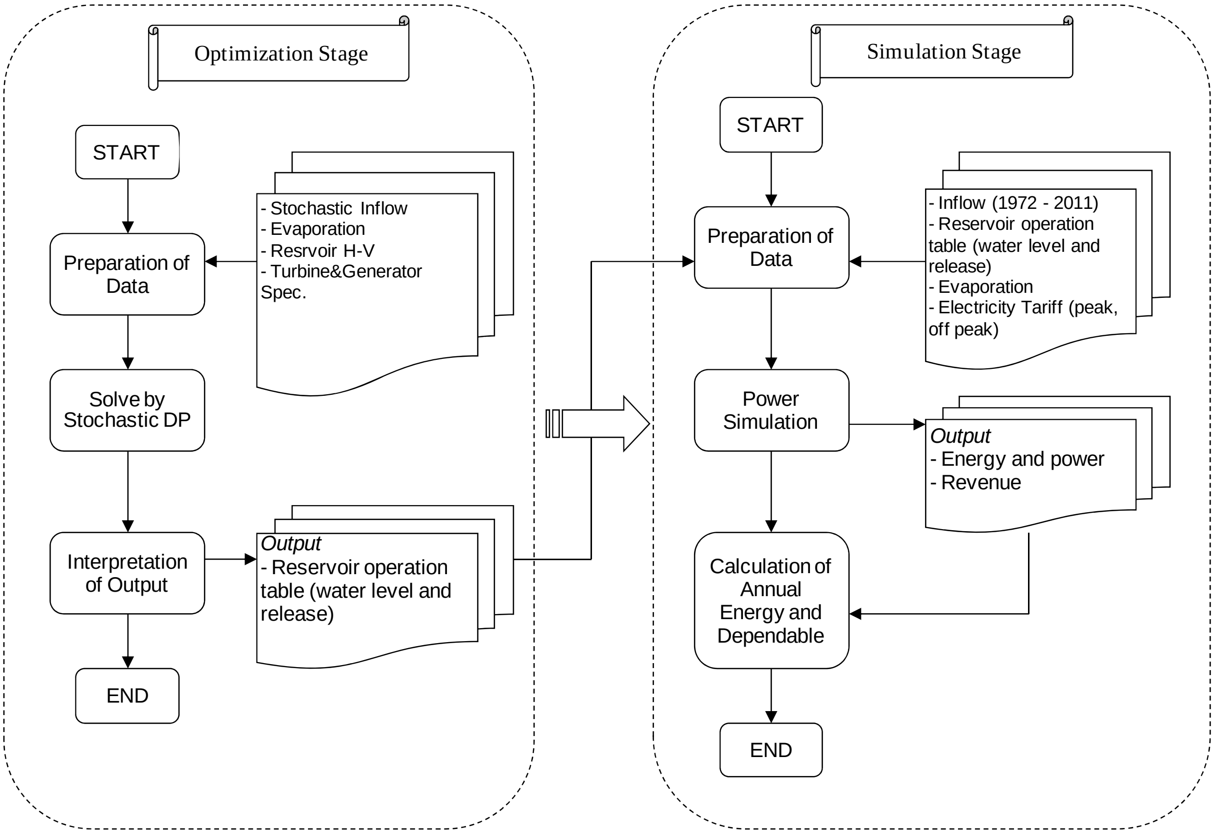
According to hearing to the Nam Ngum 1 hydropower station, since LITHO are not able to run in the current computers system, PARSIFAL is not fully utilized, therefore currently Nam Ngum reservoir operation is done by empirical manner. As Nam Ngum 2 is planned to start the commercial operation in January 2013, the Nam Ngum 1 reservoir needs the tool to support establishing reservoir operation rule as soon as possible.

[4] EdF, "PARSIFAL Methodological guidelines," EdF pôle industrie, division ingenierie et services, 2000, France

5.2.4 Review of Nam Ngum 1 Reservoir Operation Plan

(1) General

This study aims to find the optimum reservoir operation rule for expanded Nam Ngum 1 hydropower station with 40MW and to simulate the power generation with developed reservoir operation rule. The reservoir operation rule is developed by applying optimization technique to maximize or minimize the specified objective function. The power generation simulation is conducted using daily inflow for 40 years from 1972 to 2011 with the developed reservoir operation rule. The flow of the study for reservoir operation optimization is shown in Figure 5.2.6.



Data Source; Nam Ngum 1 Hydropower Station Extension Feasibility and Engineering Study (1995), and Nam Ngum 1 Hydropower Station

Figure 5.2.6 Flow of Reservoir Operation Study

(2) Reservoir Operation Optimization Method

In this study, Stochastic Dynamic Programming(SDP) is used to seek the optimum reservoir operation plan. SDP is a one of the method of dynamic programming which assumes the inflow as the stochastic random variable. Dynamic programming itself is a method to seek the optimum path to maximize or minimize the objective function in the planning horizon. The concept of the model and optimum path identified by dynamic programming is shown in Figure 5.2.7.

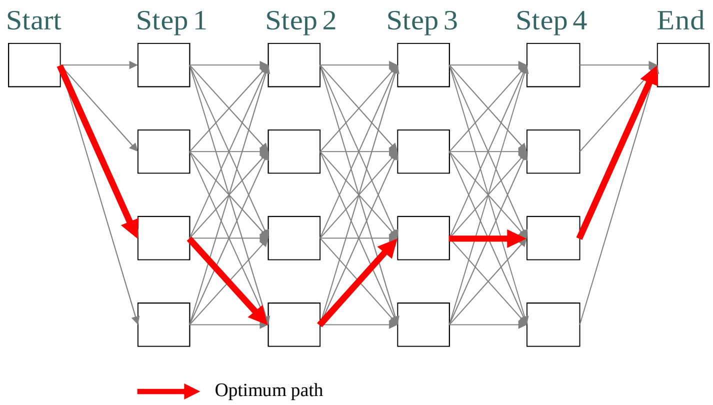
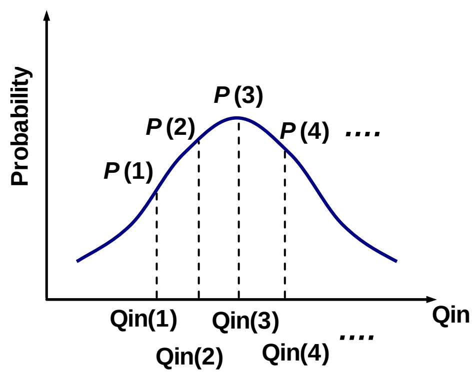


Figure 5.2.7 Concept of Seeking Optimum Path in Dynamic Programming

When the SDP is applied to the reservoir operation optimization, the inflow is treated as random variable with probability and the objective function is expected value of aggregated objective value multiplying the probability. The inflow considered as random variable with probability is shown in Figure 5.2.8.



Inflow with Probability in day "t"

Prepared by the Study Team

Figure 5.2.8 Concept of Inflow with Probability

In SDP, inflow is given by the random variable with probability, and the optimum solution is corresponding to the degree of disperse of probability density function. Thus application of SDP is advantageous especially the region where has some variability in inflow.

The use of SDP to reservoir operation was tested by Butcher[5] (1971), and the method used to PARSIFAL and LITHO. Thus the SDP is a one of the common method for reservoir operation optimization.

(3) Objective Function

The objective function of DP form as recursive function. The general formula of the objective function in dynamic programming is expressed in the formula below.

$$V_t(x) = \max\{E(f_t(x_t,x_{t+1},u_{t,p})) + V_{t+1}(f_{t+1}(x_{t+1},x_{t+2},u_{t+1}))\}$$

In dynamic programming, $V_t(x)$ is calculated from t=1 to T, and find $x(t)$ which maximize the objective function. In this study, as the existing optimization tool is daily step, therefore t is daily time step. And T= 365 days. "*E()*" is a operator to obtain expected value. "$f_t()$" is the output at day t and output is daily energy if the objective is to simply maximize the annual energy.

The items to be optimized are entered to $f_t()$ i.e. energy or peak power output, and optimum reservoir operation will be different to what kind of items entered.

In the previous NN1 expansion preparatory survey, it was understood that the expansion project like NN1 expansion has generally no increment in the energy production by expansion, the financial viability is less important than the economic evaluation as financial evaluation generally focuses on the increment energy surplus. Thus in the previous NN1 expansion survey presumed that the evaluation was more focused on the economic than financial aspects, reservoir operation study aimed to maximize the energy production while securing firm capacity. Since the objective of the NN1 expansion is the same to the previous NN1 preparatory survey, therefore the same approach is used, that is to maximizing annual energy while securing firm capacity.

The previous NN1 preparatory assumed that the large amount of electricity was to be imported from EGAT from year 2015, therefore the minimizing power import from EGAT was also included in the objective function. While the study on power supply and demand in central region in Lao PDR was conducted by JICA in 2012 and it identified that the power export from EDL to EGAT will exceed power import in 2017 in annual balance. Thus the minimization of power import is not significantly important for NN1 operation thus the minimization of power import from EGAT is eliminated in the study.

(4) Reservoir Operation Rule

The output of SDP is the target reservoir volume corresponding to discretized reservoir volume at time steps t day. The concept of the reservoir operation rule given by SDP is shown in Figure 5.2.9.

5 Butcher, W., Stochastic dynamic programming for optimum reservoir operation, *Water Resources Bulletin.*, 7(1), 115-123, 1971

As shown in Figure 5.2.9, SDP gives the target reservoir volume to each discrete reservoir volume for 365 days. The actual output of SDP will be figures instead of arrows. The output of SDP for NN1 reservoir maybe too large to presented in the report and the table will not be presented in the report.

Discrete	Time Step (Daily)									
Reservoir Volume	1	2	3	·	·	*t*	·	·	364	365
V_1	→	↘	↘			–			→	→
V_2	→	↘	↘			–			↗	↗
V_3	→	→	↘			–			↗	↗
·										
V_i	|	|							|	|
·										
V_N	→	→	→			–			↗	↗

→ Reservori volume does not change
↗ Increase reservoir volume
↘ Decrease reservoir volume

Prepared by the Study Team

Figure 5.2.9 Concept of Reservoir Operation Rule Table Given by SDP

(5) Operation of Other Reservoirs

In the previous NN1 preparatory survey, the reservoir operation of hydropower stations in the Nam Ngum river basin other than NN1 hydropower station was considered. Such hydropower stations include Nam Leuk, Nam Mang 3 and Nam Lik 1/2.

The optimization of reservoir operation together with those hydropower stations resulted in that the effect of the NN1 expansion to the Nam Leuk and Nam Mang 3 hydropower reservoir operation was found to be limited. This was the same although the operation of Nam Lik 1/2 was optimized in same time.

Considering the actual operation, NN1 and other hydropower station which are operated by EDL-Gen determine the weekly operation. However, the reservoir operation of Nam Leuk and Nam Mang 3 does not depart far from their reservoir operation rule curve. This is due to that the relative reservoir capacity to inflow is not enough to regulate the seasonal fluctuation of inflow. Therefore, the operation of the reservoir is dominated by the inflow season fluctuation, and this will eventually operate the reservoir along the reservoir operation rule curve. As for Nam Lik 1/2, the project is Independent Power Producer (IPP) scheme therefore the operation follows the power purchase agreement which was signed between EDL and Nam Lik 1/2. The operation of Nam Lik 1/2 is less flexible than those of EDL's hydropower station.

In this context, even though NN1 is expanded, the previous study concluded that the effect of the expansion to the operation of other hydropower station is limited. Therefore in this study, the NN1 reservoir operation is solely considered for optimization and reservoir operation "with" and "without" expansion is studied.

(6) Study Case

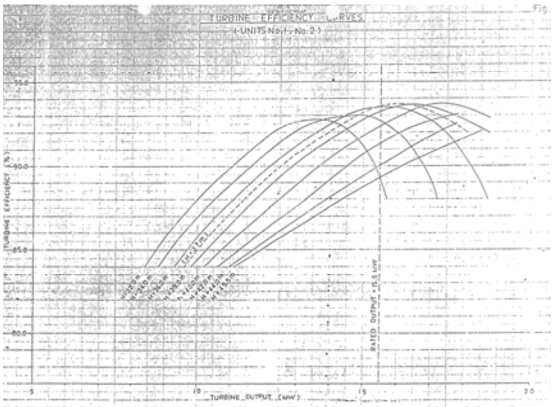
The study considers “with” and “without” 40MW expansion of NN1 hydropower station. Both case presumes NN2 run as commercial operation.

(7) Constraints

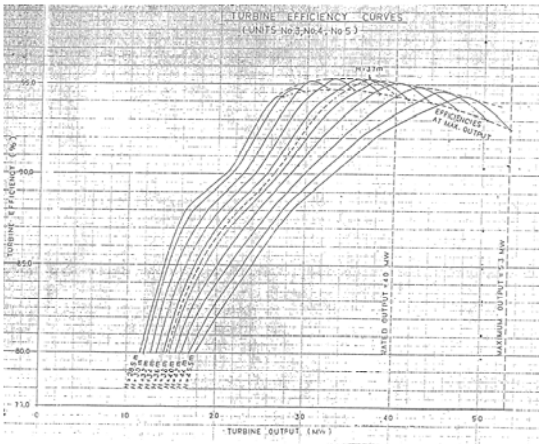
The constraints of the optimization is reservoir capacity, maximum and minimum discharge through turbine as hard constraints, and the soft constraint, which is not physical constraint, is the environmental release for downstream which amounts to 117m^3/s.

(8) Efficiency of Turbines

The efficiency of existing turbines of No.1,2,3,4 and 5 are shown in Figure 5.2.10.



No.1, 2



No.3, 4, 5

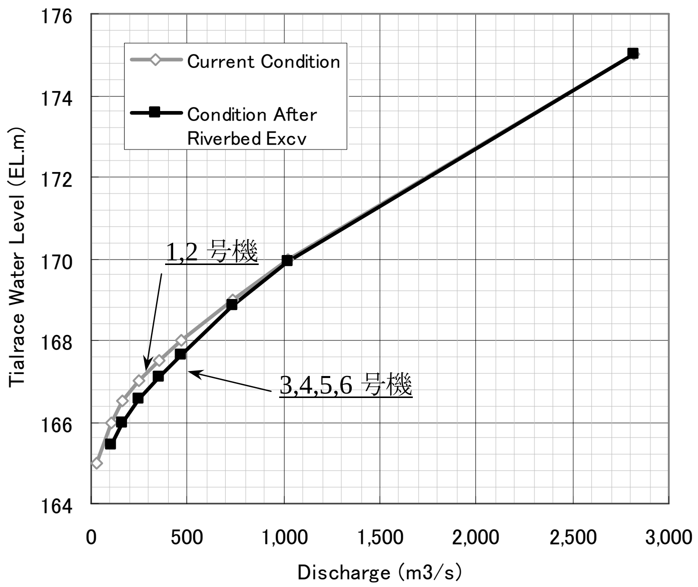
Source; “Study and suggestion on the operation of the Nam Ngum hydroelectric power station, Mar. 1992“

Figure 5.2.10 Turbine Efficiency Curves

The relation among discharge, head and power output was developed in the previous NN1 preparatory survey and the result was also used in this study.

(9) Tailrace Rating Curve

The tailrace water level rating No. 1 and 2 is the same to the current rating, and for unit 3, 4, 5, 6 uses rating curve after riverbed excavation. H-Q rating curve is shown in Figure 5.2.11.



WL (El.m)	Q (m3/s)
175.0	2,815
169.9	1,025
168.9	735
167.7	467
167.1	351
166.5	247
166.0	167
165.5	105

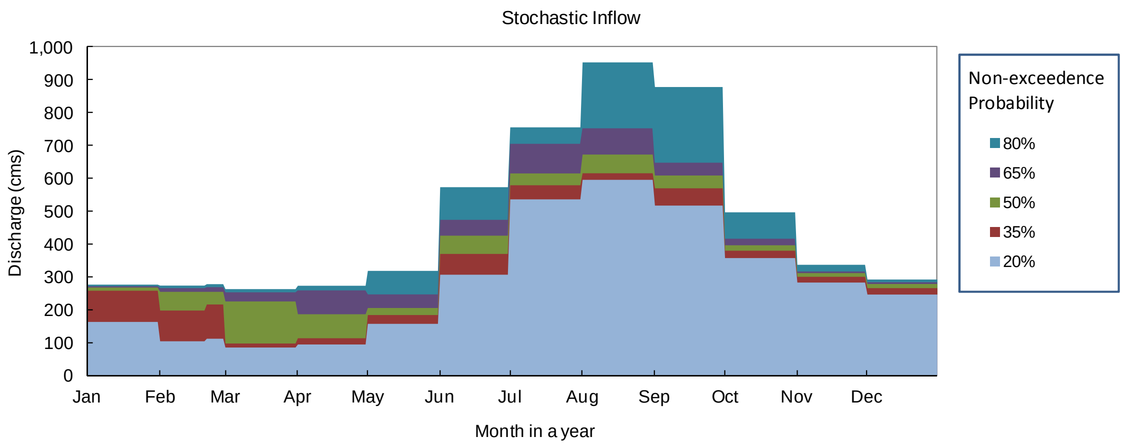
Source; Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion (2010)

Figure 5.2.11 Tailrace Water Level Rating Curve After Riverbed Excavation

(10) Daily Inflow with Probability for SDP

The daily inflow with probability is constructed with the inflow to NN1 reservoir from 1972 to 2011. As this study conditioned on the NN2 operation, inflow to NN1 reservoir is simulation result of NN2 reservoir operation routine.

As previously described, the inflow is considered as stochastic random variable. The daily inflow is discretized for five steps of non-exceedence probability. Figure 5.2.12 shows the discretized probability daily inflow for 365 days.



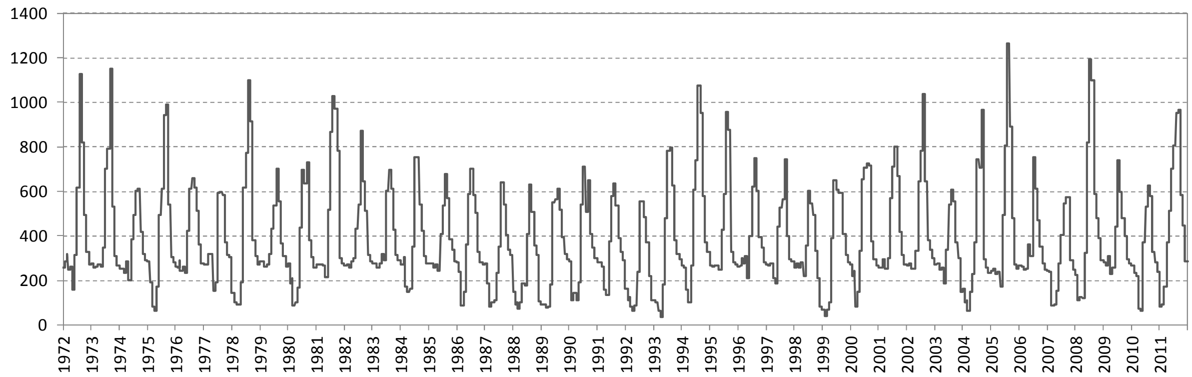
Prepared by the Survey Team

Figure 5.2.12 Discretized Stochastic Inflow to the Nam Ngum 1 Reservoir

(11) Inflow for Reservoir Operation Simulation (1972 to 2011)

The inflow to NN1 reservoir between 1972 to 2011 which assume with NN2 case are shown in Figure

5.2.13.

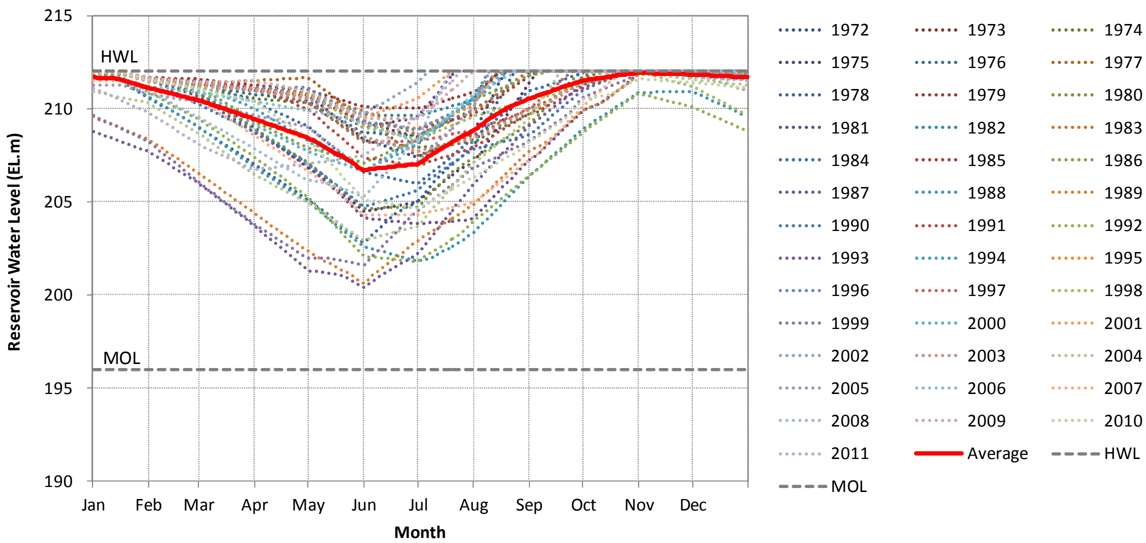


Prepared by the Survey Team

Figure 5.2.13 Inflow into the Nam Ngum 1 Reservoir from 1972 to 2011

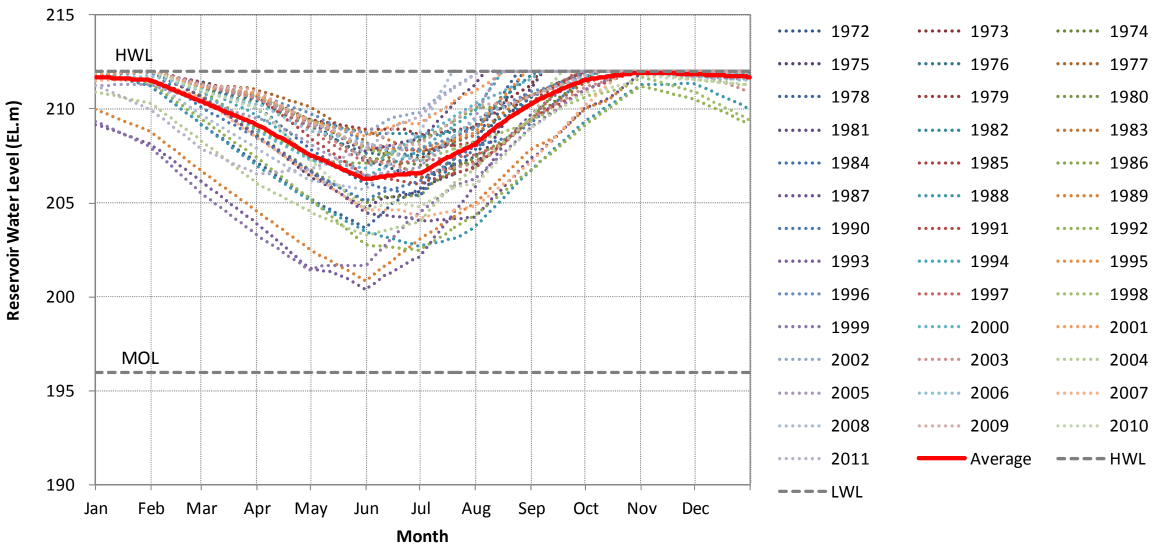
(12) Result of Reservoir Operation Simulation: Reservoir Water Level

The reservoir operation optimization is conducted by SDP and the reservoir operation simulation is carried out using the inflow to NN1 reservoir from 1972 to 2011. The resulted NN1 reservoir water level for "without" expansion case is shown in Figure 5.2.14, and "with" expansion case is shown in Figure 5.2.15.



Prepared by the Survey Team

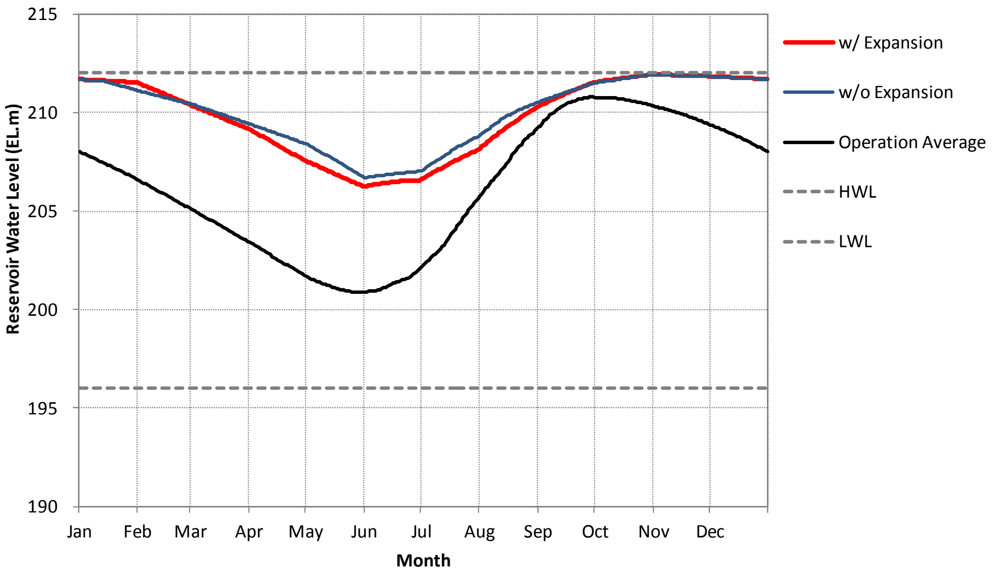
Figure 5.2.14 Nam Ngum 1 Reservoir Operation for without Expansion Case



Prepared by the Survey Team

Figure 5.2.15 Nam Ngum 1 Reservoir Operation for with Expansion Case

The average water level for “with” and “without” expansion is shown in Figure 5.2.16.



Prepared by the Survey Team

Figure 5.2.16 Nam Ngum 1 Reservoir Operation for with Expansion Case

Figure 5.2.16 also shows the average recorded reservoir water level from 1982 to 2011 by black colored line. The figure shows that water level of “with” and “without” expansion case maintained in higher water level than that of average water level record. This is due to inflow regulation by NN2 reservoir. Comparing “with” and “without” expansion case found that the water level of “with” expansion case is slightly lowered from May to September. But the difference is less than one meter. This tendency is the same to the previous preparatory survey.

(13) Result of Reservoir Operation Simulation: Annual Energy and Dependable Capacity

The annual energy and dependable capacity for peak and off-peak hours are tabulated in Table 5.2.3. It is noted that the dependable capacity is a power output of the powerhouse taken at 95% exceedence probability in power output duration curve.

Table 5.2.3 Annual Energy and Dependable Power for “without” and “with” Expansion

Item	w/o Expansion	w/ Expansion
Annual Energy	1,117	1,176
Peak		
Dependable capacity (18:00-22:00)	114	151
Dependable capacity (9:00-18:00)	114	106
Off-Peak		
Dependable capacity (22:00-0:00)	39	38
Dependable capacity (0:00-9:00)	38	38

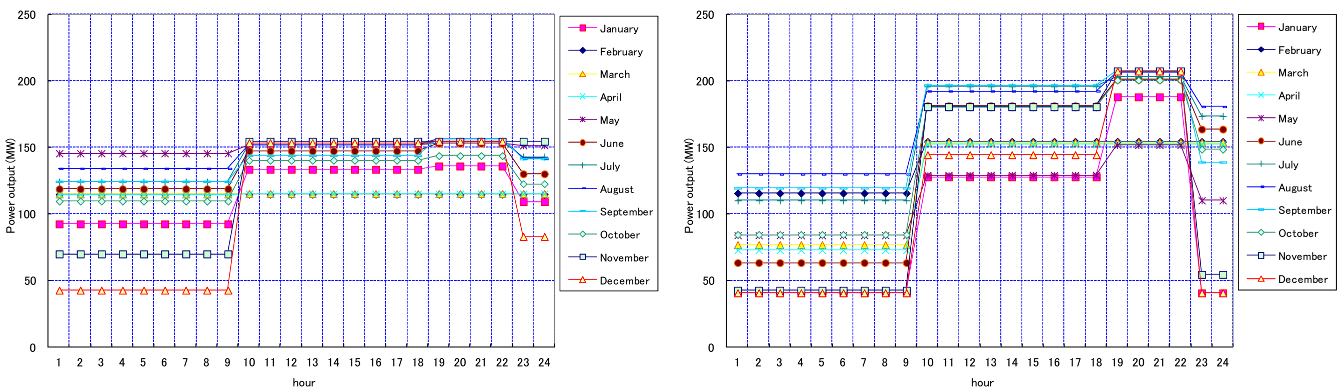
Prepared by the Survey Team

In previous NN1 preparatory survey, the average annual energy “without expansion” was calculated to 1071 GWh, and 1171GWh for “with” expansion case. This means that the energy is increased for 46GWh in “without” expansion and 49GWh for “with” expansion. One of the reason of increasing energy is that the minimizing power import is eliminated from the objective thus, the reservoir operation has more flexibility in operation.

This indicates that if the power import is increased and NN1 is operated so as to minimize the annual import, the annual energy of NN1 is limited.

(14) Result of Reservoir Operation Simulation: 24 hour output

The average 24 hour power output for “with” and “without” expansion is shown in Figure 5.2.17.



Without Expansion With Expansion

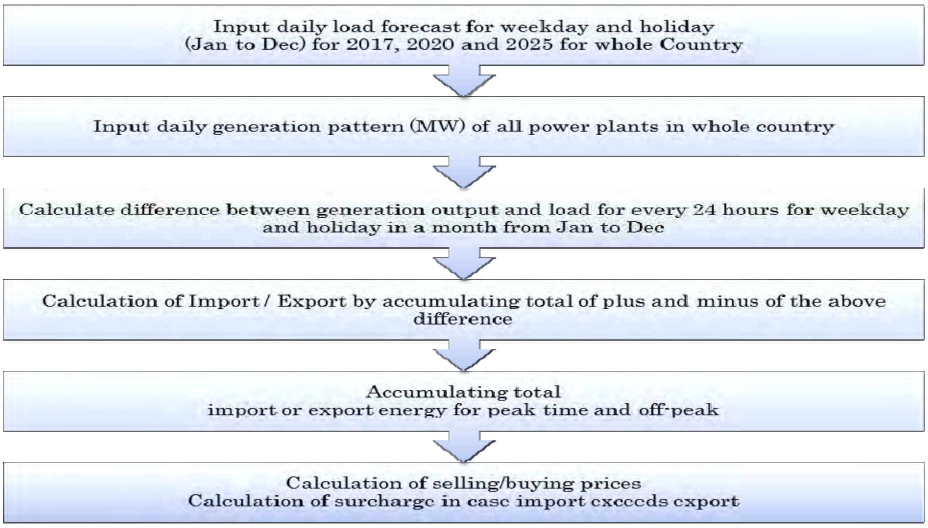
Prepared by the Survey Team

Figure 5.2.17 Nam Ngum 1 Reservoir Operation for with Expansion Case

Figure 5.2.17 shows that the expansion of NN1 hydropower station increases the power output in day time peak from 9:00 to 18:00 and night time peak from 18:00 to 22:00, while the power output in off-peak is decreased.

(15) Prospective Power Import/Export with Thailand after NN 1 Hydropower Station Expansion

In the previous JICA Study on the Power Supply and Demand in the Central Region of Lao PDR, as for the estimation of prospective import and export energy in cases with and without expansion of NN1, the difference of load and generation output (with and without NN1 expansion) for the whole country were calculated at hourly intervals to estimate the imported and exported energy to Thailand. Finally, the result of the import and export of energy in the above simulation were converted to the selling and buying prices of electricity to Thailand, as shown in the Figure 5.2.18.

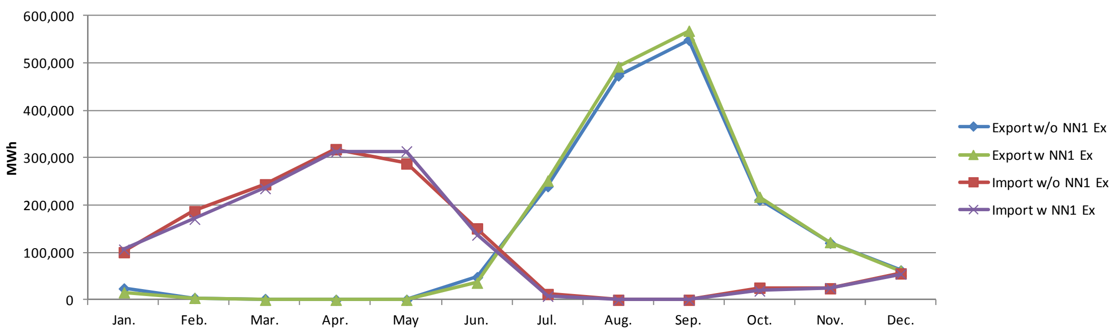


Prepared by Study Team

Figure 5.2.18 Flow of Method for Simulation of Power Import or Export

1) Power Export/Import for 2017 (in case of NN1 40 MW expansion)

Table 5.2.5 and Figure 5.2.19 show the power import and export in 2017 simulated by the same methodology taken in the JICA Study on the Power Supply and Demand in the Central Region of Lao PDR, in consideration of 24 hours operation pattern of NN1 hydropower station as mentioned in the above paragraphs.



Prepared by Study Team

Figure 5.2.19 Power Import/Export with and w/o NN1 Expansion (2017)

Table 5.2.4 Power Import/Export with and w/o NN1 Expansion (2017)

	w/o NN1 Expansion					(MWh)	40MW Expansion					(MWh)
	Export			Import			Export			Import		
	Off-peak	Peak	Total	Off-peak	Peak	Total	Off-peak	Peak	Total	Off-peak	Peak	Total
Jan.	23,928	0	23,928	44,870	55,863	100,733	16,005	0	16,005	51,944	54,680	106,624
Feb.	3,959	0	3,959	82,370	104,759	187,129	4,049	0	4,049	75,128	95,217	170,345
Mar.	1,653	0	1,653	106,204	137,786	243,991	194	0	194	107,205	128,000	235,205
Apr.	0	0	0	173,173	144,797	317,970	0	0	0	175,799	136,689	312,488
May	0	0	0	133,296	154,422	287,718	0	0	0	153,346	160,668	314,014
Jun.	47,971	0	47,971	47,257	103,528	150,785	36,055	0	36,055	42,044	94,843	136,887
Jul.	215,914	24,139	240,053	3,686	8,579	12,265	219,724	32,109	251,833	2,303	5,523	7,826
Aug.	358,690	114,968	473,659	0	0	0	365,700	126,698	492,398	0	0	0
Sep.	410,110	138,919	549,028	0	0	0	415,908	152,037	567,946	0	0	0
Oct.	192,276	18,966	211,242	5,638	19,941	25,580	192,182	25,465	217,647	3,853	15,309	19,162
Nov.	84,081	36,575	120,656	12,385	11,880	24,265	80,143	41,715	121,858	16,502	8,979	25,481
Dec.	55,897	6,290	62,187	32,981	22,912	55,893	56,682	5,159	61,841	34,494	20,215	54,709
Total	1,394,479	339,856	1,734,335	641,861	764,468	1,406,329	1,386,642	383,184	1,769,826	662,618	720,123	1,382,740

Prepared by Study Team

In 2017, the power import and export are nearly balanced on an annual basis. During dry season, the import exceeded the export. On the contrary, during wet season the export exceeded the import. When NN1 is expanded, the power import is reduced by 23.6 GWh, whereas the power export is increased by 35.5 GWh for the year of 2017. This means that the balance of power trade with Thailand is improved by 59.1 GWh when NN1 is expanded with 40 MW.

Table 5.2.5 Comparison of Power Import/Export with and without NN1 Expansion in 2017

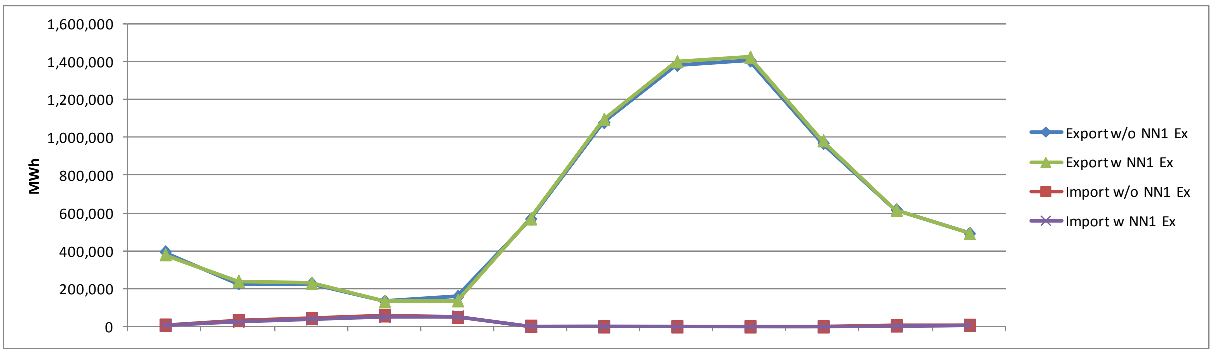
(MWh)

2017		Off-Peak	Peak	Total
w/o NN1 Ex	Export	1,394,479	339,856	1,734,335
	Import	641,861	764,468	1,406,329
	Balance	752,618	-424,612	328,006
w NN1 Ex	Export	1,386,642	383,184	1,769,826
	Import	662,618	720,123	1,382,740
	Balance	724,025	-336,939	387,086
Difference	Export	-7,837	43,328	35,491
between	Import	20,757	-44,345	-23,588
with and w/o	Balance	-28,594	87,673	59,080
Note: Balance : Export-Import				

Prepared by Study Team

2) Power Export/Import for 2020 (in case of NN1 40 MW expansion)

Table 5.2.6 and Figure 5.2.20 show the result of simulation of power import and export in 2020. As indicated in Figure 5.2.20, power import will not be required, and the power export will rapidly increase from June to December of 2020.



Prepared by Study Team

Figure 5.2.20 Power Import/Export with and w/o NN1 Expansion (2020)

Table 5.2.6 Power Import/Export with and w/o NN1 Expansion (2020)

	w/o NN1 Expansion					(MWh)	40MW Expansion					(MWh)
		Export			Import			Export			Import	
	Off-peak	Peak	Total	Off-peak	Peak	Total	Off-peak	Peak	Total	Off-peak	Peak	Total
Jan.	220,980	173,757	394,737	8,858	0	8,858	205,555	174,994	380,549	8,482	0	8,482
Feb.	140,933	87,824	228,757	32,079	1,033	33,112	143,844	96,572	240,417	27,056	239	27,295
Mar.	148,200	79,874	228,074	43,691	1,098	44,789	141,979	88,385	230,364	39,505	248	39,752
Apr.	82,972	50,807	133,779	50,834	7,960	58,794	75,723	57,266	132,989	47,022	5,500	52,522
May	104,719	54,510	159,229	46,864	2,789	49,654	89,164	48,884	138,048	51,902	2,867	54,769
Jun.	369,658	199,306	568,964	2,753	0	2,753	361,998	207,992	569,989	1,796	0	1,796
Jul.	679,053	399,243	1,078,296	0	0	0	683,195	411,320	1,094,515	0	0	0
Aug.	899,614	480,526	1,380,140	0	0	0	907,644	491,236	1,398,880	0	0	0
Sep.	893,199	511,142	1,404,341	0	0	0	898,992	523,636	1,422,628	0	0	0
Oct.	607,025	362,363	969,388	0	0	0	608,717	373,494	982,211	0	0	0
Nov.	328,865	288,268	617,134	5,285	0	5,285	319,756	296,309	616,065	4,230	0	4,230
Dec.	272,896	219,577	492,473	7,732	0	7,732	271,203	221,143	492,346	6,767	0	6,767
Total	4,748,114	2,907,197	7,655,311	198,096	12,881	210,976	4,707,770	2,991,231	7,699,001	186,760	8,854	195,614

Prepared by Study Team

As shown in the comparison of power import and export below, the power export will be increased by 43.7 GWh and import will be decreased by 15.4 GWh.

Table 5.2.7 Comparison of Power Import/Export with and without NN1 Expansion in 2020

(MWh)

2020		Off-Peak	Peak	Total
w/o NN1 Ex	Export	4,748,114	2,907,197	7,655,311
	Import	198,096	12,881	210,976
	Balance	4,550,019	2,894,316	7,444,335
w NN1 Ex	Export	4,707,770	2,991,231	7,699,001
	Import	186,760	8,854	195,614
	Balance	4,521,010	2,982,377	7,503,387
Difference	Export	-40,345	84,034	43,689
between	Import	-11,335	-4,027	-15,362
w and w/o	Balance	-29,009	88,061	59,052
Note: Balance : Export-Import				

Prepared by Study Team

3) Charge on Power Import and Export

According to the tariff for power trade with Thailand shown below, the electricity prices for power import and export were calculated under the conditions with and without NN1 expansion.

Table 5.2.8 Unit Price for Export and Import with Thailand

Unit: Bath/kWh

Tariff	Export	Import
Peak	1.6	1.74
Off-Peak	1.2	1.34

Source: EDL

Prices of Power Import and Export for 2017

Since the annual energy of export is higher than import in 2017, EDL is not required to pay the surcharge. In case of no NN1 expansion, EDL will receive THB 26.9 million from EGAT as electricity expense, as shown in Table 5.2.9. After NN1 expansion, the payment from EGAT to EDL will increase to THB 136.1 million.

