Lao People's Democratic Republic

Brief Description of the Design for

Don Sahong Modification Hydropower Project

DON SAHONG POWER COMPANY

中国电建集团昆明勘测设计研究院有限公司
KUNMING ENGINEERING CORPORATION LIMITED

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Approved:

WangGuojin 王国进	Xiang Jun 向军	WuSaibo 武赛波	ChenJiaheng 陈家恒

Verified:

CaoYubo 曹渝波	YangZijun 杨子俊	XiaJianrong 夏建荣	Hu Chuanbin 胡传彬
Zhang Hui 张辉	Han Hao 韩昊	MaRenchao 马仁超	Chen Li 陈砺
Hu Yong 胡勇			

Reviewed:

WangXianzhi 王显治	Lu Peng 卢鹏	Wang Qiang 王强	ZouMaojuan 邹茂娟
ChenWenbin 陈文斌	Xu Tao 徐涛	Cui Zhi 崔稚	Zhang Chong 张冲
YangChuan jun 杨传俊	ChenJiacai 陈家才		

Checked:

HuangHailong 黄海龙	LuoKaisha 罗开莎	HeNengying 贺能英	PanXuemei 潘雪梅
ShenShanan 沈善安	Hu Zhe 胡喆	Chen Qi 陈琪	Zhang Yang 张阳
YinZhenhua 印振华	Hu Lingzhi 胡灵芝	LiJiancheng 李建成	

Prepared:

LinChunlan 林春兰	ZhangJiangchao 张江潮	YangXiaofeng 杨肖锋	MengFanhao 孟繁皓
CenDairong 岑黛蓉	WangShenghua 王胜华	LiHongru 李鸿儒	Wei Yuan 魏源
ZhengDexiao 郑德晓	Yi chun 易春	Yang Li 杨礼	Zhang Shuai 张帅
YuMingyuan 于明远	Wang Jin qian 王金乾		

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1.1 Overview

DON SAHONG Hydropower Project (DSHPP) is located on Hou Sahong River on the right bank of Khone Phapheng Falls at the border between Laos and Cambodia on one of mainstream branches of Mekong River in Champasak Province of Laos.

The external traffic conditions of DSHPP are good. On the left bank, Road 13# is connected to Pakse, the third biggest city of Laos and Vientiane, the capital of Laos. The Project site is about 150km away from upstream (U/S) Pakse City, about 839km away from Vientiane, the capital of Laos, about 270km away from Ubon, Thailand, about 897km away from Bangkok, the capital of Thailand, and about 450km away from Phnom Penh, the capital of Cambodia.

The DSH Modification HPP(DSHMP) is located on the right bank of DSHPP. The powerhouse of the Modification project is about 70m away from the first-phase existing powerhouse. The project consists of the left-bank non-overflow embankment, the right-bank non-overflow embankment, headrace, the powerhouse annex, the auxiliary powerhouse annex the erection bay and the switchyard annex, etc.

The embankment is a concrete gravity dam with the crest elevation of 76.90m and the maximum height of 25.95m. The dam crest on the right bank is about 94m long . The dam crest on the left bank is about 65m long. The non-overflow embankments on the left and right banks enclose a U/S approach channel of the Modification project. The basic section of the embankment is a triangular section with a D/S slope ratio of 0.75, the U/S face above EL.56.9 is vertical, and the U/S face slope ratio below EL.56.9 is 1:0.3.

The powerhouse annex consists of the intake, the U/S bulkhead gate, the main powerhouse, the D/S auxiliary powerhouse, the tailrace emergency gate and tailrace. The installed capacity of the Modification powerhouse is 65MW, the design discharge is 400m^3/s, the rated head is 17.8m, and the unit installation elevation is EL.43.1m. The unit of the Modification project has no sluicing mode requirement. The erection bay is arranged on the left side, and the large components of the unit are directly transported from the transformer access of DSHPP to the erection bay. The original switchyard has been provided with transmission system for one more unit on the river side, and the double-circuit TL of the first-phase project is shared.

1.2 Necessity for Modification

Based on the comprehensive analysis of power load, on grid price and transmission line, the power supply scope of the Modification project is recommended to be Cambodia.

More water may be used for power generation through lowering the U/S water level of reservoir of DSHPP during the wet season. In combination with analysis about hydraulic calculation results, the inflow periods that HPP could use additional 400m^3/s inflow for power generation account for over 40% of time throughout-the-year inflow, the power generation periods of Modification units are secured, and power generation with surplus water in the flood season may be fully utilized after Modification project. In this case, it may realize reasonable and full utilization of hydro resources.

The construction funds for the Modification project will be loaned from Malaysia with low interests. The project income can guarantee repayment of loans, and the annual project benefit will be the net income of DSPC, the owner of Malaysia after the loans are paid off. Upon completion it will transmit the additional power to Cambodia for exporting to earn foreign currency, which will play a further supporting role in Lao national economic development.

The additional unit will also enable DSPC to carry out major planned maintenance works on the turbine-generator units during the dry season to ensure uninterrupted supply to EDL, in turn ensuring EDL can meet its PPA obligation to EDC to avoid incurring any penalties. Therefore, analyzing from the perspective of supporting national economic development of Laos and ensuring reliable and uninterrupted supply to EDL to help EDL meets its obligation to EDC, it is economically feasible and essential to construct DSH Modification HPP.

1.3 Engineering construction conditions

1.3.1 Hydrology and Meteorology

DSHPP is located at Laos-Cambodia border on a branch of mainstream Mekong River in Champasak Province, Laos. The project area is located on the Hou Sahong Channel, on the right side of Khon Phapheng Falls. Hou Sahong River Channel belongs to the Mekong River Basin. Mekong River Basin is subject to control of southwest monsoon and northeast monsoon, with clear distinction of dry and wet seasons. June – November is the wet season, while December – the following May is the dry season. Since the average annual precipitations of Mekong River Basin are subject to the impacts of such factors as geographic location, terrains and landforms, there are great differences between the upper reaches and the lower reaches of the basin. According to statistics of precipitation data from most measured meteorological (hydrological) stations in Mekong River Basin, the average annual precipitations in Mekong River Basin are between 1,240mm – 2,300mm, and the days of average annual precipitation is between 70d – 137d. To be specific, the precipitation during the flood season of June – November is between 1,050mm – 2,100mm, accounting for about 80% of the precipitation all the year round, while the precipitation during the low-flow season of December– the following May accounts for about 20% of precipitation all the year round, and the precipitation is about 130mm - 230mm. The maximum 24h precipitation in Mekong River Basin is between 70mm - 310mm.

1.3.2 Transportation Conditions

The external traffic conditions of DSHPP are good. Road #13 on left bank is connected to Pakse, the third biggest city of Laos and Vientiane, the capital of Laos. The Project site is about 150km away from U/S Pakse City, about 839km away from Vientiane, the capital of Laos, about 270km away from Ubon, Thailand, about 897km away from Bangkok, the capital of Thailand, and about 450km away from Phnom Penh, the capital of Cambodia. The existing access roads and the already built on-site roads of DSHPP would be sufficient and only short construction

accesses are required to be built.
The cement is to be provided from Thakhet Cement Plant, with a haul distance of about 513km, while the fly ash is to be purchased from Rayong, Thailand, with a haul distance of 1,129km.
Oils and explosive materials may be purchased in Laos, but the guarantee rate is not high. Storage is necessary by making use of warehouse built for DSHPP or new warehouse.
The concrete aggregate is to be processed with fresh stones excavated and stacked in phase I project by new artificial aggregate system to be built.
The E&M equipment and heavy and large components would be procured in China, shipped to LEAM Chebang and followed by road transportation. The construction equipment may utilize the available equipment for DSHPP as much as possible, and if insufficient, equipment may be purchased or leased in Vientiane and Thailand.
The electric power for construction purpose would be T-connected from 11kV TL built for DSHPP, and one construction transformer 11kV/3.0km is set for the purpose of the Project. Water for construction purpose may be directly taken from reservoir of DSHPP or pumped from the D/S river channel.

1.3.3 Engineering Geology

The region where the Modification project is located belongs to a relatively stable tectonic block; PGA of the Modification project is consistent with that of first-phase project, that is, PGA of OBE is 0.05g, MDE_1 0.10g, MDE_2 0.15g, seismic basic intensity is Mag. V.

Topography of project area is gentle and lithology of stratum is uniform. Bedrock consists of dacite with tuff of T_{1-2}, which are rated as medium hard-hard rock, attitude N65°~70°, SE∠50°~70°. No soluble rock strata is found in the area; landslide, collapse, debris flow and stress relieved are not developed, physical and geological phenomena are mainly rock weathered; groundwater is mainly bedrock fissure water, water are not corrosive to concrete. There are no considerable engineering geological problems that restrict the Modification project.

Powerhouse foundation consists of class II and III rock mass, there is no deformation, sliding, and seepage stability problem. Right, left embankment, and erection bay foundation to be placed in the moderately weathered and highly weathered rock mass respectively, which can meet requirements of design.

Concrete aggregate is recommended to continue to use excavated materials, mainly consisting of the first-phase underwater, river channel excavated materials. Aggregate are mainly stored in disposal area above emergency spillway and both banks of Hou Sahong river channel inlet, with an average distance 4km from powerhouse. For clay core materials of cofferdam, it is recommended to use Quaternary alluvial and residual silty clay layer and completely weathered layer excavated in Modification project area. Both reserves and quality meet the requirements for concrete aggregate and core earth material.