Table 5.2.9 Electricity Prices for Power Import and Export to Thailand (2017)

Without NN1 Expansion (2017)							
	Export			Import			Payment
	Off-peak	Peak	Total	Off-peak	Peak	Total	(*1000Baht)
Jan.	28,713	0	28,713	60,126	97,202	157,328	128,615
Feb.	4,750	0	4,750	110,375	182,281	292,656	287,906
Mar.	1,984	0	1,984	142,314	239,748	382,062	380,078
Apr.	0	0	0	232,052	251,948	483,999	483,999
May	0	0	0	178,616	268,694	447,310	447,310
Jun.	57,565	0	57,565	63,324	180,139	243,463	185,899
Jul.	259,097	38,622	297,719	4,940	14,927	19,867	-277,852
Aug.	430,429	183,949	614,377	0	0	0	-614,377
Sep.	492,132	222,270	714,401	0	0	0	-714,401
Oct.	230,732	30,346	261,077	7,555	34,698	42,253	-218,824
Nov.	100,897	58,520	159,417	16,596	20,671	37,267	-122,150
Dec.	67,077	10,064	77,141	44,195	39,866	84,061	6,920
Total	**1,673,375**	**543,770**	**2,217,145**	**860,093**	**1,330,175**	**2,190,268**	**-26,877**
							(Pay to EGAT by EDL)

With NN1 Expansion (2017)							
	Export			Import			Payment
	Off-peak	Peak	Total	Off-peak	Peak	Total	(*1000Baht)
Jan.	19,206	0	19,206	69,604	95,143	164,748	145,542
Feb.	4,858	0	4,858	100,672	165,677	266,349	261,491
Mar.	233	0	233	143,655	222,720	366,375	366,141
Apr.	0	0	0	235,571	237,838	473,409	473,409
May	0	0	0	205,483	279,563	485,046	485,046
Jun.	43,266	0	43,266	56,339	165,027	221,366	178,100
Jul.	263,669	51,375	315,044	3,086	9,610	12,697	-302,347
Aug.	438,840	202,717	641,557	0	0	0	-641,557
Sep.	499,090	243,260	742,350	0	0	0	-742,350
Oct.	230,619	40,744	271,363	5,163	26,638	31,801	-239,561
Nov.	96,172	66,744	162,916	22,113	15,623	37,736	-125,180
Dec.	68,018	8,255	76,273	46,222	35,174	81,395	5,123
Total	**1,663,971**	**613,095**	**2,277,065**	**887,908**	**1,253,014**	**2,140,921**	**-136,144**
							(Pay to EDL by EGAT)

Prices of Power Import and Export for 2020

Table 5.2.10 Electricity Prices for Power Import and Export to Thailand (2020)

Without NN1 Expansion (2020)							
	Export			Import			Payment
	Off-peak	Peak	Total	Off-peak	Peak	Total	(*1000Baht)
Jan.	265,176	278,011	543,187	11,869	0	11,869	-531,318
Feb.	169,120	140,518	309,638	42,986	1,798	44,784	-264,854
Mar.	177,840	127,798	305,638	58,546	1,910	60,456	-245,182
Apr.	99,567	81,291	180,857	68,117	13,851	81,968	-98,889
May	125,663	87,216	212,879	62,798	4,854	67,652	-145,227
Jun.	443,589	318,890	762,479	3,689	0	3,689	-758,791
Jul.	814,863	638,790	1,453,653	0	0	0	-1,453,653
Aug.	1,079,537	768,841	1,848,378	0	0	0	-1,848,378
Sep.	1,071,839	817,827	1,889,666	0	0	0	-1,889,666
Oct.	728,430	579,781	1,308,211	0	0	0	-1,308,211
Nov.	394,638	461,229	855,868	7,082	0	7,082	-848,786
Dec.	327,475	351,323	678,798	10,361	0	10,361	-668,437
Total	**5,697,737**	**4,651,515**	**10,349,252**	**265,448**	**22,412**	**287,860**	**-10,061,392**
							(Pay to EDL by EGAT)
With NN1 Expansion (2020)							
	Export			Import			Payment
	Off-peak	Peak	Total	Off-peak	Peak	Total	(*1000Baht)
Jan.	246,666	279,990	526,656	11,367	0	11,367	-515,289
Feb.	172,613	154,516	327,129	36,255	417	36,672	-290,457
Mar.	170,375	141,416	311,791	52,936	431	53,367	-258,424
Apr.	90,867	91,626	182,494	63,009	9,570	72,579	-109,914
May	106,997	78,214	185,211	69,549	4,988	74,537	-110,674
Jun.	434,397	332,787	767,184	2,406	0	2,406	-764,778
Jul.	819,834	658,112	1,477,947	0	0	0	-1,477,947
Aug.	1,089,173	785,977	1,875,150	0	0	0	-1,875,150
Sep.	1,078,791	837,818	1,916,608	0	0	0	-1,916,608
Oct.	730,460	597,590	1,328,050	0	0	0	-1,328,050
Nov.	383,708	474,094	857,802	5,668	0	5,668	-852,134
Dec.	325,443	353,829	679,272	9,068	0	9,068	-670,204
Total	**5,649,324**	**4,785,970**	**10,435,294**	**250,259**	**15,406**	**265,664**	**-10,169,629**
							(Pay to EDL by EGAT)

In simulation of power import and export for 2020, since the power export is growing and far exceeded the import, EDL is not required to pay any buying cost to EGAT. Whereas, EGAT pays electricity cost to EDL on actual consumption of EGAT. If EGAT purchases all surplus power from EDL, the price was estimated at THB 10,061 million in case of no NN1 expansion, and THB 10,170 million in case NN1 expansion is constructed, as shown in Table 5.2.10.

CHAPTER 6 BASIC DESIGN OF OPTIMUM EXPANSION PLAN

6.1 PRINCIPAL WATER LEVEL AND WATERWAY DIMENSIONS

6.1.1 RATED RESERVOIR WATER LEVEL FOR UNIT 6

(1) Change of Reservoir Operation Pattern

The reservoir data of the existing NN1 power station are as follows:

Flood water level (PMF):		EL. 215.0m（identical to dam crest level）
Normal max. operation level:		EL. 212.0m
Minimum operation level:		EL. 196.0m
Water surface area (at EL. 212 m):		370 km^2
Effective storage volume (EL.212 - EL.196):		4.7×10^9 m^3
Annual inflow,	Total:	11.9×10^9 m^3 (375.5 m^3/s)
	From NN2 (main stream):	6.2×10^9 m^3 (197.5 m^3/s)
	From residual basins:	5.7×10^9 m^3 (178.0 m^3/s) (including flow from Nam Song & Nam Luek)

Figure below shows the NN1 reservoir storage volume curve available at present.

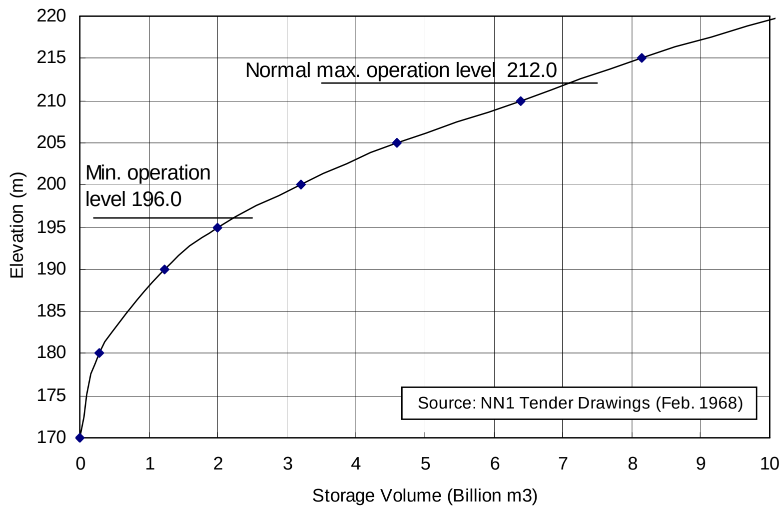


Figure 6.1.1 NN1 Reservoir Storage Curve

The Nam Ngum 2 hydropower project puts into operation in 2011. The NN2's reservoir has an effective storage capacity of 2.99 billion m^3, which is large enough to store almost half of the annual river flow at the NN2 site. Presently, inflows to the NN1 reservoir widely fluctuate from around 50 m^3/s in the dry season to more than 800 m^3/s during the rainy season. However, once the NN2 is completed, variation of outflow from the NN2 to the NN1 reservoir is considerably be flattened owing to the NN2's reservoir storage effect. Based on the NN2's flow regulation function, the rate of inflow during the dry season will increase to around 150 m^3/s. On the other hand, the flood inflow rate to NNI reservoir decreases.

The annual variations on the water level of the existing reservoir that were recorded under the existing conditions without NN2 are shown in the figure below.

Source: NN1 Power Station

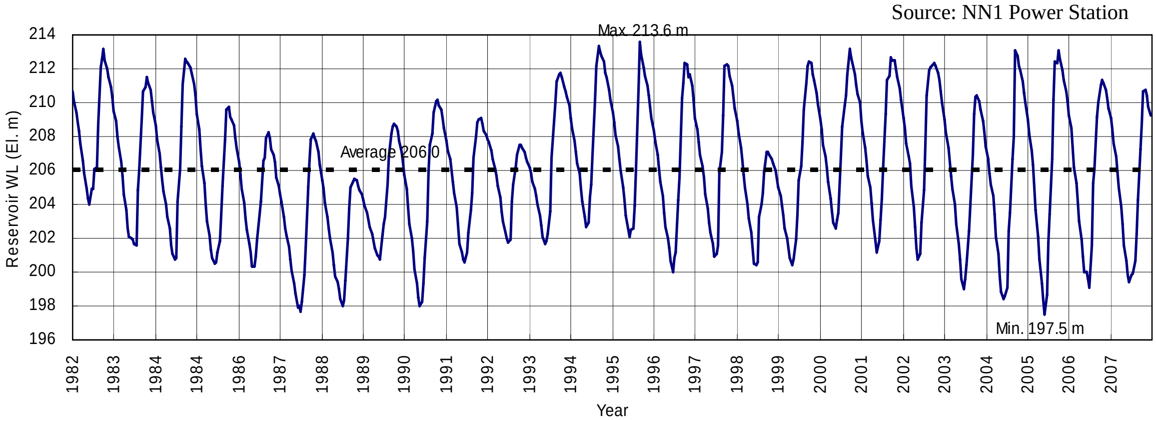


Figure 6.1.2 Reservoir WL under Existing Condition (Actually Observed in 1982-2007)

Meanwhile, the annual variations on the water level of the existing reservoir after expansion were simulated by the Survey Team by inputting the monthly inflow data of 36 years (1972-2007). The reservoir simulation result of the 40-MW expansion case with NN2 is shown in the figure below.

Prepared by: JICA Survey Team

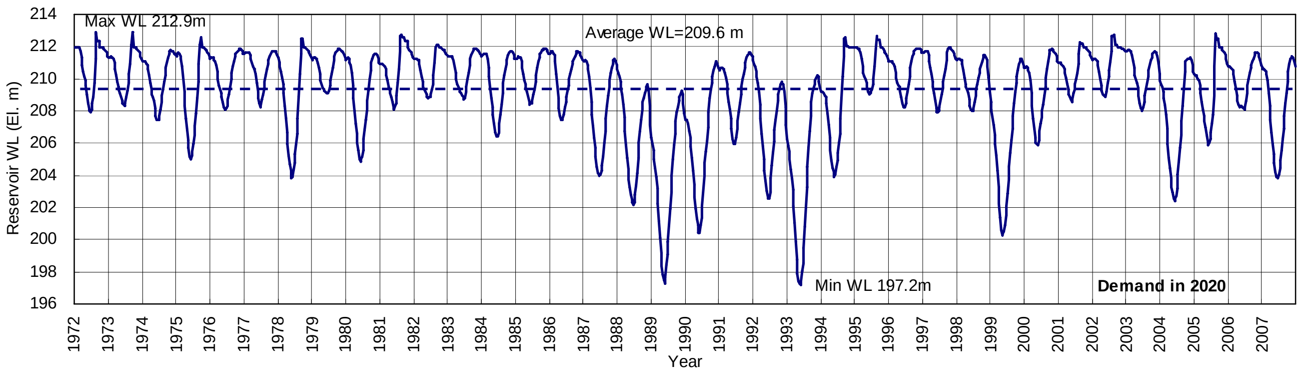


Figure 6.1.3 Simulated Reservoir WL with 40MW Expansion (with NN2)

The frequency of occurrence for various reservoir water levels is illustrated in Figure 6.1.4 for each case of “before expansion without NN2” and “after expansion with NN2”.

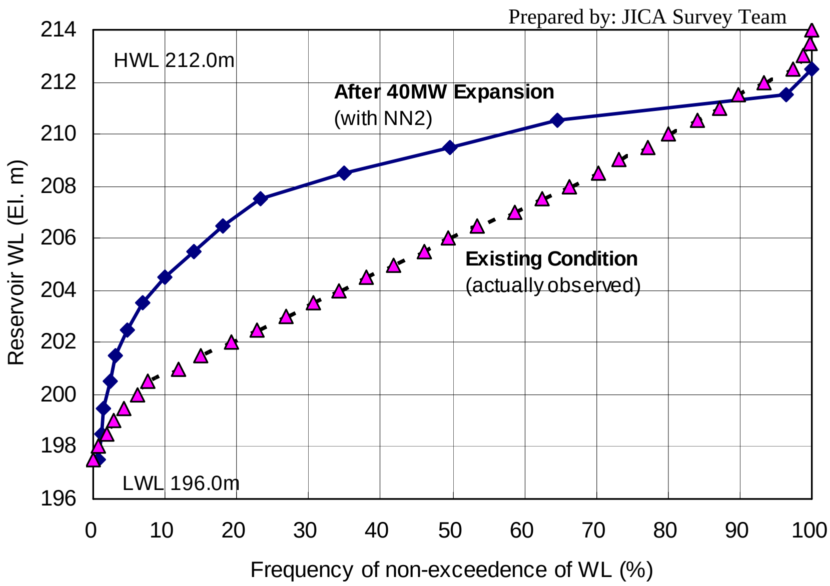


Figure 6.1.4 Reservoir WL Frequency Before and After Expansion

The following table shows the summary of the various water levels considering the conditions before and after expansion.

Table 6.1.1 Reservoir Water Level Rise after Expansion

	Reservoir Water Level	Existing condition without NN2 (EL. m)	After 40 MW expansion with NN2 (EL. m)	WL rise (m)
1	Max. WL	213.6	212.9	-0.7
2	Long-term average	206.0	209.6	+3.6
3	95 % dependable	199.6	202.7	+3.1
4	Min. WL	197.5	197.2	-0.3

Prepared by the JICA Survey Team

Based on the table above, the long-term average water level is EL. 206.0 m without NN2. However, the average water level estimated for the condition after expansion (40 MW) will go up to EL. 209.6 m. This means that the NN1 power station after expansion will be operated under the reservoir water level 3.6 m higher than the case without NN2. While the 95% dependable water level is EL. 199.6 m under the existing condition, it will rise up to EL. 202.7 m after the 40-MW expansion.

(2) Rated Reservoir Water Level for New Unit 6

The rated head specified for the existing units 3 to 5 is 37.0 m. As the tailrace water level under full operation is EL. 168.0 m and head-loss is 1.0 m, the rated reservoir water level of the existing units is EL. 206.0 m (=168.0m+1.0m+37.0m).

However, as shown in Table 6.1.1, the NN1 power station after expansion will be operated with the reservoir water level higher than EL. 202.7 m during most (95%) of the time. The long-term average water level after expansion is approximately EL. 209.6 m. This is 3.6 m higher than the average water level in the existing condition.

Therefore, the reservoir water level for deciding the rated head of the new unit 6 is selected to be EL. 209.6 m. Application of the higher rated water level contributes to reduce the size of the unit 6 turbine and consequently to save cost.

6.1.2 RATED TAIL WATER LEVEL FOR UNIT 6

The tail water rating curve (H-Q curve) of the NN1 powerhouse indicated in the 1968 tender drawings is available for the present study (refer to Figure 6.1.5). Water level and discharge records actually observed recently well coincide with the existing curve as plotted in Figure 6.1.5.

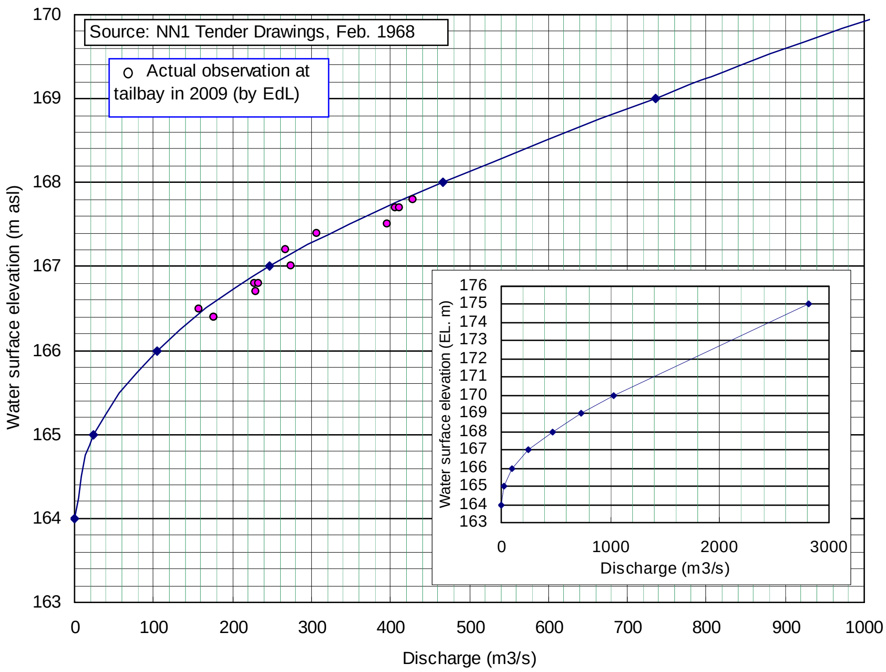


Figure 6.1.5 NN1 Power Station, Tail Water Rating Curve

Through the excavation of the exposed riverbed located at about 500 m downstream of the powerhouse, tailrace water level (tail water level) is lowered, the effective head is increased, consequently increasing the generated energy. As this excavation contributes to improvement of project economy, this is included in the scope of the project and regarded as the basis for tailwater level setting.

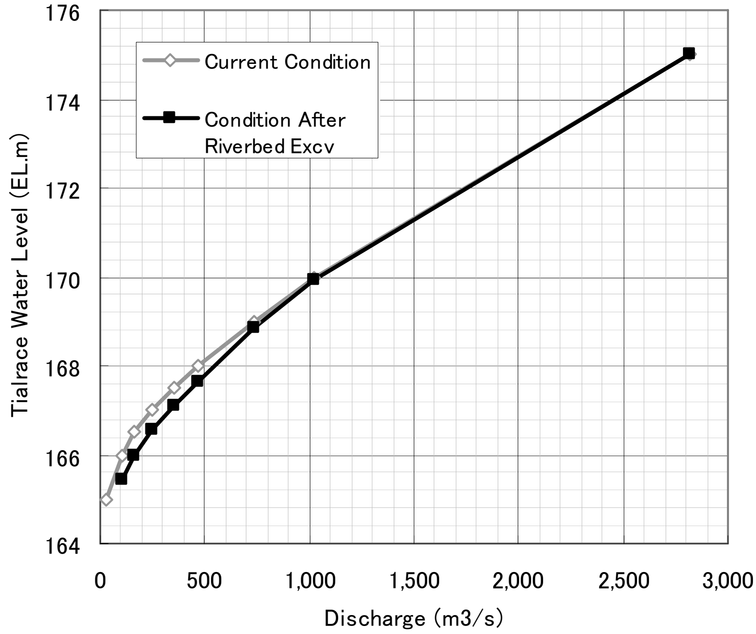
Based on the above analysis, the lowered depths of tailrace water level are estimated as shown below.

Table 6.1.2 Difference of Tailrace Water Level Before and After Riverbed Excavation

Q (m^3/s)	105	167	247	351	440	467	735	1,025	2,815
U/S WL - Before (EL.m)	166.2	166.5	166.9	167.3	167.6	167.7	168.9	169.9	174.9
U/S WL - After (EL.m)	165.7	166.0	166.4	166.9	167.2	167.3	168.8	169.8	174.9
Difference of Tailrace Water Level (m)	-0.54	-0.54	-0.46	-0.40	-0.35	-0.34	-0.14	-0.06	-0.01

Prepared by the JICA Survey Team

The tailrace water level rating curve after riverbed excavation based on the above estimation is shown below.



Prepared by the JICA Survey Team

Figure 6.1.6 Tailrace Water Level Rating Curve After Riverbed Excavation

The above drawdown of tailwater level is considered for Unit 6 and 3~5. For Unit1 and2, such drawdown will not be considered, as suggested in the previous preparatory survey in 2010.

When the existing five units of turbines are all operated with the rated outputs, the total turbine discharge will be 462.1 m^3/s. On the other hand, the rated discharge of the turbine unit 6 is 111.2 m^3/s. Accordingly, the total turbine discharge for six units of turbines including unit 6 will reach to 573.3 m^3/s. Tailwater level against this discharge is EL. 168.2m and accordingly this is regarded as the rated tailwater level for Unit 6.

6.1.3 RATED HEAD FOR UNIT 6

(1) Loss of Head in Unit 6 Waterway

The turbine discharge for 40MW output varies with the turbine effective head. If the effective head is 40 m for unit 6, the turbine discharge is estimated to be 111.2 m^3/s. Applying the penstock diameter of 5.5 m as selected in Section 9.1.2 below, loss of head in the unit 6 waterway is estimated as follows:

Turbine discharge (max.) of unit 6: 111.2 m^3/s

Head loss (max.),	Intake and gate:	0.19 m
	Penstock pipe:	0.69 m
	Draft tube outlet:	0.30 m
	Tailrace channel:	0.02 m
	Total:	1.20 m

(2) Rated Head for Unit 6 Turbine

Based on the above studies, the rated head (effective head = gross head - head loss) for the turbine of additional unit 6 is computed as follows:

Rated reservoir water level:	EL. 209.6 m
Rated tail water level:	EL. 168.2 m
Head loss in water way (Q=111.2 m^3/s):	1.20 m
Effective head:	40.2 m ➔ 40.0 m

The effective head of 40.0 m is therefore selected as the rated head for the additional unit 6.

6.2 INTAKE

6.2.1 INTAKE

6.2.1.1 INTAKE TYPE

The scheme shown in the left column of Table 6.2.1 was recommended best in the former Feasibility Report. Although the recommended scheme provides high reliability in construction, it has been pointed as problem to solve that the enclosure works would be exceptionally-expensive for a temporary facility (10.7M USD) of which weight cannot be lightened without restriction of the reservoir water level.

In this Phase-2 study the lightening of the enclosure works has been requested to improve economic efficiency of the project. As mentioned in Clause 6.2.3, the enclosure cost can be successfully reduced to 5.6M USD upon the above purpose with the closure method revised to a bulkhead type. Accordingly the design of the permanent facilities is forced to be revised as shown in right column of Table 6.2.1.

Table 6.2.1 Facilities of Intake

	FS (Phase-1, 2010 Jan)	FS (Phase-2, 2012 Oct)
Power Output	40 MW	same as on the left
Waterway Layout	Diversion though dam piercing (No.20 BL)	same as on the left
Temporary Enclosure Works	Channel-shaped steel enclosure (30 m height)	Bulkhead (12m Height)
Intake Gate	High-pressure slide gate at downstream of dam piecing (Capable of closure under current)	Roller gate installed in tower at downstream of dam piecing (Capable of closure under current)
Inspection Gate	Stop-logs settled through groove at the upstream surface of dam (Same as the existing units)	Stop-logs settled through the gate groove just upstream of the intake gate
Trashrack	Removable through groove at the upstream surface of dam (Same as the existing units)	Fixed at the dam upstream surface
Lining in Dam Piercing	Steel Lining	Concrete Lining

Prepared by JICA Survey Team

That is,

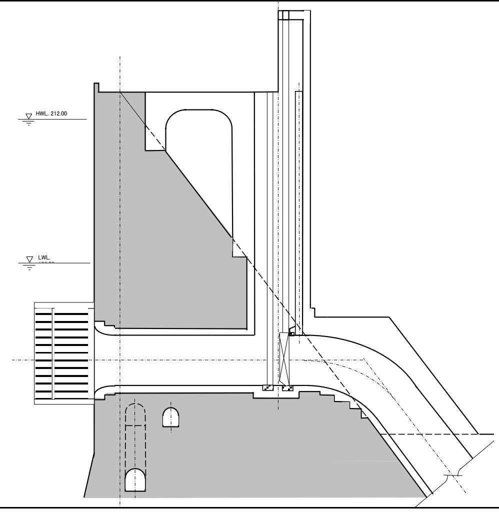
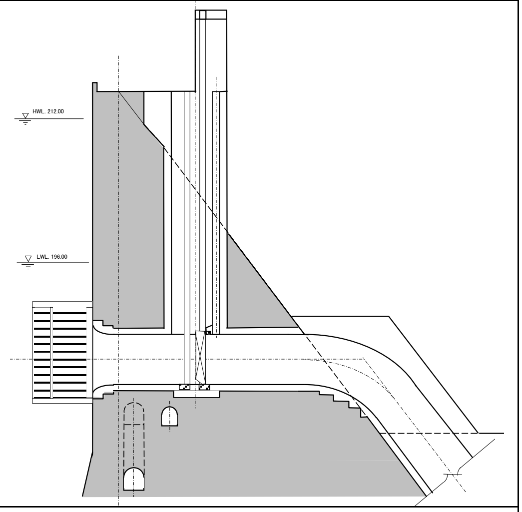
- It is not considered proper to install the grooves onto the dam surface in the same way as the existing units, since they cannot be installed precisely enough underwater after removal of the bulkhead. Accordingly the trashrack shall be of fixed type for the additional unit. Moreover the upstream of the intake gate shall be closed for inspection of the gate grooves with the existing stop logs (5.6m wide, 0.45m thick and 2.0m×12pcs high) by means of a truck crane chartered in each case.
- As far as sticking to an intake gate of high-pressure slide type proposed in the former FS report without stop logs installed on the upstream surface of the dam, the inspection gate as well is

supposed to be the same type of high-pressure slide inevitably. However that case the problem in maintenance cannot be solved that the inspection gate leaf cannot be maintained above the water. Therefore the intake gate is revised to roller type slid in the tower downstream of the dam through the studies described in Clause 6.2.1.2.

- The lining of the intake adit shall be of concrete because penstocks cannot be transported from the upstream side in case of a bulkhead closure.

6.2.1.2 SITUATION OF INTAKE GATE

Table 6.2.2 Situation of Intake Gate

	Gate Tower	**Gate Shaft**
Profile		
Transportation of Gate	Should be transported through the bridge vertical to the dam crest road	Can be directly lifted from a trailer on the dam crest road
Stability	Inner hydro-static pressure and seismic force above EL.190m should be borne.	Inner hydro-static pressure and seismic force above EL.200m should be borne.
Constructability	Horizontal interval of 13m from the dam crest road	Horizontal interval of 5m from the dam crest road
Construction Schedule	Tight to complete the whole gate tower by the break through of the dam	Not so tight as on the left
Transition of Penstock	Distance from end of square section (gate groove) to start of circular section (bending) is not long enough (1.5m).	Not particular
Landscape Design	Effort needed to reduce magnificence in looking.	Similar to that of the existing units and more comfortable in looking
Const. Cost	3.98 Million USD	3.87 Million USD
Remarks	Not particular	High level analyses needed to evaluate interaction of the adit and the shaft

Prepared by JICA Survey Team

Estimation has been made between two locations of intake gate as shown in Table 6.2.2. Another layout installed on the upstream surface of dam is neglected in Phase-2 study because of difficulty of installation and adjustment, which was discussed in Clause 8.3.5 4) of the final report in Phase-1 study.

As a result of the estimation, the gate shaft design is considered superior to the gate tower in every aspect of transportation of gate, stability, constructability, transition of penstock, landscape design and construction cost. However, high-level analyses is needed to evaluate the effect of interactive action to the hollow caused by both the digging adit and shaft, of which effect can be evaluate by a conventional analyses in case of singular excavation. Consequently the tower alternative is chosen in Phase-2 while more advantageous shaft alternative could be taken after the hollow stability analyzed in further study.

Loaded inner hydro pressure, the section of the tower is designed oval avoiding any corner and a steel liner is placed inside the tower. The seismic force is transmitted to the dam body by means of the reinforced connecting bridge.

6.2.1.3 INTAKE CENTER ELEVATION OF UNIT-6

(1) Minimum Operation Reservoir Water Level

By the NN2's flow regulation effect, the NN1 reservoir water level will be kept at considerably higher level than the existing level even in the dry season. According to the generation simulation inputting the inflow data of 36 years, the analyzed 95% dependable water level of the NN1 reservoir after the 40 MW expansion (with NN2) is El. 202.7 m.

However, the minimum level will fall to about El. 197 m, which is almost twice in a 36-year simulation. This water level is close to the minimum operational level (El. 196 m) specified for the existing units. Therefore, this water level El. 196.0 m is adopted as the minimum operational reservoir level for unit-6.

(2) Intake Submergence

The diameter of the intake adit and the penstock is determined 5.50m on the economic estimation described in Clause 6.2.3. Intake entrance level should be deep enough from the water surface in order to avoid the formation of vortex and consequent air-entraining into the intake conduit. Required intake submergence above the top of intake conduit is calculated as follows referring to Knauss's equation.

$$h = cD\frac{v}{\sqrt{gD}}$$

where:
- h = required intake submergence above intake conduit crown (m)
- c = coefficient (= 2.43 estimated from the existing intake of units 3 to 5)
- D = diameter of conduit (= 5.5 m)
- v = flow velocity in conduit (m/s) with reservoir level operational minimum (196m)

- Estimated flow velocity, v	4.38 m/s (Discharge 104 m^3/s)
- Required submergence, h	8.0 m
- Intake conduit center level = 196.00-8.00-5.50/2=	El. 185.25 m

Therefore, the elevation of the intake conduit center is decided to be El. 185.25 m.

The principal features of intakes in the existing 3-5 units and additional 6th unit of 40MW are shown in. **Table 6.2.3**. The basic drawings of the intake are shown in Appendix F, C-101.

Table 6.2.3 Principal Features of Intake

	Existing Units Nos.3 to 5 (40 MW)	Additional Unit No. 6 (40 MW)
Penstock Diameter	6.00m	5.50 m
Intake center elevation	El. 186.00 m	El. 185.25 m
Max. discharge	111.2 m^3/s	111.2 m^3/s

Prepared by JICA Survey Team

6.2.2 PIERCING DAM

6.2.2.1 PERFORMANCES OF DAM PIERCING IN JAPAN

Dam re-development projects have been recently executed in Japan for a lots of purposes, flood-control, power generation, water supply, agriculture, environmental improvement and so on. And dam piercing comes to be regarded as one of the most reliable methods for dam re-development through 30 performances during 37 years. The characteristics of the method are described below.

・To raise economic efficiency by minimizing waterway length

・To reduce risks to affect stability of dam body (foundation, grout zone and etc.)

・To reduce construction amount by using of dam body as a part of intake or enclosing works

・ Precise excavation technology and experience needed not to affect concrete outside excavation area

Dam piercing performances in Japan are shown in **Table 6.2.4** and **Photo 6.2.1～2**.

Photo 6.2.1 Inside View of Dam Piecing (Okutadami Dam)

Photo 6.2.2 Front View of Dam Piecing (Akiha Dam)

Table 6.2.4 Performances of Dam Piercing in Japan

Original Features of Dam						Dam Piercing						
No	Dam	Completion Year	Type	Height (m)	Owner	Piercing Year	Purpuse	Piercing Dimension (m)			Method	
								Width	Height	Length	Enclosure	Piercing
1	Fujiigawa	1956	G	37.5	Pref.	1975	②	8.0	7.5	19.7	D	O
2	Okiura	1945	G	40	MOC	1987	⑤	4.4	4.4	9.0	—	G
3	Tamagawa (coffer-dam)	—	G	—	MOC	1988	⑤	4.4	4.4	8.0	—	G
4	Akiha	1958	G	89	Jpower	1989	①	6.5	6.5	21.0	E	I
5	Sarutani	1957	G	74	MOC	1989	④	2.7	2.7	5.8	E	O
6	Yoroibata	1957	G	58.5	MOC	1990	⑤	4.4	4.4	28.9	C	G
7	Kakkomi	1955	G	34	Jpower	1991	③	1.8	2.0	4.5	D	I
8	Naiba	1953	G	50	Pref.	1993	④	2.5	2.5	30.5	E	G
9	Kuki	1963	G	28	Jpower	1995	③	1.0	1.0	3.0	D	I
10	Mitani	1922	G	27	Pref.	1995	⑤	3.0	2.8	12.6	D	I
11	Nishiyama	1903	G	31.8	Pref.	1996	⑤	3.4	3.4	14.7	D	O
12	Gakkougawa	1970	G	48	Pref.	1996	①	2.6	2.6	21.0	C	G
13	Sugano	1976	G	87	Pref.	1996	③	4.2	4.2	25.4	C	O
14	Tase	1954	G	81.5	MOC	1997	④	5.0	5.0	40.9	C	G
15	Samani	1974	G	44	Pref.	1997	③	1.5	1.5	12.5	S	B
16	Futagawa	1966	G	67.4	Pref.	1998	③	1.5	1.5	25.0	S	B
17	Aono	1987	G	29	Pref.	1999	③	1.8	1.8	4.1	S	I
18	Nanairo	1965	AG	61	Jpower	1999	③	2.6	2.6	6.0	D	I
19	Mitaka	1944	G	32.6	Pref.	2000	②	2.0	3.0	12.5	C	G
20	Ikari	1957	G	112	MOC	2001	④	5.0	5.0	50×2	C	G
21	Haginari	1966	G	61	Pref.	2001	③	2.5	2.5	26.6	C	G
22	Miyagouchi	1963	G	36	Pref.	2002	③	2.7	2.7	17.0	C	G
23	Okutadami	1961	G	157	Jpower	2003	①	6.2	6.2	32.3	O	I
24	Yuduruha	1974	G	42	Pref.	2003	④	2.8	3.0	10.2	D	I
25	Miyagawa	1956	G	88.5	Pref.	2004	③	2.1	2.1	36.0	S	G
26	Haji	1973	G	50	MOC	2006	④	3.9	3.9	23.0	C	G
27	Horonai	1940	G	21.1	Pref.	2008	⑤	Unknown			D	I
28	Sugesawa	1967	G	73.5	MOC	2010	④	2.4	2.4	37.0	C	G
29	Tsuruda	1965	G	117.5	MOC	2014	①	6.4	6.4	50×2	C	G
30	Tsuruda	1965	G	117.5	MOC	2014	④	6.0	6.0	60×3	C	G

Dam Type G: Gravity, AG: Arch Gravity
Owner Pref.: Prefectural Government、MOC: Ministry of Construction、Jpower: JPOWER
Purpose ① Power Generation、②Other Water Utilization、③Environmental Improvement、④Flood Control、⑤Other Purpose
Enclosure C: Channel Type Enclosure、D: Drawdown of Reservoir、E: Existing Closing Facility、S: Small Scale Enclosure、O: Other Method
Piercing G: Grinding Break、I: Breaking after Isolation、B: Large-Diameter Bowling、O: Other Method

6.2.2.2 APPRECIATE METHOD FOR NAM NGUM DAM PIERCING

(1) Dimension and Section

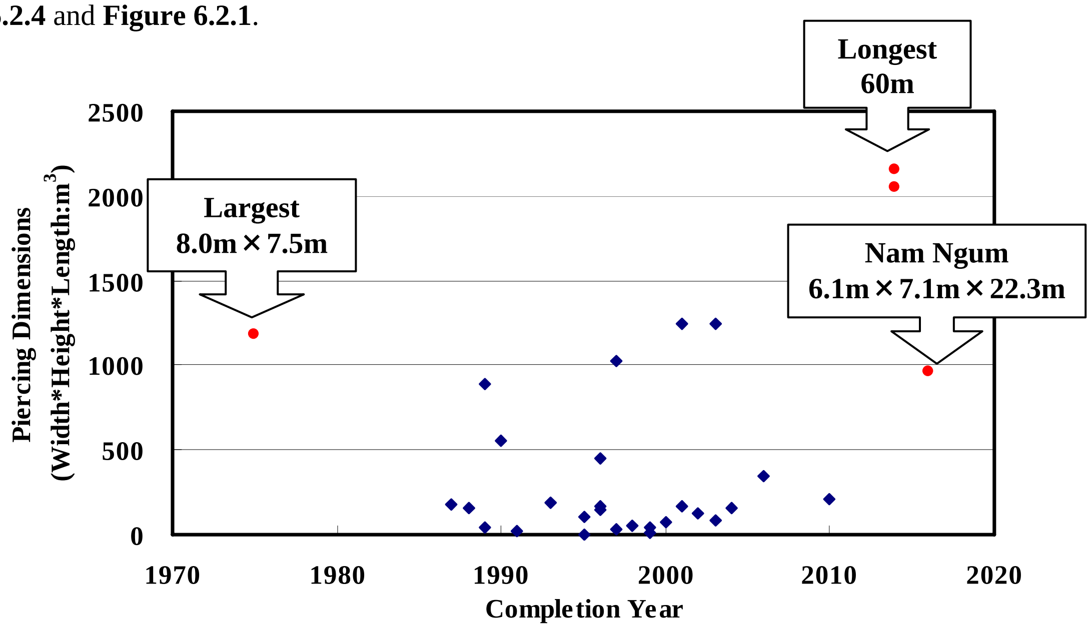
As mentioned in Clause 6.2.1.1, the Inner section of intake adit is designed square on consideration of constructability, because it is lined with concrete upstream of the gate tower. The inner diameter is designed vertical long of 4.5m×5.5m from a point of reducing piercing width having an equivalent area of ϕ 5.5m. The concrete lining is.0.8m thick. The section is enlarged bellmouth-like in 2m long from the inlet. The principal features of the dam piercing are exhibited in **Table 6.2.5**.

Table 6.2.5 Principal Features of Piercing Dam

Items	Dimensions
Inner dimension of Waterway	4.5 m(B)×5.5m(H)
Dimension of Inlet	6.5 m(B)×7.5m(H)
Lining Thickness	0.8 m
Piercing Length	22.33 m
Center Elevation	EL.185.25

Prepared by JICA Survey Team

The excavation width is a more dominant factor than height with the stability of hollow. In general the width is desirable not to exceed a third of the block width. The above features seem to involve no major problems in execution of piercing with the excavation width almost within the desirable range (6.1m to 18m of block width) and the dimensions within those of the past performances shown in **Table 6.2.4** and **Figure 6.2.1**.



Prepared by JICA Survey Team

Figure 6.2.1 Scale of Dam Piercing in Japan

(2) Dam Piercing Method

Slot Drilling Machinery **Grinding Breaker**

Photo 6.2.3 Typical Construction Machinery for Dam Piecing

Although **Table 6.2.4** shows us that the most common method of dam piercing in Japan is one-process breaking just by means of grinding breakers (**Photo 6.2.3 Right**), in this case of Nam Ngum that method is not considered adequate because of the below reasons.

- Lower working efficiency anticipated in case of concrete dams using stiff aggregates like Nam Ngum to grind the dam body to entire chips.
- Difficult to charter in Laos
- Too big base machine to take out through the gate tower after penetration (Refer to **Table 6.2.7** ④)

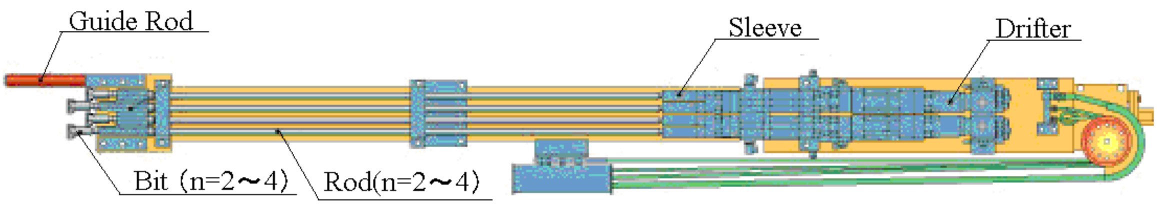


Figure 6.2.2 Detail of Hydraulic Boom

Instead, two-process breaking system is taken for Nam Ngum which is also common next to one-process system, consisting of isolation around the excavation area and following concrete fracturing with giant breakers. The slot drilling machine (**Photo 6.2.3 Left**) is proposed here for the isolation devise. This machinery is composed of a variety of crawler type carriage and attached hydraulic booms with 2-4 sets of bits as shown in **Figure 6.2.2**. Those multi-bits booms are capable of continuous drilling of 12-24cm length and max. 1.2m depth to form slit as open surface into mass concrete of dam body. Consequently that slit is helpful to prevent impact of concrete fracturing from transmitting outside of the excavation area and facilitate concrete breaking.

(3) Collision to Existing Dam Gallery

The two rows of galleries are lined in the dam axis direction in No.20 block. The nearer one among them to the dam piercing is situated 5m downstream of the dam axis, and the crest elevation is EL.180m. The gallery would fortunately never affect the dam piercing because it keeps off circa 1.5m from the bottom of the piercing even considering extra excavation.

6.2.3 INTAKE TEMPORARY ENCLOSURE

6.2.3.1 BULKHEAD ENCLOSURE

Table 6.2.4 shows us that the most common method of temporary river enclosure for dam piercing in Japan is channel type steel enclosure proposed in Phase-1 study. Originating from Yoroibata dam, this method has been regarded as of high reliability and constructability as well as high cost. A variety of efforts have been paid to reduce the cost.

When used to flood-controlling dams, the closure height is reduced to typically circa 15m by drawdown of reservoir level during construction. Further occasional reuse to another site or block can advance economic potential. On the other hand cost reduction attempt for cannel type enclosure has its limits in utilization dams where they are unwilling to restrict water level, particularly in case of a single use for a large depth enclosing like Nam Ngum. As a result, this type of enclosure inevitably is likely to cost extremely expensive as shown in the cost estimation in Phase-1.

On the other hand, instead of a large scale and costly enclosing from the bottom to reservoir surface, other trials for cost reduction have been attempted with the inner dimensions of enclosing minimized for construction needs. According to those method, a small scale of steel enclosure with four directions sealed is settled entirely submerged and access is made through a manhole from the inside of enclosure to above water. The method has been applied in Samani, Futakawa, Aono and Miyagawa dams of those piercing diameter is circa 2m.

The larger scale example can be seen in Naruko dam, that is not an enclosing for a dam piercing but a repair of side frames of an inspection gate for a discharge valve. In that repair work in 2006, they could attain good water-tightness under 26m depth from water surface with upstream enclosing by means of a bulkhead of 3.6m width, 2.7m depth and 7.9m height. (See **Photo 6.2.4～5**) Although the scale of the domestic achievements has not reached that of this site, the enlargement is thought possible enough technologically.