1.4 Engineering characteristics

Table 1.4-1 Engineering Characteristics of DSH Modification HPP

S/N and Description	Unit	Qty.	Remarks
I. Hydrology			
1. Referenced period of hydrologic data series	Annual	1960~2014	
2. Average annual flow	m^3/s	9850	Pakse Hydrological Station
3. Representative discharge			
Average annual flow	m^3/s	9850	Pakse Hydrological Station
Measured maximum discharge	m^3/s	57800	Pakse Hydrological Station (1978.8.17)
Measured minimum discharge	m^3/s	1060	Pakse Hydrological Station (1960.5.6)
Standard of construction diversion P	%	1	
Corresponding discharge	m^3/s	56000	
4. Sediment			
Average annual suspended load discharge	10^3 t	124,910	Pakse Hydrological Station
II Project scale			
1. Reservoir			
Capacity	10^6m^3	23.37	
2. Hydropower project			
Installed capacity	10^3 kW	65/62	Installed/ Maximum
Supplementary annual utilization hours	h	3600	
Regulation performance of reservoir		N/A	
Discharge for power generation and diversion	m^3/s	400	
III. Engineering structures and equipment			
1 Embankment Dam			
Basic seismic intensity		VI	
Design seismic intensity		VI	
Crest elevation	m	76.90	
Maximum dam height	m	25.95	
Crest length of the left dam	m	94	
Crest length of the right dam	m	65	
2. Headrace structures			
2.1 Intake of the HPP			
Design discharge	m^3/s	400	
Platform elevation of intake		76.90	
Bottom plate elevation of intake		34.70	
Type of the trash rack		Vertical type	
Number of the	Set	3	
Trash rack of intake	m×m	5.1×42.2	
Cleaning machine	Set	1	
Orifice dimensions of maintenance gate	m×m	15.36×17.00	

S/N and Description	Unit	Qty.	Remarks
(W×H) of intake			
Hoist	Set	1	
3. Powerhouse			
Type		Water retaining (Bulb turbine)	
Dimensions of the powerhouse	m×m(L×W)	66.85×77.97	
Installation elevation of turbine or water pump	m	43.10	
Runner diameter	m	7.20	
Hoist	Set	1	
Orifice dimensions of emergency gate (W×H) of tailwater	m×m	14.0×11.60	
5. Switchyard			
Type		Outdoor switchyard	
6. Main mechanical and electrical equipment			
Turbine	Set	1	
Rated output	kW	65,000	
Generator	Set	1	
Model		SFWG65-72/8850	
Unit capacity	kW	65,000	
7. Power transmission line			
Voltage	230kV		
Number of circuit		2	
V Construction			
1. Construction diversion			
Diversion procedure		Year-round diversion	
2. Diversion structures			
Downstream cofferdam			
Length of cofferdam	m	188.6	
Elevation on crest	m	63	
Height of cofferdam	m	13	
3. Construction period			
Total construction period	Month	31	

2 Basin Development

2.1 River Basin Development Plan

In December 1994, the Mekong River Commission (MRC) proposed an 11-cascade plan for the development of the mainstream Mekong River. From U/S to D/S, the 11 cascades consist of Pak Beng, Luang Prabang, Sayaburi, Pak Lay, Pamong, Ban Koum, Don Sahong, Stung Treng and Sambor, with a total installed capacity of 13,350 MW. All of the cascades are basically designed with a run-of-river development.

Until Nov 2021, among the 11 cascaded hydropower stations planned and developed, Pak Beng HPP is under negotiation of Power Purchase Agreement (PPA) and Concession Agreement (CA); Luang Prabang HPP has just finished PNPCA; Sayaburi HPP has put into commercial operation; Pak Lay HPP has almost same progress with Pak Beng HPP, Sanakham HPP is being reviewed in the PNPCA; Pamong and Ban Koum HPPs are located on the border river and need further study; Phou-Ngoy HPP will be submitted to MRC for PNPCA; Stung Treng and Sambor HPPs characterized by a large reservoir inundation area and high development cost, and they are still at the planning and study stages.

2.2 Effect of Future Upstream/Downstream Developments on the Energy Generation

The regulation capacity of the planned power stations in the upper reaches of DSHPP in mainstream Mekong River is weak, the planned power stations have weak runoff regulation capacity and will not affect the power generation of DSHPP. The upstream cascade of DSHPP Phou Ngoy HPP, the water levels of the two hydropower stations do not overlap, so DSHPP will not affect the upstream cascade hydropower stations.

Stung Treng hydropower station is planned in the downstream of DSHPP. The normal pool level of Stung Treng hydropower station is planned to be 55m, which overlaps with the current water level of DSHPP powerhouse. Since the DSHPP has been completed and put into operation, the normal pool level of Stung Treng should be appropriately reduced. When the normal pool level of Stung Treng hydropower station is reduced, the power generation of DSHPP will not be affected. DSHPP has weak runoff regulation capacity and will not affect the downstream cascade hydropower stations.

3 Topographical Survey

3.1 Topographical survey method and mapping area

A 1:500 topographic map of the Modification project area was obtained, with a survey area of nearly 50,000 m^2.

The scope of survey is shown in red marked area of Figure 3.1-1.

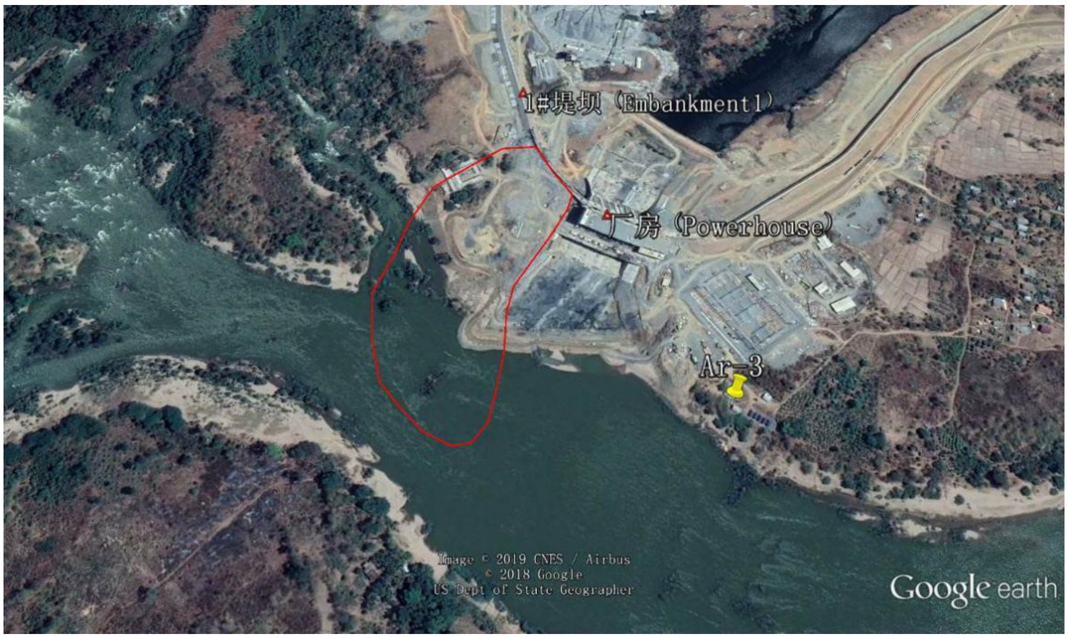


Figure 3.1-1 Survey Area

3.1.1 Survey Data Used

The Grade-4 GNSS control points IV05, IV06 and IV12 are used in the survey area.

3.1.2 Coordinate System and Elevation System

Plane coordinate system: WGS-84 coordinate system;

Elevation system: Lao 1981 national elevation benchmark;

Atmospheric refraction coefficient K = 0.12.

3.2 Results of topographical survey

3.2.1 Survey Scale

In order to accurately represent current topography, the above-water and underwater topographic mappings were performed with a scale of 1:500 and a contour interval of 0.5 m.

3.2.2 Topographic Survey

Topographic map surveying and field data collection was carried out by using the Hisind GNSS RTK mode, and the maps were edited by the digital mapping software (South Group CASS 9.1).

Underwater topography is surveyed with the section method. Direction of preset sections is roughly perpendicular to flow direction, and the survey for water edges and the underwater were simultaneously conducted. The underwater topographic survey was conducted by a depth sounder in conjunction with the integrated GNSS RTK system for data acquisition. The GNSS receiving antenna and depth sounder sonar probe were mounted on the same vertical pulse bar. The depth sounder carried out the water depth survey, and the rover GNSS receiver completed the plane and elevation positioning, and performed data acquisition, and finally obtained the three-dimensional coordinate data of the river bottom.

Surface topographic survey was conducted following the underwater survey.

4 Geological and geotechnical study

4.1 Geological field investigation and in-situ tests

4.1.1 Completed Geological Work

After the Modification project was entrusted by owner, KHIDI organized related departments to carry out further work. Once design plan was confirmed, engineers of survey and geology entered site on June 25, 2019. Quantity of main work is shown in Table 4.1-1.

Table 4.1-1 Quantity for Geological Work at Feasibility Stage of DSH Modification HPP

Exploration Item		Unit	Supplementary Exploration Stage of Detail Design	
			Project Area	Sub-total
Geological Mapping	1/1000 Geological Mapping	km^2	0.05	0.05
	1/1000 Geological Profiling	m/nos	780/8	780/8
Exploration	Borehole	m/nos	317.2/7	317.2/7
Lab test	Lab Rock Test	group	20	20
	Rock Slice Identification	group	6	6
	Water Analysis	group	2	2
Site test	Lugeon Test in Borehole	nos	43	43
	Lefranc Seepage Test	segs	14	14

4.1.2 Topography and Terrain

It is recommended that hydraulic buildings of the Modification project be arranged on the northwest side of existing powerhouse (Figure 4.1-1). The terrain is gentle. Height difference between new embankment dam (left), powerhouse and erection bay is less than 2m. Highest elevation in the area is EL.68m and lowest is EL.52m; overall northwest is high, and southeast is low.