Photo 6.2.4 Overall View of Bulkhead

Photo 6.2.5 Inside View of Bulkhead during Use

On consideration of the above achievements, the upstream enclosing with a bulkhead is proposed in Phase-2 study to reduce costs. At the same time, more minute construction planning should be requested to ensure constructability and safety than with a channel shaped enclosing, and the design of even permanent structures has been largely influenced by the temporary enclosing scheme as mentioned in Clause 6.2.1. Further study should be done in the coming definite design to estimate possibility to double as the framework of the temporary bulkhead and that of the permanent trashrack, as performed in the above example of Naruko dam.

While a hemispherical bulkhead is most rational to bear water pressure, a rectangular solid is proposed for convenience of site assembling. The inner dimensions of the bulkhead are determined so that circa 2m distance should be ensured outside the inlet bellmouth (6.5m×7.5m) and also in depth on consideration of expected inner work e.c. embedding of anchor bars. The expected features and the conceptive design of the bulkhead are shown in **Table 6.2.6** and **Appendix F** respectively**.**

Table 6.2.6 General Features of Bulkhead

Inner Diameter	10m(B)×12m(H)×2m(L)
Maximum Head at the Center Elevation	27m (HWL212m～EL.185.25m)
Support	Anchors and Bottom Brackets
Steel Weight Gate Leaf Others (Side Frame, Bracket, et al)	 120 ton 60 ton

Prepared by JICA Survey Team

6.2.3.2 EFFECT OF WATER LEVEL RESTRICTION

It was proposed in Clause 9.2.3 of the Phase-1 report that the reservoir level is desirable to restrict in EL.207m during three and a half months of drainage inside the enclosure, so that net construction cost could be reduced by 2.8 M USD subtracting deceased energy benefit of 2.1 M USD from deceased enclosure cost of 4.9 M USD. Meanwhile, since the enclosure weight is lightened, the cost reduction effect of restriction to 207m remains merely reduction of bulkhead weight by 15t (corresponding cost reduction by 0.5 M USD), resulting in relatively costly energy loss.

Restriction of water level still remains a worth discussing issue to improve safety during diving works, in particular for the intake construction at Nam Ngum which needs diving deeper than 30m under high water level. However, limited to enclosing cost, it can be apparently said that the restriction has become much less necessary.

6.2.3.3 SETTLEMENT OF TRASHRACK

After the beak through of the dam in the bulkhead, anchor bolts and inner jigs are embedded around the inlet on the dam surface for the following trashrack settlement. After the bulkhead removed, the trashrack is hanged down to where it should be and unified with the dam body or with directly bolting or undispersible underwater concrete filled into the trashrack frame. The details in the latter case are shown in Appendix F “Basic Design Drawings” C-102.

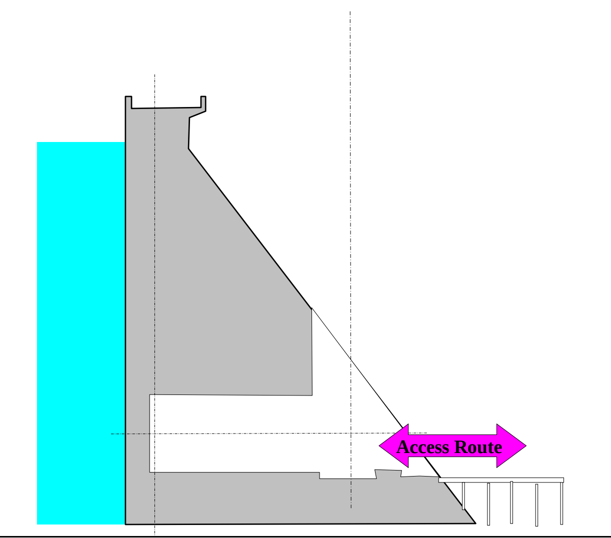
6.2.3.4 WHOLE PROCEDURE OF INTAKE WORKS

As shown in **Table 6.2.7**, the intake construction can be performed rationally with the dam piercing, the bulkhead enclosing and the downstream gate tower applied despite of large water pressure suffering with water level kept its maximum.

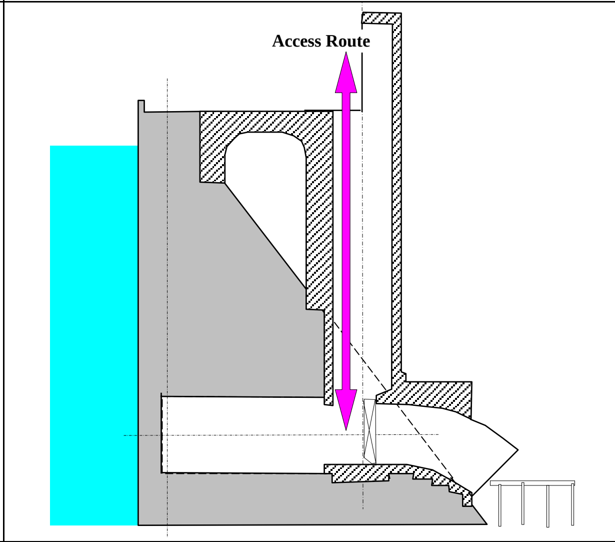
Further, after the gate tower completed (**Table 6.2.7** ②), it is advisable to close the waterway with the gate and gain access to the adit vertically through the gate tower, from viewpoints of formulating thoroughgoing safety measures to the existing power units and facilitating the downstream penstock settlement.

Table 6.2.7 Procedures of Intake Construction

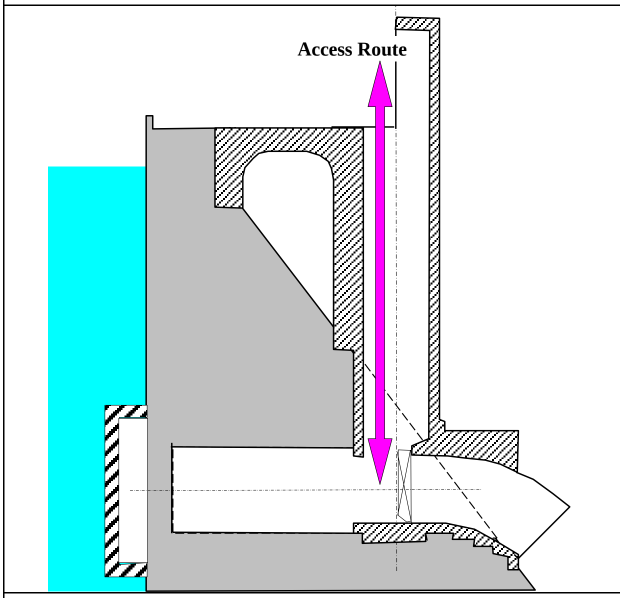
① Piercing to Dam Axis



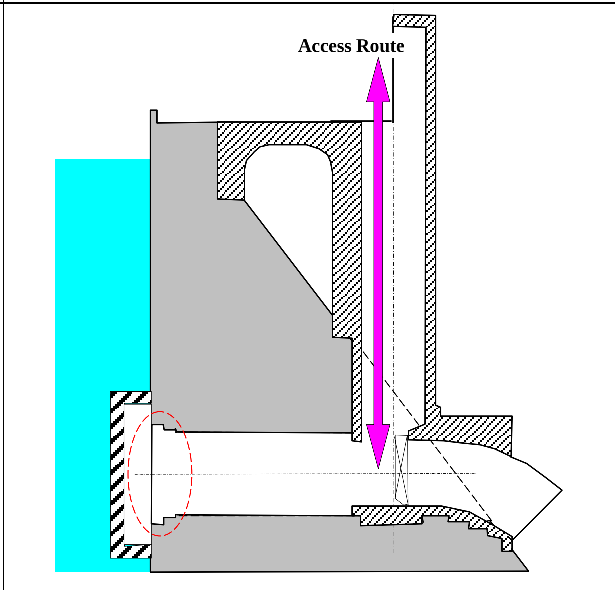
② Construction of Gate Tower



③ Settlement of Bulkhead

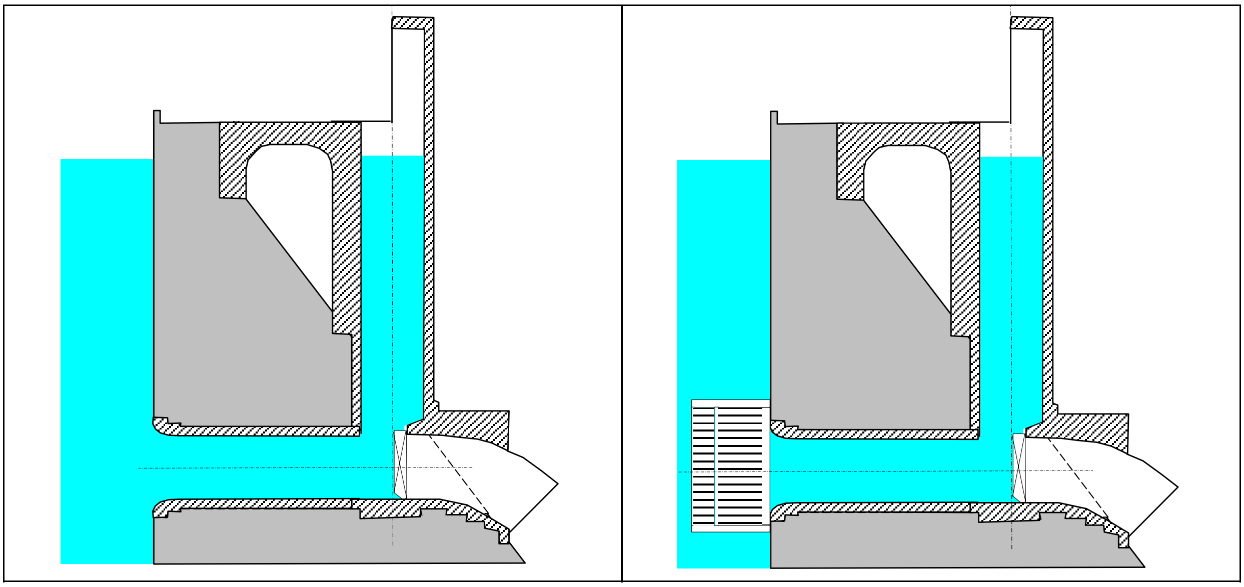


④ Break Through



⑤ Removal of Bulkhead（Water Filling）

⑥ Settlement of Trashrack



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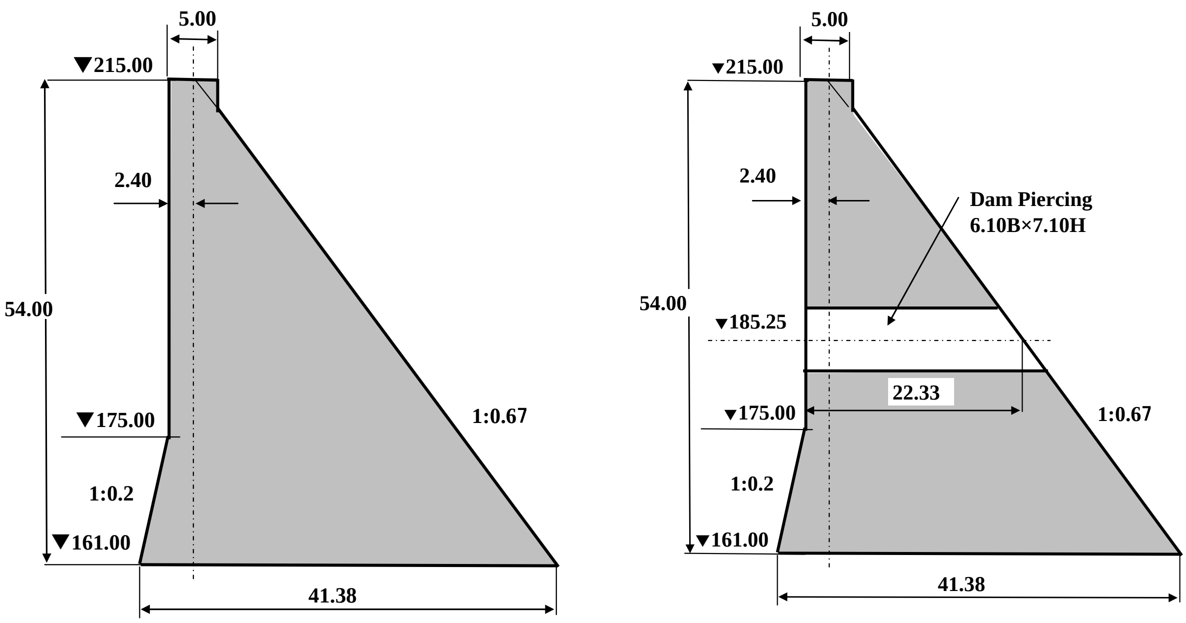
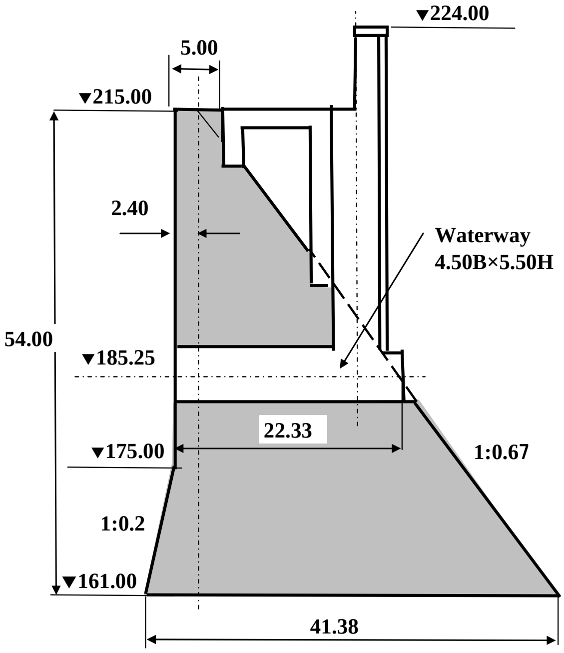
6.2.4 DAM STABILITY

6.2.4.1 CONDITIONS OF ANALYSES

The stability analyses and estimation of stress on the foundation are done for the No.20 block on the below-mentioned conditions.



Stage A : Current condition **Stage B :During Construction**



Stage C : After Completion

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Figure 6.2.3 Sections of Dam to be Analyzed

①Loads Own Weight, Hydro-static Pressure, Hydro-dynamic Pressure, Soil Pressure, Seismic Force, Uplift (Change of loads considered due to dam piercing and newly constructed structures, The features of dam piercing are shown in Table 6.2.5.)

② Sections Three Stages : A. current condition, B. during-construction and C. after-completion, （as shown in Figure 6.2.3）

③Loading Cases Four Cases : Ⅰ.Usual、Ⅱ.Unusual（Flood）、Ⅲ. Unusual（OBE k=0.061）、Ⅳ.Extreme（MCE k=0.215）

④Properties determined referring to “Final Report on Nam Ngum Hydro-electric Project First Stage (Nippon Koei Co.,Ltd. 1972)”

6.2.4.2 CRITERIA OF DAM STABILITY

Based on the discussions above, the overturning, sliding and the stress in the foundation rock are checked and validated by the Lao Electric Power Technical Standards in usual and unusual cases. In the check and validation of the extreme case, the Manual of US Army Corps of Engineer is referred to and consulted. The safety criteria are shown below.

a) Overturning

Under normal operation, the center of the application of the resultant force of the expected external forces and the self-weight shall be within the center one-third (the middle third) of the horizontal section of the dam body. In the case of an earthquake or a flood, it shall be within the center one-half (the middle half) of the horizontal section of the dam body. In the case of extreme condition, it shall be within the horizontal section of the dam body.

b) Sliding

The safety factor to be applied shall be three or more under usual conditions. It shall be two or more in the case of an earthquake or flood. It shall be 1.3 or more, in the case of extreme condition.

c) Stress on the foundation rock

The compressive stress in the foundation rock distributed at the downstream end of the dam shall not exceed the allowable stress. It shall be 1.33 times or less, in the case of extreme condition.

6.2.4.3 RESULTS

The result of the study is shown in Table 6.2.8. In every stage and under every load statue, the dam is certified stable. The detail of analyses is shown in Appendix－E.

Table 6.2.8 Results of Dam Stability

Load Condition	Criteria		Stage-A Current Condition		Stage-B During Construction		Stage-C After Completion	
Load Ⅰ (Usual)	Over-turning	e≦L/6	e＝5.15≦	L/6=6.90	e＝5.91≦	L/6=6.90	e＝4.88≦	L/6=6.90
				OK		OK		OK
	Sliding	n≧3	n= 6.91	≧3	n= 6.85	≧3	n= 6.95	≧3
				OK		OK		OK
	Max. Foundation Stress	σ≦ 400tf/m²	σ= 91	≦400	σ= 91	≦400	σ= 93	≦400
				OK		OK		OK
Load Ⅱ (Flood)	Over-turning	e≦L/4	e＝7.96≦	L/4=10.35			e＝7.48≦	L/4=10.35
				OK				OK
	Sliding	n≧2	n= 6.07	≧2			n= 6.11	≧2
				OK				OK
	Max. Foundation Stress	σ≦ 400tf/m²	σ= 95	≦400			σ= 97	≦400
				OK				OK
Load Ⅲ (OBE)	Over-turning	e≦L/4	e＝7.06≦	L/4=10.35	e＝7.84≦	L/4=10.35	e＝6.78≦	L/4=10.35
				OK		OK		OK
	Sliding	n≧2	n= 5.97	≧2	n= 5.95	≧2	n= 6.01	≧2
				OK		OK		OK
	Max. Foundation Stress	σ≦ 400tf/m²	σ= 105	≦400	σ= 105	≦400	σ= 108	≦400
				OK		OK		OK
Load Ⅳ (MCE)	Over-turning	e≦L/2	e＝13.14≦	L/2=20.69			e＝12.86≦	L/2=20.69
				OK				OK
	Sliding	n≧1.3	n= 4.22	≧1.3			n= 4.23	≧1.3
				OK				OK
	Max. Foundation Stress	σ≦1.33× 400tf/m²	σ= 151	≦400× 1.33			σ= 155	≦400× 1.33
				OK				OK

Prepared by JICA Survey Team

6.3 PENSTOCK

The penstock diameter of the existing units 3 to 5 (40MW each) is 6.0 m. This diameter looks excessively large for the new unit 6 since the space for penstock construction is very narrow and is tightly confined by the existing dam and additional powerhouse. Because the dam foundation level at the unit 6 penstock site is higher than the required level of penstock bottom foundation, a smaller diameter penstock is preferable in order to not threaten the structural safety of the dam. The optimum (economic) diameter of the unit 6 penstock is sought hereunder by comparing the construction cost savings with reduced energy benefit resulting from the application of smaller diameters such as 5.5 m, 5.0 m and 4.5 m.

(1) Construction Cost Saving

By using smaller penstock, sizes of the intake structure as well as temporary enclosure structure are reduced. Sizes of intake trash rack, stoplogs and gate are also reduced. Smaller penstock can save on construction cost. The cost saving from D=6m penstock for different diameters (D) of penstock is calculated from the costs of relevant civil works and hydraulic steel works as follows:

Table 6.3.1 Construction Cost of Waterway (in 1,000 US$)

		D = 6.0 m	**D = 5.5 m**	**D = 5.0 m**	**D = 4.5 m**
1	Civil works				
	Dam piercing	2,106	1,970	1,813	1,634
	Temporary enclosure	15,660	15,300	14,940	14,580
	Sub-total	17,766	17,270	16,753	16,214
2	Hydraulic Steel Works				
	Trash rack	52	48	36	36
	Stoplogs	441	413	343	287
	Intake gate and hoist	1,404	1,179	1,035	855
	Penstock pipe	1,498	1,302	1,120	889
	Sub-total	3,395	2,942	2,534	2,067
3	Total Cost	21,161	20,212	19,287	18,281
4	**Cost Saving from D=6.0m**	**0**	**949**	**1,874**	**2,880**

Prepared by the JICA Survey Team

As seen in this table, construction cost of US$ 949,000 is saved if the penstock diameter is reduced from 6.0m to 5.5 m. If the diameter is further reduced to 5.0 m, the cost saving becomes US$ 1,874,000.

(2) Reduction of Energy Production

By use of smaller diameter penstock for the same turbine, waterway head loss increases and consequently, energy production decreases. In order to estimate degree of energy reduction of unit 6, the power generation of all units is simulated for each of the different diameter cases for the unit 6 applying inflow data of 36 years (1972-2007). The results are shown in the following table.

Table 6.3.2 Reduction of Annual Energy and Dependable Output

		Penstock diameter			
		D = 6.0 m	D = 5.5 m	D = 5.0 m	D = 4.5 m
1	Head loss at max. turbine flow (m)	1.06	1.18	1.37	1.69
2	Energy production (GWh/y)	1,119.17	1,118.67	1,117.86	1,116.56

	Reduction from D=6m (GWh/y)	**0**	**0.50**	**1.31**	**2.61**
3	Dependable peak output (MW) **Reduction from D=6m (MW)**	144.42 **0**	144.34 **0.09**	144.20 **0.22**	144.00 **0.42**

Prepared by the JICA Survey Team

If the penstock diameter is reduced from 6.0 m to 5.5 m, energy production and dependable peak output decrease by 0.50 GWh per year and 0.09 MW, respectively. Further reduction of the diameter to 5.0 m results in reduction of 1.31 GWh/year and 0.22 MW.

(3) Economic Comparison

To compare the energy reduction with the cost saving, the annual reductions of energy production and dependable output are converted to the present values (monetary values) in economic terms as shown below.

Table 6.3.3 Economic Comparison

		D = 6.0 m	D = 5.5 m	D = 5.0 m	D = 4.5 m
1	Construction Cost Saving (1000US$)	0	949	1,874	2,880
2	Reduced Annual Benefit (1000US$/y) Energy benefit (*1) Peak output benefit (*2) Total	 0 0 0	 -38.0 -23.6 -61.6	 -101.8 -60.5 -162.3	 -203.6 -116.5 -320.1
3	Present Value of Reduced Benefit for 50 years (1000 US$) *3	0	-611	-1,610	-3,174
4	**Net Present Value, 1+3 (1000US$)**	**0**	**338**	**264**	**-294**

*1: Unit energy benefit = $0.0783/kWh
*2: Unit peak output benefit = $275.35/kW
*3: Discount rate i=10%, Production life time = 50 years
Prepared by the JICA Survey Team

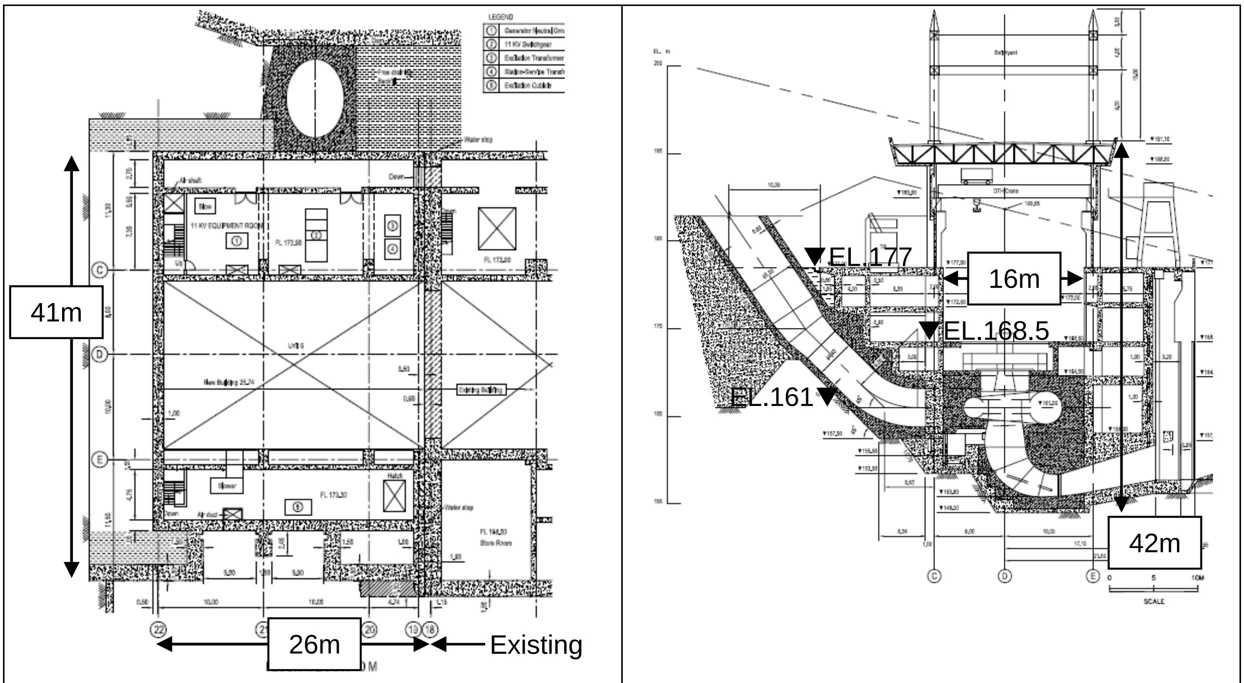
Net present value (NPV) is US$ 338,000 for the penstock diameter of 5.5 m, which is highest among the four cases compared. The diameter of 6.0 m used in the existing units 3 to 5 is not necessarily most economical for the new unit 6 since the construction of the additional intake is costly due to difficult underwater works.

6.4 POWERHOUSE AND TAILRACE

6.4.1 POWERHOUSE LAYOUT

Based on the optimum expansion plan in Chapter 8, the basic design of the powerhouse was conducted through a more detailed examination of the existing powerhouse structures, current topography and necessary equipment to be installed.

Typical plan and section of the powerhouse are shown below.



Floor Plan (EL. 172.5 & 173.0 m) | Cross Section (Unit Center)

Prepared by the JICA Survey Team

Figure 6.4.1 Plan and Section of Powerhouse

Detailed drawings of the powerhouse such as floor plans, cross sections and longitudinal sections are presented in Appendix F.

The major equipment to be installed in the powerhouse, which had been considered in the basic design, are summarized in the following table.

Table 6.4.1 Major Equipment to be Installed in Powerhouse

Floor Elevation (EL.m)	No.	Equipment to be Installed
172.5 & 173.0	1	Generator Neutral Grounding Transformer
	2	11 kV Switchgear
	3	Excitation Transformer
	4	Station-Service Transformer
168.5	1	Excitation Cubicle
	2	Low Voltage Switchgear
	3	AC/DC Distribution Panel
	4	Local Control and Relay Board
	5	Clean Water Tank
164.5	1	Unit Motor Control Center
	2	Common Motor Control Center
	3	Governor and Turbine Control Panel
	4	Governor Oil Sump Tank with Pressure Oil Pumps
	5	Pressure Oil Tank
	6	Air Compressor
	7	Primary Air Tank
	8	Brake Air Tank
158.0	1	Raw Water Tank
	2	Raw Water Strainer
	3	Water-to-Water Heat Exchanger
	4	Cooling Water Circulation Pump

Prepared by the JICA Survey Team

6.4.2 POWERHOUSE STABILITY

Stability of the powerhouse building was checked and validated as follows:

(1) Sections

i) Center of turbine/generator section in up-downstream direction (A-A section of Basic Design Drawings)

ii) Right bank section in up-downstream direction (B-B section of Basic Design Drawings)

(2) Cases

Table 6.4.2 Analysis Cases for Powerhouse Stability

Cases		Upstream WL (EL.m)	Downstream WL*) (EL.m)	Seismic Coeff. (Horizontal)
1. Normal	Usual	168.5	168.5	-
2. Earthquake	Unusual	168.5	168.5	0.061
3. Flood		177.0	177.0	-
4. Empty at up/downstream		-	-	-
5. Normal WL at upstream, Empty at downstream	Extreme	168.5	-	-

*) WL in all units full operation: 168.4 EL.m, Flood WL176.5 EL.m

Prepared by the JICA Survey Team

(3) Loads

Dead load, Inertia force (for earthquake), Hydrostatic pressure, Dynamic water pressure (for earthquake), Uplift

(4) Checking Standard

Following dam stability

(5) Results

Table 6.4.3 Analysis Results for Powerhouse Stability

Cases			Overturning (Eccentricity, m)	Sliding (Safety factor)	Max. Stress in Foundation (tf/m^2)
i) A-A Section	1. Normal	Usual	e=0.1 < B/6=6.0	-	q=10.6 < 400.0
	2. Earthquake	Unusual	e=1.5 < B/4=9.0	f=129.6 > 2.0	q=13.0 < 400.0
	3. Flood		e=2.4 < B/4=9.0	-	q=3.0 < 400.0
	4. Empty at up/downstream		e=2.7 < B/4=9.0	-	q=34.4 < 400.0
	5. Normal WL at upstream, Empty at downstream	Extreme	e=5.3 < B/2=18.0	f=29.3 > 1.3	q=34.5 < 532.0
ii) B-B Section	1. Normal	Usual	e=2.3 < B/6=6.8	-	q=16.3 < 400.0
	2. Earthquake	Unusual	e=3.3 < B/4=10.2	f=99.0 > 2.0	q=18.1 < 400.0
	3. Flood		e=9.3 < B/4=10.2	-	q=8.5 < 400.0
	4. Empty at up/downstream		e=2.0 < B/4=10.2	-	q=33.7 < 400.0
	5. Normal WL at upstream, Empty at downstream	Extreme	e=4.6 < B/2=20.4	f=62.9 > 1.3	q=32.6 < 532.0

Prepared by the JICA Survey Team

Based on the above results, it is concluded that there is no structural problem for the stability of the powerhouse building.

Total weight of the powerhouse building and its total uplift pressure in case of a flood are about 30,000 tf and 20,000 tf, respectively. Consequently, it is found that the powerhouse building is stable against uplift pressures because the total weight is 1.5 times of the total uplift pressure in case of flood.

6.4.3 TAILRACE LAYOUT

In addition to the powerhouse, basic design of the tailrace was undertaken referring to the topographic survey results around the powerhouse, which were obtained through sub-letting works. Main features of the tailrace channel are summarized below.

Table 6.4.4 Main Features of Tailrace Channel

Item	Features	
Type	Open channel	
Length	52m	
Width	from 11.5m to 20.5m	
Longitudinal Gradient	1:3 and 1:4	
Approach Elevation	Inlet	EL. 152.74m
	Outlet	EL. 164.00m
Cut Slope	Gradient	1:0.25
	Protection	Concrete facing with anchor bars

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Detailed drawings of the tailrace channel are attached as Appendix G.

6.5 ELECTRO-MECHANICAL EQUIPMENT

6.5.1 TURBINES

(1) Turbine Operational Water Levels

a) Reservoir water levels

With the NN2 Power Station, it is expected that the inflow into the NN1 Reservoir is regulated by the NN2 Power Station. The average weighted water level increases up to EL. 209.6 m. The other water levels of the NN1 Reservoir will be unchanged from the present design conditions.

Turbine unit 6 will therefore be operated under the following water levels:

- Flood water level	EL. 215.0 m
- Normal high water level	EL. 212.0 m
- Weighted average water level	EL. 209.6 m
- Low water level	EL. 196.0 m

b) Tailrace water levels

When the existing five units of turbines are all operated with the rated outputs, the total turbine discharge will be 462.1 m^3/s. On the other hand, the rated discharge of the turbine unit 6 is 111.2 m^3/s. Accordingly, the total turbine discharge for six units of turbines including unit 6 will reach to 573.3 m^3/s. On the basis of these conditions, the tailrace water levels are reviewed and revised as follows:

- Flood water level	EL. 176.5 m
- Water level at 6-unit operation with rated output	EL. 168.2 m
- Water level at 1-unit operation with rated output	EL. 165.7 m
- Water level at all-unit stopping	EL. 164.0 m

(2) Net Heads

The rated net head of turbine unit 6 is determined at 40. 0 m, which is 3.0 m higher than the rated net head of 37.0 m for the existing units 3, 4 and 5. On the other hand, the maximum net head, which is defined as a net head at one-unit operation with the rated output under the reservoir high water level, is determined at 45.5 m, which is the same rated head value as the existing turbines for units 3, 4 and 5. As a result, the turbine unit 6 will be operated in the following range of heads:

- Maximum gross head	48.0 m
- Maximum net head (at one-unit operation with rated net head)	45.5 m
- Rated net head	40.0 m
- Minimum net head	26.4 m

(3) Turbine Output

The turbine rated output and maximum output for unit 6 were determined as follows:

a) Turbine rated output

The turbine rated output is defined as a full-gate output under the rated net head and is determined at 40.9 MW, which corresponds to the generator rated output of 40 MW, on assumption that the generator efficiency is 98.0 %.

b) Turbine maximum output

When the operating net head is higher than the rated net head due to the raising of the reservoir water level, the turbine output can be increased unless the generator is overloaded by exceeding the rated output in MVA. Such upper limit of the turbine output is defined as the turbine maximum output. On the other hand, each generator of the existing units 3, 4, 5 is rated for 50 MVA (40 MW at the rated power factor 0.8) but its output is often increased to 46 MW with an operating power factor of 0.92 when the reservoir water level is sufficiently high during the rainy season. Considering the actual operating performance of the existing units 3, 4, and 5, the maximum turbine output for unit 6 is determined at 47 MW (= 46/0.98) so that it can produce 46 MW at the generator terminal when conditions permit.

(4) Type of Turbine

The turbine is of vertical-shaft Francis type, which is the same as the existing turbines for all units.

(5) Turbine Rated Speed

The turbine rated speed is selected referring to the specific speed as follows:

a) Specific speed

Specific speed of turbine is calculated by the following equation:

$Ns = N \times \sqrt{Pt}/Hn^{1.25}$

where, Ns: Specific speed (m-kW)
N: Turbine rated speed (rpm)
Pt: Turbine output (kW)
Hn: Net head (m)

b) Upper limit of specific speed for Francis turbine

Statistical implication between net head and specific speed for Francis turbine is introduced in JEC 4001 for hydraulic turbines and pump turbines. Referring to these statistical data, specific speed for a net head of 40 m is calculated as 368.6 m-kW. However, in case the specific speed exceeds 300 m-kW, the operating performance of Francis turbine will become remarkably worse. Therefore, in the selection of the turbine rated speed, the specific speed for Francis turbine should be practically limited to 300 m-kW.

c) Turbine rotational speed

Turbine rotation speed is calculated from the rated frequency and number of poles for generator by the following equation:

$N = 120 \times f/p$

Where, N: Turbine rotational speed (rpm)
f: Generator rated frequency (Hz) = 50 Hz
p: Number of poles of generator

Turbine rotational speeds corresponding to specific speed of 300 m-kW are 136.4 rpm (p = 44 poles), 142.9 rpm (p = 42 poles) and 150 rpm (p = 40 poles), and a comparison of these speeds is shown below.

Table 6.5.1 Selection of Turbine Speed for Unit 6

Turbine Output Pt (kW)	Net Head Hn (m)	Number of Poles; p	Speed N (rpm)	Specific Speed; Ns (m-kW)	Ns Upper Limit (m-kW)	Judgment
40,900	40.0	44	136.4	274.2	300	○
		42	142.9	287.3		◎
		40	150.0	301.6		×

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d) Turbine rated speed

The higher turbine speed will make the machine size smaller, and this will increase economy. Therefore, the turbine rated speed is chosen at 142.9 rpm, which is the highest speed within the upper limit of specific speed (300 m-kW).

(6) Turbine Centerline Elevation

The turbine centerline elevation is based on the tailrace water level when one (1) unit of turbine is operated at the rated output, and it is calculated by the following equation:

Turbine Centerline Elevation = $TWL_1 + H_s$ [EL. m] where, TWL_1: Tailrace water level at turbine one-unit operation with rated output = 164.0 m

H_s: Static suction head referred to the turbine centerline elevation = H_a - H_v - σ_p x H_d

H_a: Atmospheric pressure at TWL_1: 164.0 m = 10.12 m

H_v: Vapor pressure = 0.32 m

H_d: Design head of turbine = 40.0 m

σ_p: Cavitation coefficient = 0.2682

The required suction head H_s is calculated at -1.0 m and therefore it is required that the turbine centerline elevation should be set at EL. 163.0 m or lower. On the other hand, the turbine centerline elevation of the existing Unit 3, 4, 5 is EL. 161.0 m. Based on the result of the above calculation, the turbine centerline for unit 6 can be set at a different elevation from those for units 3, 4, and 5. Taking the following matters into consideration, however, the turbine centerline for unit 6 is set at the same elevation with units 3, 4, and 5, which is EL. 161.0 m.

1) Since the existing erection bay has no sufficient space to assemble the turbine and generator for unit 6, a space between units 5 and 6 should be arranged as the equipment assembly area.

2) In order to use the space between units 5 and 6 widely as an assembly bay, the generator top cover for unit 6 should be set at EL. 168.5 m, which is the floor elevation of the machine bay for unit 5, so that no step should be provided between the two units.

3) The principal dimensions of the turbine and generator for unit 6 are almost the same with those for units 3, 4, and 5. If the generator top cover for unit 6 is set at EL. 168.5 m in a similar way to units 3, 4, and 5, the turbine centerline elevation for unit 6 will consequently become EL. 161.0 m.

(7) Comparison with Existing Turbines for Unit 3, 4, 5

The operating conditions and turbine ratings are compared between unit 6 and the existing units 3 to 5. The results of the comparison are summarized as follows:

Table 6.5.2 Comparison of Turbine Operating Conditions and Ratings

Items		Unit 6	Unit 3, 4, 5	Reference
1.	Reservoir Water Level			
(a)	Flood water level	EL. 215.0 m	EL. 215.0 m	
(b)	Full supply water level	EL. 212.0 m	EL. 212.0 m	
(c)	Weighted average water level	EL. 209.6 m	EL. 206.0 m	Item 1) (a)
(d)	Low water level	EL. 196.0 m	EL. 196.0 m	
2.	Tailrace Water Level			
(a)	Flood water level	EL. 176.5 m	EL. 176.5 m	
(b)	When all units operating with rated output	EL. 168.2 m	EL. 168.0 m	Item 1) (b)
(c)	When one unit operating with rated output	EL. 165.7 m	EL. 166.2 m	Item 1) (b)
(d)	When all units being stopped (no flow)	EL. 164.0 m	EL. 164.0 m	
3.	Heads			
(a)	Maximum gross head	48.0 m	48.0 m	
(b)	Maximum net head at one unit operating	45.5 m	45.5 m	Item 2)
(c)	Rated net head	40.0 m	37.0 m	Item 2)
(d)	Minimum net head	26.4 m		Item 2)
4.	Type of Turbine	Francis turbine	Francis turbine	Item 4)

5.	Turbine Ratings			
(a)	Rated output	40,900 kW	40,000 kW	Item 3) a)
(b)	Maximum output	47,000 kW	53,000 kW	Item 3) b)
(c)	Rated speed	142.9 rpm	136.4 rpm	Item 5)
(d)	Specific speed	287.3 m-kW	298.9 m-kW	
6.	Turbine Centerline Elevation	EL. 161.0 m	EL. 161.0 m	Item 6)

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(8) Turbine Parts

a) Materials

The turbine main parts will employ the materials having high resistance against erosion and corrosion in order to achieve long-term sustainable operation with minimum maintenance work. In particular, the following parts, which are prone to damage due to cavitation pitting, will use stainless steel with high strength, cavitation resistance and weldability.

- Runner
- Guide vanes
- Upper draft tube liner

b) Bearings

In order to prevent water pollution due to grease and other pollutants, and in order to assure of easy maintenance work, it is desired that the bearings for the guide vanes will be grease-less and self-lubricating types. In addition, these kinds of bearings will also be adopted to all regulating mechanisms and other bearings that will be in constant contact with water.

(9) Inlet Valve

An inlet valve is omitted from unit 6, along the same lines of turbine design for the existing units.

(10) Main Water Supply System

Because of the structure problem for the additional powerhouse, the main water supply system for unit 6 will be provided separately from that for the existing units. The main water supply system designed to provide the cooling water to the turbine guide bearing, generator thrust and guide bearings, generator air coolers, etc for unit 6 is based on a closed-circuit water circulation system with water-to-water heat exchangers, similar to the existing water supply system.

The main water supply system for unit 6 consists of three sub-systems: for open-circuit raw water supply, water-to-water heat exchangers, and closed-circuit cooling water circulation. These sub-systems are all duplicated for normal/standby duty operation. The schematic diagram for the main water supply system is shown in Drawing No. E-012 of Appendix G.

a) Open-circuit raw water supply system

The mode of operation will be that the raw water for the cooling water system will be taken from the draft tube and then return it to the same tube through a water-to-water heat exchanger. The open-circuit raw water supply system will consist of two AC motor-driven raw water pumps, two automatic strainers, and water piping complete with all necessary pipes and valves.

b) Water-to-water heat exchangers

Each water-to-water heat exchanger will be of the plate-type with high heat-transfer efficiency and compact design.

c) Closed circuit cooling water circulation system

The closed-circuit cooling water circulation system is provided to distribute the cooled water among the water-to-water heat exchanger and the respective coolers of the turbine and generator. The closed-circuit cooling water system will consist of two AC motor-driven cooling water pumps, one clean water tank for replenishing leakage water, water flow meters, and water piping complete with all necessary pipes and valves. Clean water will be supplied from the existing clean water supply system by extending the clean water pipe.

(11) Water Drainage and Dewatering System

Because of the structure problem of the additional powerhouse, the water drainage and dewatering system for unit 6 is provided separately from those for the existing units. For this purpose, a new station sump pit is added for exclusive use of unit 6. The sump pit will collect the water discharged and leaked from the turbine and generator as well as seepage water from the powerhouse wall.

The water drainage system will consist of two AC motor-driven drainage pumps, two water level switches and water piping complete with all necessary pipes and valves to discharge the water in the station sump pit to the tailrace. The dewatering system will consists of two AC motor-driven dewatering pumps and water piping complete with all necessary pipes and valves to evacuate the water in the draft tube directly to the tailrace. Two pumps for each system will be arranged for normal/standby duty operation. The schematic diagram for the water drainage and dewatering system is also shown in Drawing No. E-012 of Appendix F.

Types and ratings of the water drainage and dewatering pumps are determined referring to the existing pumps as shown below.

Table 6.5.3 Types and Ratings of Drainage and Dewatering Pumps

Items		Unit 6	Unit 3, 4, 5
1.	Water Drainage Pumps		
(a)	Type of drainage pump	Submersible	Submersible
(b)	Displacement volume of each pump	1.0 m^3/min	0.9 m^3/min
(c)	Pumping head	30 m	30 m
2.	Draft Tube Dewatering Pumps		
(a)	Type of dewatering pump	Vertical-shaft	Vertical-shaft
(b)	Displacement volume of each pump	5.0 m^3/min	4.2 m^3/s
(c)	Pumping head	30 m	30 m

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6.5.2 GENERATOR

(1) Generator Rated Power Factor

The rated power factor of the existing generators for units 3, 4, and 5 is selected to be 0.8. On the other hand, in many hydropower projects in Lao PDR, which are recently developed or are now under construction, the rated power factor is commonly selected to be 0.9 as shown in the table below.