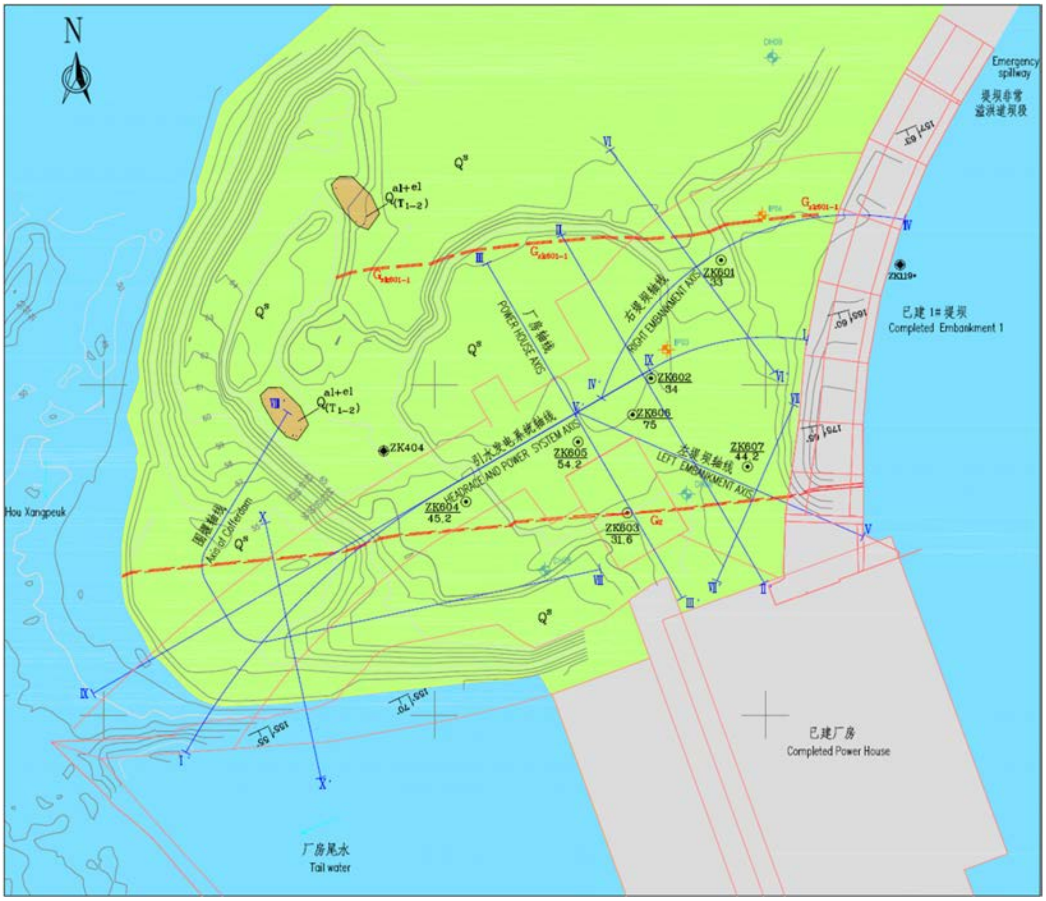


Figure 4.1-1 Recommended Project Layout

4.1.3 Stratum and Lithology

It is recommended that the Modification project area be mainly covered by artificial deposit (Q^s), and there are scattered uncovered alluvial and residual deposits (Q^{al+el}), as detailed below:

(1) Artificial deposit (Q^s)

Main components are rock block (gray white, gray black), gravels mixed with sands, silts mixed with blocks (yellow, brown dark), and the area above EL.65m is mainly covered with rock block and gravels, with a thickness of 0.5m-6m. The area of EL.52m-EL.65m is mainly covered with gravels mixed sands, silt, rock block and a small amount of construction waste, with a thickness of 1m-8m.

(2) Quaternary alluvial and residual deposit (Q^{al+el})

It is brownish red, brown sandy soil mixed with gravel, clay and sand, slightly wet and medium dense. Thickness is generally less than 2m. Vegetation root can be seen. Except for local excavated sections, they are exposed in the whole project area.

(3) Triassic Middle and Lower Series (T^{1-2}):

It consists of the sub-block~block dacite with tuff strata from abyssal facies extrusive rock. Main components of dacite are altered base plagioclase, quartz, and altered pyroxene. Main components of tuff are pyroxene and plagioclase, apatite, altered andesite, and vitreous matter (seri serica, epidote, albite, and chlorite) alternating between acid and alkali, exposed in large areas of the project area, revealing that thickness of eruption deposit is greater than 100m..

4.1.4 Geological Structure

Geological structure of project area is simple, and faults and folds are not distributed. It is a monoclinic structure formed by intermittent volcanic eruption and re-deposition. Its trend is generally east-west, dipping to south with a dip angle of about 60°, and thickness exceeds 5,000m.

There is no grade I and II fault developed in project area; only the structural planes with grade III and below are developed. See Table 4.1-2 and

Table **4.1-**3.