Table 6.5.4 Generator Rated Power Factors for Other Hydropower Stations in Lao PDR

Hydropower Station	Generator Output	Rated Power Factor
Nam Leuk	34.5 MVA	0.90
Nam Man 3	22.5 MVA	0.90
Nam Lik 1/2	58.8 MVA	0.85
Nam Lik 1	35.5 MVA	0.90
Nam Ngum 5	70.6 MVA	0.85

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Based on these available data, a comparison of the rated power factor for unit 6 is made between 0.8 and 0.9 as shown below.

Table 6.5.5 Comparison of Generator Rated Power Factor between 0.8 and 0.9

Rated Power Factor	0.8	0.9
Turbine Rated Output	40,900 kW	40,900 kW
Turbine Max. Output	45,900 kW	40,900 kW
Unit Rated Output	40,000 kW	40,000 kW
Unit Max. Output (under power factor of 0.9)	45,000 kW	40,000 kW
Generator Rated Output	50,000 kVA	44,400 kVA
Transformer Rated Power	50,000 kVA	50,000 kVA
Cost (C)	+622,367 USD	0 USD
Annual Energy Production	+2 GWh	0 GWh
Benefit from energy production for 50 years (B)	+1,189,776 USD	0 USD
(B) - (C)	+567,409 USD	0 USD
Turbine Design Conditions (a) Turbine rated net head = 40.0 m (b) Turbine rated speed = 142.9 rpm (c) Turbine specific speed = 287.3 m-kW		
Present Worth Factor Calculating Conditions (a) Lifetime of Unit 6 = 50 years (b) Discount rate = 10 %/annum		

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As a result of this comparative study in Table 9.4.5, the power factor of 0.8 will bring greater benefit and more advantageous than the power factor of 0.9. Accordingly, the generator rated power factor for unit 6 is determined at 0.8.

(2) Generator Rated Output

Based on the turbine rated output 40.9 MW, generator rated power factor 0.8 and the generator efficiency 0.98 (assumed value), the generator rated output is calculated at 50 MVA as shown below:

Generator rated output = (Turbine rated output) x (Generator efficiency) /

(Generator rated power factor)
= 40.9 x 0.98 / 0.8
= 50.0 MVA

(3) Type of Generator

The generator for unit 6 is of three-phase, vertical-shaft, synchronous alternator with umbrella type construction, which is the same as the existing generators for units 3, 4, and 5.

(4) Generator Rated Voltage

The generator rated voltage is selected at 11 kV along the same lines of the existing generators for units 3, 4 and 5.

(5) Generator Neutral Grounding System

The neutral point of the generator stator winding will be grounded through a neutral grounding transformer with a secondary resistor, along the same lines of the existing generators for units 3, 4, and 5.

(6) Generator Fire Fighting System

The generator will be provided with water spray-type fire fighting system along the same lines of the existing generators for all units. The water for the generator fire fighting system will be supplied from the existing clean water tank by extension of the water pipe.

(7) Synchronizing Method of Generator

The generator synchronizing will be made by the 115 kV circuit breaker on the main transformer circuit, along the same lines of the existing generators for units 3, 4, and 5.

(8) Generator Main Bus

The segregated phase bus duct will be used as the generator main bus for connection between the generator and the main transformer. This is because the segregated phase bus duct is superior in quality and will guarantee the safety of the system. The ratings of the segregated phase bus duct will be rated for 12 kV, 3,000 A, 40 kA.

6.5.3 MAIN TRANSFORMER

(1) Type and Cooling Method

The main transformer is of single-phase, oil-immersed, two-winding, outdoor installation type intended to be connected directly to the generator in such a way that it may be subjected to load rejection conditions. Single-phase transformer is selected along the same lines of the existing main transformers for units 3, 4 and 5. The cooling method is selected at natural oil circulation forced air cooling (ONAF) along the same lines of the existing main transformers for units 3, 4 and 5. The new main transformer for unit 6 should be designed to have the same construction and dimensions with the existing main transformers for units 3, 4 and 5, so that the new transformer should be interchangeable with the existing spare single-phase transformer.

(2) Main Transformer Rated Power

The rated power of the main transformer should be 16,666 kVA/phase (50,000 kVA for three-phase), which is the same value of the existing single-phase transformer for units 3, 4 and 5.

(3) Main Transformer Fire Fighting System

The main transformer will be provided with water spray type fire fighting system for each single-phase transformer, along the same lines of the existing main transformers for the other units. The water for the main transformer fire fighting system will be supplied from the existing clean water tank by extending the existing distribution water pipe.

6.5.4 115 kV Outdoor Switchyard Equipment

(1) 115 kV Bus Arrangement

The existing outdoor switchyard is of conventional, outdoor open type bus-and-switch arrangement for 115 kV switchgear and is located on the roof of the powerhouse. The 115 kV bus is arranged for “main and transfer bus scheme” in which a transfer bus is added to the single-bus scheme.

(2) Additional 115 kV Switchgear for Unit 6

The existing 115 kV outdoor switchyard will be expanded by about 25 m, as shown in Drawing Nos. E-021 and E-022 in Appendix G, for additional installation of the following 115 kV switchgear for unit 6:

1) One circuit breaker rated for 123 kV, 1250 A, 31.5 kA
2) Three disconnectors rated for 123 kV, 1250 A, 31.5 kA (for 3 s)
3) Three single-phase current transformers rated for 123 kV, 300/5 A, 31.5 kA (for 3 s)
4) Three (3) single-phase capacitor voltage transformer for 123 kV, 115/√3//0.11/√3 kV
5) Three (3) single-phase surge arresters

The single-line diagram for the additional 115 kV switchgear for unit 6 is shown in Drawing No. E-002 in Appendix F.

(3) Additional Installation of 115 kV Disconnector for Main Bus Sectionalizing Purpose

In order to permit flexible and convenient operation of the 115 kV main bus to minimize the period of power interruption due to unexpected fault and maintenance work, one 115 kV disconnector will be added to the 115 kV main bus for the purpose of sectionalizing the main bus, as shown in Drawing Nos. E-001 and E-021 in Appendix G. This 115 kV sectionalizing disconnector will be installed on the existing beam structure between unit 3 and unit 4 (between 115 kV transmission lines TL2 and TL3).

(4) Replacement of 115 kV Main Bus Conductor

The existing conductor for the 115 kV main bus is a HDCC (hard-drawn copper conductor) 325 mm^2 and its continuous current carrying capacity is just 875 A at its permissible operating temperature of 90 °C. On the other hand, the maximum continuous current in the 115 kV main bus will reach to 1,305

A after completion of unit 6. Therefore, the conductors for the 115 kV main bus will be replaced by HDCC 725 mm^2 for the following reasons:

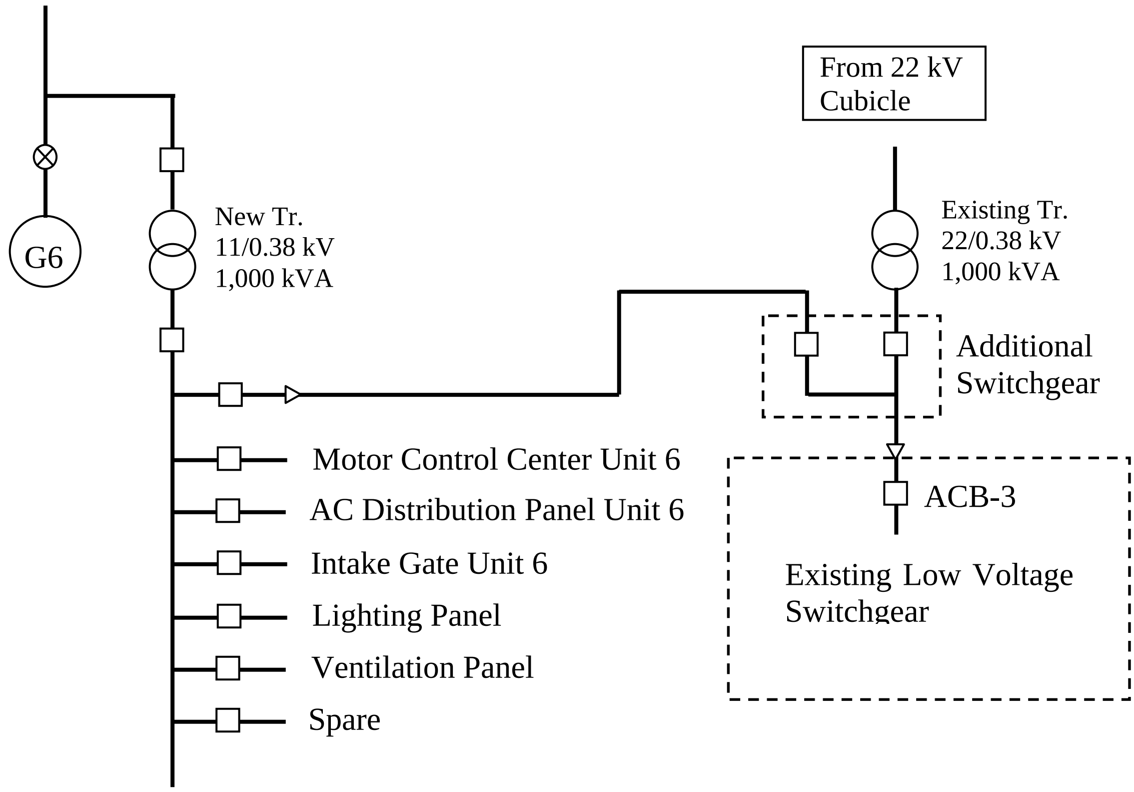
1) HDCC is also used for the other conductors connected to the 115 kV main bus and such other conductors will remain unchanged even after the 115 kV main bus conductors are replaced by new ones. In order to avoid any problem on mis-coordination with different kinds of conductors, it is preferable that the new main bus conductor should be of the same kind as the existing conductors (HDCC).
2) All the clamps and connectors on the existing 115 kV main bus will also be replaced by new ones together with the 115 kV main bus conductors. In order to prevent electrolytic corrosion with different kind of conductor, it is preferable that the new main bus conductor should be of the same kind as the existing conductor (HDCC).
3) In case of HDCC, the minimum required size is 725 mm^2 for the current carrying capacity of 1,305 A.

The scope for the replacement of the 115 kV conductors includes the existing main bus conductors in the area of units 3, 4, and 5 and 115kV cable head for GIS, which is shown in Drawing No. E-001 in Appendix F.

6.5.5 STATION-SERVICE POWER SUPPLY SYSTEM

There are two existing station-service transformers; one is 11/0.38 kV transformer and the other is 22/0.38 kV transformer. Each of the two existing station-service transformers is rated for 1,000 kVA and has sufficient extra capacity to serve for the additional equipment/facilities for unit 6. However, the 22/0.38 kV station-service transformer is connected to the 22 kV circuits, which are served for power supply to the local consumers. When the 22 kV circuit is used as a power source for the station-service transformer, station-service power supply is liable to become unstable especially in rainy season. Judging from this situation, the 22/0.38 kV station-service transformer will not be reliable as a power source for station-service power supply.

On the other hand, the existing low voltage cubicle has no spare circuit breakers and its modification to add another circuit breaker will also be difficult from the complexity of the circuits. Therefore, the existing low voltage cubicle will not be available to supply power to the additional equipment/ facilities for unit 6. As a possible solution for this problem, it is suggested that one (1) 11/0.38 kV station-service transformer should be added as a part of Unit 6 and should be arranged to change over the station-service power supply from the existing 22/0.38 kV transformer to the additional 11/0.38 kV transformer or vice versa, as shown in Figure 6.5.1.



Prepared by JICA Survey Team

Figure 6.5.1 Station-Service Power Supply System for Unit 6

6.5.6 DC POWER SUPPLY EQUIPMENT

(1) Stationary Batteries

Each of two sets of the existing stationary batteries has sufficient extra capacity for DC power supply to the additional equipment/facilities for unit 6, and therefore, these will be available as needed. The existing stationary batteries were replaced by new ones in 2004, hence, there is a concern that the stationary batteries' life may expire before this expansion project's completion in 2015. It is therefore planned to replace the two sets of existing stationary batteries by new ones. The new stationary batteries will be designed for the same specifications with the existing ones as follows:

1) Type: Sealed construction, valve regulated type lead acid batteries
2) Capacity: 300 AH at 10-hour discharge rate
3) Number of cells: 53 cells/set

(2) Battery Chargers

Each of two existing battery chargers will have sufficient extra capacity for DC power supply to the additional equipment/facilities for unit 6, and thus, will be used as they are.

(3) DC Distribution Panel

The existing DC distribution panels have no sufficient number of spare circuit breakers for DC power distribution to the additional equipment/facilities. Therefore, one DC distribution panel will be provided in alignment with the new AC control source distribution panel, in the area adjacent to the additional unit.

6.5.7 CONTROL AND PROTECTION SYSTEM

(1) Local Control and Relay Board

One local control board, one relay board, and one automatic control board will be installed in the new cubicle room, which is located adjacent to the machine bay for unit 6, in the same manner as the existing system for units 3, 4 and 5. Concerning the electrical protective relays for the generator and main transformer, digital type relays will be used in accordance with current design practice. For the automatic control board, a programmable logic controller will be used in accordance with current design practice.

(2) Remote Control Board

One remote control board for unit 6 will be installed in the existing control room, in alignment with the existing control board for unit 5. The new remote control board will be of bench type to be well-coordinated with the existing panel design. The new remote control board will be linked with the programmable logic controller by way of an optical data way for high-speed data transfer.

6.6 MECHANICAL EQUIPMENT

6.6.1 ARRANGEMENT OF INTAKE FACILITIES

Through the study for selection of optimum expansion plan, the fixed wheel gate on the downstream of dam with stoplogs is selected as the optimum plan for the gate structure. The intake facilities arrangement of the selected plan is shown in Figure 6.5.1 below.

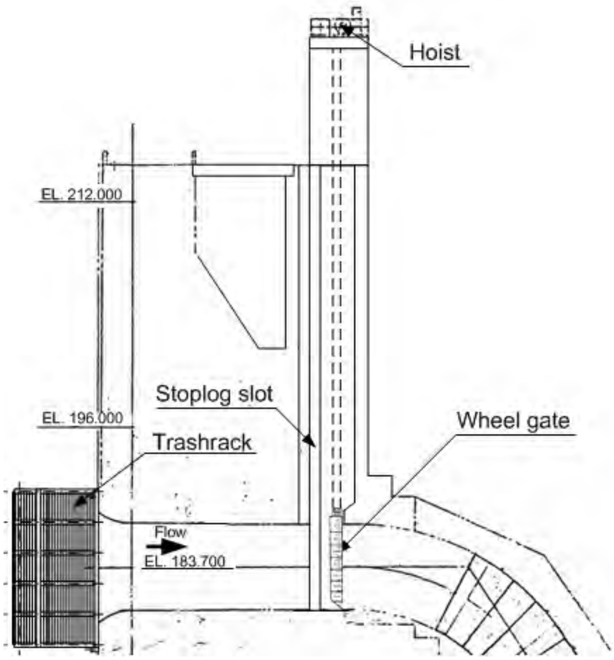


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Figure 6.6.1 Arrangement of Intake Facilities

The arrangement of facilities is summarized as below:

a) Fixed trash racks are provided on the upstream surface of the intake bell mouth.

b) Fixed wheel type of intake gate is installed in the tower shaft provided on the downstream face of the dam as the guard gate of the guide vane.

c) The stoplogs are provided as the maintenance gate for the intake gate in the same tower shaft.

d) For the operation of stoplogs, the lifting equipment is separately installed on the hoist tower of intake gate.

The basic design results of the respective intake facilities are described as follows:

6.6.2 INTAKE TRASHRACKS

(1) Principal dimension of trashracks

According to the intake dimension of civil structures, the principal dimensions of the trash racks are as follows:

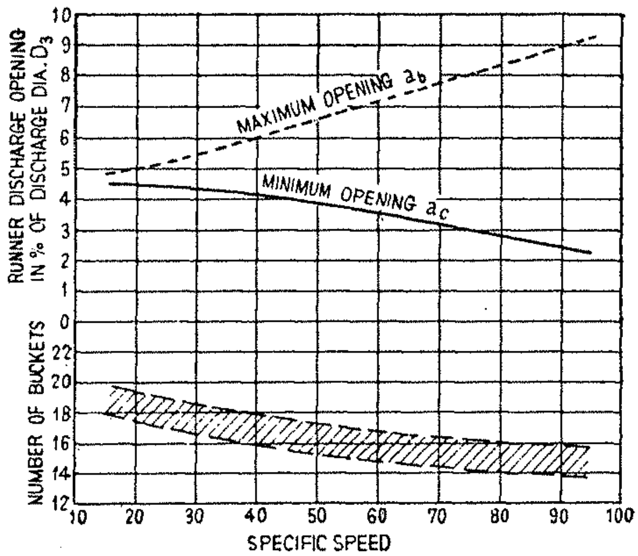
Clear span: 3,000mm (pass way width: 12,000mm)
Clear height: 10,000mm
Number: Four (4) span

(2) Design velocity at trashracks

The water flow velocity at trashracks shall be calculated from the total area of four span of the clear span, namely 120 m^2. The average velocity passing through the trashracks is 0.98m/s at 118m^3/s maximum discharge flow.

(3) Pitch and dimension of screen bar

In the case of the Francis turbine, the pitch of screen bars is generally decided so as to be less than the minimum opening of runner vanes. Although the detailed dimension of the runner is not yet defined in the basic design stage, the minimum opening of runner vane is decided based on Figure 6.5.2 below.



Source: Trashracks and Raking Equipment, Water Power, 1960, p9

Figure 6.6.2 Experience Data for Approximate Determination of Clear Openings in Francis Runners

As the specific speed (Ns) is indicated by the unit of ft-HP in Figure 6.5.2, the figures should be multiplied by 3.81 to convert into the unit of m-kW. The estimated Ns is nearly 300 m-kW but limited to be 300 m-kW at maximum in the basic design, 79 ft-HP is equivalent to 300 m-kW in Figure 6.5.2. From the Ns of 79 ft-HP, the minimum opening of the runner vanes will be 2.9% of the turbine discharge diameter. The estimated minimum opening is 130 mm from the expected turbine discharge diameter of 4600 mm. Although the screen bar pitch of existing trashracks is 75 mm, the bar pitch should be decided to be larger to strengthen the screen bars by increasing the bar thickness and preventing the head loss from increasing due to the screen. Considering the bar pitch of the existing trash racks, the bar pitch is decided to be 100 mm.

(4) Supporting span of intake trashracks

The foundation for frame of trashrack is arranged within the area of bulkhead cover to install the foundation and anchors in the dry condition for keeping the accuracy of alignment and flatness of plane of anchors. The supporting point of trash racks is located between the end point of bellmouth and edge of foundation for bulkhead cover accordingly the supporting span of trashrack is decided from the supporting point.

(5) Material of screen bar and frame

As for the structural frames of the trash racks, and the screen panels which are fixed and welded together on the same frames, it is advisable to use rolled steels material for the trashracks which are more economical and easier to assemble. Corrosion allowance of 1 mm is considered for the screen bars and frames.

(6) Others

For fixed trashracks, screen panel is fixed on the frames with bolts and nuts taking the future removal into consideration. Though the trashracks made of stainless steel are also considerable, the mild steel is adopted because of cost.

6.6.3 INTAKE STOPLOGS

(1) Principal dimension of stoplogs

The principal dimensions of the intake structures are shown as below:

Clear span:	4,500 mm
Clear height:	5,500 mm
Number:	One span

As for the dimensions of the existing stoplog segment, clear span and leaf height are 5,000mm and 2,040mm respectively. The dimensions of guide frames in the expansion plan will be decided according to the dimensions of the existing stoplog segment to be used commonly for all units. It is planned to minimize the cost of stoplog by the common use of the existing stoplog segments.

As the existing gantry crane is not commonly used for the expanded intake facilities because the lifting center of stoplog is not on the same line with the existing intake facilities, new lifting equipment is provided. Since the existing stoplog weight of one segment is around six (6) tons or less, the standardized lifting equipment is considered to be adopted taking the procurement cost into consideration.

(2) Supporting span of stoplogs and arrangement of sealing seat

The supporting and sealing spans of the existing stoplogs are 5,240 mm and 5,140 mm respectively. Taking account of the dimensions of the existing stoplog segment, the arrangement and structure of guide frames will be decided for the expanded stoplog facilities. Though the depth of side slot for stoplog will be slightly deep considering the clear span of 4,500mm, the supporting and sealing frames can be arranged and installed in the intake tower shaft.

(3) Guide frame

To transfer the water pressure load acting on the stoplog to the concrete structure, the side supporting frames will be provided with the heavy structure. Because the side guide frames only function as the guide rails for the location from the top of the stoplog to the dam crest, only side guide rails will be embedded.

Because the guide rails without concrete encasement are totally exposed in water, stainless steel is adopted as the material of guide rails taking account of difficulty of future maintenance in water.

6.6.4 INTAKE GATE

(1) Design data of intake gate

From the study of the optimum expansion plan, the design data of intake gate are decided as below:

Type:	Fixed wheel type of gate
Quantity:	one set
Clear span:	4,500 mm
Clear height:	5,500mm
Design head:	29.5 m
Sealing system:	Downstream four edges rubber seal
Hoisting method:	Wire rope winch type hoist

(2) Material and structure of intake gate

The intake gate is comprised of three main parts as mentioned below:

Gate leaf: The leaf is of frame structure operated by hoisting equipment. As the leaf is of the welded structure, rolled steels for welded structure are to be adopted for the material of the leaf taking account the weldability of steel structure. Stainless steel materials are adopted for fixing plates and bolts for seal rubber taking the future maintenance into consideration. As for the fixed wheels as the part of supporting the gate leaf, the stainless steel material will be adopted for the wheel shaft and roller bearing be adopted for the shaft bearing to reduce the friction forces.

Guide frame: The guide frames are of the welded girder structures embedded in the concrete of gate slot to transfer the water pressure load acting on the gate leaf through the fixed wheels. Although rolled steels for welded structure are mainly adopted for the material of the guide frame taking account the weldability of steel structure, stainless steel materials are also adopted for the surface of track frame and sealing frame.

Hoist: Wire rope winch type of hoist will be installed on the hoist deck provided above the dam crest because the wire rope winch is suitable for the long height lifting and the maintenance is easier in comparison with the hydraulic type hoist. The hoist has a function of lowering the gate leaf with its own weight in case of the emergency shut down operation. A fun brake will be provided to keep lowering speed when the hoist lowers the gate leaf with its own weight.

(3) Hoisting speed

The intake gate is kept at fully raised position and closed when the turbine is maintained. The intake gate is operated under balanced water pressure condition. In normal case, it is unnecessary to operate for a short time; accordingly, the hoisting speed is decided to be 300 mm/min, considering the operation time of approximately 30 minutes for stroke of 5,500 mm open or close.

In case of shut down operation for any problem with the guide vanes, the intake gate is required to be closed quickly, generally within around a few minutes. Accordingly, the hoisting speed of shut down is decided to be 1000 mm/min.

(4) Arrangement of equipment

A local control panel is installed on the hoist deck and a remote control panel is installed in the control room of the power station.

(5) Others

By-pass pipes and valves are provided to the gate leaf to achieve pressure balance, with water filling the steel penstock located downstream of gate, when the gate is operated. The by-pass valves are operated through the lifting beam equipped with the gate leaf and controlled from the local or remote control panel.

An air pipe of 1,200 mm inside diameter is provided on the downstream side of gate for air supply during the shut down operation. The air pipe is installed in the intake tower shaft up to the dam crest.

6.6.5 STEEL PENSTOCK

The minimum shell plate thickness of the steel penstock is decided in accordance to the technical standards for gates and penstocks in Japan. To calculate the plate thickness, the following formula is applied.

$$t = \frac{D + 800}{400}$$

where, t: Minimum plate thickness (mm)

D: Internal diameter (5,500mm)

From the above, the minimum plate thickness is found to be 16 mm. For the 16mm shell plate thickness, the allowable water head is 68 m. Since the design head of expansion plan is 65 m, with the design static head and water hammer, the minimum plate thickness of 16mm is enough to withstand against the internal pressure.

As for the design external pressure, the pressure will not work on the penstock because the seepage water will be drained by the drain pipe. However, half of the head difference between the HWL of the reservoir and the center of penstock is deemed to act on the embedded penstock in the dam considering the safety. In case stiffeners are provided against external pressure, the material weight and man-hour of manufacturing cost more than increasing the plate thickness without stiffener. Accordingly, no stiffener is considered for the design of the penstock.

6.6.6 DRAFT TUBE STOPLOGS AND GANTRY CRANE

(1) Stoplogs

The dimension of the draft tube outlet will be decided according to the existing stoplogs to be used commonly for the expansion plan. In the expansion plan, new stoplog segments will not be provided to the new generating unit, but only guide frames. Because of the common use of the existing stoplog segments, the guide frames to be installed in the expansion plan are of the same guide frames installed in the existing generating unit.

(2) Gantry Crane

In addition to the common use of draft tube stoplog segments, the existing draft tube gantry crane is also commonly used for the expansion plan. The traveling rails and power supply cable are extended up to the new draft tube of the generating unit. The power supply cable including cable reel will be replaced totally in the expansion plan.

CHAPTER 7 IMPLEMENTATION PLAN AND COST ESTIMATE

7.1. OUTLINE OF THE PROJECT

The proposed optimum plan for the Nam Ngum 1 (NN1) Hydropower Station Expansion Project is to extend the existing machine hall towards the spillway and provide a new generator with 40.0 MW capacity as the unit 6, according to the basic design of the JICA preparatory survey in 2009. The NN1 Hydropower Station raises its generation capacity to 195.0 MW in total from the existing 155.0 MW, through the implementation of the expansion project. The NN1 power station has the following chronicles in its commissioning operation.

- 1971: 15,000 kW x 2 sets for No. 1 and 2 generators
- 1975: 40,000 kW x 2 sets for No. 3 and 4 generators
- 1984: 40,000 kW x 1 set for No. 5 generator
- 2004: Up-rating 2,500 kW x 2 sets for No.1 and 2 by rehabilitation
  Total generating capacity before expansion: 155.0 MW

The principal features of the proposed expansion project for the new unit 6 under the basic design study are as follows:

- Rated head : 40.0 m
- Intake center level : EL. 185.25 m
- Penstock diameter : 5.5 m
- Intake gate : Roller gate (Capable of closure under current)
- Turbine : Francis type, rated output 40,900 kW
- Generator : Umbrella type, rated output 50,000 kVA
- Main transformer : Single phase type, rated capacity 16,666 kVA x 3

The proposed layout of the expansion project has the following characteristics.

- A new intake at the upstream dam face is located between the intake for unit 5 and the spillway.
- A new penstock is installed at the downstream of the new intake gate.
- The existing power station is extended to accommodate the new turbine, generator and ancillary plant of unit 6.
- A tailrace is constructed at the downstream of the powerhouse extension.

The expansion project, located in Viengkham, Keo Oudom District, Vientiane Province in the northeast direction of Road No. 13N, is approximately 90 km from Vientiane. The Project includes three major construction works namely, 1) civil works, 2) hydro-mechanical works, and 3) electro-mechanical works. No stoppage of the existing NN1 power plant is planned during the construction of the expansion works.

7.2. PROJECT IMPLEMENTATION

(1) Executing Body

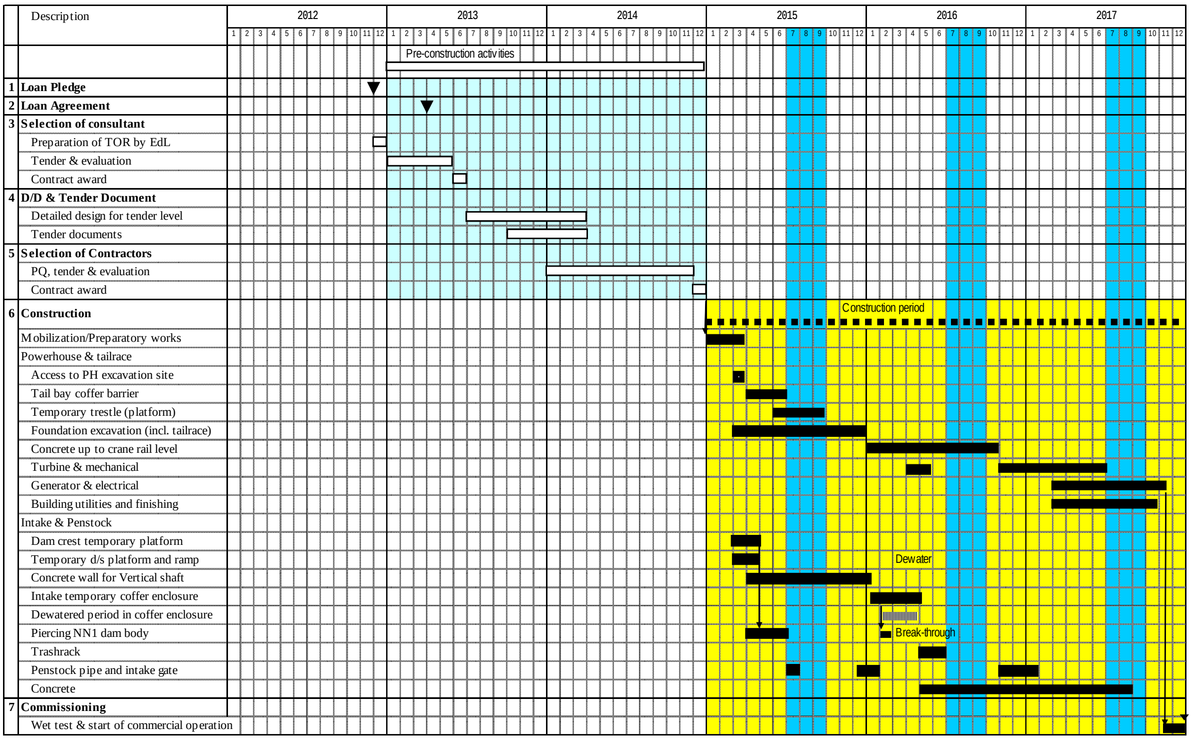
The Project will be implemented by EDL. EDL will organize a Project Management Unit (PMU) for project implementation. After completion of all the construction works, EDL-Gen will be responsible for operation and maintenance as mentioned in Section 9.2.

The selected international consulting engineer and associated local consulting firms will be employed for the detailed design, preparation of tender documents, and construction supervision, to assist EDL.

(2) Implementation Schedule

The Project is proposed to be implemented in five (5) years including pre-construction stage and conducted as shown in the subsequent Figure 7.2.1 (or Appendix G-1). Work items for the project implementation are summarized below.

- Financial arrangement
- Selection of consultant
- Detailed design and preparation of tender documents
- Tender and selection of contractors
- Construction execution, construction supervision and environmental management
- Commissioning tests and trial operation
- Completion (Start of commercial operation)



Prepared by the JICA Survey Team

Figure 7.2.1 Overall Tentative Implementation Schedule

(3) Financial Source

For the funding arrangement, Japan's official soft Yen loan for Least Developed Countries (LDC) is expected to be applied for the Project.

(4) Procurement Plan and Contract Packages

In selecting the contractors for the Project, the International Competitive Bidding (ICB) process will be expected to be adopted in principle. Initially, however, the bidders will be screened through a pre-qualification process. The contractor will be selected in accordance with the guidelines of JICA.

The contract packages will include the following three lots for ensuring sufficiency of magnitude and successfully attract international bidders, allow smooth construction management and control of the overall Project to be maintained, and other related matters.

- Lot 1: Civil works
- Lot 2: Hydro-mechanical works
- Lot 3: Electro-mechanical works

7.3. CONSTRUCTION PLAN AND SCHEDULE

(1) Scope of Works

For the NN1 power station expansion project, the scope of works is summarized as follows:

➢	A Civil works	A1 Preparatory works
		A2 Intake and penstock
		A3 Powerhouse and tailrace
		A4 Roof switchyard
		A5 Removal of rock outcrop in downstream
➢	B Hydro-mechanical works	B1 Intake and penstock
		B2 Draft tube stoplog facility
➢	C Electro-mechanical works	C1 Generation equipment

(2) Civil Works

<u>Access to Site</u>

Mechanical and electrical equipment, construction plant, and the main construction materials are expected to be transported from or through Thailand by road, via the Friendship Bridge across the Mekong River. Access from there to the expansion site is via RN 13 to Ban Phonhong, and then by a paved road to Ban Thalat and the bridge over the Nam Ngum River.

<u>Construction Resources</u>

The expected raw materials to be used for the expansion works include cement, sand, gravel and stone, timber, water. Cement supply is assumed to be from Thailand, unless the quality of those produced in

Lao PDR is confirmed to be acceptable. Concrete aggregates are assumed to be taken from the Nam Lik riverbed deposits. Locations and photographs for Riverbed deposits and borrow bits are shown in appendix-G3-2, 3.

To expand for the new unit 6 generator, several types of construction equipment, such as bulldozer, dump truck, and crane, will be required. Middle to light class equipment with operator may be available on rental basis at Vientiane, Lao PDR. However, heavy-lifting crane may need to be mobilized from Thailand. A concrete mixing plant will be necessary to supply concrete.

Skilled labor such as divers for welding and rigging works under the Nam Ngum reservoir water for temporary enclosure and open air, drilling operator for piercing the dam body, operators of heavy lifting cranes and other specialized tasks will have to be recruited from ASEAN countries and Japan.

Construction Sequence

The construction works will be conducted under two sections such as intake and penstock (upstream side), and powerhouse and tailrace (downstream side). These shall be executed almost in parallel after mobilization.

Construction Schedule

Construction schedule is formulated as part of the construction plan, and presented in bar chart form in Appendix G-2. This is intended to show detailed timing of works to be carried out from commencement to final taking-over by each civil works contractor, including hydraulic steel works and electrical/mechanical works. This schedule should clearly show which work items are on critical path.

Preparatory Works

Temporary construction facilities should be initiated prior to commencement of main civil works. These include preparatory works such as access roads, contractor’s office and accommodations, and employer’s and engineer’s office and accommodations. These facilities are constructed in the downstream left bank, mainly close to the NN1 dam. Required area is approximately 2.0 ha. Appendix G-3-1 shows a layout plan for these temporary facilities and yards. Waste disposal site is proposed at the left bank and downstream of the power station, within a 2.0-km hauling distance

Temporary Enclosure

Access to the intake works area is the 5.5 m wide Nam Ngum dam crest. The existing traveling crane on rails and the crest will be temporarily removed to the right abutment side to allow access for items of plant of greater dimension.

A temporary coffer enclosure in the reservoir is required for the construction of intake. The bulkhead gate as the steel coffer structure has been planned in the basic design stage. H-type and angular steel materials (SM 490 or equivalent) are applied as the main coffer materials. The temporary enclosure coffer plans have the following dimensions situated in the new intake side of the reservoir.

Inside volume: 10m x 12m x 2.0 m (240m^2)

Maximum Depth: Depth from the center of the penstock 26.75 m (EL. 212m – EL.185.25m)

Required steel will be approximately 159 tons in total. The steel materials are assembled as gate-type steel structure on the ground outside the reservoir to meet the coffer size mentioned above. The weight of the bulkhead gate-type steel structure is 120 tons and the weight of the door stop steel structure is 39 tons. Number of components assembled for such the bulkhead gate-type steel structure is 6 sets. Each piece of steel structure is assembled on the flat barge (200ton) in the reservoir The bulkhead gate-type on the flat barge is transported to under the stage equipped with winches (5tonx2sets, 1tonx2sets), by which the bulkhead gate-type is lifted and is temporarily put on supporting brackets. The bulkhead gate-type is fixed to the door stop installed on the upstream surface of the dam body, supported by chemical type anchoring (l = 40-50 cm, M36 x 176 pcs). After installation of the bulkhead gate the dewatering should be executed by a submergible pump through the well provided from the bulkhead gate to dam crest.

The coffer works will be carried out in the following sequence, within about 10.0-month duration. The duration from dewatering in the bulkhead gate to the removal of bulkhead gate should be kept in the dry season:

(Coffer installation)

1) Preparatory works (0.25 month) → 2) Assembling barge(1.0month) → 3) Survey/ centering/level check (0.5 month)→ 4) Setting the door stop and the brackets to dam body (3.0 months) → 5) Assembling the bulkhead gate- type on flat barge (4.0 months) → 6) Installation of the bulkhead gate-type (1.0 month) → 7) Dewatering (0.5month) → Finish

(Coffer demolition)

1) Preparatory works (0.25 month) → 2) Removal of the bulkhead gate-type (0.5month) → 3) Demolition of the bulkhead gate-type (1.0 month) → 4) Site clearing (0.25 month) → finish

The erection of maximum load being the bulkhead gate-type (120ton) will have to be clarified for the study. The lifting work for the assembled gate-type will be by four winches (5ton x 2sets, 1ton x 2sets) to be equipped on the stage on the dam crest. The flat barge (200ton) is provided for assembling the bulkhead gate-type and the flat barge (100ton) is provided for the diving works. These coffer works are to be done under water by skilled divers, that require complete safety measures, quality control and construction management.

Working platform will be constructed on the crest of dam (block no. 19 and 20) for the intake and penstock works including coffer enclosure. This platform will be 18.0 m long and 10.1 m wide.

Reservoir water level will be controlled during temporary coffer construction. Major equipment required for the temporary coffer enclosure will be as follows.

Equipment	Specification	Application	Notes
Winches & platform	Winch(5t)x2sets Winch(1t) x 2sets		Coffer setting/removal

Crawler crane	100t class for setting door stop, fixing frame, support bracket.	Assembling/ loading	Max. weight 20t, Max working radius 12m. Truck crane is applicable
Crawler crane	100t class	Assembling/ transportation	Max. weight 20t, Max. working radius 12m. Truck crane is applicable
Trailer truck	20t class	Transportation to dam crest	Transportation of a part of the bulkhead from assembly site to dam crest.
Flat barge	200t class	Assembling bulkhead and transportation	Transportation of bulkhead to dam crest on a flat barge in reservoir
Boat	100PS	Tow for a flat barge	Including transportation of workers
Flat barge	100t class	Base for divers	
Concrete pump car	60m3/hr	Pouring concrete	Common use of P.house, 1-unit
Uni-float barge with safety net and film preventing muddy water			For divers in front of the existing penstock

Working conditions of diving work for the underwater temporary enclosure work are as follows:

The composition of diving team	: 5~6 parties (1party is composed of two divers)
Method of diving	: Diving under air system
Working day	: Continuous working even during Saturday and Sunday
Cycle of diving	: One time diving work by a party per a day
Cycle of work	:80min diving work per day(actual work: 70min,30m in depth） after work taking 30min~60min for rest

Intake and penstock

Major construction work items and approximate quantities required for the intake and penstock are as follows:

1) Construct temporary working platform at EL. 181.0 m and access ramp

2) Piercing dam, hole section 5.7m x 6.7 m, length 22.5 m for horizontal part of penstock, and bell mouth section 6.5 m x 7.5 m, Gate tower outer diameter of 6.6m, piercing volume of 1,450 m^3 in total

3) Cover concrete of 1,130 m^3 for penstock (bell mouth to inclined part above EL. 177 m)

The slot-drilling and breaking method will be adopted for the dam piercing. Slot drilling machine will be a 20-ton machine equipped with bit diameter of 65 mm by 120mm wide. Breaker of 1,400 kg class will be used for further breaking. Using the slot-drilling and the breaker, the penstock hole is bored through the dam with the remaining concrete from bell mouth part of penstock to upstream, which is made a breakthrough after completion of a temporary coffer enclosure and dewatering in coffer. Concrete are filled after the formwork installation. Major equipment required for the dam piercing will be as follows. The required number is 1 unit of each type of equipment, assuming 1.5m piercing length progress by one cycle.

Equipment	Specification	Application	Notes
Slot drilling	Diameter:65mm width:120mm		Mini backhoe as base machine
Backhoe	Crawler type 20t class	For breaking	6.7m Height for utilizing debris material
Breaker	Hydraulic 1,400kg class	For breaking	
Wheel loader	0.9m3 class	Loading muck for disposal	
Dump truck	10t class	Hauling muck	
Breaker	Hydraulic 1,400kg class	For breaking	Common for secondary breaker
Concrete pump car	60m3/hr class	Fill concrete	Common use with power house

*One cycle 1.5m

Dewatering period in the coffer enclosure is scheduled for 3.5 months. Breakthrough of piercing for the remaining concrete from bell mouth part of penstock to upstream is to be performed in the initial stage of the dewatering period after completion of the gate tower. This is intended so that the succeeding works, such as bell mouth concrete, lining concrete and other works, could be done within the dewatering period.

Before removal of bulkhead the inside penstock between the bulkhead and the upstream gate is filled with water for keeping nothing to be pressured against the bulkhead. Bulkhead is dismantled with winches of 5ton; 2sets and 1ton; 2sets on platform at dam crest.

Powerhouse and Tailrace

Major civil works are 1) foundation excavation of the powerhouse and tailrace, 2) underwater excavation outside tailrace, and 3) building and tailrace concreting. The construction of powerhouse and tailrace, including the electro-mechanical works, has a critical path of 36.0 months within this expansion project. This is implied in the following work order and duration.

Mobilization	: 2.0 months
Access way preparation (draft tube deck)	: 1.0 month
Foundation excavation (above EL. 168 m)	: 4.0 months
Foundation excavation (below EL. 168 m)	: 5.0 months
Building concrete (up to OHT crane runway base)	: 9.0 months
Crane runway steel girders	: 1.0 month
Turbine spiral casing	: 2.0 months
Spiral case second concrete	: 2.0 months
Installation of generator and electrical auxiliaries	: 8.5 months
Wet test for commissioning	: 1.5 months
Total	: 36.0 months

The excavation for the extension of the powerhouse will cover the area between the ends of the present building and the spillway. The powerhouse and tailrace excavation will be carried out through two steps, namely, open excavation of 39,000 m^3 above EL. 168 m (upstream side) and pit excavation of 24,000 m^3 below EL. 168 m from the bottom (downstream side).