Table 4.1-2 Grade of Structural Planes in Project Area

Grade	Type	Grading Basis		Engineering geological significance	Degree of identification at this stage	Code and representative structural planes
		Width of fractured zone (m)	Length of fractured zone (m)			
I	Regional and dominant fault	＞10	Tens of kilometers	It can cause the lack of stratum, affect structural stability of region, and pose an impact on cascade development plan and selection of dam sites.	Identified	Chinese and English names
II	Major fault	1.0-10	＞1,000m	There is a relatively obvious offset distance, which affects stability of mountain and has a great impact on layout of the hydraulic structures.	Identified	F
III	Medium scaled fault and extruded zone	0.25-1.0	100m-1,000m	It has a significant impact on deformation stability of surrounding rock masses of slope, foundation and tunnel.	Basically identified	F, G
IV	Minor fault and extruded planes	0.005-0.25	10m-100m	It affects rock mass structure and control the block stability of surrounding rock masses of foundations, slopes and tunnel.	Development pattern is basically identified.	f, g
V	Joints and fissures	＜0.005	Less than 10m	It affects integrity of the rock mass, weaken the strength of rock mass, and affect stability of local rock blocks.	Statistics on development pattern by zones	J

Table 4.1-3 Statistics of Main Developed Structural Planes in Project Area

Grade of structural planes	No.	Type	extension length (m)	Spacing (cm)	Attitude	Description
III	G_2	Consequent bedding crush zone	>100		N70°-80°E, SE∠50°-60°	Width is less than 1.5m, and the inside is extruded flaky rock, fractured rock and a small amount of mud filling, in black color
	Gzk601	Consequent bedding crush zone	>100		N70°-80°E, SE∠50°-60°	The width is about 0.5m, the fractured tuff debris, in grayish black
V	1	bedding	>10	10-200	N70°-80°E, SE∠50°-60°	It is featured with undulations, open on surface and closed in drilled core; the graphite coating is seen, and slightly weathered and fresh rock mass is closed; the spacing is generally greater than 50cm.
	2	Near vertical structural plane orthogonal to bedding	1-5	10-50	N10°-25°W, SW∠65°-90°	Open on the ground surface; drilled cores reveals as closed in highly weathered rock, but rare in moderately weathered rock.
	3	Consequent structural plane with gentle dip angle	<3	10-50	N70°-80°E, NW∠30°	Open on ground surface; drilled cores reveals as closed in highly weathered rock, but rare in moderately weathered rock.
	4	Near horizontal structural plane	<3	10-50	N70°E, NW/SE∠0°-30°	Slightly open on ground surface; extremely rare in lower part of highly weathered rock mass

4.1.5 Physical and Geological Phenomena

There are no soluble rock strata in project area; landslides, collapses, debris flows and stress relieved are not developed. The physical and geological phenomenon is mainly weathered of rock masses.

Weathered degree of rock mass in project area is divided into completely, highly weathered, moderately weathered, slightly weathered and fresh.

Weathered degree and thickness of rock mass are mainly controlled by factors such as lithology, development degree of structural planes, topography and groundwater. The dacite is hard rock with strong anti-weathering ability, while the tuff is soft to medium hard rock with relatively weak weathering resistance, and the weathered sandwich is often formed near ground surface.

The overall weathered degree of project area is relatively uniform. Depth of completely weathered boundary is generally 5m-10m, highly weathered boundary is generally 6m-14m, and moderately weathered boundary is generally 12m-17m, below such depth is slightly weathered - fresh rock mass. Most of riverbed parts are slightly weathered - fresh rock mass, locally moderately weathered and its thickness generally less than 1m.

4.1.6 Hydrogeological Conditions

Abyssal facies extrusive rock is distributed in the project area. Groundwater is mainly bedrock fissure water, and a small amount of pore water in loose rock is distributed in Quaternary overburden and completely weathered rock. Both are recharged by atmospheric precipitation and discharge to Mekong River, and groundwater recharges river. Groundwater level changes greatly in dry season and rainy season, and in dry season is low and flat with a depth of generally 6m-7m, and in rainy season is relatively high and steep, which is generally 0.5m-1.0m below the original surface.

Bedrock permeability mainly depends on the development degree, properties and connectivity of structural planes such as joints and fissures. Abyssal facies extrusive rock is developed in project area, and the permeability characteristics of rock mass are closely related to degree of weathered. The rock mass near ground surface is deep in weathered, with highly permeable; the lower rock mass is shallow in weathered, and permeability of rock mass is weak. The results of water pressure tests and water injection tests in boreholes reveal that Quaternary and completely weathered zones are mainly composed of silt and silty clay, which is weakly permeable (10^{-5}cm/s ≤ K<10^{-4}cm/s). Structural planes in highly weathered rock mass are developed, mostly open, with a moderate water permeability of 10^{-4}cm/s ≤ K <10^{-2}cm/s; structural planes in upper part of moderately weathered rock mass are developed, mostly medium permeable (8Lu≤q<30Lu); except for the development of bedding planes in lower part of moderately weathered rock masses, the other structural planes are not developed, generally featured with weak water permeability (1Lu≤q<10Lu); For slightly weathered - fresh rock mass, only bedding planes are slightly developed, and its spacing is generally greater than 50cm, mostly closed, with slight and weak permeability. On-site pressure tests show that Lugeon value is mostly less than 10Lu, and value within 10m depth below moderately weathered boundary is mostly less than 5Lu, and some of sections are nearly 1Lu.