The excavation above EL. 168 m should commence from the upstream side and finish early to ensure that construction of the working platform starts timely at EL 181.0 m, for the piercing of the dam body for the penstock and intake gate.

It will be required to provide a temporary coffer at the river side. Existing concrete wall and natural rock at crest EL 171 m should be utilized for the coffer upon reinforcement, through grouting and rock anchoring. Existing concrete deck on the tailrace side of the powerhouse building shall be used as haul road of excavated muck upon removal of the stoplog crane on the deck.

Rock excavation in the powerhouse extension area should be executed using rock breakers or blasting, depending on the hardness and degree of jointing encountered. Where the use of heavy breakers or blasting is required, the transmission of vibration to the existing machine foundations will be limited by line drilling at the perimeter of the excavation with the use of delay detonators. Water jet method will be studied in the detailed design stage. Rock bolting and shotcrete will be required on all cut slopes.

Excavation in the tailrace area would be carried out using 0.8 m^3 class backhoe base machine equipped with 1,400 kg class giant breaker. Loading and hauling will be executed using a combination of 0.8 m^3 class backhoe and 10-ton class dump truck. In order to load excavated muck below EL.168m crawler crane (100t) equipped with vessels is provided on existing concrete deck. Waste disposal site will be provided at the left bank of the Nam Ngum River, within 2.0 km hauling distance.

The excavation volume of underwater outside the tailrace and coffer is 2,600 m^3, which will require a giant breaker for excavation and 0.8 m^3 class backhoe for loading on pontoon barge. A small barge will be provided for the hauling of excavated soil and rock.

Required concrete volume is approximately 15,000 m^3 in total. Concrete aggregates will be taken from Nam Lik riverbed deposits. A 60 m^3/h class batcher plant will be provided at the left bank of the Nam Ngum River, close to the construction site. Agitator truck of 5 m^3 class and concrete pump car will be utilized for concrete placement. The chute method will also be applied for pouring concrete. A tower crane will also be provided and erected at the upstream side of the tailrace in the north side for the powerhouse concrete, and other works.

Removal of Rock Outcrops at Downstream Stretch

The volume of rock outcrops to be removed at the downstream stretch of powerhouse is estimated at 13,000 m^3. The underwater removal works will be done using a blasting method and a giant breaker on flat barge. A 0.8 m^3 class backhoe on the flat barge will be used for the loading of excavated rock and soil, and a small barge will be provided for the hauling of excavated soil and rock.

(3) Hydro-mechanical Works

The construction items of the hydro-mechanical works for the 40 MW NN1 expansion are as follows.

Intake and penstock	1) Trash rack, 43t
	2) Stoplog, 18 t
	3) Intake gate and hoist, 57 t
	4) Gantry crane rails and cable extension, LS
	5) Penstock steel pipe, 100 t
Draft tube stoplog facility	1) Gantry crane rails and cable extension, LS
	2) Draft tube stoplog slot guide rails

The hydro-mechanical works are carried out by a selected contractor under the contract package for lot 2, comprising the design, manufacture, delivery, installation and water-filling in the penstock and gate operating tests. These works are accomplished to meet the construction time schedule of civil works. The installation of hydro-mechanical equipment is scheduled to start from the second year after the site delivery and requires 15.5 months duration, including the design and manufacture. The trash rack will be installed during the dewatered condition of the temporary coffer enclosure carried out for 3.5 months. Said installation will be executed using 4 sets of winches on platform installed temporarily at the dam crest.

The roller type gate in the gate tower will be installed during about 1.5 months before the installation of the trash rack using the winches on the platform at the dam crest. The 5.5 m-diameter penstock will be installed in order of the part of the upper horizontal, lower bend, inclined pipe and upper bend in the second to third year. Concrete filling follows the installation. The spiral casing and other equipment will be installed using a station crane. Secondary concrete will be placed using a concrete pump car.

(4) Electro-mechanical Works

The construction items for the 40 MW NN1 expansion electro-mechanical works are as follows.

Generating equipment	1) Turbine and auxiliaries, LS
	2) Generator and auxiliaries, LS
	3) Transformers, LS
	4) Indoor switchgear, LS
	5) Outdoor switchyard equipment, LS
	6) Control and protection equipment, LS
	7) Auxiliary equipment, LS
	8) Miscellaneous materials, LS

The electro-mechanical works are done by a selected contractor under the contract package for lot 3. This comprises the works and same procedures as for the hydro-mechanical works. The period assumed for the works is 22 months after the site delivery for electro-mechanical equipment, excluding the draft tube steel liner, which is planned for earlier delivery in about 8 months. The draft tube steel liner and spiral casing are planned to be installed in the second year. The spiral casing is installed using a powerhouse station crane. Other works are executed in the third year. The second stage concrete for the draft tube is poured in the second year, and for the spiral case, in the third year after the installation.

The advantageous arrangement is achieved by extending the existing main machine hall over the new unit so as to utilize the existing main station crane, lay down and loading areas. The roof extension of the power station superstructure accommodates the additional high voltage switchyard bay, as for the existing units.

7.4. COST ESTIMATION

(1) Conditions and Assumptions for Cost Estimate

- It is assumed that implementation period for the expansion project is about five years.
- Estimation of construction costs is carried out on the basis of the construction plan and schedule, elaborated based on estimated construction work quantities from the basic design and cost data collected and analyzed in the field survey.
- The cost estimation is conducted for the following major items, in which foreign currency (JPY) and local currency (Kip) components are separated:
    - Direct construction cost (on each package of civil, electrical/mechanical, etc.)
    - Indirect cost
    - General costs in head office and field office
    - Consulting service cost for design and construction supervision
    - Executing agency's expenditures for administration, land preparation, environmental management, etc.
    - Import tariff and value added tax (VAT) in Lao PDR.
    - Contingency (price and physical)
    - Interest during construction
- Base cost consists of direct cost for civil works, hydro-mechanical works, electro-mechanical works and cost for consulting services.
- Fiscal year is April – March.
- Exchange rate to US$:
  US$ 1.00 = JPY 79.7
  US$ 1.00 = Kip 7,890.3
- Base year for the cost estimate is September 2012
- For civil works cost, the unit price of each work item is first estimated taking into account the construction method and work quantity. The work item cost is then calculated by multiplying the work quantity by the corresponding unit price. Unit prices are quoted based on labor price, material price, normal machine price in Laos, and special machine price investigated in Southeast Asia. Productivity of items is based on past experience in Southeast

Asia. As to uncommon civil works, like the piercing concrete in dam body, records of productivity for similar works in Japan are used and special machine prices are collected from Japan.

- Costs for hydro-mechanical and electro-mechanical equipment are estimated on the basis of the consultant's database related to recent international bid prices for similar works.
- Consulting service cost comprises related costs and fees. A proposed TOR for the consulting services are as follows.
  - Review of basic design
  - Tender design, additional survey (topographic survey, geology, material), detailed design, preparation of tender documents
  - Supporting work of tender (tender evaluation, contract support)
  - Construction supervision
  - Advising for environmental management
- Tentative manning schedule for the consulting services is shown in Appendix G-8 including type of experts.
- Direct cost for the consulting services estimates referring the other on-going project cost data such as World Bank financing project for the following major cost items.
  - International airfare
  - Per-diem allowance
  - Accommodation allowance
  - Vehicle rental
  - Office rental
  - International and domestic communication charge
  - Office supply and operation
  - Sub-contracts cost
- Environmental management cost is included in the owner's administration cost.
- No Value Added Tax (VAT) of Lao PDR is included considering the tax exemption measure exclusive for the Project by the Government.
- No import duties on construction resources (materials and equipment) are included considering the tax exemption measure exclusive for the Project by the Government of Lao PDR.
- Land acquisition and compensation cost is considered zero account due to the constitution of Lao PDR under Article 17.
- Rate of interest during construction is estimated at 0.55%.
- Commitment charge is counted with 0.1%.
- Administration expenses for the executing agency are estimated at 5.0% of the total construction cost.

- Price contingency is estimated at 2.1% for foreign currency portion. For the local currency portion, 8.3% average annual inflation rate is applied.
- Physical contingency is estimated at 10% of total construction cost and 5.0% of total consultant services cost.
- Annual disbursement schedule is estimated based on the estimated costs and overall implementation schedule.

(2) Financial Cost of the Project

The financial cost estimated in the basic design stage is summarized below. Total fund requirement is shown in Appendices G-4.

Total of foreign currency portion (FC)	: JPY	4,226 million
Total of local currency portion (LC)	: Kip	143,306 million
Total of FC and LC	: JPY	5,673 million

(3) Summary of Base Cost

Appendices G-5 show the summary of Base Cost.

Civil works:	JPY	1,786 million
Hydro-mechanical work:	JPY	140 million
Electro-mechanical works:	JPY	1,657 million
Consulting services:	JPY	686 million
Total:	JPY	4,269 million

CHAPTER 8 ECONOMIC AND FINANCIAL ANALYSIS

8.1 ECONOMIC ANALYSIS

8.1.1 METHODOLOGY

The economic analysis aims at measuring the economic benefits of the expansion project to the national economy. The cost-benefit analysis will be performed by applying the discounted cash flow method based on economic values. Indices used in this economic evaluation are Economic Internal Rate of Return (EIRR), Net Present Value (NPV) and Benefit-Cost (B/C) Ratio.

The EIRR is a discount rate at which the present value of two cash flows, i.e., benefit and cost, becomes equal, as defined in the following equation:

$$\sum_{t=0}^{n} C_t /(1+r)^t - \sum_{t=0}^{n} B_t /(1+r)^t = 0$$

Where;

C_t : Cost
B_t : Benefit
t : Year
n : Project Life (Year)
r : Discount Rate (= EIRR)

8.1.2 BASIC ASSUMPTIONS

The opportunity cost of capital refers to an interest rate at which the appropriateness of an investment can be justified by comparing with the EIRR of a particular project. A rate of 10% is used based on the rates used for other projects in Lao PDR, such as "Master Plan Study on Small-hydro in Northern Laos" (JICA, 2005) and "Preparatory Survey on Nam Ngum 1 Hydropower Station Expansion in Lao PDR" (JICA, 2010). This rate is used as the discount rate to calculate present values.

The project life for the analysis is 55 years; i.e. 50 years of service life of civil work facilities and five years of construction period.

Market values are usually distorted with transfer payments such as taxes and subsidies. These transfer payments are transferred to the government that acts on behalf of the society. Then, in the case of economic analysis, they should not be treated as costs. These have to be eliminated from market values of cost and benefits as a whole. Given basic principles of economic anlaysis, following assumptions were adopted in converting financial price into economic price.

(1) Standard Conversion Factor

The standard conversion factor of 0.95, which is widely used in similar projects with international organizations, is applied as coefficient to calculate the economic price of the local currency portion of the construction costs originally expressed in market price.

(2) Cost Estimate

Estimation of costs is based on the price level of 2012. Costs of the existing facilities constructed before the project is considered as sunk cost and excluded from the analysis.

(3) Price Escalation

Price escalation is not considered in the analysis; economic values are expressed in constant price.

(4) Tax

Taxes and duties such as VAT are considered as transfer items and excluded from the analysis.

(5) Interest during Construction

Interest during construction is excluded from the calculation since the analysis aims at calculation of the project IRR of total capital used.

8.1.3 ECONOMIC COST OF THE PROJECT

The economic cost of the project is calculated based on the project cost estimation presented in Chapter 7. The annual operation and maintenance (O&M) cost and reinvestment (replacement cost) are also estimated. The economic cost is calculated by excluding transfer items such as taxes and conversion of the local currency portion with the standard conversion factor presented above.

(1) Initial Investment (Construction Cost)

The initial investment at economic price sorted by major item is shown in the table below.

Table 8.1.1 Initial Investment Cost (Economic Price)

(Unit: US$ 1,000)

Description	1st Year		2nd Year		3rd Year		4th Year		5th Year		Total		
	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	Total
I. Construction Cost													
Civil Works	0	0	1,179	654	4,715	2,617	4,715	2,617	3,536	1,962	14,146	7,850	21,996
Hydro-mechanical Works	0	0	124	21	498	83	498	83	373	63	1,493	250	1,743
Electro-mechanical Works	0	0	1,631	97	6,523	387	6,523	387	4,893	290	19,570	1,160	20,730
Total Base Cost	0	0	2,934	772	11,736	3,087	11,736	3,087	8,802	2,315	35,209	9,260	44,469
Physical Contingency (10%)	0	0	293	77	1,174	309	1,174	309	880	232	3,521	926	4,447
Total Construction Cost	0	0	3,228	849	12,910	3,395	12,910	3,395	9,683	2,547	38,730	10,186	48,916
II. Consulting Services													
Base Cost	1,605	39	1,435	41	1,781	57	1,769	58	1,758	56	8,348	251	8,599
Physical Contingency (5%)	80	2	72	2	89	3	88	3	88	3	417	13	430
Total Construction Cost	1,685	41	1,506	43	1,871	60	1,858	61	1,846	59	8,766	263	9,029
III. Administration Cost													
Administration Cost	0	82	0	269	0	875	0	874	0	678	0	2,779	2,779
TOTAL (I to III)	1,685	123	4,734	1,161	14,781	4,330	14,768	4,331	11,529	3,283	47,496	13,228	60,724
TOTAL (FC + LC)	1,808		5,895		19,110		19,098		14,812		60,724		

Prepared by JICA Survey Team

(2) O&M Cost

The annual O&M cost of the constructed facilities are calculated based on the following conditions:

- Civil Works : 0.5% of initial investment cost of civil works excluding temporary works
- Hydro-mechanical Works: (i) 0.75% of initial investment for the intake gate and hoist
  (ii) 0.25% of initial investment cost of trash rack and stop log
- Electro-mechanical Works: 1.0% of initial investment for total electro-mechanical works

Table 8.1.2 O&M Cost (Economic Price)

(Unit: US$ 1,000)

Item	Construction Cost (incl. Physical Contingency)	Factor	O&M Cost
Civil Works (excl. Temporary Works)	13,712	0.50%	69
Hydro-mechanical Works			
Intake Gate and Hoist	595	0.75%	4
Trash Rack and Stop Log	475	0.25%	1
Electro-mechanical Works	22,593	1.00%	226
Total	---	---	300

Prepared by the JICA Survey Team

(3) Reinvestment (Replacement Cost of Equipment)

The reinvestment cost is estimated for hydro-mechanical and electro-mechanical works over a period of 30 years after commissioning.

- Hydro-mechanical Works: 5% of initial investment for intake gate and hoist
- Electro-mechanical Works: (i) 70% of initial investment for turbine and generator
  (ii) 100% of initial investment for other equipment

Table 8.1.3 Reinvestment Cost (Economic Price)

(Unit: US$ 1,000)

Item	Construction Cost (incl. Physical Contingency)	Factor	Reinvestment Cost
Hydro-mechanical Works	595	5%	30
Electro-mechanical Works			
Turbine and Generator	17,958	70%	12,571
Others	4,635	100%	4,635
Total	---	---	17,236

Prepared by the JICA Survey Team

8.1.4 ECONOMIC BENEFIT

The economic benefit of the project is the incremental benefit between “without project” case and “with project” case.

In this analysis the benefit is estimated as the economic value of the alternative power source to NN-1 hydropower station. In the current situation of the C1 grid, the imported power from Thailand could be regarded as the alternative power source to the project. However, EDL and EGAT of Thailand interchange energy to each other and the electricity tariffs set for the cross-border trade are on low level so that it is not appropriate to estimate the project’s benefit based on such tariff level.

For this reasons, the economic benefit is measured by the capacity benefit (kW value) and the energy benefit (kWh value) increased by the expansion project through valuation of alternative thermal power.

(1) Selection of the Alternative Thermal Power Plant

In the alternative thermal power method, the costs of construction and operation of an alternative thermal power plant are assumed as the economic benefit of the subject hydropower station. The capacity benefit (kW value) of the hydropower is represented by the annualized construction cost and fixed operational cost; and the energy benefit (kWh value) is calculated as the variable costs of the thermal power such as fuel cost.

The alternative thermal power for the evaluation should be suitable to the domestic energy supply situation. Lao PDR is a landlocked country and its product imports for primary energy are basically limited to land transport. Its petroleum product supply for transport and domestic uses is dependent on imports from neighboring countries like Thailand. The country imported approximately 700 thousand barrels of petroleum products in 2010 (source: CIA World Fact book), while the country did not import natural gas due to non availability of gas transport infrastructure. Accordingly, power plant fueled with petroleum oil is considered as the alternative thermal power rather than natural gas-fired power plant because of difficulty in fuel import and transport. On the other hand, PDP[1] plans construction of lignite thermal power plants in Hongsa (300 MW x 2 units) in the northern region and Kalum (100 MW) in the southern region. However, lignite coal-fired power is normally considered as base power supply and has limited mobility to meet peak demand thus deemed unsuitable to be an alternative to the hydropower station.

Given background, “diesel power plant” and “liquid fuel-fired (simple cycle) gas turbine” were selected as alternative thermal power plant. Major assumptions of the both alternative thermal power plant options adopted for the analysis are as follows;

Table 8.1.4 Major Assumption Diesel Power Plant and Simple Cycle Gas Turbine

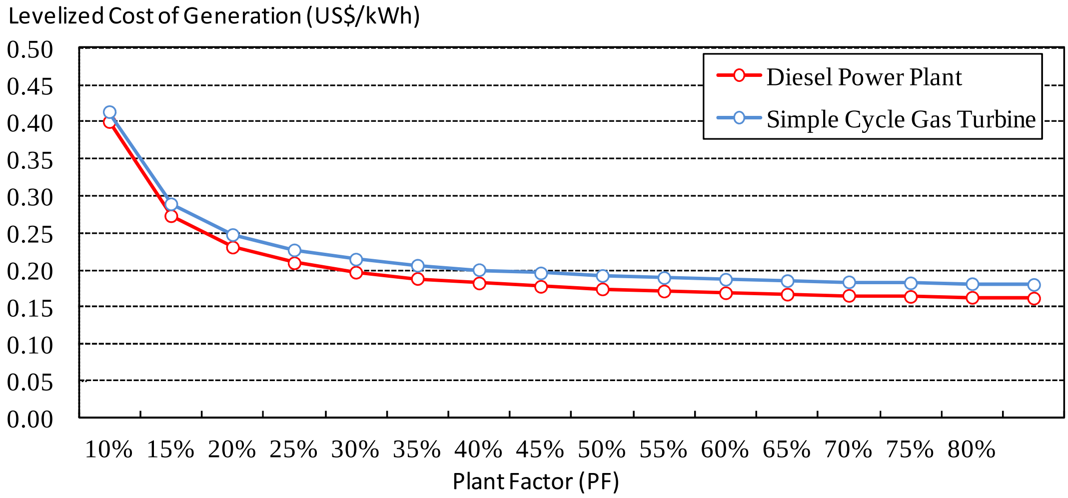
	Diesel power plant	Simple Cycle Gas Turbine
Fuel Type	Fuel Oil A (A-type Heavy Oil)	
Fuel Cost	0.6376 US$ per liter*1	
Calorific Value of Fuel	9,340.7 kcal/liter	
Construction Cost per kW	US$ 590 (Jan 2008)*2	US$ 635 (Jan 2008)*3
- Adjustment *7	US$ 658 (Jan 2012)	US$ 708 (Jan 2012)
Net Thermal Efficiency	43.0%*4	38.0%*5
Variable O&M Cost	US$ 0.0032 per kWh*4	US$ 0.0051 per kWh*6
Fixed O&M Cost	US$ 19.74 /kW/year*4	US$ 11.82 /kW/year*6
Economic Life	20 years	

Note:
*1 Average of import CIF price of Fuel Oil A (2% Sulfur) between Jan 2009 to May 2012, Lao State Fuel Company
*2 Average cost of 203-MW reciprocating diesel engine generator plant with in USA (US$ 590 per kW) and 5 MW Diesel Engine-Generator Plants in India (US$ 590 per kW), the cost includes such as mechanical and electrical auxiliaries, general facilities and engineering and installation. ESMAP Technical Paper 122/09, Dec. 2009. Transportation cost (4%) added.
*3 Average cost of 25 MW Simple Cycle Plant -Aeroderivative Gas Turbine (US$ 830 per kW) and 150-MW Simple Cycle Plant-

1 Power Development Plan PDP2010-2020 (Revision-1), EDL, August 2011

Heavy-Frame Gas Turbine (US$ 440 per kW) in India, the cost includes civil work, equipment, material, labor and installation. ESMAP Technical Paper 122/09, Dec. 2009.
*4 Feasibility Study on the Sihanoukville Combined Cycle Power Development Project in the Kingdom of Cambodia, 2002
*5 Simple Gas Turbine AD (oil) 35 MW, Energy Technology Expert.com 2009 September
*6 Cost Estimates for Thermal Peaking Plant, Electricity Commission, June 2008
*7 Transportation Cost is assumed to be 4% of construction cost. Price level was converted using CPI between 2008-2012 (7.21%)
Prepared by the JICA Survey Team

Using above-mentioned assumption, levelized generation cost of each alternative was calculated as the following figure. The figure indicates relation between plant factor (horizontal axis) and levelized generation cost at the respective plant factor (vertical axis). As the higher plant factor (PF) of generating unit, the lower generation cost will become. As the figure indicates, the diesel power station is more cost efficient than the liquid fuel-fired single cycle gas turbine; hence, the diesel power station is adopted as the alternative thermal power for the analysis.



Prepared by JICA Survey Team

Figure 8.1.1 Levelized Cost of Generation of Diesel Power Plants and Gas Turbine

(2) Calculation of Economic Benefit

The kW and kWh values were estimated based on following methodology.

1) Adjustment Factors

Generally speaking, a hydropower unit is normally more mechanically reliable than a thermal unit. Also, a hydropower unit has more flexibility in terms of fast-start capability and quick response to changing loads. In order to reflect these characteristics, an adjustment is applied to increase the capacity value of the hydropower project. This increase is applied because somewhat more thermal capacity is required than hydro capacity to reliably carry a given increment of peak load in a system. Power benefit can be calculated by multiplying firm capacity of hydropower station, kW- value and kW adjustment factor. Following formula is used for calculating the kW adjustment factor.

Such adjustment factors were calculated to adjust the difference between thermal power and hydropower in power and energy loss rates (see table below).

Table 8.1.5 Adjustment Factors of Thermal Plant

Item	Hydropower		Diesel Power Plant	
Transmission Loss	6.00% /1	A	6.00% /1	E
Overhaul and maintenance	0.00% /2	B	7.67% /1	F
Auxiliary Power Consumption	0.50% /1	C	4.00% /1	G
Forced outage	0.50% /1	D	2.19% /1	H
kW Adjustment Factor /3	-		1.142	I
kWh Adjustment Factor /4	-		1.036	J

注:
/1 F/S on the Sihanoukville Combined Cycle Power Development Project in the Kingdom of Cambodia, JICA (Jan. 2002)
/2 Scheduled overhaul and maintenance of hydropower is taken into calculation of energy generation
/3 I = ((1-A)*(1-B)*(1-C)*(1-D)) / ((1-E)*(1-F)*(1-G)*(1-H))
/4 J = ((1-A)*(1-C)) / ((1-E)*(1-G))
Prepared by JICA Survey Team

2) kW Value

The kW values are calculated based on the construction and fixed operating costs of the diesel power plants are shown in the following table.

Table 8.1.6 Calculation of kW Value

Item	Unit	Diesel Power
A Construction Cost per kW	US$/kW	657.8
B Economic Life	Years	20
C Discount Rate	%	10.0%
D Capital Recovery Factor		0.1175
E Fixed O&M Cost	US$/kW/Year	19.74
F kW Adjustment Factor		1.142
G kW Value (Power Value)	US$/kW	110.78

Note: G =(A x D + E) x F
Prepared by JICA Survey Team

3) kWh Value

The kWh values are calculated based on fuel cost and variable cost of the diesel power as shown in the following table.

Table 8.1.7 Calculation of kWh Value

Item	Unit	Diesel Power
A Fuel Type		Fuel Oil A (2% Sulfur)
B Fuel Price	US$/liter	0.6376
C Calorific Value of Fuel	kcal/liter	9340.66
D Thermal Efficiency	%	43.0%
E Heat Rate	kcal/kWh	2.000.02
F Fuel Consumption	Liter/kWh	0.21412
G Fuel Cost	US$/kWh	0.1365
H Variable O&M Cost	US$/kWh	0.0032
I kWh Value Adjustment Factor		1.0365
J kWh Value (Energy Value)	US$/kWh	0.1448

Note: J =(G + H) x I
Prepared by JICA Survey Team

4) Calculation of Annual Benefit

The following table shows the calculation of economic benefit based on kW and kWh values as well as generated energy and dependable capacity of the expansion project.

Table 8.1.8 Annual Energy and Capacity Benefits

Item	Unit	Without Project	With Project	Net
Annual Energy	GWh	1,117.00	1,176.00	59.00
Dependable Peak Capacity	MW	114.0	151.0	37.00
Energy Benefit: kWh Value	US$1,000	161,779	170,325	8,545
Capacity Benefit: kW Value	US$1,000	10,059	13,324	3,265
Total Annual Benefit	US$1,000	171,839	183,649	11,810

Prepared by JICA Survey Team

8.1.5 CALCULATION OF EIRR

The cash flow projection is developed based on the economic cost and benefit presented above. Based on Table 8.1.9, the calculated EIRR is 16.3%. The computed NPV is US$32,295 thousand and B/C is 1.71 with 10% discount rate. The results show the EIRR exceeding the 10% social discount rate and with positive NPV value. Therefore, the project is evaluated economically feasible.

Table 8.1.9 Calculation of EIRR (Base Case)

Year		Cost			Benefit			Net Benefit
		Construction & Reinvestment	Operation & Maintenance	Total	Capacity Benefit	Energy Benefit	Total	
1	2013	1,808	0	1,808	0	0	0	-1,808
2	2014	5,895	0	5,895	0	0	0	-5,895
3	2015	19,110	0	19,110	0	0	0	-19,110
4	2016	19,098	0	19,098	0	0	0	-19,098
5	2017	14,812	0	14,812	0	0	0	-14,812
6	2018	0	300	300	4,099	8,545	12,644	12,344
7	2019	0	300	300	4,099	8,545	12,644	12,344
8	2020	0	300	300	4,099	8,545	12,644	12,344
9	2021	0	300	300	4,099	8,545	12,644	12,344
10	2022	0	300	300	4,099	8,545	12,644	12,344
11	2023	0	300	300	4,099	8,545	12,644	12,344
12	2024	0	300	300	4,099	8,545	12,644	12,344
13	2025	0	300	300	4,099	8,545	12,644	12,344
14	2026	0	300	300	4,099	8,545	12,644	12,344
15	2027	0	300	300	4,099	8,545	12,644	12,344
16	2028	0	300	300	4,099	8,545	12,644	12,344
17	2029	0	300	300	4,099	8,545	12,644	12,344
18	2030	0	300	300	4,099	8,545	12,644	12,344
19	2031	0	300	300	4,099	8,545	12,644	12,344
20	2032	0	300	300	4,099	8,545	12,644	12,344
21	2033	0	300	300	4,099	8,545	12,644	12,344
22	2034	0	300	300	4,099	8,545	12,644	12,344
23	2035	0	300	300	4,099	8,545	12,644	12,344
24	2036	0	300	300	4,099	8,545	12,644	12,344
25	2037	0	300	300	4,099	8,545	12,644	12,344
26	2038	0	300	300	4,099	8,545	12,644	12,344
27	2039	0	300	300	4,099	8,545	12,644	12,344
28	2040	0	300	300	4,099	8,545	12,644	12,344
29	2041	0	300	300	4,099	8,545	12,644	12,344
30	2042	0	300	300	4,099	8,545	12,644	12,344
31	2043	0	300	300	4,099	8,545	12,644	12,344
32	2044	0	300	300	4,099	8,545	12,644	12,344
33	2045	0	300	300	4,099	8,545	12,644	12,344
34	2046	0	300	300	4,099	8,545	12,644	12,344
35	2047	17,236	300	17,536	4,099	8,545	12,644	-4,892
36	2048	0	300	300	4,099	8,545	12,644	12,344
37	2049	0	300	300	4,099	8,545	12,644	12,344
38	2050	0	300	300	4,099	8,545	12,644	12,344
39	2051	0	300	300	4,099	8,545	12,644	12,344
40	2052	0	300	300	4,099	8,545	12,644	12,344
41	2053	0	300	300	4,099	8,545	12,644	12,344
42	2054	0	300	300	4,099	8,545	12,644	12,344
43	2055	0	300	300	4,099	8,545	12,644	12,344
44	2056	0	300	300	4,099	8,545	12,644	12,344
45	2057	0	300	300	4,099	8,545	12,644	12,344
46	2058	0	300	300	4,099	8,545	12,644	12,344
47	2059	0	300	300	4,099	8,545	12,644	12,344
48	2060	0	300	300	4,099	8,545	12,644	12,344
49	2061	0	300	300	4,099	8,545	12,644	12,344
50	2062	0	300	300	4,099	8,545	12,644	12,344
51	2063	0	300	300	4,099	8,545	12,644	12,344
52	2064	0	300	300	4,099	8,545	12,644	12,344
53	2065	0	300	300	4,099	8,545	12,644	12,344
54	2066	0	300	300	4,099	8,545	12,644	12,344
55	2067	-5,745	300	-5,445	4,099	8,545	12,644	18,089
Total		72,214	15,007	87,222	204,940	427,260	632,200	544,978
Discount Rate:		10.0%	PV (Cost):	45,546			PV (Benefit):	77,841
							EIRR:	16.31%
							NPV:	32,295
							B/C:	1.71

Prepared by the JICA Survey Team

8.1.6 SENSITIVITY ANALYSIS

(1) Conditions for Analysis

Economic benefit-cost analysis is based on forecasts of quantifiable variables such as construction costs, energy generation and fuel price for alternative thermal power plant. The values of these variables are estimated based on the most probable forecasts, which cover a long period of time. The values of these variables for the most probable outcome scenario are influenced by a great number of factors, and the actual values may differ considerably from the forecasted values, depending on future developments. It is therefore useful to consider the effects of likely changes in the key variables on the viability of a project. Sensitivity analysis was made using following adverse scenarios.

Case 1 The project cost increase by (a) 10%; (b) 20%

Case 2 The fuel cost of alternative thermal power decreases by (a) 10%; (b) 20%

Case 3 The project cost increases by 20% and the fuel cost of alternative thermal power decreases by 20%

(2) Results

The results of the sensitivity analysis are shown in Table 8.1.10 below. The computed EIRRs in the different cases range from 12.2% to 15.4% which exceed the 10% discount rate. Even in Case 3 with the most unfavorable conditions, the project shows that it is still economically feasible.

Table 8.1.10 Results of Sensitivity Analysis

Case			EIRR	NPV
Base Case			16.3%	US$ 32.30 million
Case 1	Project Cost Increase	(a) 10%	15.0%	US$ 27.74 million
		(b) 20%	13.9%	US$ 23.19 million
Case 2	Fuel Cost of Alternative thermal Decrease	(a) 10%	15.4%	US$ 21.16 million
		(b) 20%	14.4%	US$ 22.02 million
Case 3	Project cost increase 20% + fuel cost of alternative thermal decreases 20%		12.2%	US$ 12.91 million

Prepared by JICA Survey Team

8.2 FINANCIAL ANALYSIS

8.2.1 METHODOLOGY

The financial analysis aims at evaluating the project's financial profitability from the executing agency's viewpoint through calculation of the financial internal rate of return (FIRR). The same assumptions in economic analysis are applied for the project life, cost estimation, price escalation, and interest during construction.

As mentioned in Chapter 9, EDL and EDL-Gen will share rights and responsibilities during implementation and operation phase of the Project. Therefore, essentially, both EDL and EDL-Gen are regarded as the owner of the project. For this reasons, calculation of FIRR was made from view point of the EDL group as a whole.

8.2.2 FINANCIAL COST

The costs of the expansion project consist of the initial investment cost (construction cost) estimated at market (financial) price in Chapter 7, the O&M cost and the reinvestment (replacement cost) calculated based on the conditions presented in the economic analysis.

(1) Initial Investment (Construction Cost)

Table 8.2.1 shows the initial investment (construction cost) at financial price by major item.

Table 8.2.1 Initial Investment Cost (Financial Price)

(Unit: US$ 1,000)

Description	1st Year		2nd Year		3rd Year		4th Year		5th Year		Total		
	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	FC	LC	Total
I. Construction Cost													
Civil Works	0	0	1,179	689	4,715	2,754	4,715	2,754	3,536	2,066	14,146	8,263	22,409
Hydro-mechanical Works	0	0	124	22	498	88	498	88	373	66	1,493	263	1,757
Electro-mechanical Works	0	0	1,631	102	6,523	407	6,523	407	4,893	305	19,570	1,221	20,791
Total Base Cost	0	0	2,934	812	11,736	3,249	11,736	3,249	8,802	2,437	35,209	9,747	44,957
Physical Contingency (10%)	0	0	293	81	1,174	325	1,174	325	880	244	3,521	975	4,496
Total Construction Cost	0	0	3,228	894	12,910	3,574	12,910	3,574	9,683	2,681	38,730	10,722	49,452
II. Consulting Services													
Base Cost	1,605	41	1,435	43	1,781	60	1,769	61	1,758	59	8,348	264	8,612
Physical Contingency (5%)	80	2	72	2	89	3	88	3	88	3	417	13	431
Total Construction Cost	1,685	43	1,506	45	1,871	63	1,858	64	1,846	62	8,766	277	9,043
III. Administration Cost													
Administration Cost	0	86	0	284	0	921	0	920	0	714	0	2,925	2,925
TOTAL (I to III)	1,685	129	4,734	1,222	14,781	4,558	14,768	4,558	11,529	3,456	47,496	13,924	61,420
TOTAL (FC + LC)	1,814		5,956		19,338		19,326		14,985		61,420		

Prepared by JICA Survey Team

(2) O&M Cost

Table 8.2.2 shows the O&M cost of the project including physical contingency.

Table 8.2.2 O&M Cost (Financial Price)

(Unit: US$ 1,000)

Item	Construction Cost (incl. Physical Contingency)	Factor	O&M Cost
Civil Works (excl. Temporary Works)	13,986	0.50%	70
Hydro-mechanical Works			
Intake Gate and Hoist	600	0.75%	4
Trash Rack and Stop Log	478	0.25%	1
Electro-mechanical Works	22,661	1.00%	227
Total	---	---	302

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(3) Reinvestment (Replacement Cost)

Table 8.2.3 shows the reinvestment cost (replacement cost) of the project including physical contingency.

Table 8.2.3 Reinvestment Cost (Financial Price)

(Unit: US$ 1,000)

Item	Construction Cost (incl. Physical Contingency)	Factor	Reinvestment Cost
Hydro-mechanical Works	600	5%	30
Electro-mechanical Works			
Turbine and Generator	18,012	70%	12,608
Others	4,649	100%	4,649
Total	---	---	17,287

Prepared by the JICA Survey Team

8.2.3 FINANCIAL BENEFIT

FIRR in the EDL's viewpoint is calculated in case that the EDL domestic tariff revenue is taken as the financial benefit of the project. Taking into account the tariff increase recently approved by the government (20% in 2012 and annual 2% from 2013 to 2017), it applies the average domestic tariff as of 2017 (741 Kip/kWh or 9.39 US cents) increased from the current level (559 Kip/kWh). The projection applies the same assumptions, cost estimates and generation outputs as in the previous FIRR calculation. The financial benefits are estimated as per the table below.

Table 8.2.4 Financial Benefit (Electricity Revenue)

Item	Unit	Without Project	With Project	Net
Annual Energy	GWh	1,117.00	1,176.00	59.00
Loss Rates				
Auxiliary Consumption	%	0.5%	0.5%	
Forced Outage	%	0.5%	0.5%	
Transmission Loss	%	6.0%	6.0%	
Electricity Sold	GWh	1,039.51	1,094.41	54.91
Electricity Revenue	US$1,000	97,610	102,765	5,156

Prepared by the JICA Survey Team

8.2.4 WEIGHTED AVERAGE COST OF CAPITAL (WACC)

The financial viability of the project is evaluated based on a comparison of its FIRR to the Weighted Average Cost of Capital (WACC). The WACC represents the cost incurred by the entity in raising the capital necessary to implement the project. Since most projects use several sources to raise capital and each of these sources may seek a different return, the WACC represents a weighted average of the different returns paid to these sources.

WACC is expressed as a percentage, like interest, and is used to see if certain investments or project are worthwhile to undertake. For example if a certain investment or a whole finance structure of a project with a WACC of 5%, the investment or the project should be made that give a higher FIRR than the WACC of 5%. The post-tax WACC in real term can be worked using following formula.

$$WACC = W_e\left(\frac{1+r_e}{1+i}-1\right)+W_d \times\left(\frac{1+r_d \times(1-t_c)}{1+i}-1\right)$$

where

we:	Weight of the equity	wd:	Weight of the debt	tc:	Corporate tax rate
re:	Cost of the equity	rd:	Cost of the debt (pre-tax)	i:	inflation rate

Using following assumption, the post-tax real WACC was computed as 4.63% applying the minimum rate test of 4%[*2] for cost of debt.

Table 8.2.5 Calculation of WACC

Item	Debt	Equity	Note
Weight	85%	15%	Debt: Equity Ratio: 85:15, estimate
Nominal Cost	0.550%	10.00%	Debt: General Condition of ODA Loan for Laos, Equity: Estimate
Corporate Tax Rate	35.00%	-	Tax adjustment is made only for debt portion
Tax Adjusted Cost	0.358%	10.00%	Nominal Cost x (1 – corporate tax rate)
Inflation Rate	-2.005%	1.756%	Debt: Inflation rate gap between Japan (-0.249%) – Major advanced economy: G7 (1.756%), 2007-2011 average Equity: Major advanced economy (G7) 2007-2011 average
Real Cost	2.411%	8.102%	(1+nominal cost)/(1+inflation rate)-1
Minimum Rate Test	4.000%	8.102%	Following ADB Guideline, each component should be at least 4.0%. If not, replace the derived value with 4.0%.
Weighted Component of WACC	3.400%	1.215%	Debt: weight 85% x E (4.000%), Equity: 15% x E (8.102%)
WACC	4.625%		Weighted Component of WACC: Debt + Equity

Prepared by the JICA Survey Team

8.2.5 CALCULATION OF FIRR

The cash flow projection is developed based on the aforementioned financial cost and benefit to calculate the FIRR tabulated in Table 8.2.6. The calculated FIRR is 6.72%, which is marginally higher than the WACC of 4.63%. Accordingly, the project is deemed financially viable when utilizing

2 Source: the Guidelines for the Financial Governance and Management of Investment Projects Financed, ADB

Japanese ODA loan. Cheap domestic tariff level is considered as a major factor contributory to the low FIRR. The increase in peak capacity cannot be reflected in the FIRR calculation because of the absence of TOD rates in the domestic tariff system.

8.2.6 SENSITIVITY ANALYSIS

Financial benefit-cost analysis is based on forecasts of quantifiable variables such as construction costs, energy generation and electricity tariff. The values of these variables for the most probable outcome scenario are influenced by external and/or internal factors. It is therefore useful to consider the effects of likely changes in the key variables on the viability of a project. Sensitivity analysis was made using following adverse scenarios.

Case 1 The project cost increase by (a) 10%; (b) 20%

Case 2 EDL's average domestic retail tariff in 2018 lower than the envisaged by (a) 10%; (b) 20%

Table 8.2.7 Results of Sensitivity Analysis

Case			FIRR	NPV
Base Case			6.72%	US$ 19.76 million
Case 1	Project Cost Increase	(a) 10%	5.98%	US$ 13.77 million
		(b) 20%	5.34%	US$ 7.79 million
Case 2	Domestic Average Tariff lower than the envisaged	(a) 10%	5.91%	US$ 11.80 million
		(b) 20%	5.05%	US$ 3.83 million
Case 3	Project Cost increase by 20% and Domestic Tariff lower by 20% than the envisaged		3.83%	- US$ 8.14 million

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As shown in the above table, other than case 3, the project is sufficiently robust to withstand the adverse assumptions. However, when substantial cost overrun and insufficient tariff increase will happen simultaneously (case 3: most negative scenario), the project will lose its financial viability. Therefore, EDL need to carefully supervise capital investment cost during implementation period, also need to implement domestic tariff increase as planned. Particularly, domestic tariff revision needs to index linked, means that it shall increased with inflation, to ensure real tariff increase.

Table 8.2.6 Calculation of FIRR (Base Cse)

(Unit: US$ 1,000)

Year		Cost			Benefit	Net Benefit
		Construction & Reinvestment	Operation & Maintenance	Total		
1	2013	1,814	0	1,814	0	-1,814
2	2014	5,956	0	5,956	0	-5,956
3	2015	19,338	0	19,338	0	-19,338
4	2016	19,326	0	19,326	0	-19,326
5	2017	14,985	0	14,985	0	-14,985
6	2018	0	302	302	5,156	4,854
7	2019	0	302	302	5,156	4,854
8	2020	0	302	302	5,156	4,854
9	2021	0	302	302	5,156	4,854
10	2022	0	302	302	5,156	4,854
11	2023	0	302	302	5,156	4,854
12	2024	0	302	302	5,156	4,854
13	2025	0	302	302	5,156	4,854
14	2026	0	302	302	5,156	4,854
15	2027	0	302	302	5,156	4,854
16	2028	0	302	302	5,156	4,854
17	2029	0	302	302	5,156	4,854
18	2030	0	302	302	5,156	4,854
19	2031	0	302	302	5,156	4,854
20	2032	0	302	302	5,156	4,854
21	2033	0	302	302	5,156	4,854
22	2034	0	302	302	5,156	4,854
23	2035	0	302	302	5,156	4,854
24	2036	0	302	302	5,156	4,854
25	2037	0	302	302	5,156	4,854
26	2038	0	302	302	5,156	4,854
27	2039	0	302	302	5,156	4,854
28	2040	0	302	302	5,156	4,854
29	2041	0	302	302	5,156	4,854
30	2042	0	302	302	5,156	4,854
31	2043	0	302	302	5,156	4,854
32	2044	0	302	302	5,156	4,854
33	2045	0	302	302	5,156	4,854
34	2046	0	302	302	5,156	4,854
35	2047	17,287	302	17,589	5,156	-12,433
36	2048	0	302	302	5,156	4,854
37	2049	0	302	302	5,156	4,854
38	2050	0	302	302	5,156	4,854
39	2051	0	302	302	5,156	4,854
40	2052	0	302	302	5,156	4,854
41	2053	0	302	302	5,156	4,854
42	2054	0	302	302	5,156	4,854
43	2055	0	302	302	5,156	4,854
44	2056	0	302	302	5,156	4,854
45	2057	0	302	302	5,156	4,854
46	2058	0	302	302	5,156	4,854
47	2059	0	302	302	5,156	4,854
48	2060	0	302	302	5,156	4,854
49	2061	0	302	302	5,156	4,854
50	2062	0	302	302	5,156	4,854
51	2063	0	302	302	5,156	4,854
52	2064	0	302	302	5,156	4,854
53	2065	0	302	302	5,156	4,854
54	2066	0	302	302	5,156	4,854
55	2067	-5,762	302	-5,460	5,156	10,616
Total		93,508	72,945	15,112	88,056	257,787

FIRR:	**6.72%**
NPV:	**19.763**
B / C:	**1.33**

Prepared by JICA Survey Team

8.3 EFFECTS TO ELECTRICITY TRADE BALANCE

As explained in 8.1.4, the economic analysis is made through the alternative thermal power method to calculate the project's effect to the national economy. On the other hand, the imported energy could be also regarded as the alternative to the economic benefit of the project. Hence, in this section, the economic effect of the project to the electricity trade balance with Thailand (EGAT) is estimated based on the demand-supply forecast presented in Chapter 5, as supplement to the economic analysis through the alternative thermal power method.