Two water samples were taken from Hou Sahong reservoir and ZK606 for analysis. According to water analysis results, and as per the corrosiveness standard of hydraulic concrete, water has no corrosion to concrete.

4.2 Laboratory tests for rock and soil material

4.2.1 Test Result of Rock and Soil

Total of 20 groups of rock samples were taken from borehole at project area for lab physical and mechanical tests, including 17 groups of dacite and 3 groups of tuff.

According to the test results, wet compressive strength of dacite is 35.4MPa - 143.4MPa, with an average of 79.5MPa, and softening coefficient is 0.63-0.90, with an average of 0.78. Considering that some rock samples damaged along structural planes, overall it is rated as hard rock. The wet compressive strength of tuff is 50.6MPa-68.1MPa, with an average of 61.4MPa and softening coefficient is 0.69, with an average of 0.69. It is rated as medium hard - hard rock.

4.2.2 Structure of Rock Masses

The rock mass quality of the Modification project area is divided into four major categories and seven sub-categories.

Table 4.2-1 Classification of Rock Mass Structure in Project area

Rock Structure		Characteristics of rock mass structure	Rock mass structure in project area
Class	Sub-class		
Massive structure	Integral structure	Rock mass is integral and massive, structural plane is not developed, and spacing is greater than 100cm.	Slightly weathered - fresh giant massive dacite with tuff
	Massive structure	Rock mass is relatively integral, massive, and structural plane is slightly developed, and spacing is generally 50cm to 100cm.	Slightly weathered - fresh massive dacite with tuff
	Sub-massive structure	Rock mass is relatively integral, sub-massive, and structural plane is moderately developed, with a spacing of 30cm - 50cm.	Moderately weathered (lower zone) sub-massive dacite with tuff
Mosaic structure	Mosaic structure	Rock mass integrity is poor, it's tightly interlocked – less tightly interlocked, and structural plane is relatively developed- very developed, and spacing is generally 10cm - 30cm.	Moderately weathered (upper zone) sub-massive dacite with tuff
Cataclastic structure	Blocky-fractured structure	The integrity of rock mass is poor, and rock fragments and muddy materials are filled between rock blocks. The interlocking is moderately tight-relaxed and structural plane is developed- very developed. Spacing is generally 30cm-10cm.	Moderately weathered (lower zone) blocky-fractured dacite with tuff
	Cataclastic structure	Rock mass is relatively fractured, and there are lithic and muddy materials filling between the rock blocks. The interlocking is loose and slack, and structural plane is very developed. Spacing is generally less than 10cm.	Highly weathered (upper zone) cataclastic structure dacite with tuff
Loose granular structure	Clastic structure, fragmental structure	Rock mass is fractured, and rock block is accompanied with rock debris, or the mud material are trapped in rock blocks, and interlocking is loose.	Completely weathered dacite with tuff

In general, moderately weathered (lower zone) and slightly weathered-fresh rock mass in the project area are dominated by sub-massive structure-massive structure, and completely weathered and highly weathered (upper zone) rock mass is dominated by cataclastic structure and loose granular structure, and highly weathered (lower zone) and moderately weathered (upper zone) is dominated by mosaic structure.

4.3 Regional geology and earthquake

4.3.1 Regional Geology

Western part of DSH Modification HPP is border between Laos and Thailand. It belongs to southeastern margin of the Korat Plateau and is dominated by plateau landforms. Central part is the Mekong River erosion deposit plain. River surface elevation is 50m-80m, and transition to east is featured with low hills, to east of Ban Hat, it is the Boloven Plateau.

According to Map of Geology and Mineral Resources in South Laos (scaled at 1:500,000) (see Figure 4.3-1), the main distribution strata near project area are as follows:

(1) Triassic Middle and Lower System (T_{1-2}):

The upper part is rhyolite, rhyolite dacite, dacite and tuff, with a thickness of 750m – 1,000m, while the lower part is conglomerate, coarse-grained sandstone, sandstone, siltstone, argillaceous shale and rhyolite and tuff interbed with a thickness of 550m–1,500m, which is widely distributed near the left bank of the Mekong River about 2km on the east side of the project area, and is underlain by the overburden.

(2) Jurassic system (J_{1-2}):

The upper part is sandstone, siltstone and calcareous mud beds, with a thickness of about 600m, while the lower part is calcareous conglomerate, calcareous sandstone, calcareous siltstone and mudstone, bioclastic limestone, with a thickness of 230m - 250m, which is far from the project area, mainly distributed on the right bank of the Mekong River 20km northwest of the project area.