(1) Electricity Trade Tariff

The current electricity trade tariff with EGAT is shown in Table 8.3.1. In C1 grid, EDL exports its excess energy to EGAT and also imports energy as needed. The tariff system for C1 has characteristics of (i) small price difference between peak time and off-peak time and (ii) THB 0.14/kWh higher basic import tariff than export to EGAT. In case EDL imports exceed exports in a year, additional surcharge payment is required. The surcharge calculation is based on the domestic tariff in Thailand. In short, the excess import by EDL is virtually charged similar prices to those for large-scale customers in Thailand.

Table 8.3.1 Electricity Trade Tariff with EGAT

	Note	Export to EGAT	Import from EGAT
Peak	Mon-Fri: 09:00 – 22:00	1.60 THB/kWh	1.74 THB/kWh
Off-peak	Mon-Fri: 22:00 – 09:00 Holidays: 24 Hours	1.20 THB/kWh	1.34 THB/kWh

Source: EDL

(2) Change in Trade Balance by the Project

Table 8.3.2 shows the projected change in the electricity trade balance by the NN1 expansion in 2017, 2020 and 2025. Peak power supply strengthened by the project will improve the trade balance with EGAT by US$ 3.4 million to US$ 4.1 million annually. These are regarded as the economic benefit of the project if the imported energy is deemed as the alternative to the energy from NN1 hydropower station.

Table 8.3.2 EDL Trade Deficit and Surcharge Payment

Year	Unit	Trade Balance of EDL over EGAT		
		A. Without Project	B. With Project	C. Benefit (B-A)
2017	1,000 THB	-58,568	74,127	132,695
	1,000 US$	-1,828	2,314	4,142
2020	1,000 THB	10,061,392	10,169,629	108,237
	1,000 US$	314,026	317,404	3,378
2025	1,000 THB	7,189,885	7,306,842	116,957
	1,000 US$	224,403	228,054	3,650

Note: Exchange used, 1 US$= 32.04 Thai Baht, Bank of Thailand May 2012
Prepared by the JICA Survey Team

On the other hand, in the point of view of EDL, or the executing agency of the project, this projected change in trade balance could be also considered as financial benefit in its financial management.

(3) Estimation of EIRR

The EIRR is estimated by applying the improvement of trade balance as benefit (the benefit in 2025 is assumed for the yearly benefit from 2026). Other preconditions are adopted from the economic analysis. The calculated EIRR and NPV are 3.78% and US$ -24.7 million, respectively. Estimated EIRR is far lower than the discount rate of 10%. The low IRR in this analysis is primarily because of the low tariff level with small peak energy value. It does not necessarily reflect the economic value of alternative energy source to the project for Lao PDR.

CHAPTER 9 ORGANIZATIONAL FRAMEWORK FOR PROJECT IMPLEMENTATION AND O&M

9.1 PROJECT IMPLEMENTATION

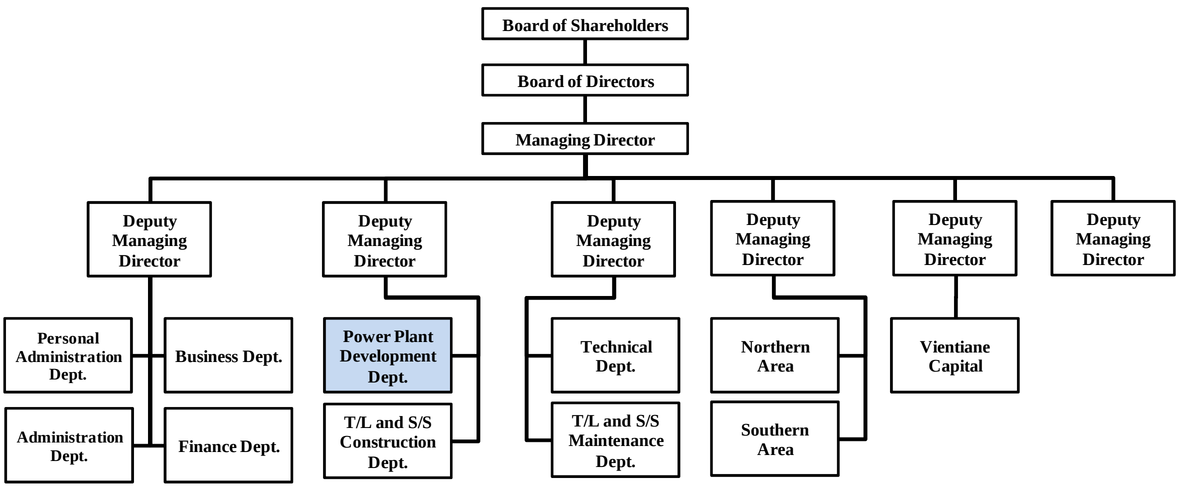
(1) Project Implementation System

Electricite du Laos (EDL) will be the implementing agency for the Nam Ngum 1 Hydropower Station Expansion, including its design, procurement and construction. EDL will establish, as their common practice, the Project Management Unit (PMU) which has specific function and authority for implementing the Nam Ngum 1 expansion.

(2) Jurisdiction, Organization and Staffing

EDL was established in 1959 as an electricity department of the Ministry of Public Utilities. EDL was then incorporated as a public service corporation in 1997. According to the directives of the Government of Lao for its business restructuring on electricity industries, while EDL is still responsible for development of hydropower projects, operation and maintenance of the completed projects had transferred to newly established EDL-Gen (profile of EDL-Gen and its responsibilities will be mentioned in 9.2). Also, EDL is in charge of electrical transmissions in the national level as well as the design, construction, operation/ management of power distribution equipment, and managing importing and exporting power with neighboring countries.

Figure 9.1.1 shows the present organization of EDL.



Source: EDL

Figure 9.1.1 Organization of EDL

Among the structure above, Power Plant Development Department is in charge of the study, design, procurement and construction of EDL's hydropower projects. This department consists of eight (8) offices including five (5) PMUs as seen in Table 9.1.1.

Table 9.1.1 Power Plant Development Department

Section	No. of Staffs	Function
Department Office	14	Coordination of each office
Generation Design Study Office	13	Survey, F/S, design of dam/power projects
Machinery Maintenance Office	21	Planning of maintenance & repair
PMU (Houay Lamphan Gnai)	41	Construction supervision till 2015
PMU (Nam Khan 2)	37	Construction supervision till 2015
PMU (Nam Khan 3)	4	Construction will start at the end of 2012.
PMU (Nam Sana)	19	Construction supervision till 2014
PMU (Nam Hinboun)	2	Construction will start at the end of 2012.

Source: EDL

Meanwhile, Environment Office in Transmission Line and Substation Construction Department is in charge of environmental and social considerations of EDL's hydropower projects.

(3) Financial Affairs and Budget

Table 9.1.2 presents the financial statements of EDL from 2007 to 2011. Its salient features are characterized as follows:

1) Profitability

EDL has recorded a constant net profit from 2007 to 2010. Its operational profit rates have been as low as 1% to 4%, except in 2008 when the revenue was significantly higher, reflecting an energy sales increase by 279 GWh from the previous year. However, the company ran a large deficit in 2011, partially due to commencement of power purchase from newly established EDL-Gen.

After the EDL-Gen's establishment in December 2010, seven hydropower station previously owned and operated by EDL and related liability and employee has transferred to EDL-Gen. Power purchase price between EDL and EDL-Gen was designed to cover full cost of service. This enables EDL-Gen to gain reasonable profit (see "9.2 (3) Financial Affairs and Budget of EDL-Gen" for detail). On the other hand, the government failed to increase the domestic tariff originally envisaged during 2011. These resulted in EDL's loss making operation in the year. To ameliorate EDL's financial conditions, in March 2012, Ministry of Energy and Mining approved 20% tariff increase during 2012, and 2% increase per year during 2013 -2017.

The return on assets (ROA) was also low at around -0.1% to 2.9%, mainly due to its low domestic tariff level. EDL has constantly received in-kind subsidy in the form of additional capital contribution from the government, which accounts for 12,480 million Kip in 2010 and 67,748 min 2011.

2) Debt

As a state-owned company, EDL funding relies on capital contribution from the government and borrowings from external assistance loans from JBIC, World Bank, ADB, etc., denominated in foreign currencies. Its debt equity ratio accounts for around 0.65 to 0.75 indicating that the company had been not heavily in debt during the period. However, the ratio was worsened to 1.30 in 2011 due to additional borrowing for the new projects (including two hydropower projects; Nam Khan 2: 127 MW and Houay Lampan Ngai: 88MW). After the commencement of commercial operation of the hydropower stations, related liabilities will be transferred to EDL-Gen.

The recent debt service coverage ratios (0.90 in 2010 and 0.57 in 2011) show that the operating cash flow of EDL cannot cover the debt service, mainly due to its low profitability.

3) Liquidity

The current liquidity ratio in 2010 (0.81) and 2011 (0.50) is below 1.0, indicating that the company has less capacity to meet short-term obligations. On the other hand, the debtor days, which indicates the average revenue collection period, has been improved from 123 days in 2007 to 67 days in 2011.

Table 9.1.2 Summary of Financial Status of EDL (2007-2011)

(million Kip)

Item	2007	2008	2009	2010	2011
BALANCE SHEET					
Assets	7,767,989	8,165,134	9,433,554	8,986,514	12,900,719
Current Assets	**695,103**	**877,666**	**894,051**	**705,260**	**908,061**
Cash and Cash Equivalents	215,886	393,712	356,683	126,200	70,703
Account Receivables (trade & other receivables)	359,902	350,224	341,534	349,475	367,017
Other Receivables (other current assets)	14,481	18,792	39,132	49,039	254,989
Inventories	104,834	114,938	156,702	180,546	215,352
Fixed Assets	**7,072,886**	**7,287,468**	**8,539,503**	**8,281,254**	**11,992,658**
Joint Venture Investments	301,414	427,682	557,751	3,256,990	3,277,312
Fixed Assets	6,771,472	6,859,786	7,981,752	5,024,264	8,715,346
Liabilities and Equity	7,767,989	8,165,134	9,433,554	8,986,514	12,900,719
Liabilities	**2,903,186**	**3,030,090**	**4,055,443**	**3,485,000**	**7,302,477**
Current Liabilities	**511,419**	**688,091**	**896,660**	**875,512**	**1,817,923**
Trade and Other Payables	267,994	313,235	552,752	589,335	1,272,540
Current Income Tax Liabilities	0	51,982	11,906	62,530	6,296
Current Portion of LT Borrowings	189,877	274,682	296,352	175,835	504,646
Other Current Liability	53,548	48,192	35,650	47,812	34,441
Non-current Liabilities	**2,391,767**	**2,341,999**	**3,158,783**	**2,609,488**	**5,484,554**
Long-term Borrowings	2,310,498	2,107,640	3,077,652	2,609,488	5,484,554
Other Non-current Liabilities	81,269	234,359	81,131	0	0
Equity	**4,864,803**	**5,135,044**	**5,378,111**	**5,501,514**	**5,598,242**
Contributed Legal Capital (share capital)	618,210	618,210	655,800	668,228	735,976
Retained Earnings	1,806,842	2,165,560	2,373,199	2,475,053	2,459,297
Revaluation Surplus	2,305,168	2,166,868	2,166,868	2,166,868	2,166,868
Other Reserves	134,583	184,406	182,244	191,365	236,101
INCOME STATEMENT					
Revenues	1,067,457	1,274,384	1,485,535	1,688,969	1,952,050
Cost of Sales	(815,454)	(765,631)	(1,042,199)	(1,069,593)	(1,902,779)
Gross Profit	**252,003**	**508,753**	**443,336**	**619,376**	**49,271**
Administrative Expenses	(200,948)	(271,514)	(423,283)	(503,299)	(453,640)
Profit from Operations	**51,055**	**237,239**	**20,053**	**116,077**	**(404,369)**
Non-operating Income	180,878	143,908	277,427	180,080	518,380
Other Non-operating Income (Exchange Difference)	1,607	24,132	105,691	33,654	52,238
Financial Expenses (interest expenses)	(102,480)	(91,091)	(118,447)	(132,728)	(136,299)
Profit Before Income Tax	**131,060**	**314,188**	**284,724**	**197,083**	**29,950**
Income Tax Expense	(26,728)	(81,291)	(56,554)	(34,817)	(45,706)
Net Profit for the Year	**104,332**	**232,897**	**228,170**	**162,266**	**(15,756)**
Item	**2007**	**2008**	**2009**	**2010**	**2011**
FINANCIAL RATIOS					
Profitability					
(1) Operational Profit Rate	4.8%	18.6%	1.3%	6.9%	-20.7%
(2) Return on Assets	1.3%	2.9%	2.4%	1.8%	-0.1%
Debt					
(3) Debt Equity Ratio	0.60	0.59	0.75	0.63	1.30
(4) Debt Service Coverage Ratio	1.32	1.79	1.39	0.90	0.57
Liquidity					
(5) Current Ratio	1.36	1.28	1.00	0.81	0.50
(6) Receivables Turnover	2.97	3.64	4.35	4.83	5.32
(7) Debtor Days	123.1	100.3	83.9	75.5	68.6

Note: (1) Operational Profit Rate = Profit from Operations / Revenues
(2) Return on Assets = Net Profit / Total Assets
(3) Debt Equity Ratio = Total Liabilities / Total Equity
(4) DSCR = Cash Generated from Operations / (Repayments of Borrowings + Financial Expenses)
(5) Current Ratio = Current Assets / Current Liabilities
(6) Receivables Turnover = Revenues / Account Receivables
(7) Debtor Days = 365 days / Receivables Turnover

Source: JICA Study Team based on Audited Financial Statement of EDL 2008, 2010 and 2011

(4) Required Skills

In general, problems concerning; i) procurement or ii) environment have often become the apparent impediments for smooth project implementation under ODA.

EDL has experienced implementation of Nam Leuk hydropower project which was financed by international fund institutions of ADB and JBIC (JICA). Through that experience, EDL has acquainted with general principles and procedures laid down in the guidelines by respective institutions. It is judged that with a proper assistance they will be able to manage the project implementation of the Nam Ngum 1 expansion without the need for modification of their current organization, except establishing the PMU.

(5) Experience of Implementation of Similar Project

Experience of implementation of similar project by EDL after 1997 is tabulated in Table 9.1.3.

Table 9.1.3 Experience of Implementation in Similar Project by EDL

Location	Power Plant	Installed Capacity (MW)	Fund Source	Status
North	Nam Khan 2	130	China	On-going
Central				
Vientiane	Nam Leuk	60	ADB, JBIC	Completed
Vientiane	Nam Mang 3	40	China	Completed
Vientiane	Nam Song	6	EDL	Completed
South				
Saravanh	Xeset 2	76	China	Completed
Xekong	Hoay Lamphan Gnai	88	China	On-going (COD: 2012)
Total		**400**		

Source: EDL

9.2 OPERATION AND MAINTENANCE

(1) Operating Structure after the Completion of the Project

As mentioned, EDL will implement the Nam Ngum 1 expansion project. Then after completion of the project, EDL-Gen will be the responsible agency for operation and maintenance of the project facilities.

EDL-Gen was established in 2010 in accordance with the Prime Minister's decision No.180 (PMO 180). This decree separated the six existing hydropower plant assets of EDL[1] and their operation. Currently 75% of EDL-Gen's shock is owned by EDL, while remaining 25% is owned by private investors.

Assets and liabilities of the head office building and the six existing hydropower projects previously owned by EDL have been transferred to EDL-Gen[2] at its incorporation date on 15 December 2010. At the same time, operation and maintenance of these power stations were transferred to EDL-Gen, based on concession agreement[3]. At the end of concession period, EDL-Gen must transfer to the Government of Laos or its nominee all the company's right in the projects and assets held by the company for operating the projects.

However, in case of the Nam Ngum 1 expansion project, asset and liability transfer scheme might be different from the previous cases. During the concession period, EDL might lease project facilities to EDL-Gen and will receive lease fee from EDL-Gen. It is thought that lease fee will be determined in order to cover debt service payment from EDL to MoF. At the time of study, methodology and condition of the lease arrangement between EDL and EDL-Gen was discussed among concerned agencies of Laos side, and had not determined yet. Implementation scheme and lease arrangement between EDL and EDL-Gen should be confirmed before the project implementation.

(2) Jurisdiction, Organization and Staffing

The current model of EDL-Gen's business is to own and operate the EDL Hydropower Generation Assets, and sell all of the electricity production to EDL, which is responsible for the transmission and distribution in Lao PDR.

EDL-Gen currently owns power generation assets with a combined installed capacity of 387 MW and an average annual energy of about 1,800-1,900 GWh per year. Through its operating power plants, EDL-Gen currently controls approximately 16 percent of the total installed generation capacity in Lao

[1] Six transferred hydropower stations on 15 December 2011 are Nam Ngum 1 (155 MW), Nam Leuk (60 MW), Nam Mong 3 (40 MW), Xeset 1 (45 MW), Xeset 2 (76 MW) amd Xelabam (5 MW). Total net assets transferred to EDL to EDL-Gen was 2,605,792 mil. Kip, which consists of property, plant, equipment and supplies (3,927,926 mil. Kip), account receivable (3,737 mil Kip), long-term borrowing and interest payable (-1,543,113 mil. Kip) and accounts payable (-96 mil. Kip)

[2] Based on the Prime Minister's decision No.180, in addition to the existing six hydropower project, the Nam Song hydropower plant, which commissions in 2012, will be also transferred to EDL-Gen.

[3] The existing concession agreement for these six power plants provides for a term of 30 years, together with a renewal period of 10 years.

PDR, including EDL IPPs and Non-EDL IPPs.

According to the MOU on the Transfer of the Project Assets between EDL-Gen and EDL dated 8 July 2011, EDL will also transfer the assets and liabilities of Houay Lamphan Gnai (88MW, COD: 2015) and Nam Khan 2 (130MW, COD: 2014) to EDL-Gen before or on the commercial operation date of both projects.

In addition, on 8 July 2011, EDL-Gen has entered in to the MOU with EDL on EDL's shares transfer of the four hydropower IPP projects. In July 2012, pursuant to the MOU, EDL-Gen purchased the shares held by EDL representing EDL's equity shareholdings in IPPs as follows. The acquisition of four IPPs costs EDL-Gen around US$ 202 million. In order to raise fund for this transaction, EDL-Gen newly issued shares worth US$ 200 million in July 2012 (detail will be mentioned in the following section).

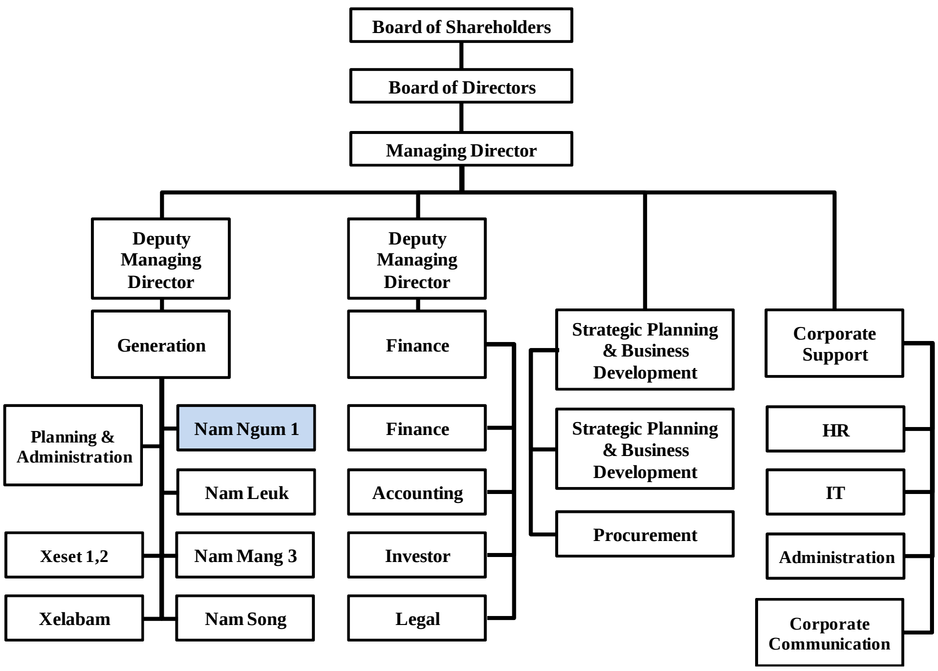
Table 9.2.1 Shares Transfer of IPP to EDL-Gen

Power Plant	Installed Capacity	Percent of Total Share
Theun-Hinboun + Expansion	440 MW	60%
Houy Ho	152 MW	20%
Nam Lik 1-2	100 MW	10%
Nam Ngum 2	615 MW	25%

Source: EDL-Gen

In short, EDL-Gen will increase its power generation capacity by i) acquiring EDL's stake in several existing and planned Independent Power Producer (IPPs) in Lao PDR and ii) acquiring concession rights of EDL's projects through assets and liabilities transfer from EDL or lease contract with EDL.

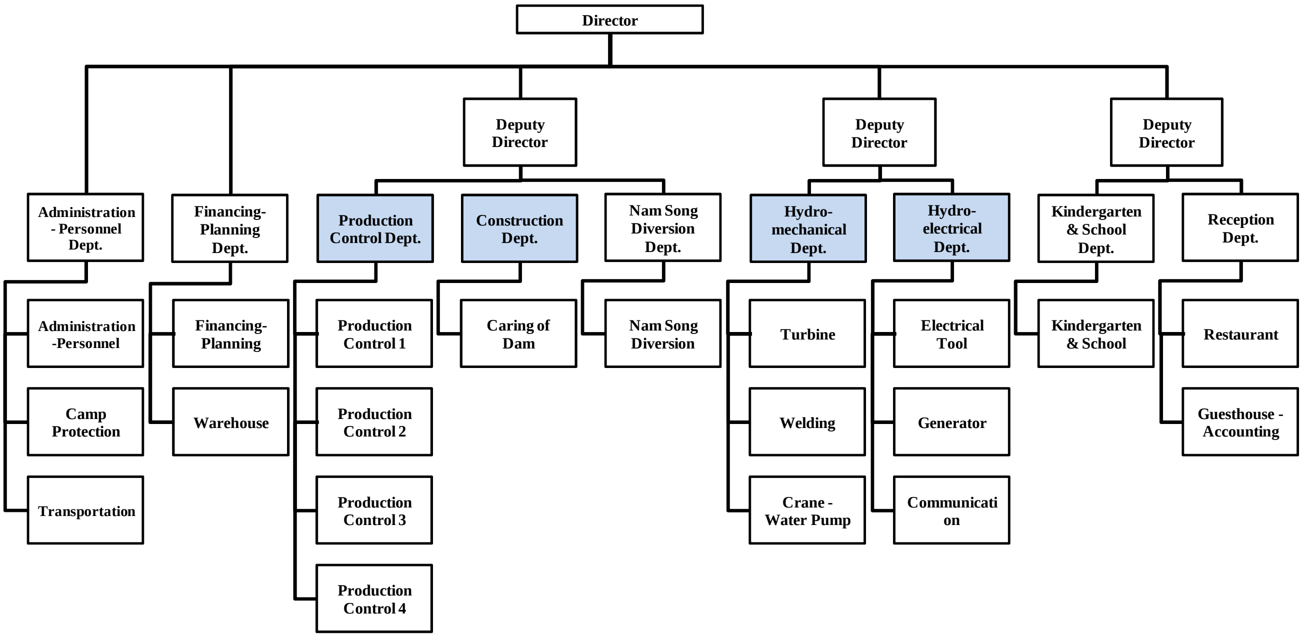
Figure 9.2.1 shows the present organization of EDL-Gen.



Source: EDL-Gen

Figure 9.2.1 Organization of EDL-Gen

Figure 9.2.2 shows the present organization of Nam Ngum 1 Hydropower Plant.



Source: EDL-Gen

Figure 9.2.2 Organization of Nam Ngum 1 Hydropower Plant

Organization of the Nam Ngum 1 Hydropower Plant consists of nine departments. Of which, five departments are in charge of technical issues.

Table 9.2.2 Departments which are in Charge of Technical Issues in Nam Ngum 1

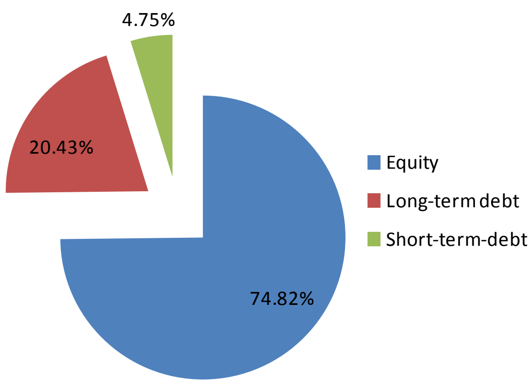
Department	No. of Staffs	Function
Production Control	28	Daily operation and monitoring of NN1
Civil Construction	10	Construction & maintenance of civil works
Nam Song Diversion	15	Daily operation and maintenance of Nam Song
Hydro-mechanical	19	Maintenance turbine, crane, etc.
Hydro-electrical	26	Maintenance of generator, communication equip. etc.

Source: EDL

(3) Financial Affairs and Budget

The capital structure of EDL-Gen as of December 2011 is as seen in Figure 9.2.3.

While EDL holds 75% of the company shares, the rest is owned by private investors. EDL-Gen has been listed on the Lao Securities Exchange since December 2010. Among the remaining 25% shares, 10.0% is owned by Ratch-Laos Company Limited and RH-International (Singapore), 1.25% is owned by EDL and EDL-Gen officers, and 13.75% is owned by other investors (as of end of 2011).



Source: EDL-Gen, as of Dec. 2011

Figure 9.2.3 Capital Structure of EDL-Gen

The recent financial status of EDL-Gen is presented in Table 9.2.3.

Table 9.2.3 Summary of Financial Status of EDL-Gen

Item	Dec 2010 *	2011
BALANCE SHEET		
Assets	5,052,537	5,238,572
Current Assets	**1,114,774**	**854,140**
Cash and Cash Equivalents	884,782	342,795
Short-term Investment	0	100,000
Trade and Other Receivables	225,367	402,764
Spare Parts and Supplies, net	4,625	3,749
Other Current Assets	0	4,832
Non-current Assets	**3,937,763**	**4,384,432**
Pre-operating Expenses, net	2,382	1,982
Advance Payment for Investment	0	434,923
Assets under Concession, net	3,935,381	3,947,527
Liabilities and Equity	5,052,537	5,238,572
Liabilities	**2,426,233**	**1,319,108**
Current Liabilities	**1,123,645**	**248,832**
Accounts Payable	20,258	874
Current Portion of LT Borrowings	197,742	211,921
Accrued Expenses	19,184	22,228
Accrued Income Tax	2,289	13,786
Other Current Liabilities	884,172	23
Non-current Liabilities	**1,302,588**	**1,070,276**
Long-term Borrowings, net	1,302,588	1,070,276
Equity	**2,626,304**	**3,919,464**
Share Capital	2,605,792	3,474,388
Share Premium	0	15,577
Legal Reserve	2,051	58,408
Retained Earnings	18,461	371,091
INCOME STATEMENT		
Revenues	37,229	881,748
Cost of Sales	(9,768)	(204,671)
Gross Profit	**27,461**	**677,077**
Other Income	69	9,781
Foreign Excange Gains (Loss), net	(1,739)	(3,895)
Profit Before Expense	**25,791**	**682,963**
Administrative Expenses	(597)	(48,013)
Profit Before Financial Costs and Tax	**25,194**	**634,950**
Financial Costs - Interest Expense	(2,393)	(41,278)
Profit Before Corporate Income Tax	**22,801**	**593,672**
Income Tax Expense	(2,289)	(30,104)
Net Profit for the Year / Period	**20,512**	**563,568**
FINANCIAL RATIOS		
Profitability		
(1) Operational Profit Rate	-	72.0%
(2) Return on Assets	-	10.8%
Debt		
(3) Debt Equity Ratio	0.92	0.34
(4) Debt Service Coverage Ratio	1.02	2.22
Liquidity		
(5) Current Ratio	0.99	3.43
(6) Receivables Turnover	0.17	2.19
(7) Debtor Days	2,210	166.7

Note: (1) Operational Profit Rate = Profit from Operations / Revenues
(2) Return on Assets = Net Profit / Total Assets
(3) Debt Equity Ratio = Total Liabilities / Total Equity
(4) DSCR = Cash Generated from Operations / (Repayments of Borrowings + Financial Expenses)
(5) Current Ratio = Current Assets / Current Liabilities
(6) Receivables Turnover = Revenues / Account Receivables
(7) Debtor Days = 365 days / Receivables Turnover
* Operational period from December 16th to 31th, 2010

Source: JICA Study Team based on Audited Financial Statement of EdL 2008, 2010 and 2011

In contrast with the low profitability of EDL as a domestic electricity provider, EDL-Gen has fair profitability as shown in its 10.8% ROA in 2011. The return on equity is calculated as 14.4%. EDL-Gen's capital structure mainly consists of equity investment and debt finance accounts for only 25.2%. The low debt equity ratio (0.34)[4] and high debt service coverage ratio (2.22)[5] indicate that there would be room for further debt finance for investment in the generation capacity development. The existing borrowings of EDL-Gen are derived from the transfer of EDL's long-term borrowings for past generation projects, which are external loans from ADB and other financial institutions.

In July 2012, EDL-Gen increased its capital stock by 358 million (worth 200 million US$ or 1,611 billion Kip) to acquire part of stake of four IPP (Theun Hinboun: 60%, Houay Ho: 20%, Nam Lik 1-2: 10% and Nam Ngum-2: 25%). Since debt of EDL-Gen is expected to increase sharply from US$ 135 million in 2011 to US$ 771 million by the end of 2012, debt equity ratio is forecasted to increase from abnormally low 0.34 in 2011 to 0.84 in 2012. However, these values were still far below the company's policy of 1.5. If acquisition of four IPPs had been wholly made not capital increase but debt financing, debt equity ratio of the company would be 1.53, which exceed the threshold of 1.5.

(4) Required Skills

The Nam Ngum 1 Hydropower Station has been operated for over 37 years by the power station staff. The power station has sufficient number of operators and maintenance crews with enough experience on O&M of the power station. Therefore, they will be able to manage the customary O&M of the additional equipment of unit 6 without the need for modification of their current organization.

Electro-mechanical Equipment

The additional equipment will be operated under the following three operation modes in the same manner as the existing equipment:

Table 9.2.4 Operation Mode of Electro-mechanical Equipment

Mode	Method	Application
Remote-Automatic Operation	The remote-automatic operation is carried out from the existing control room in front of the remote control board for unit 6.	It will be applied to the daily operation of the additional equipment.
Local-Automatic Operation	The local-automatic operation is carried out from the local control board to be installed in the new cubicle room next to the machine bay for Unit 6. The automatic start-stop operation of Unit 6 is performed under automatic sequential control with the aid of the programmable logic controller.	It will be utilized for the purpose of testing and trial operation or when the remote-automatic control system is out of service.
Local-Manual Operation	The local-manual operation of the additional Unit 6 is carried out at the equipment bay in front of the governor cabinet, the turbine control cubicle, the generator excitation cubicle and the motor control centers for the associated auxiliary equipment. The local-manual operation of the switchgear is carried out in front of its switchgear cubicles or its local control cabinet in the outdoor switchyard.	It will be carried out for the purpose of testing and trial operation after the associated equipment is overhauled, repaired or replaced.

Source: JICA Study Team

[4] ADB requested EdL-Gen to maintain debt equity ratio below 1.5.
[5] Typically, in case electric power generating industry, debt service coverage ratio (DSCR) should exceed 1.2~1.5.

Ordinary maintenance work for the additional equipment will be carried out periodically in the same manner as the existing equipment to maintain their performance.

In addition to the ordinary maintenance works, overhauling of the turbine and generator will be performed at least every five years, which includes carrying out detailed inspection and repair of the damaged parts to restore their performance.

(5) Experience of Operation and Maintenance

Experience of operation and Maintenance of similar project by EDL-Gen is tabulated in Table 9.2.5

Table 9.2.5 Experience of O&M in Similar Project by EDL

Location	Power Plant Name	Installed Capacity (MW)	COD	Period of O&M (Years)
Central				
Vientiane	Nam Ngum 1	155	1971	41
Vientiane	Nam Leuk	60	2000	12
Vientiane	Nam Mang 3	40	2005	7
Vientiane	Nam Song	6	2012	0
South				
Saravanh	Xeset 1	45	1991	21
Saravanh	Xeset 2	76	2009	3
Champasak	Xelabam	5	1969	43
Total		**387**		

Note: Periods of O&M above includes years before separation from EDL.
Source: EDL-Gen

CHAPTER 10 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

10.1 UPDATE INFORMATION IN PREPARATORY SURVEY ON NN1 PROJECT (PHASE1)

In this chapter, the result of the preparatory study conducted in 2009 (the Study) was reviewed and updated since it has been 3 years passed after the completion of the Study. Besides, the content of this chapter is to be an annex to the Environmental and Social Impact Examination report (the Report), which was the result of Initial Environmental Examination (IEE), and used for further steps of this project. The following is updated information on environmental and social consideration for the Study as of September 2012.

10.1.1 LEGAL FRAMEWORK

(1) Laws and regulations in the Lao PDR

Table 10.1.1 shows the list of laws and regulations related to the environmental assessment and relevant to the electricity project.

Table 10.1.1 Laws and Regulations Relevant to the Project

No	Law	Enacted No. and Year	Key Contents
1	Constitution	No.25/NA May 2003	States responsibility for all organization and citizen to protect the natural environment and natural resources of the State
2	Environmental Protection Law	No. 02-99/NA April 1999	Specifies principles, rules and measures to manage, monitor, restore and protect the environment, natural resources and biodiversity Ensures sustainable socio-economic development
3	Decree on Environmental Impact Assessment	No.112/PM February 2010	Establishes uniform environmental assessment requirements and procedures for all development projects
4	Environment Impact Assessment Guidelines	MoNRE November 2011	Gives instructions for preparing an EIA report pursuant to the Decree on Environmental Impact Assessment,
5	Agreement on National Environmental Standards	No.2734/WREA December 2009	Establish national environmental standards as a basis for environmental monitoring and pollution control on water, air, soil and noise
7	Water and Water Resources Law	No.02-96/ NA October 1996	Regulates the management, exploitation, development, protection and sustainable use of water and water resources
8	Decree on the Compensation and Resettlement of the Development Project	No.192/PM July 2005	Defines principles, rules, and measures on compensation and resettlement on the development project

No	Law	Enacted No. and Year	Key Contents
9	Regulation for Implementing Decree No.192/PM on Compensation and Resettlement of People Affected by Development Projects	No.2432/STEA November 2005	Defines principles, rules and measures on compensation and resettlement of the development project
10	Technical Guidelines on Compensation and Resettlement in Development Projects	Prime Minister's Office STEA February 2011	Gives instructions for implementing social impact assessment of development project focusing on the principles and procedures on compensation and resettlement
11	Land Law	No.04/NA Oct 2003	Provides rules on management, protection and use of land
12	Law on Aquatic Animals and Wild Life	No.07/NA December 2007	Provides principles and measures to protect and manage wildlife and aquatic animals
13	Law on National Heritage	No.08/NA November 2005	Determines the principles, regulations and measures for the administration, use, protection, conservation, restoration, rehabilitation of the national culture, history and natural heritage
14	Electricity Law	No.03/NA Dec 2008	Requires the minimization of impact on natural environment and society in design, construction and operation phase of electricity development project Instructs the necessity for conducting Environmental Assessment (EA) for the development project
15	Electric Power Technical Standards	No.052/MIH February 2004	Provides technical standards for electricity project

Source: JICA Survey Team

(2) Environmental Safeguard by JICA

Relevant JICA policies include:
Guidelines for Environmental and Social Considerations (2010)

It is prepared for the development project assisted by JICA. It stipulates principles, examination of measures, and scope of impacts to be assessed regarding environmental and social considerations.

10.1.2 ENVIRONMENTAL PROCEDURE FOR THE PROJECT

An environmental compliance certificate (ECC) shall be obtained from the Ministry of Natural Resources and Environment (MoNRE) by the project developer before starting construction works.[1] In the case of Nam Ngum 1 Hydropower Station (NN1) project, initial environmental examination (IEE) was required in order to obtain the ECC. In 2010, the initial environmental and social examination (IESE) reports, comprises of IESE main report and environmental and social management plan (ESMP), were authorized and the ECC was issued by the Water Resources and Environmental Administration (now the work is taken by the MoNRE).

The ECC is valid through the operation period of the project. The ECC, however, will automatically expire and cannot be used if the project does not start construction works within two years from the date of issuance.[2] The ECC needs to be extended every two years until the commencement of the construction phase provided there is no change on the project's design and/or planning. In the case of

[1] Article 4 General Principles, Decree on Environmental Impact Assessment, No.112/PM, 2010
[2] Article 18 Expiry date of the environmental compliance certificate, Decree on Environmental Impact Assessment, No.112/PM, 2010

NN1 project, the EDL had made a request to the MoNRE for the extension of the ECC in March 2012. The request was accepted and the ECC was extended in July 2012.

10.1.3 INSTITUTION CONCERNED FOR ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

Ministry of Natural Resources and Environment (MoNRE): The MoNRE was established in 2011 and has been taken the tasks designated for the Water Resources and Environment Administration (WREA). It is a principal government agency for formulating and guiding environmental policy in Lao PDR. It develops environmental strategies, policies, regulations, programs and projects, reviews result of environmental impact assessment, implements monitoring projects and conducts research and training activities. Environmental and Social Impact Assessment Department (ESIAD) is responsible for reviewing environmental assessment (EA) report submitted by Development Project Responsible Agency (DPRA: in the case of this project, DPRA is the Division of Environmental Engineering under Department of Energy Policy and Planning in Ministry of Energy and Mines) issuing ECC to project developer and supervise monitoring activities by project developer according to environmental management plan in EA report. Figure 10.1.1 shows the organization chart of the ESIAD and the MoNRE.

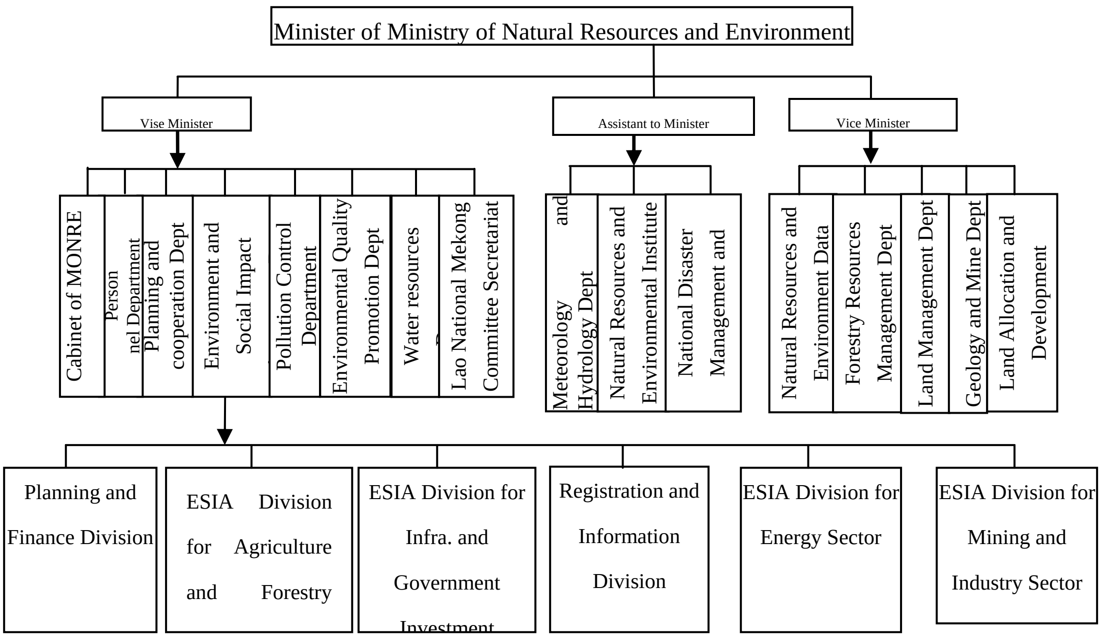
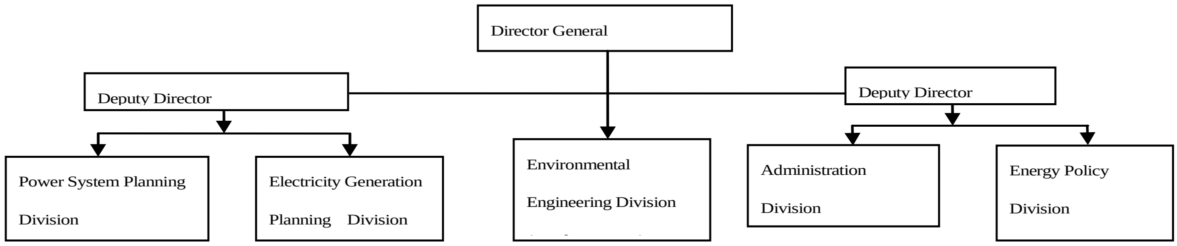


Figure 10.1.1 Organization Chart of ESIAD in MoNRE

Ministry of Energy and Mines (MEM): The Division of Environmental Engineering under Department of Energy Policy and Planning in the MEM is assigned as Development Project Responsible Agency (DPRA) for review reports on IEE in coordination with local administrations and concerned agencies, make written comments and then report to the MoNRE of considering the ECC insurance.[3] It also has a duty to monitor outputs of implementing mitigation measures addressed in ESMP and make reports

3 Article 9, Decree on Environmental Impact Assessment No.112/PM, 2010

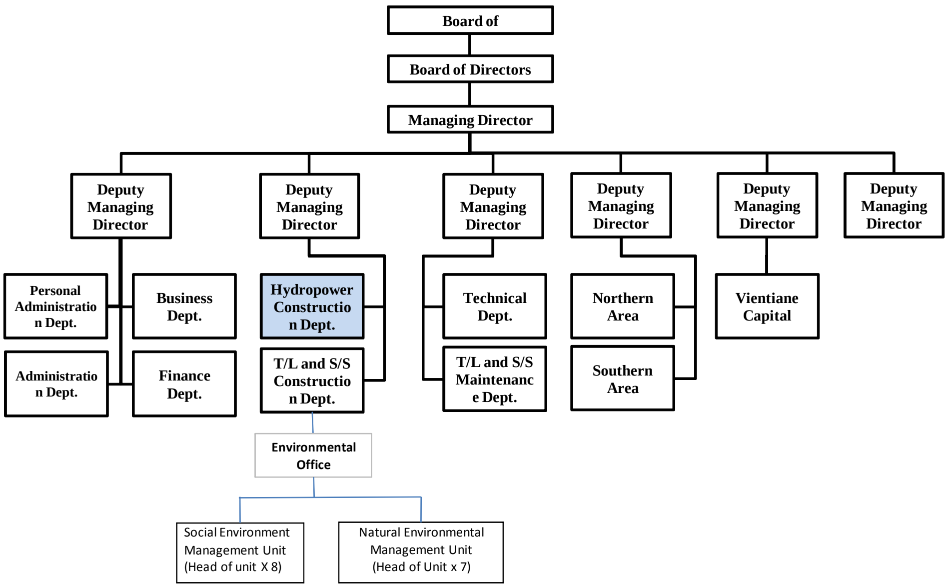
to the MoNRE and local administration regularly.[4] The organization chart of the Division of Environmental Engineering in the MEM is shown in Figure 10.1.2.



Source: JICA Survey Team

Figure 10.1.2. Organization Chart of Division of Environmental Engineering in MEM

Electricite Du Laos (EDL): The EDL is the project developer of this project. The Environmental Office under the Transmission Line and Substation Construction Department in the EDL is responsible for implementing assessment on natural and social environment for the project, preparing assessment report, organizing information dissemination meetings at village, district and provincial level and carrying out monitoring addressed in ESMP and reporting to the MoNRE and the DPRA, relevant agencies and local administration regularly.[5] The organization chart of the Environmental Office in the EDL is shown in Figure 10.1.3.



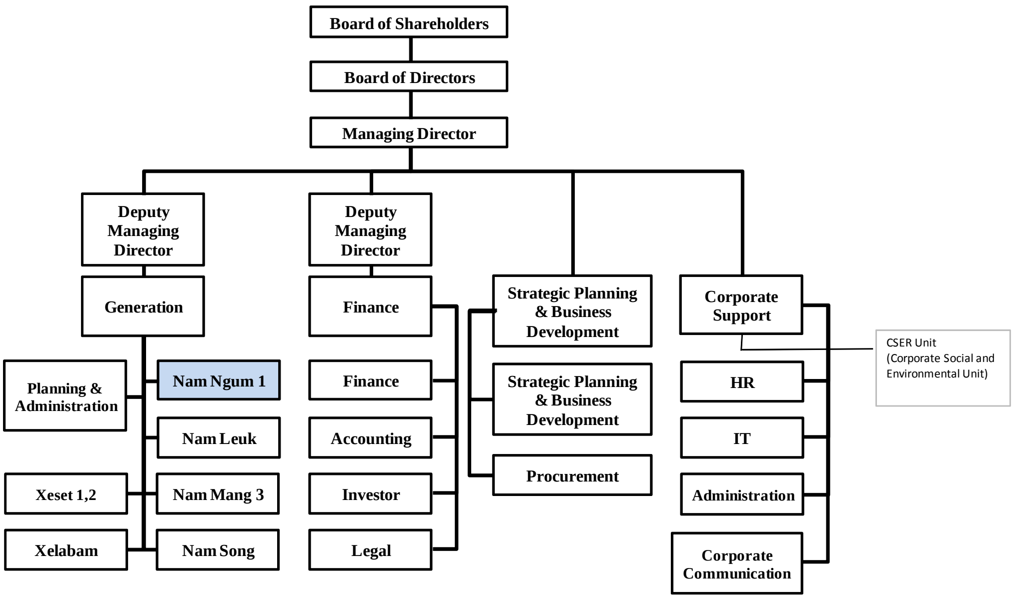
Source: JICA Survey Team

Figure 10.1.3 Organization Chart of Environmental Office in EDL

Electricite Du Laos Generation Public Company (EDL-Gen): The EDL-Gen was spine off from the EDL in 2010 taking the sector of electricity generation in the EDL. The hydropower station has been

[4] Article 24, Decree on Environmental Impact Assessment No.112/PM, 2010
[5] Article 23, Decree on Environmental Impact Assessment No.112/PM, 2010

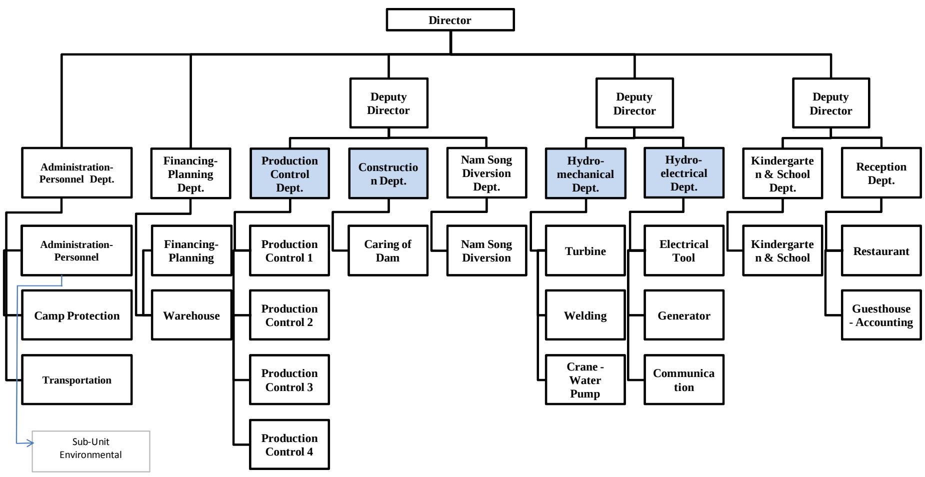
constructed and will be constructed by the EDL belongs to and to be operated by the EDL-Gen. Corporate Social and Environmental Responsibility Unit (CSER) is to be responsible for the environmental and social monitoring during project's operation phase. Detail of the task is still under way. The organization chart is shown in Figure 10.1.4.



Source: JICA Survey Team

Figure 10.1.4 Organization Chart of EDL-Gen

Nam Ngum Hydropower Station (NN1): Environmental sub-unit is in charge of environmental management. Three officers are assigned for monitoring forest in reservoir area, managing vegetation at Dam site, supporting community development around the NN1 and monitoring water level in downstream of the NN1. The organization chart is shown in Table 10.1.5.



Source: JICA Survey Team

Figure 10.1.5 Organization Chart of NN1

10.1.4 ENVIRONMENTAL AND SOCIAL CONDITIONS WITHIN THE PROJECT AFFECTED AREA

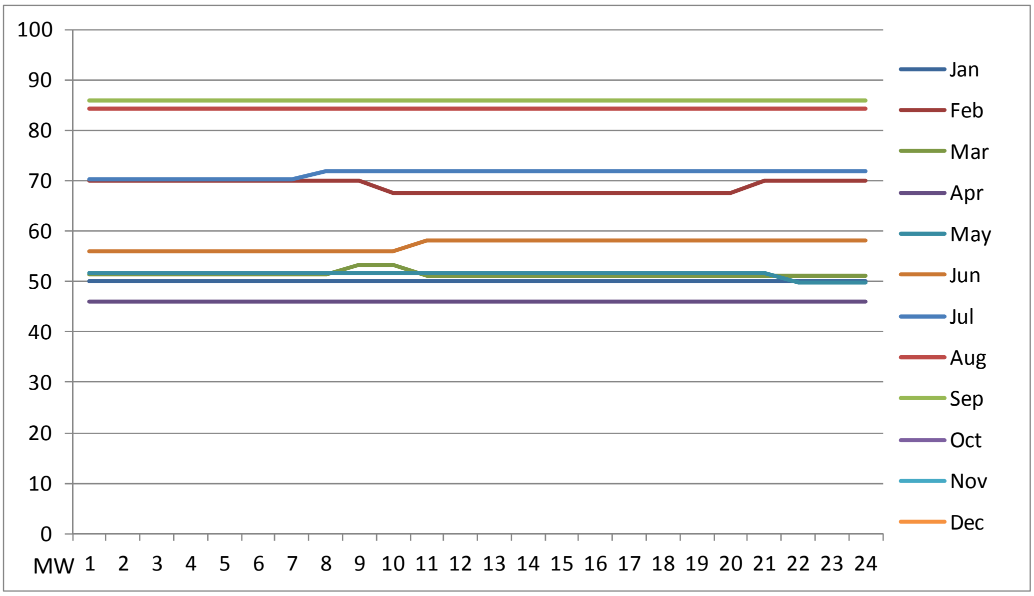
In the Report, it was concluded that upstream of NN1 is not directly affected by this project, since there is no need for reservoir creation, reservoir enlargement, land acquisition or forestry cutting. Meanwhile, it was predicted in the Report that riverside residents using river water of the Nam Ngum at the downstream of NN1 would be affected due to the increase water level fluctuation enhanced peak operation after expansion work. Accordingly, information update is only focused on the downstream of NN1.

It was confirmed that there has been neither any significant changes in geography nor activities in the downstream of the NN1 since the completion of the Study. Thus, the project affected area remains the same as the area set in the Study, which covers up to 1 km from the Nam Ngum River edge along with 50 km downstream of the Nam Ngum River from the Nam Ngum dame site. The following is the main findings within the project affected area for information update.

(1) Natural Environment

1) Hydrology

Figure 10.1.6 shows hourly discharge in Nam Lik 1/2 Hydropower Station from January 2012 to August 2012. To date, the Nam Lik keeps base operation of about 50MW.



Source: JICA Survey Team

Figure 10.1.6 Operation Pattern of Nam Lik 1/2 in 2012

2) Water Quality

During May until August 2011, it was reported that massive fishes bred in the fish firming cage where it locates near the Thalat Bridge and 4 km from the NN1 Dam site, died off and eight fish farmers were affected by this incident. After conducting the investigation by the Institute of Natural

Resources and Environmental Research together with district and provincial officers, it was concluded that the water in low rate of Dissolved Oxygen (DO) released from the Nam Ngum 2 Hydropower Plant was the cause of this incident. As a result, operational improvement was recommended to the Nam Ngum 2 Hydropower Plant by the Vientiane Province. According to the monthly water quality monitoring, which has been started conducting since January 2012 by the Institute of Natural Resources and Environmental Research, nothing abnormal has been detected to present. [6]

(2) Social Environment

The information on demography, economic status and river related activities in affected areas were updated in conducting hearing with village heads within the affected area.[7] The number of affected villages decreased from 24 to 21 due to the reasons such as merger of villages and change of village boundary. Summary of demography, economic status and river related activities within the affected area is shown in Table 10.1.2.

Table 10.1.2 Demography, Economic Status and River Related Activities in Affected Villages

No.	Category	Amount	Remarks	Source
1	Riverside < 1 km villages Downstream < 50 km of NN1	21	Villages in affected area	Hearing from Village Heads
2	Riverside < 1 km villages Downstream < 50 km of NN1	25,040	Population in affected area	
3	Riverside < 1 km villages Downstream < 50 km of NN1	5076	Households in affected area	
4	GDP/Capita/Income	944	Average in affected area	
5	Income source			
	Agriculture	61%		
	Fish farming	0.18%		
	Trading	18%		
	Government services	10%		
	Others	10.52%		
6	Vulnerable households	55	Households in affected area	
7	No. of irrigation users	920		
8	No. of riverbank garden users	845		
9	No. of navigation business	2		
10	No. of fishery	311		
11	No. of fish farming	11		

Source: JICA Survey Team

[6] The information was confirmed at the Institute of Natural Resources and Environment Research, however, detailed monitoring result was not provided because the data is under process for discloser to outsiders. (as of 4 June, 2012)

[7] The village hearing were conducted under two study, Study on Power supply and Demand in Central Region in Lao People's democratic Republic and Preparatory Study on NN1 Expansion (Phase2). The hearing of following10 villages were conducted from 24 May 2012 to 26 May 2012: Sengsavang, Thinkeo, Thalat, Muangkao, Donkouat, Thinyoung, Keun-Kang, Hatxai, Nakhong and Cheng. The hearings of following 11 villages were conducted from 28 Aug 2012 to 31 Aug 2012: Thaxan, Nanin, Hatxaykhoun, Veunsan, Thaphoxai, Pakkayoung, Keun-Neua, Pakcheng, Viengkham, Boungphao and Lingxan.

10.1.5 SCOPING

The scoping result in the authorized IESA report (the Report) was reviewed if there is any condition changed since 2009. Consequently, it is concluded any revision necessary except for temporary effect on aquatic animals at the time of removing downstream rock shelves.

Some effect resulting from construction activities during construction phase are predicted. However, any local people living within 1 km from dam site except for NN1 staffs and the surrounding area of NN1 is owned by EDL. Thus, except for the negative impact resulting from the activities related to transportation of construction materials, there is only small negative impact predicted from the NN1 expansion project on local people residing near the project construction site.

The only continuous negative impact is predicted on activities using river in downstream of the NN1, where water level fluctuation is to be increased due to change of operation pattern in the NN1 after expansion. The impact, however, is predicted to be not significant.

As it was addressed in the Report, it is concluded that environmental and social impact of the NN1 expansion project are basically not significant or positive (creating job opportunities in affected area and decreasing CO2 emissions). Negative impacts can be avoided or minimized by implementing conventional construction management with proper instruction and operation and preparing proper operation rule. The scoping result in the Report is shown in Table 10.1.3.[8] The environmental check list is shown in Appendix C-1.

Table 10.1.3: Scoping

No.	Impacts	Rating	Brief Description
Construction Phase			
1.Anti Pollution			
1.1	Air Pollution	C	Limited air pollution is expected due to heavy machinery
1.2	Water Pollution	C	Temporary water pollution due to concrete mixing, aggregate collection and excavation during construction is expected. This would be local and small but should be minimized. Water quality monitoring is necessary during operation.
1.3	Waste	C	Demolished material needs disposal to adequate site.
1.4	Soil Contamination	-	No soil contamination is expected but proper insulation oil treatment is needed.
1.5	Noise and Vibration	C	Site is away from residential area. No noise and vibration problem from site is expected. Material transportation near access road needs consideration with speed limit.
1.6	Ground Subsidence	-	No ground subsidence is expected.
1.7	Offensive Odor	-	No offensive odor is expected.
1.8	Bottom Sediment	-	No bottom sediment change is expected since reservoir already exists and no change is added on reservoir condition.
1.9	Accidents	C	Proper safety management during expansion works needs to be provided at responsibility of contractor with CEMP implementation
2. Natural Environment			
2.1	Protected Area	-	Protected area is not included in downstream.
2.2	Flora, Fauna and Biodiversity	C	Effect on flora, fauna, or biodiversity is not expected. Rare species are not reported in affected areas. Temporary effect is expected on aquatic animals at the time of removing downstream rock shelves.
2.3	Hydrological Situation	-	No disturbance to the hydrological situation is expected.
2.4	Topography and Geographical Features	C	Excavation, spill and wastage embankment give a little change to the geographical feature but not significant.
2.5	Landfill Site Management	-	Amount of waste for landfill is very small.
2.6	Soil Erosion	-	Not expected.

[8] In order to clarify the impact, the Table was divided into two parts, Construction Phase and Operation Phase. These two phases were described in the same parameter in the Report, however, the content of the Table is based on the original Table.

2.7	Groundwater	-	No effect on groundwater is expected.
2.8	Coastal Zone (Mangroves, Tidal Flats, etc,.)	-	No effect on coastal zone is expected.
2.9	Meteorology	-	No effect on meteorology is expected.
2.10	Global Warming	-	Not expected
3. Social Environment			
3.1	Involuntary Resettlement	-	No resettlement or compensation is needed.
3.2	Local Economy, Employment, Livelihood	C+	Positive impact such as creation of local employment is expected.
3.3	Cultural Heritage	-	No cultural heritage is reported in affected areas
3.4	Landscape	C	New powerhouse and downstream bed rock excavation affects to landscape at the dam site, but this is not significant
3.5	Indigenous and Ethnic Minority	-	People in affected area is highly mobile and no problem on indigenous and ethnic people is reported
3.6	Land Use and Utilization of Local Resources	-	No land use or change of local resources is expected.
3.7	Social Institutions ad Local Decision-Making	-	No social institutions will be affected
3.8	Existing Social Infrastructures and Services	C	Facility is to be used temporary by labor coming from outside.
3.9	Misdistribution of Benefit and Damage	-	No misdistribution of benefit and damage is expected.
3.10	Local Conflict of Interests	-	No local conflict is expected.
3.11	Water Usage or Water Rights of Common	-	Not expected
3.12	Sanitation	C	Sanitation of workers during construction work needs to b properly managed.
3.13	Hazards (Risk)	-	No hazard is expected.
Operation Phase			
1.Anti Pollution			
1.1	Air Pollution	-	Not expected
1.2	Water Pollution	-	Not expected
1.3	Waste	-	Not expected
1.4	Soil Contamination	-	Not expected
1.5	Noise and Vibration	-	Not expected
1.6	Ground Subsidence	-	Not expected.
1.7	Offensive Odor	-	Not expected.
1.8	Bottom Sediment	-	Not expected.
1.9	Accidents	C	Warning board shall be installed on the rapid increase of water level due to the change of operation shift from off-peak to peak
2. Natural Environment			
2.1	Protected Area	-	Not expected
2.2	Flora, Fauna and Biodiversity	-	Not expected
2.3	Hydrological Situation	C	River discharge will increase during peak generation hours and decrease off-peak hours. Maintenance flow should be secured not to disturb downstream activities such as boat and fishery.
2.4	Topography and Geographical Features	-	Not expected
2.5	Landfill Site Management	-	Not expected
2.6	Soil Erosion	-	Not expected, since the discharge increase in the project would be much smaller that natural food. Flood already occurred every year after dam construction in 1971. Weak soil has already been flushed away.
2.7	Groundwater	-	Not expected.
2.8	Coastal Zone (Mangroves, Tidal Flats, etc,.)	-	Not expected.
2.9	Meteorology	-	No effect on meteorology is expected.
2.10	Global Warming	C+	It will has positive impact due to utilization of spilled water in rainy season for energy, which can save fossil fuel in EGAT in Thailand owing to the reduction of power import from EGAT
3.Social Environment			
3.1	Involuntary Resettlement	-	No resettlement or compensation is needed.
3.2	Local Economy, Employment, Livelihood	C+	In broad sense, the stability of electricity generation contribute to the development of local economy
3.3	Cultural Heritage	-	Not expected
3.4	Landscape	-	Not expected
3.5	Indigenous and Ethnic Minority	-	Not expected
3.6	Land Use and Utilization	-	Not expected

	of Local Resources		
3.7	Social Institutions and Local Decision-Making	-	Not expected
3.8	Existing Social Infrastructures and Services	C	Maintenance flow has to be secured not to affect Irrigation during off-peak hours in dry season.
3.9	Misdistribution of Benefit and Damage	-	Not expected.
3.10	Local Conflict of Interests	-	Not expected.
3.11	Water Usage or Water Rights of Common	C	Minimum maintenance flow has to secure to give no affect on Irrigation and water pumping use at downstream in dry season.
3.12	Sanitation	-	Not expected
3.13	Hazards (Risk)	-	Not expected

Rating
A: Serious impact is expected, B: Some impact is expected, C: Small impact is expected, +Positive impact is expected, U: Extent of impact is unknown and examination is needed, Impact may become clear as study progresses, -: No impact is expected

Source: IESA Report of NN1 Hydropower Station Expansion 2009, revised by JICA Survey Team

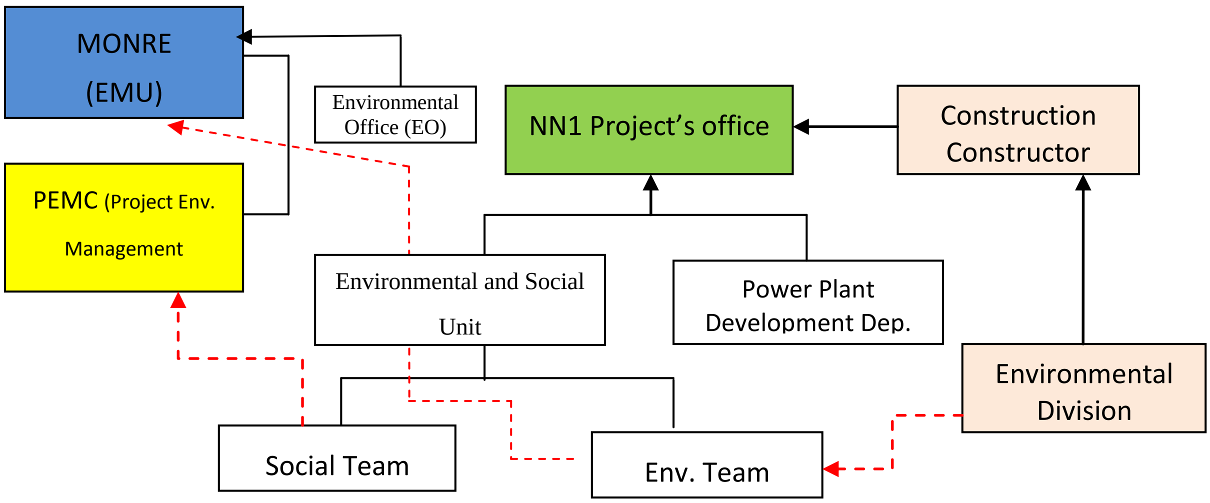
10.1.6 STUDY ON ALTERNATIVES

12 alternatives were studied from technical as well as environmental point of view in Chapter 4.2.10. It was concluded that the major negative impact is predicted not from the site-specific cause but the scale of expansion capacity. The major negative impacts were expected specifically on the riverbank gardening activity during dry season due to the increase of water level fluctuation in downstream of the Nan Ngum River. As for the no-project case and 40 MW expansion case, no negative impact is expected resulting from the increase of water level fluctuation. If the expansion capacity increases more than 60 MW, the households practicing riverbank gardening is to be affected due to the increase of water level fluctuation.

10.1.7 INSTITUTIONAL ARRANGEMENT ON ENVIRONMENTAL MANAGEMENT

(1) Construction Phase

The diagram on institutions concerned for implementing the ESMP in construction phase is shown in Figure 10.1.7 and roles and responsibilities is shown in Table 10.1.4.



Source: JICA Survey Team

Figure 10.1.7 Institutional Arrangements in Construction Phase

Table 10.1.4: Roles and Responsibilities for Institutions Concerned

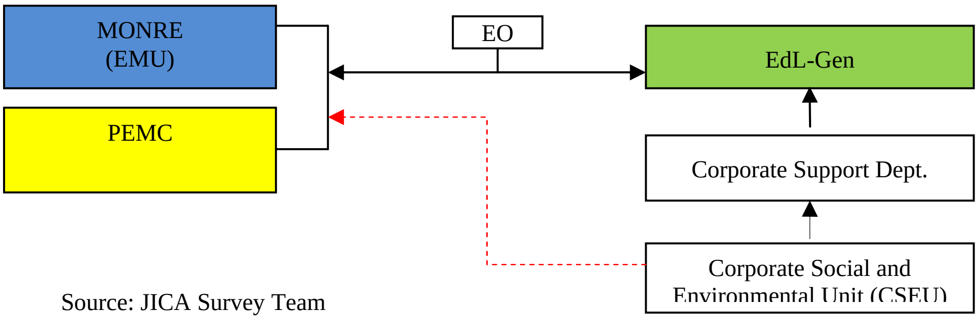
Institution	Roles and Responsibilities	Key parties
NN1 Project's Office	- Establish Environmental and social unit assigned from Environmental Office in EDL - Develop the Construction Environmental Management Plan (CEMP) for project subcontractors. - Assist Vientiane Province to establish Project Environment Management Committee (PEMC) prior to construction	EdL
Environmental Management Unit (EMU)	- Supervise environmental management activities implemented by environmental and social units in NN1 Project Office	- MONRE - MONRE of Vientiane Province - MoNRE of Keoudom, Viengkham and Thoulakhom District
Project Environment Management Committee (PEMC)	- Ensure the implementation of Social part of ESMP* is met the standard requirement - This committee acts as Grievance Committee (see detail in the article below (3)Grievance Mechanism)	- Provincial Governor (Chair) - Provincial Energy and Mine Department - Provincial Natural Resource and Environmental Department - All Concerned districts - Natural Resource and Environmental Division - All concerned village authorities
Environmental Office (EO)	- Overall responsible for all of the Environmental and social matters in EDL Development Projects. - Report to MONRE on the Project implementation of - Supervise all the works of the NN1 Environmental and Social Management Unit.	- EO (EDL)
Environmental and Social Unit	- Plan and implement all the works regarding environmental and social issues at Project Site - Comprised of social team and environmental team	- EdL Project Office (Construction Phase)
Social Team	- Implement social part of ESMP during construction and operation phases - Monitoring or inspection of compliance of CEMP in all construction sites	- EdL Project Office

Institution	Roles and Responsibilities	Key parties
Environmental Team	- Implement Environmental part of ESMP during construction phase - Monitoring or inspection of compliance of CEMP in all construction sites	- EdL Project Office
Corporate Social and Environmental Responsibility Unit (CSER Unit)	- Implement ESMP during operation phase	- Corporate Support Department, EDL-Gen
Environmental Division	- Ensure the implement of CEMP in all construction site	- Contractor

*As for the Nam Ngum expansion project, management plan regarding environment and social part were compiled together and entitled as Environmental and Social Management Plan (ESMP).
Source: JICA Survey Team

(2) Operation Phase

After construction period the project will be handed over to EdL-Gen, and ESMP tasks will be implemented by Corporate Social Responsibility Unit (CSR Unit) and Environmental Sub-Unit at NN1 Hydropower Plant. CSR unit together with Environmental Sub-Unit at NN1 Hydropower Plant will take responsibility on implementation and monitoring of the ESMP. The diagram on institutions concerned for implementing the ESMP in construction phase is shown in Figure 10.1.8.



Source: JICA Survey Team

Figure 10.1. 8 Institutional Arrangements in Operation Phase

(3) Grievance Mechanism

The institution body of Project Environmental Management Committee (PEMC) also acts as grievance redress committee. The committees comprises of the same members in the Project Environmental Management Committee (PEMC). The grievance redress procedure is summarized in Table 10.1.5.

Table 10.1.5: Grievance Redress Procedure

Step1	All complaints as grievances relating to any aspect of the project or sub-project should be properly documented by project officials (Environmental/Social Unit) and addressed through consultations. If the APs are not satisfied with the decision of the project authorities within 15 days from the filing of the complaint or when the problems and issues that cannot be addressed to the satisfaction to affected communities and individual APs, the complaints can then forwarded to the grievance redress committee (GRC).[9]
Step 2	If the APs do not receive any responses from the GRC within 20 days of filling the complaint or if the matter is not resolved to the satisfaction of the AP, the representatives of the APs on behalf of the APs will submit the complaint to the head office of the project owners and MoNRE.[10]

[9] There are two levels of GRC, one at village level and the other at provincial level. The complaint submit the complain fist at village level then if it cannot solved, the complain goes to the provincial level.
[10] In practice, the complain goes to the Livelihood Restoration Committee, not to MoNRE

Step 3	If the matter still remains unresolved within 20 days of filling the complaint to the project owner and MoNRE[11] and at the request of the APs, the representatives of APs forward the complaint to the Court of Law and follow up with the relevant authorities. The decision of the Court of Law would be the final.

Source: Technical Guidelines on Compensation and Resettlement of People Affected By Development Projects, WREA (2011)

10.1.8 MITIGATION MEASURES

The mitigation measures in the Report was reviewed and updated. Basically, no revision was made except for “environmental permits”, “explanation to public” and “ecosystem” in the environmental and mitigation plan. The updated plan is shown in Table 10.1.6. In addition, the following are the updated information needs to be remarked in the context of environmental impact and its mitigation plan.

Material collection and waste: The location of sand and gravel collection site (gravel pit) designated in the Report had to be changed due to the depletion of sand. The detail location is shown in Appendix G-.3.2. Though, the travel distance from the pit to the construction site is to be longer than to the previous designated site, which increase the disturbance of traffic and local people along the road, the expected negative effect is not significant and to be minimized by applying conventional mitigation measures.

Landscape, water quality and ecosystem: Removal of rock outcrop at 70 m downstream of tailrace is to be carried out in order to increase annual energy output. During excavation work, the water quality is to be degraded and ecosystem around the site is to be disturbed, however, the work is temporally and the effect is to be minimized by applying conventional mitigation measures.[12]

Operation Pattern: In the Report, it was addressed that for off-peak time, water level decrease for the case of 40 MW operation is 0.4 m – 0.5 m which would be no problem for downstream, however, case 18 MW with decrease at 0.8 m – 1.1 m will affect to some people in the downstream of NN1. Thus, it was recommended that off-peak operation shall be generated with at least 40MW. In addition, operation change from off-peak time to peak time also needs consideration. When off-peak time is shifted to peak time at once, discharge is increased at 2.2 m to 2.5m within a few minutes. This rapid water level increase may induce accident at downstream. Thus, as it was concluded in the Report, step-wise increase by 80MW at maximum has to be kept when shifting from off-peak to peak operation.

Warning system: It is necessary to install warning signboard to explain about rapid water level increase at the time of shifting from off-peak to peak operation for the people using water in the downstream of the Nam Ngum 1. In the detailed design, the location for the signboard shall be studied. In addition, the necessity of setting up automatic warning system shall be studied. In this year, the speaker for warning the increase of water level due to the opening of spillway gate in some village of

[11] Same as Step 2, the complain goes to the Livelihood Restoration Committee, not to MoNRE in practice.
[12] In the previous Study, the excavation was addressed under consideration. The plan was, however, studied as an option in the IESA

the Nam Ngum 1 were installed and the number of village with the speaker is expected to cover more in the downstream of the Nam Ngum 1 next year. It can be one of the options to use this system for warning operation shift.

Table 10.1.6: Environmental Management and Mitigation Plan

Description	Environmental Impact	Mitigation Plan	Responsibility
1. Study Stage (conducted in IESE)			
Environmental Permits	-	Environmental Compliance Certificate (ECC) was obtained in 2010 and it was extended in 2012 for anther 2 years. The ECC is valid through the operation period of the project, however, it will automatically expire and cannot be used if the project does not start to operate within two years from the date of issuance. Accordingly, the ECC needs to be extended every two years until the commencement of the operation provided there is no change on the project's design and/or planning.valide	Edl
Explanation to the Public	-	Public consultation meeting was held at village level during conducting social assessment survey from May to June 2009. The public consultation meeting in district, provincial and central level was organized in July 2009 for disseminating the result of IESA and the opinions from the meeting was incorporated into the final IESA report.	EdL
2. Construction Stage			
2.1. Anti-pollution measures			
Air quality	Dust increase on earth road during dry season	-Sprinkle water to control dust -Minimize travel distance	Contractor
	Increase of emission	-Regular checking of engine and exhaust of machinery and its recording and reporting	Contractor
	Dust increase during aggregate collection	-Respiratory protection for worker at site	Contractor
Water quality	Increase of suspended soil, particular matter and DO	-Regular water sampling and quality analysis at downstream of construction site. In case not acceptable level, find reason and trap waste water	Environmental Team/Engineer
Waste	Production of large amount of demolished concrete and excavated soil	-Dispose of materials to approved area so as not to disturb scenery and not to contaminate water	Contractor
Soil contamination	Leakage of insulation oil and machinery oil possibly affects	-Capture insulation oils in barrel and use oil proof sheet to avoid any leakage	Contractor
Noise and vibration	Not significant since site is apart from villages, but access road is affected	-Instruction to driver to comply speed limit -Check proper material loading and uploading - Use silencer and muffler for equipment	Contractor
Management of abandoned sites	Site	-Site rehabilitation with topsoil recovery, reshaping, revegetation and remediation with site clan up work - Stabilization of water disposal area	Contractor
2.2 Natural Environment			
Subsidence	Not expected	-	-
Odor	Not expected	-	-
Sediment	Not expected	-	-
Protected areas	Not expected	-	-
Ecosystem	Removing downstream rock shelves have effect on the ecosystem around the site	- Provision of minimizing the disturbance under water	Engineer
Topography and geology	Collapse of cut stone and deterioration of mud stone foundation may happen	-Prevention with rock support and prompt concrete work in construction	Engineer
2.3 Social Environment			
Sanitation	Camping of construction workers health problem and disease may happen	-Provision of proper sanitation with septic facilities -Prohibition of untreated human waste to enter any watercourse	Contractor
Living and Livelihood	Not expected	- Source workforce from qualified locals and orient workers on desirable working relationship with skill enhancement and employment program (positive)	Contractor
Landscape	Removing downstream rock shelves have effect on the ecosystem around the site	-Provision of explanation to villagers and tourist for the meaning that the work	Environmental Team/Engineer
3. Operation Stage			
Hydrology / social and economic environment public safety	Water level decrease during off-peak team, depending on Nam Lik flow in dry season	-Daily monitoring downstream water level including the Nam Lik. Avoid zero or single 18 MW operation for off-peak hours to keep downstream water level. -Precaution to downstream communities for rapid increase/decrease of rever water level with sing board and public consultation. Keep present output increase rate and conduct gradual opening as possible.	CSER Unit
4. Monitoring and Audit			
Environmental audits	-	-Undertake third party monitoring audits	MoNRE
Environmental Monitoring	-	-Monitoring by Environmental and Social Unit (Construction Phase) and CSER Unit (Operation Phase) for compliance of ESMP	Environmental and Social Unit (Construction Phase), CSER Unit (Operation Phase)

Source: Based on IESA Report of NN1 Hydropower Station Expansion 2009 revised by JICA Survey Team

10.1.9 ENVIRONMENTAL AND SOCIAL MONITARING PLAN

It is concluded that there is no revision or update necessary for the environmental and social monitoring plan (ESMP) at this time except for the monitoring on ecosystem at the construction site during construction phase and water quality monitoring, which the period of monitoring was prolonged. The ESMP shall be reviewed and updated as appropriate taking account of the result in detailed design phase. Besides, the plan on the operation phase in the ESMP shall be reviewed and updated as appropriate during construction phase and submit to the MoNRE for approval six months before commencement of operation.[13] The environmental and social monitoring plan is shown in Table 10.1.7. The following is the point to be remarked for conducting environmental and social monitoring plan.

Operation Pattern (Nam Lik ½): In 2012, the Nam Lik 1/2 keeps base operation with 50MW at the dry season. With the discharge of 80 m^3/s from Nam Lik 1/2 at this output and 573.3 m^3/s of the expected maximum discharge from the Nam Ngum with 40 MW expansion, the total discharge is to be 653.3 m3/sec. This is under the affected level of total discharge (699m3/s). [14]The discharge from Nam Lik 1/2 shall be monitored continuously. In case increase of discharge from Nam Lik 1/2 with off and on peak operation confirmed, adjustment of peak operation of the Nam Lik 1/2 may be needed to avoid the overlapping of peak discharge in dry season. The discharge requirement presumes the maintenance flow is based on that the Nam Lik River flow at least equals to the draught discharge. If the discharge is less than the draught discharge, IESE confirmed that the reduction of the flow would affect to the downstream inhabitants. Therefore, the Nam Lik 1/2 hydropower project is required to release the water at least to fulfill the draught discharge at the confluence of the Nam Lik River and Nam Ngum River.

Water quality monitoring: After the commencement of the NN2, the water with low rate of Dissolved Oxygen was released and it went under the reservoir of the Nam Ngum 1 and finally released to the downstream of the NN1. Consequently, it caused mass fish died from the fish firming near the Thalat Bridge, which is 4km from the Nam Ngum Dam. In order to avoid this kind of incident in the further, it is recommended to continue to conduct periodic water quality checkup in operation phase. Although the water quality monitoring is addressed only as a task in D/D for the purpose of collecting baseline data as well as in Construction phase for monitoring the affect from construction activities. In the operation phase, it is recommended to check the water quality at the entry point of water from the Nam Lik1/2 to the Nam Ngum reservoir and exit point of water from the Nam Ngum 1. In case any abnormal is detected, the NN1 promptly inform the result of water quality checkup to the water user's in the upstream of the NN1 and urge the recovery so as to minimize the effect on the downstream of NN1. For this purpose, NN1 possesses its own portable water quality equipment, which can detect the minimum requirement parameter such as turbidity, PH and DO on-site water and to train the staff in D/D and continue to monitor the water quality until project's operation phase.

Suggested monitoring form is shown in Appendix C-2. New water quality standards enacted in 2009

[13] Article 13, Decree on Environmental Impact Assessment No.112/PM, 2010
[14] Figure was taken from Figure 4.2.10.2 Affected Riverside Users in Chapter4.2.10

related to the NN1 project is shown in Appendix C-3.

Table 10.1.7 Environmental and Social Monitoring Plan

Description	Mitigation Plan	Responsibility	Monitoring	Frequency
1. Study Stage (conducted in IESE)				
Environmental Permits	Environmental Compliance Certificate (ECC) was obtained in 2010 and it was extended in 2012 for anther 2 years. The ECC is valid through the operation period of the project, however, it will automatically expire and cannot be used if the project does not start to operate within two years from the date of issuance. Accordingly, the ECC needs to be extended every two years until the commencement of the operation provided there is no change on the project's design and/or planning.valide	Edl	-	Done
Explanation to the Public	Public consultation meeting was held at village level during conducting social assessment survey from May to June 2009. The public consultation meeting in district, provincial and central level was organized in July 2009 for disseminating the result of IESA and the opinions from the meeting was incorporated into the final IESA report.	Edl and constants	-	Done
2. Construction Stage				
2.1. Anti-pollution measures				
Air quality	-Sprinkle water to control dust -Minimize travel distance	Contractor	Contractor	Daily
	-Regular checking of engine and exhaust of machinery and its recording and reporting	Contractor	Engineer	Monthly
	-Respiratory protection for worker at site	Contractor	Engineer	Daily
Water quality	-Regular water sampling and quality analysis at downstream of construction site. In case not acceptable level, find reason and trap waste water	Environmental Team/Engineer	Environmental Team/Engineer	Monthly
Waste	-Dispose of materials to approved area so as not to disturb scenery and not to contaminate water	Contractor	Engineer	Weekly
Soil contamination	-Capture insulation oils in barrel and use oil proof sheet to avoid any leakage	Contractor	Engineer	Weekly
Noise and vibration	-Instruction to driver to comply speed limit -Check proper material loading and uploading - Use silencer and muffler for equipment	Contractor	Engineer	Weekly
Management of abandoned sites	-Site rehabilitation with topsoil recovery, reshaping, revegetation and remediation with site clan up work - Stabilization of water disposal area	Contractor	Engineer	At finishing stage
2.2 Natural Environment				
Ecosystem	-Provision of minimizing the disturbance under water	Engineer	Engineer	Monthly
Topography and geology	-Prevention with rock support and prompt concrete work in construction	Engineer	Environmental Team	Before construction
2.3 Social Environment				
Sanitation	-Provision of proper sanitation with septic facilities -Prohibition of untreated human waste to enter any watercourse	Contractor	Engineer	Weekly
Living and Livelihood	- Source workforce from qualified locals and orient workers on desirable working relationship with skill enhancement and employment program (positive)	Contractor	Engineer	Work commencement
Landscape	-Provision of explanation to villagers and tourist for the meaning that the work	Environmental Team/Engineer	Environmental Team	At finishing stage
3. Operation Stage				
Hydrology / social and economic environment public safety	-Daily monitoring downstream water level including the Nam Lik. Avoid zero or single 18 MW operation for off-peak hours to keep downstream water level. -Precaution to downstream communities for rapid increase/decrease of river water level with sign board and public consultation. Keep present output increase rate and conduct gradual opening as possible.	CSER Unit	-	Daily
Water quality	-Regular water sampling and quality analysis at entry point of the NN1 reservoir and at the NN1 Dam site. In case the quality is not acceptable level at the entry point, find reason and inform to the upstream water users.	CSER Unit	-	Monthly
4. Monitoring and Audit				
Environmental audits	Undertake third party monitoring audits	MoNRE	-	A year after construction
Environmental Monitoring	Monitoring by EMMU for compliance of ESMP	Environmental and Social Unit (Construction Phase),CSER Unit (Operation Phase)	MoNRE, PEMC	Quarterly

Source: Based on IESA Report of NN1 Hydropower Station Expansion 2009 revised by JICA Survey Team

10.1.10 COST ESTIMATION

Cost regarding the environmental management was recalculated based on the revised ESMP. Overall cost, cost in detailed design phase, cost in construction phase and cost in operation phase is shown in Table 10.1.8, Table 10.1.9, Table 10.1.10 and Table 10.1.11 respectively.

Table 10.1.8 Overall Cost Regarding Environmental Management

Description		Unit price	Qty	Unit	Amount
Detailed Design					
	Environmental Specialist (International)	32,146	1	P/M	32,146
	Hydrologist	3,764	2	P/M	7,528
	Environmental Monitoring *			LS	23,600
	Miscellaneous expenses		Lump sum		26,000
Sub- Total					***89,274***
Construction					
	Environmental Specialist (International)	32,146	3	P/M	96,437
	Environmental Specialist (Local)	3,764	18	P/M	67,754
	EMU Monitoring	LS		LS	13,080
	Miscellaneous expenses				104,400
Sub- Total					**281,671**
Operation					
	Environmental Specialist	3,764	3		11,292
	Hydrologist	3,764	2		7,528
	EMU Monitoring		LS		2,460
	Environmental audit cost	5,000	1		5,000
	Miscellaneous expenses		LS		32,400
Sub- Total					***58,681***
TOTAL					**429,625**
Contingency 10%					42,962
Grand Total					**472,587**

*Including water quality monitoring equipment

Table 10.1.9 Cost Regarding Environmental Management in Detailed Design Phase

Administration

Description	Unit price	Qty	Unit	Amount
Administration*	20000	1	LS	20000
Reporting	500	2		1000
Car rental for Expert	2,500	2		5,000
Total				**26,000.00**

*Including setting up Environmental Team and Social Team

Environmental Monitoring

Description	Unit price	Qty	Unit	Amount
Maintienance	200	6	M/D	1200
Menta 2 Water Quality Monitoring Equipment	10000	1	set	10000
Lab test	100	6		600
Water Quality Monitoring	300	6		1,800
Training			LS	10,000
Total				**23,600.00**

*Car rental and per diem for provincial and district representative
** Collecting baseline data
***Training on water quality monitoring for 2 days, one trainer and 10 trainees

Table 10.1.10 Cost Regarding Environmental Management in Construction Phase

Administration

Description	Unit price	Qty	Unit	Amont
Lab Test	100	18		1800
Sampling bottle and contianer	150	54		8100
Administration	1,000	18		18,000
Miantenance	200	18		3,600
Car Rental for Expert	2,500	18		45,000
Total				**76,500.00**

Environmental/Social Team (EDL)

Description	Unit price	Qty	Unit	Amont
Field Work*	90	36		3240
Driver	35	36		1260
Vehicle, petrol, other	150	36		5,400
Reporting	500	36		18,000
Total				**27,900.00**

*2 staff (Environmental Team and Social Team)

EMU (MoNRE)

Description	Unit Price	Qty	Unit	Amont
EMU central, province and district*	135	12		1620
EMU province and district**	90	36		3240
Driver	35	12		420
Vehicle, petrol, other	150	12		1800
Reporting	500	12		6000
Total				**13,080.00**

*Quarterly monitoring 3 persons from MoNRE at district, province and central level
**These two representatives will work closely with Environmental Team

Table 10.1.11 Cost Regarding Environmental Management in Operation Phase

EDL-Gen/Corporate Social Responsibility Unit

Description	Unit price	Qty	Unit	Amont
Lab test	100	12		1200
Field Work	90	12		1080
Diver	35	12		420
Maintenance	200	12		2400
Vehicle, petrol, other	150	12		1800
Reporting	500	12		6000
Car Rental for Expert	2500	3		7500
Administration	1000	12		12000
Total				**32,400.00**

*2 staff (1 for Environment, 1 for Social)
**Maintenance of Water Quality Equipment

EMU MoNRE

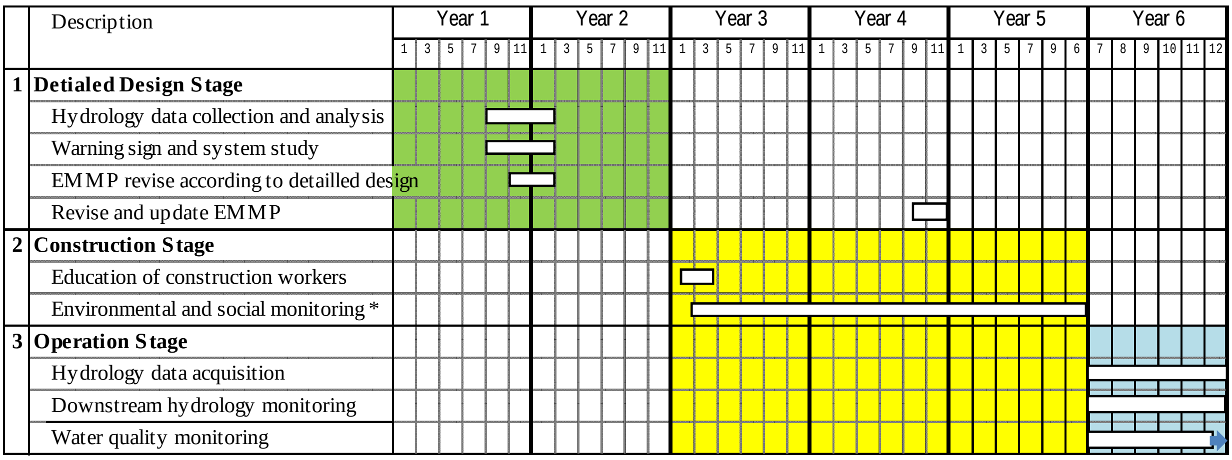
Description	Unit price	Qty	Unit	Amont
EMU central, province and district*	135	3		405
Driver	35	3		105
Vehicle, petrol, other	150	3		450
Reporting	500	3		1500
Total				**2,460.00**

*Comprised of monitoring after construction, external auditing and after 1 year project's operation

10.1.11 IMPLEMENTATION SCHEDULE

Following is the updated schedule on environmental management addressed in the Report. The implementation period for" Hydrology data collection and analysis" and "Warning sign and system study" was reduced from 9 months to 6 months from original schedule in the Report in order to adjust to overall schedule for the Detailed Design, which is planned from the 9th month of the year 1 to 2nd month of the year 2. The task "Revision of EMSP and submit to MoNRE for approval" was added during construction period in order to meet the requirement stipulated in the article 13 in the Decree on Environmental Impact Assessment (2010) that "…six months before operation, the project developer must evaluate implementation of the environmental and social management plan …and submit to WREA (MoNRE) for approval…". Besides, the periodical monitoring on water quality is added in operation stage and this task is to be continue during operation stage. The updated implementation schedule is shown in Table 10.1.12. In construction phase,

Table 10.1.12 Implementation Schedule



*It includes all activities addressed in ESMP
Source: JICA Survey Team

10.1.12 PUBLIC INVOLVEMENT

In order to disseminate the project objectives and impacts due to the NN1 hydropower station expansion as well as to collect information and opinion from villagers of villages concerned and local authorities, public consultation was implemented at village level and central level including authorities concerned at district and provincial level as a part of IESE in 2009. The result of the meeting was incorporated into the Report. Summary of the public consultation meeting at village level is shown in Appendix C-4-1 and Minutes of the Public Consultation at central level is shown in Appendix C-4-2.

As for the further step, it is strongly recommended to hold a public consultation meeting again before starting construction. In the meeting, at least following topics needs to be covered;

- Public awareness for the construction works,
- Information dissemination on detailed assessment of downstream water level change and,
-Warning and information provision about water level acute change at the shift of peak and off-peak time.

10.2 SOCIAL CONSIDERATAIONS

10.2.1 COMPENSATION POLICY

A compensation principles and procedures are stipulated in "Decree on the Compensation and Resettlement of the Development Project (Oct 2005)". It is addressed that "Project owners must compensate project's affected peoples for their lost rights to use land and for their lost assets (structures, crops, trees and other fixed assets) in full or in part, at replacement cost". Besides, Technical Guidelines on Compensation and Resettlement in Development Project (2005 STEA) provides detail instruction on land acquisition and compensation procedures.

10.2.2 AFFECTED ASSETS

As it was described in the previous part, main negative impact was predicted on water fluctuation range in downstream of the Nam Ngum River due to change of operation pattern after the completion of capacity expansion in NN1. In particular, the estimated water level increases around 0.4 m to 0.5 m would affect productivity of riverbank gardening during dry season. In order to estimate the impact from the water level increase, hearings at village level were conducted in all 21 affected villages. The summary of the hearing is shown in Table 10.2.1, the location of affected villages is shown in Appendix C-5 and questionnaire of hearing is shown in Appendix C-6-1 (village level) and Appendix C-6-2 (households) respectively. The result of hearing is attached in Appendix C-7-1～C-7-5.

Demography: It was confirmed that total number of households were 5,076, number of households practicing riverbank gardening were 845. Riverbank gardening is practiced all affected villages except for the villages of Sengsavang, Munagnkao, Thaphoxay and Thin-Nyoung. It is especially popular in the village of Donkouat and Hatxai where 80 % and 79.8 % of total households are practiced respectively.

Buffer zone: It is the area between the lowest water level of the river and the bottom of riverbank garden secured from daily and seasonal water level fluctuation, ranges from 0.5 m to 20 m among affected villages.

Ownership of riverbank gardening area: Riverbank gardening area[15] belongs to the Government and Land Title (permanent land use rights)[16] for the area is not issued in all affected villages. The use of the riverbank area is customary recognized by village authority in all affected villages and it is transactional without issuing official document. The transaction is carried out between individuals except for the Bounphao Village where the transaction is managed by village authority.

[15] Riverbank garden area here means the area from the top of the riverbank to the river.
[16] Land belongs to the Government. The use of land is certified and it is transactional. There are two categories for the certificate; Land Certificate (temporary use right of agricultural land or forest land) and Land Title (permanent land use rights).

Table 10.2-1: Households Practicing Riverbank Garden, Buffer Zone and Ownership

No.	Village	District	Total No. of Households	No. of Households Practicing Riverbank Gardening	Total Area of Riverbank Garden (ha)	Buffer Zone (m)	Ownership of Riverbank Garden
1	Thinkeo	Keoudom	218	1	0.18	2	Customay use
2	Sengsavang		313	0	0	0	-
3	Thalat		207	30	N/A	N/A	Customary use
4	Thatxan		165	50	N/A	0.5	Customary use, tax not imposed on using
5	Hatkhoun	Viengkham	64	25	2.5	0.5	Customary use, tax not imposed on using
6	Nanin		122	30	N/A	0.5	Customary use, tax not imposed on using
7	Veunsan		282	58	3	1	Customary use
8	Muaungkao		201	0	0	0	No river bank activities
9	Thaphoxai		104	0	0	0	No river bank activities
10	Pakkagnoung		530	50	N/A	0.5	Customary use, tax not imposed on using
11	Pakcheng		150	3	N/A	1	Customary use
12	Donkouat		185	148	N/A	2	Customary use
13	Thin-Nyoung		310	0	0	0	No river bank activities
14	Viengkham		131	3	5	0.5	Customary use, most area belong to HHs of Keun-Neua
15	Keun-Nua	Thoulakhom	342	25	N/A	1	Customary use, land beloneg to Ban Veingkham
16	Keun-kang		368	35	N/A	0.5	Customary use, tax Imposed on use
17	Hatxai		213	170	N/A	1	Customary use, tax Imposed on use
18	Boungphao		340	30	18	5	Customary use, Emerged land is belonged to District, HHs rent emerged land from village authority with 750 USD/ha (1 USD = 8,000), right of using river bank area can be leased and transferred among individuals
19	Nakhong		166	12	N/A	4	Customary use
20	Lingxan		297	25	15	20	Customary use, tax imposed on using
21	Cheng		368	150	N/A	2	Customary use, lease price among villagers is 75 USD/ha
Total			5076	845	—	—	—

Source: JICA Survey Team

As a result, the increase of 0.5 m from present water level is not expected to affect on the productivity of riverbank gardening since the area is within the buffer zone. Thus, any compensation or resettlement is predicted. However, actual affecting water level to downstream people will be found only after the commencement of operation. Accordingly, water level and discharge observation shall be conducted during operation phase at least for the first year of dry season. Besides, the NN1 shall open the window for receiving public comment on water level change during this period.[17]

10.3 CONCLUSION AND RECOMMENDATION

10.3.1 CONCLUSION

Unlike construction of a new dam and hydropower project, no significant and irreversible impact on the social and natural environment is expected in the Nam Ngum 1 Hydropower Station Expansion Project. The expansion project needs neither creation of reservoir nor construction of new transmission lines. In terms of socio-economic impact, no relocation or land acquisition is required. Compensation is not necessary in the selected optimum scale of the project. As a result of IESE study, it is concluded that environmental and social impacts of the NN1 expansion project are basically insignificant. Negative impacts can be avoided or mitigated by conventional construction management with proper instruction and operation under the Environmental and Social Management Plan.

On the other hand, continuous impact that may affect to natural and social environment is expected due to larger daily water level fluctuation in downstream of the Nam Ngum River. This is due to the change of operation pattern in NN1 power station after the expansion work. The downstream river water level is reduced during off-peak time and increased in peak-time. The downstream discharge fluctuation comes from the change of output and discharge at the NN1. River side gardening may be possibly affected by the water level increase during peak time. On the other hand, boat transportation and fishery may be affected by water level decrease during off-peak time. Irrigation and river water pumping may also be affected by the water level decrease. These water level fluctuations will happen only in the dry season. Based on the results of social survey and hydrological analysis in IESE, the water level fluctuation range was confirmed to be within the allowable level at the downstream in case of 40 MW expansion.

10.3.2 RECOMMENDATION

The following is the recommendation for further steps.

Operation pattern (NN1):

-Off-peak operation shall be generated with at least a single unit of 40MW in order to keep the water level within -0.4 m ～ -0.5 m to present water level, which would be no effect on the activities in downstream of NN1.

-When shifting from off-peak to peak operation, step-wise increase by 80MW at maximum has to be kept

[17] As it was reported in “Study on Power Supply and Demand in Central Region in Lao PDR (August 2012)”, one of the island, which has been used for new year festival during 3 days of new year holidays within the boundary of Dongkouat Village in the downstream of the NN1, would be affected by the increase of water level due to the expansion during the festival. Information shall be collected at the time of festival in D/D phase or construction phase. Accordingly, the information shall be used for the baseline data at the time of monitoring during operation phase.

not the water level to increase rapidly. Additional output increase should be conducted after 30 minutes or 1 hour to reach the maximum operation.

Operation pattern (Nam Lik ½):

-The Nam Lik Hydropower Station is required to release the water at least to fulfill the draught discharge at the confluence of the Nam Lik River and the Nam Ngum River.

- Actual discharge from the Nam Lik 1/2 shall be monitored continuously to determine whether the discharge pattern of the Nam Lik 1/2 does not cause adverse effect to activities in the downstream of the NN1. If adverse impacts are detected, adjustment of discharge pattern shall be requested to the Nam Lik 1/2.

Water quality monitoring: Although the water quality monitoring is addressed as a task in D/D for the purpose of collecting baseline data as well as in Construction phase for monitoring, it is recommended to continue to conduct periodic water quality checkup in operation phase especially to detect the water from upstream of NN1 for avoiding effect on reservoir or water in the downstream of NN1.

Warning system: : It is necessary to install warning signboard to explain about rapid water level increase at the time of shifting from off-peak to peak operation for the people using water in the downstream of the Nam Ngum 1. In the detailed design, the location for the signboard shall be studied. In addition, the necessity of setting up automatic warning system shall be studied.

CHAPTER 11 PROJECT EFFECT

11.1 PROJECT PURPOSE AND PERFORMANCE INDICATORS

The expansion of NN1 is projected to concentrate its power generation in peak time instead on off-peak time. Furthermore, the expansion reduces unnecessary water release through the spillway, and subsequently the increase of annual power generation can be expected. These two points are the direct effect of the expansion; that is, the project purpose (Outcome).

In order to conduct a project evaluation which is consistent from ex-ante till ex-post, JICA adopts performance indicators. Especially for ODA Yen Loan, operational and effectiveness indicators are used as the performance indicators to grasp level of achievement of the project purpose.

The operational indicator is an indicator to measure operational condition of the project. Meanwhile, the effectiveness indicator is an indicator to measure production condition of effect due to the project.

Target values of these indicators are set as follows. Target year is set at 2020, which is two years after completion of the Project.

Table 11.1.1 Performance Indicators

	Project Purpose	Operational Indicator	Effectiveness Indicator
1	Power generation in peak time	Plant factor of Unit 6: 68.8 %	Firm power output of NN1: 151 MW
2	Increase of power generation	Annual power generation of Unit 6: 241 GWh	Annual power generation of NN1: 1,176 GWh

Source: JICA Survey Team

11.2 INDIRECT EFFECT

Besides the direct effects which are listed in the above, the following indirect effect can be expected from the expansion of NN1.

(1) Stable Power Supply

Over-reliance on power import and IPP domestic power generation projects may lead to difficulty for EDL to control the power system operation flexibly according to the demand which changes from time to time. EDL is required to secure more EDL-owned power stations for domestic supply in the future for stable power supply. The expansion of NN1will contribute to this.

(2) Profitability

Peak power supply strengthened by the Project will improve the trade balance with EGAT by THB 108.2 million (US$ 3.38 million) annually in 2020. This is regarded as the economic benefit of the project if the imported energy is deemed as the alternative to the energy from NN1 hydropower station.

As seen in the economic and financial analysis in the preceding chapter, the NN1 expansion project has certain profitability which will not cause a burden to EDL and EDL-Gen in future. FIRR of the project is 6.72%. Accordingly their resources can be allocated for implementation of other power projects, which will contribute to further reinforcement of power supply capacity.

(3) Reduction of GHG Emission

The expansion of NN1 will increase the annual power generation of NN1. This causes reduction of GHG (Greenhouse Gas) emission by thermal power plants. As the alternative thermal power plants, two cases are considered, that is, 1) new installation of diesel power plants in Laos, and 2) existing thermal plants in Thailand. According to JICA's estimation method, in case of the latter, the thermal which has the highest emission is regarded as the alternative to the extent of 5% of total grid capacity.

For the new installation of diesel power plants in Laos, it is assumed that the thermal efficiency and carbon content in the fuel are 43% and 20.2, respectively. Accordingly the emission coefficient of CO2 is estimated at 0.620 kg-CO2/kWh.

Meanwhile, based on IEA's data for 2009, the thermal efficiency and emission coefficient of CO2 for oil, gas and coal fired thermal plants in Thailand are estimated as seen in the Table 11.2.1. The thermal which has the highest emission is the coal-fired plant, and its emission coefficient is estimated at 0.951 kg-CO2/kWh, which is larger the one of the new diesel power plants in Laos.

Table 11.2.1 GHG Emission Coefficient in Thailand

	Electricity	Energy Input	Thermal Efficiency	Carbon Content	Fraction Factor	Emission Coeffcient
	GWh	ktoe	%	tC/TJ		kg-CO2/kWh
Oil	710	172	35.5	20.0	0.990	0.744
Gas	104,943	20,497	44.0	15.3	0.995	0.459
Coal	29,596	6,847	37.2	26.8	0.980	0.951

Source: JICA Survey Team

Considering the coal-fired power plant in Thailand as the alternative thermal, rough estimation of reduction of GHG emission for the Project is obtained as seen in Table 11.2.2.

Table 11.2.2 GHG Emission Estimates

Annual Energy Production	Natural Gas (Combined Cycle)		Hydropower (NN1 expansion)	
GWh/y	g CO_2 equiv./ kWh	ton CO_2 equiv./ year	g CO_2 equiv./ kWh	ton CO_2 equiv./ year
59	951	56,109	0	0
			Reduction	56,109

Source: JICA Survey Team

(4) Countermeasure against Aging of Existing Facilities

The existing power generation facilities have been installed in series since 1971. All of the units are getting older although units except Unit 4 have already been rehabilitated. The yearly maintenance is carried out only during the dry season to minimize invalid water release and there is no ample space to adjust the timing of the maintenance. The expansion of additional one unit would contribute not only the decrease of power generation time ratio and maintenance cost but also to the planning of maintenance with sufficient time period and safety power generation.

(5) Job Creation Effect

The expansion of NN1 will also contribute to poverty reduction and social development; that is, job creation. Although there will not be much job creation opportunity in the operation and maintenance stage, the Project will employ about 300 labors for construction, at its peak time, of which most will be procured in the surrounding area of the Project, especially the downstream reach of the Project.

Average income and ratio of vulnerable households in the area is described hereinafter for reference purpose.

Table 11.2.3 Average Income and Vulnerable Households

No.	Village	Average Income (USD/capital/year)	Household	Vulnerable Households	Vulnerable Households (%)
1	Thinkeo Village	N/A	218	0	0
2	Sengsavang Village	750	313	0	0
3	Thalat Village	N/A	207	0	0
4	Thatxan Village	700	165	0	0
5	Hatxaykhoun Village	1200	64	0	0
6	Nanin Village	700	122	1	0.8
7	Veunsan Village	600	282	0	0.0
8	Muangkao Village	850	201	0	0.0
9	Thaphoxai Village	1200	104	4	3.8
10	Pakkagnoung Village	1200	530	5	0.9
11	Pakcheng Village	1100	150	0	0.0
12	Donkouat Village	750	185	5	2.7
13	Thing young Village	800	310	3	1.0
14	Viengkham Village	800	131	2	1.5
15	Keun-Nua Village	1,876	342	0	0.0
16	Keun-Kang Village	1,400	368	2	0.5
17	Hatxai Village	850	213	30	14.1
18	Boungphao Village	900	340	1	0.3
19	Nakhong Village	760	166	N/A	-
20	Lingxan Village	800	297	2	0.7
21	Cheng Village	700	368	0	0.0

Source: JICA Survey Team

There are few vulnerable households found in the downstream area of the Nam Ngum River (especially the area designated as affected area from this project) except for the Hatxai Village. [1]Accordingly, the area is considered to be economically stable. As the rate of household engaging in agricultural sector is large (61 % in total main income comes from agricultural sector), it is predicted to have big potential of labor especially during dry season when farmers would have more spare time. Thus, the creation of job opportunity by this project is expected to contribute positive impact to local economy. As for the negative impact to the local society from the project, basically it is not predicted.[2]

[1] The vulnerable households in the Hatxai Village is comprised of the landless households migrated from outside for working in the factory in this village.

[2] Negative impact from the project is discussed in Chapter 10 environmental and social considerations.

CHAPTER 12 CONCLUSION AND RECOMMENDATIONS

The Survey is started in July 2012, with the aim to conduct necessary study for appraisal such as objective and effect, outline, cost, implementation schedule, construction and procurement plan, implementation system, operation and maintenance system, and environmental and social considerations of Nam Ngum 1 hydropower station expansion project so as to implement as the ODA yen loan project.

The previous preparatory survey in 2010 recommended to expand NN1 with a scale of 40 MW. The Survey re-examined the project from the technical, economical & financial, and environmental view points, and concluded that the same scale and layout of the expansion as in 2010 is the optimum option and feasible. The conclusions and recommendations are discussed below.

12.1 CONCLUSION

(1) Optimum expansion plan

Twelve candidates of the expansion alternatives ranging from 40 MW to 120MW were taken into account in the start of this Survey. In choosing these alternatives, the results of the previous preparatory survey in 2010 were referred to and new layouts of intake/coffering as well as left bank waterway were additionally taken up. The selected prospective alternatives were compared in detail by analyzing power generation, designing of powerhouse expansion layout and estimating construction cost.

As the result, Alternative A1 (40 MW) is judged to be highest in cost performance among the twelve alternative options considered. Alternative A1 is to build a new unit bay building for 40 MW plant in the space between the existing powerhouse and the spillway. The existing OHT cranes and draft tube gates can be utilized for the additional unit. The layout of the new powerhouse is most compact and economical among all options. Since the length of penstock and tailrace is short and waterway head loss is less, available water head can be most effectively utilized for power generation. Environmental impact is less compared with other expansion scale (60MW~120MW).

By comprehensively judging from technical, economical and financial points, Alternative A1 (40 MW) is selected as the optimum expansion plan for the Nam Ngum 1 power station.

(2) Reservoir Operation

Optimum reservoir operation rule is studied for expanded Nam Ngum 1 hydropower station with 40MW to simulate the power generation with developed reservoir operation rule. Outcrop at the downstream reach of NN1 is assumed to obtain the tailwater level.

In the previous NN1 expansion survey presumed that reservoir operation study aimed to maximize the energy production while securing firm capacity. Since the objective of the NN1 expansion is the same to the previous NN1 preparatory survey, therefore the same approach is used, that is to maximizing annual energy while securing firm capacity.

The previous NN1 preparatory assumed that the large amount of electricity was to be imported from EGAT from year 2015, therefore the minimizing power import from EGAT was also included in the objective function. While the study on power supply and demand in central region in Lao PDR was conducted by JICA in 2012 and it identified that the power export from EDL to EGAT will exceed power import in 2017 in annual balance. Thus the minimization of power import is not significantly important for NN1 operation thus the minimization of power import from EGAT is eliminated in the study.

The result indicates that the average annual energy “without expansion” would be 1,117 GWh, and 1,176GWh for “with” expansion case (increment of 59 GWh). This means that the energy is increased for 46GWh in “without” expansion and 49GWh for “with” expansion compared with the previous preparatory survey in 2010. One of the reason of increasing energy is that the minimizing power import is eliminated from the objective thus, the reservoir operation has more flexibility in operation.

(3) Basic design

The basic design for the optimum expansion plan was carried out. The design conditions required for the basic design are discussed below:

Rated Reservoir Water Level for New Unit 6

The present long-term average water level is EL. 206.0 m. However, the average water level estimated for the condition after expansion (40 MW) goes up to EL. 209.6 m which is 3.6 m higher than the present status. Thus the rated water level for unit No. 6 is set at EL. 209.6m.

Rated Tail Water Level for New Unit 6

Through the excavation of the exposed riverbed located at about 500 m downstream of the powerhouse, tailrace water level (tail water level) is lowered, the effective head is increased, consequently increasing the generated energy. As such excavation will contribute to improvement of project economy, it is included in the project scope and regarded as the basis for setting the tail water level.

The released discharge from the six turbines including unit 6 under the rated operation is 573.3 m3/s. As the result of non-uniform flow calculation, the water level with this discharge is EL. 168.2m. This is regarded as the rated tail water level for unit No.6.

Rated Head for New Unit 6

The head loss for unit 6 is 1.2m with the maximum plant discharge. Accordingly, effective head for unit 6 is 40.2m (=209.6-168.2-1.2). In this Survey, the rated head for unit 6 is set as 40m.

Optimum Penstock Diameter for Unit-6

As the result of economic comparison, the penstock diameter for the new unit 6 is decided to be 5.50 m.

Intake Center Elevation of Unit-6

EL. 196.0 m is adopted as the minimum operation reservoir level for unit-6. The intake entrance level should be deep enough from the water surface in order to avoid formation of vortex and consequent air-entraining into the intake conduit. Therefore, the elevation of the intake conduit center is decided to be EL. 185.25 m.

Intake and Penstock

The dam body is pierced and a new intake gate is installed at a tower provided at the downstream of the dam body. A 5.5m diameter penstock is provided at its downstream. The hole of dam piercing is lined with concrete.

Channel-shaped steel enclosure was recommended best in the previous preparatory survey. Although the recommended scheme provides high reliability in construction, it has been pointed as problem to solve that the enclosure works would be exceptionally-expensive for a temporary facility of which weight cannot be lightened without restriction of the reservoir water level.

In this Survey the lightening of the enclosure works has been requested to improve economic efficiency of the project. The enclosure cost can be successfully reduced with the closure method revised to a bulkhead type. Accordingly the design of the trashrack is changed to fixed type, and the intake gate is to roller gate type.

Dam Stability

Dam stability and stress in the foundation rock are checked applying temporary enclosure (steel girder type support). The dam block No. 20 is the section to be studied. Change in load conditions due to a piercing dam or temporary enclosure is considered. Result of the study proves the dam is stable with the temporary enclosure of steel girder support type.

Powerhouse

Taking account of the existing powerhouse structure, topographic condition and required facilities to be accommodated, the powerhouse is designed to consist of four floors.

Electrical and Mechanical Equipment

The rated turbine output, rated generator output and rated transformer capacity are set at 40.9 MW, 50 MVA, and 16.666 kVA/phase (50,000 kVA for three-phase), resoectively.

A roller gate is equipped at the upstream of upper bend of the penstock, with stoplog. The penstock pipe has sufficient strength against the inner pressure with a minimum required thickness. The existing stoplog segment for draft tube and gantry crane are commonly used for the new unit.

(4) Implementation plan and cost estimation

The grand total of construction cost has been estimated at ¥5,673 million including the cost for consulting services. The total construction period from preparation works to commencement of power generation is 36 months, and power generation would be commenced in 2018.

(5) Economic and Financial Analysis

The EIRR of the expansion plan is calculated with kW value and kWh value of diesel power. The calculated economical internal rate of returns (EIRR) is 16.31% and it is judged to be economically feasible.

The FIRR of the expansion plan is calculated with benefit of the tariff revenue from domestic consumers. The computed financial internal rate of returns (FIRR) is 6.72% and it is judged to be financially feasible also.

(6) Organizational Framework for Project Implementation and O&M

EDL will be the implementation agency for the NN1expansion including its design, procurement and construction. EDL will establish the Project Management Unit (PMU) which has specific function and authority for implementing the NN1 expansion. The developed power plant will be transferred to EDL-Gen for operation and maintenance.

(7) Environmental and Social Consideration

Unlike construction of a new dam and hydropower project, no significant and irreversible impact on the social and natural environment is expected in the Nam Ngum 1 Hydropower Station Expansion Project. The expansion project needs neither creation of reservoir nor construction of new transmission lines. In terms of socio-economic impact, no relocation or land acquisition is required. Compensation is not necessary in the selected optimum scale of the project. As a result of IESE study, it is concluded that environmental and social impacts of the NN1 expansion project are basically insignificant. Negative impacts can be avoided or mitigated by conventional construction management with proper instruction and operation under the Environmental and Social Management Plan.

On the other hand, continuous impact that may affect to natural and social environment is expected due to larger daily water level fluctuation in downstream of the Nam Ngum River. This is due to the change of operation pattern in NN1 power station after the expansion work. The downstream river water level is reduced during off-peak time and increased in peak-time. The downstream discharge fluctuation comes from the change of output and discharge at the NN1. River side gardening may be possibly affected by the water level increase during peak time. On the other hand, boat transportation and fishery may be affected by water level decrease during off-peak time. Irrigation and river water pumping may also be affected by the water level decrease. These water level fluctuations will happen only in the dry season. Based on the results of social survey and hydrological analysis in IESE, the water level fluctuation range was confirmed to be within the allowable level at the downstream in case of 40 MW expansion.

(8) Project Effect

Project purpose will be 1) power generation in peak time, and 2) increase of power generation. To grasp level of achievement, target values of effectiveness indicators are set; the firm power output in peak time at 151 MW, and the annual power generation at 1,176 GWh in 2020.

12.2 RECOMMENDATOIN

In Laos, the domestic demand of peak power and energy are increasing with an average rate of 10%. The increase of power demand of day time and night time peak is remarkable. On the other hand, IPP hydropower projects aiming at domestic power supply are under planning and construction. However, these domestic IPPs are not big in reservoir capacity compared with NN1 and the power plants for peak power supply are minor. Therefore, the expansion of NN1 power station, which has high potential of peak power generation with huge reservoir, aiming at power supply for domestic peak demand is effective. The early implementation of the expansion of NN1 is recommended.

Through the processes of fund procurement, additional geological survey, detailed design and other preparatory works this expansion plan would be able to start power generation in 2018. The following issues should be resolved prior to its implementation:

(1) The detailed design should be carried out by following chapter to be described and the results of the additional investigations. The opinion of the staff of the NN1 power station should be taken in the preparation of the tender documents.

(2) Although the new intake structure will be constructed by piercing of dam body, the reservoir water level should be kept so as to keep the power generation. Therefore, the installation of temporary closure at reservoir side with deep underwater operation will be an important issue. In this regard, the detailed design and construction planning with attention to safety and economic efficiency should be established considering the experiences of same type of expansion in Japan.

(3) With regard to the intake, the gate shaft design is considered superior to the gate tower in every aspect of transportation of gate, stability, constructability, transition of penstock, landscape design and construction cost. However, high-level analyses is needed to evaluate the effect of interactive action to the hollow caused by both the digging adit and shaft, of which effect can be evaluate by a conventional analyses in case of singular excavation. Consequently the tower alternative is chosen in this Survey while more advantageous shaft alternative could be taken after the hollow stability analyzed in the detailed design.

(4) Since the new power station building will be constructed just beside of the existing power station building, it is possible that the vibration due to foundation excavation may affect the existing

power generation facilities and power generation itself. This issue shall be further studied in detail considering geological conditions for establishment of safety measures in the detailed design stage.

(5) The NN2 hydropower station has commenced the power generation in 2011, and the inflow into the Nam Ngum Reservoir is flattened throughout a year. Thus, the operation ratio of power generation facilities is increased, and the power generation time in dry season becomes longer. Therefore, the long term maintenance plan shall be made to ensure the time for the regular maintenance. Furthermore, the maintenance plan after the expansion shall be studied to evaluate the degree of its contributions.

(6) In IESE of this survey, this discharge requirement presumes the maintenance flow is based on that the Nam Lik River flow at least equals to the draught discharge. If the discharge is less than the draught discharge, IESE confirmed that the reduction of the flow will affect to the downstream inhabitants. Therefore, the Nam Lik 1/2 hydropower project is required to release the water at least to fulfill the draught discharge at the confluence of the Nam Lik River and Nam Ngum River. Furthermore, there is a possibility that peak discharges of Nam Lik 1/2 and NN1 will overlap in the downstream reach. Thus, the actual release from the Nam Lik 1/2 should be monitored continuously to determine whether the discharge pattern of the Nam Lik 1/2 does not cause adverse effect to the downstream inhabitants. If the adverse impacts are recognized, adjustment of discharge release pattern shall be requested to Nam Lik 1/2.

CHAPTER 13 POINTS TO CONSIDER FOR PROJECT IMPLEMENTATION

13.1 DETAILED DESIGN

Points to consider for Detailed Design is shown in Table 13.1.1.

13.2 PROCUREMENT

The Consultant will be selected in accordance with JICA's "Guide for Evaluation procedure for procurement of Consultant".

The expansion plan includes construction with special methods by dam piercing and temporary coffering for that. Accordingly, those experiences should be counted in Pre-Qualification so that experienced contractor will be selected.

In case of ODA yen loan, JICA recommends the project executing agencies to use "Sample Bidding Documents under Japanese ODA Loans - Procurement of Works, June 2009" as the basis for preparation of the contract documents. In those sample bidding documents, "Conditions of Contract for Construction for Building and Engineering Works Designed by the Employer, Multilateral Development Bank Harmonized Edition" prepared by FIDIC is adopted. Fair risk-share among the Employer and the Contractor is a prerequisite for smooth implementation of the projects. This principle is applicable to this NN1 expansion project also.

13.3 TECHNICAL ASSISTANCE

Germany consultant of Lahmeyer International (LI) studied the reservoir operation plan of Nam Ngum 1 hydropower station applying the generalized stochastic dynamic programming software developed by LI named LITHO (Lahmeyer International Hydro-Thermal Optimization). However, as LITHO program does not run on the current windows operating system, therefore the program is no longer used to seek the optimum reservoir operation plan.

EDF (Electricite du France) has provided reservoir operation optimization program, which is called PARSIFAL, and ADB funded NNRBDSP project. Currently the Nam Ngum 1 hydropower station tries to use the tool to seek the reservoir operation plan. PARSIFAL is a generalized software packages for hydro-thermal mix power source system. The formulation of reservoir operation plan by PARSIFAL is rather complicated and it requires two hours for calculation. Therefore, the program has not been fully utilized by EDL to develop reservoir operation planning.

Technical assistance to EDL to provide a proper tool for reservoir operation planning is recommended.

Table 13.1.1 Points to Consider for Detailed Design

1 TOPOGRAPHY/GEOLOGY/MATERIAL SURVEY	The following surveys shall be carried out: (1) Topographic survey a) Cross section survey of the powerhouse expansion construction area topography (including underwater area) b) River cross section survey of rock outcrop area in the downstream river channel (2) Geological investigations a) Geology of foundation (core boring, etc.) • Excavation area below downstream toe of dam (Block No. 20) • Excavation area below spillway wall • Rock barrier to be left between existing and new tailbay (including grout injection test) • Rock outcrop area to be removed in downstream river channel b) Core boring in rock outcrop area in the downstream river channel (3) Concrete material test a) Concrete aggregate: Tests of strength, gradation, etc. of river deposit sand and gravel in Nam Lik River and survey for estimating available quantity b) Cement: Physical and chemical properties of cement produced in Lao PDR and supply capacity of cement factory
2 ENVIRONMENT	An Environmental and Social Management Plan (ESMP) was reviewed to avoid or mitigate negative social and natural impacts of the expansion project during construction and operation and maintenance. In the detailed design stage, further review of the following items will be necessary: - Environmental mitigation plan, environmental monitoring plan, and contractor environmental management plan (CEMP) were prepared in this survey. Those should be reviewed in detailed design stage. CEMP should be included in the bidding of contractors. - Off-peak operation should generate with at least a single unit of 40 MW. Zero generation should be avoided to confirm maintenance flow at downstream. Single operation with 18 MW unit may be operated in case discharge of the Nam Lik is more than 117 m^3/s. The hydrology data should be updated and the above condition should be reviewed accordingly in the detailed design. - Hourly discharge should be measured and detailed hydrology data should be collected at NN1 dam site, at downstream of the Nam Ngum and at the Nam Lik during detailed design and first half year after the start of operation to reconfirm the downstream effects. - The effect of water level increase due to peak operation of Nam Lik 1/2 should be checked in the dry season. If the peak level of the Nam Ngum and the Nam Lik is overlapped at the downstream of the confluence, request should be made to the IPP of Nam Lik 1/2 so that large water level increase at downstream can be avoided. It needs to confirm to Nam Lik 1/2 to secure maintenance flow so that discharge of the Nam Lik become more than 90% dependable discharge. - When shifting from off-peak to peak operation, step-wise increase by 80 MW at maximum has to be kept. Additional output increase should be conducted after 30 minutes or 1 hour to reach the maximum operation. Operation rule should be set accordingly. - It is necessary to install warning signboard to explain about rapid water level increase (2.0-2.3 m) at the time of shifting from off-peak to peak time at riverside, where fishing, washing, pumping, gardening, and swimming is done. In the detailed design, the location where a signboard is needed should be confirmed. In addition, the necessity of setting up an automatic warning system should be studied.
3 DESIGN	(1) Civil Works a) The foundation rock below downstream toe of the dam block No. 20 will be removed for additional powerhouse. The structural safety of the dam and foundation should be verified by stability analysis and, if necessary, the foundation strengthening plan should be established. b) The foundation rock beside the spillway wall will be deeply excavated for

	construction of new powerhouse and tail bay. The structural safety of the excavated rock slope should be verified by stability analysis and slope stabilization measures should be established. c) The intact rock between the existing tail bay and the new tail bay will be left unexcavated and the unexcavated rock body will be utilized as coffer wall during construction. The structural safety of the unexcavated rock body against external water pressure should be verified by stability analysis and, if necessary, methods of strengthening the rock body should be established. d) A large size horizontal hole will be excavated in the existing concrete dam body. Stresses in the concrete around the hole should be computed to verify that no excessive tensile and compressive stresses may occur around the hole. (2) Electromechanical Equipment The following items will be examined in the detailed design of the electromechanical equipment. a) Construction of turbine and generator Each generator for unit 3, 4, and 5 is arranged for a special construction to support the thrust bearing from the turbine head cover. It is therefore required that the design of the turbine and generator for unit-6 should be the same construction with the existing units. b) Dimensions and construction of main transformer It is required that the main transformer for unit-6 should be interchangeable with the existing spare transformer of single-phase type. Therefore, the design of the main transformer for unit 6 shall have the same dimensions and construction of the existing units. On the other hand, the 11 kV main bus between the 11 kV cubicle and the main transformer will employ the segregated phase bus (SPB) which is different from the existing one. It is therefore required that the SPB should be designed for successful connection to the existing spare transformer. c) Construction of remote control board The remote control board for unit-6 will be installed in the existing control room aligned with the existing remote control board for unit-5. It is therefore required that the design of the new remote control board should be the same construction with the existing control board for unit-5. d) Data transfer between equipment for unit 6 in NN1 and national load dispatch center EdL is constructing a national load dispatch center in the head office building in Vientiane. The signals of plant status in relation to unit 6 including turbine, generator, transformer, switchgear, etc. will be required to be sent to the control center. This data transfer system shall be well coordinated with design of the national load control center, especially for data transfer item, communication method and communication protocol. e) Installation route of new cables In order to establish the control system and station-service power supply system for unit-6, the power and control cables will be installed in the following sections: - Control cables between the new local control board for unit-6 and the new remote control board for unit-6 in the existing control room - Power and control cables between the new low voltage switchgear cubicle for unit-6 and the exiting low voltage switchgear - Power cables between the new DC distribution panel and the existing DC distribution panel for units 1 and 2 in the existing control room The exact routes of the above cables should be examined in the detailed design stage. f) Replacement of existing 115 kV main bus conductors and additional installation of 115 kV main bus sectionalizing disconnector Replacement of the existing 115 kV main bus conductors as well as additional installation of a 115 kV main bus sectionalizing switch will require shutting down of all units 3, 4, and 5 at the same time. Allowable period for the three units shutdown will be off-peak time only (mid-night, early morning, Saturday and Sunday). Therefore, it is required to make a good schedule so that these

	work can be completed within the allowable period. (3) Mechanical Equipment The following points should be examined for mechanical equipment in detailed design stage. a) Intake trashracks - Study of the installation procedure by diving operation for anchors of screen frames taking account of nonflatness of dam surface - Study of the structure of screen panels taking account of future repair/replacement of panels by diving operation b) Intake gate - Study in case of elimination of bypass valve and pipe equipped with the intake gate leaf - Study of operation manner for intake stoplogs in case of use of the existing stoplog segments c) Intake and draft tube gantry cranes - Modification of cable reel for gantry cranes - Study of removal of control cabin for intake gantry crane d) Steel penstock - Study of accessories such as seepage ring, corrector pipes for seepage water, penstock drain pipe and valves, etc.
4 INFLUENCE TO EXISTING STRUCTURE	Effect by construction works to the existing structures or equipment located near the expansion work will be studied in the detailed design stage, and necessary countermeasures shall be established. a) The magnitude of influence of vibration caused by excavation work for making a large hole in the dam should be verified by vibration analysis and the allowable maximum limit of vibration for the dam body should be defined. b) The magnitude of influence of vibration caused by rock excavation work in the new unit-6 bay area should be verified by vibration analysis and the allowable maximum limit of vibration for existing powerhouse building and generating equipment should be defined. c) The existing access way to the main transformers will be blocked by a temporary ramp way (elevated steel bridge) for the work of piercing dam. Maintenance/ repair work of the main transformers will be difficult due to the ramp way. Protection method of the transformer for safety and transformer repair method for emergency should be established. d) Both gantry cranes for the intake and the draft tube outlet need to be relocated temporarily during the expansion work. The intake stoplogs and draft tube gates cannot be handled by the gantry cranes during the relocation. Method of handling the stoplogs or gates in case of emergency should be established.

Source: JICA Survey Team