(3) Quaternary Holocene series alluvium and diluvium (${}_{ab}Q_2$):

The sand, pebble and gravel and loose clay deposited on the riverbed or river floodplain, with a thickness of 1m-6m, is mainly distributed in the project area of DSHPP and the Mekong River plain, about 20km long in the vicinity.

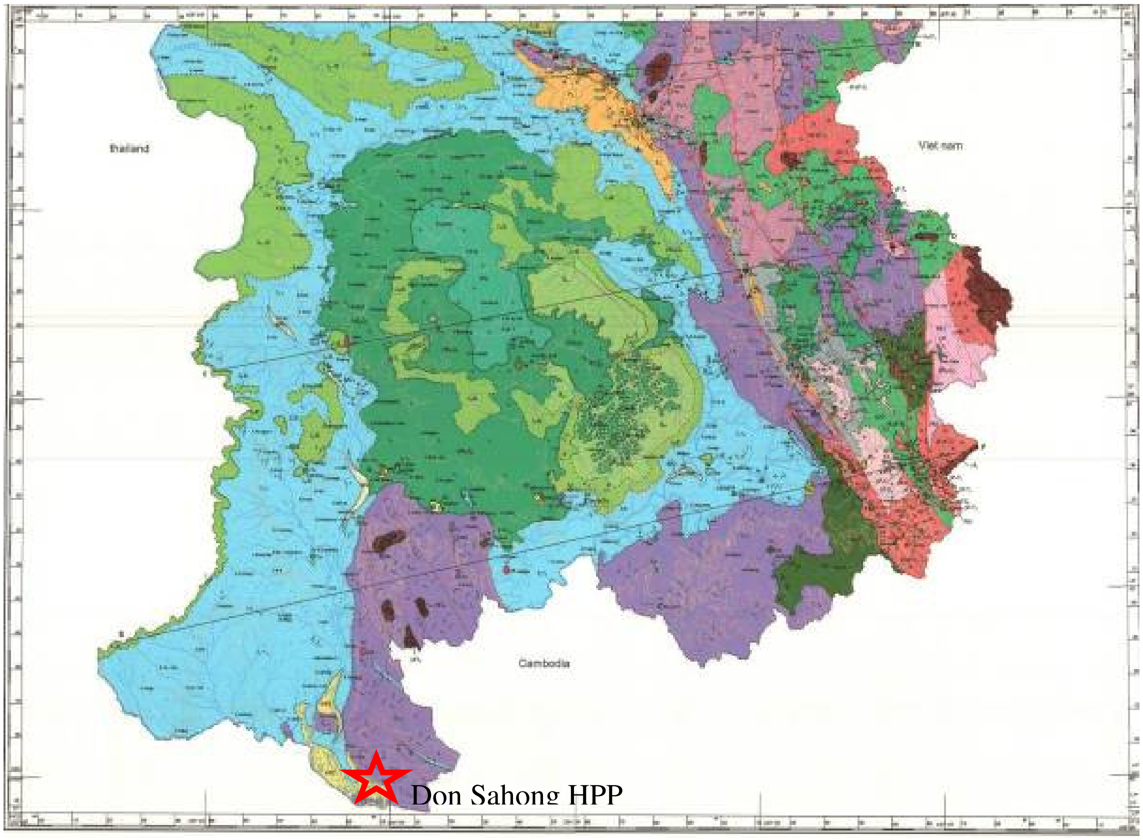


Figure 4.3-1 Map of Geology and Mineral Resources in South Laos

DSH Modification HPP is located in Mekong Fold Belt of the Vientiane-Kon Tum Micro Massif, which belongs to the South China~South China Affiliated (Eurasian) Landmass Group, where Mesozoic tectonic activities as well as Tertiary and Early Pleistocene magmatic activities are intense. Most regional tectonic movements resulted in Triassic faults formed on ancient folds. Since the Cenozoic era, the crust has been slowly lifted in this area, forming several falls on the Mekong River near the project area—Khon Phapeng, Lee Phee, Li Phi, etc. Structural features in the region are mostly in the NW~SE strike. The nearest large-scale fault is located near Siem Reap within the border of Cambodia, lying in the NW~SE direction, about 160km away from the project area and extending approximately 40km. In addition, there is a NW-SE fault developed about 280km from the project area within the border of Laos, which runs from Thakhek, passes Nasi and ends in Thua Thien-Hue Province, Vietnam, with a total extension of over 320km. There are no major faults distributed within 25km of the project area and in the site.

The structural traces of near-field area are featured with obvious concentric rings, which belong to upturning syncline with an axial direction of SSE. The river flow direction and structural plane are affected by axial and tangential directions and show strong regularity. The Hou Sahong channel is gradually deflected from SN direction to near EW direction from about 1.5km to 0.8km U/S of the site, which is, gradually deflected from the axial direction to tangential direction of the syncline. There are two sets of well-developed joints in the region: bedding joint and near-vertical joint orthogonal to bedding face, and their strikes are consistent with tangential and axial directions of the syncline, as shown in Figure 4.3-.

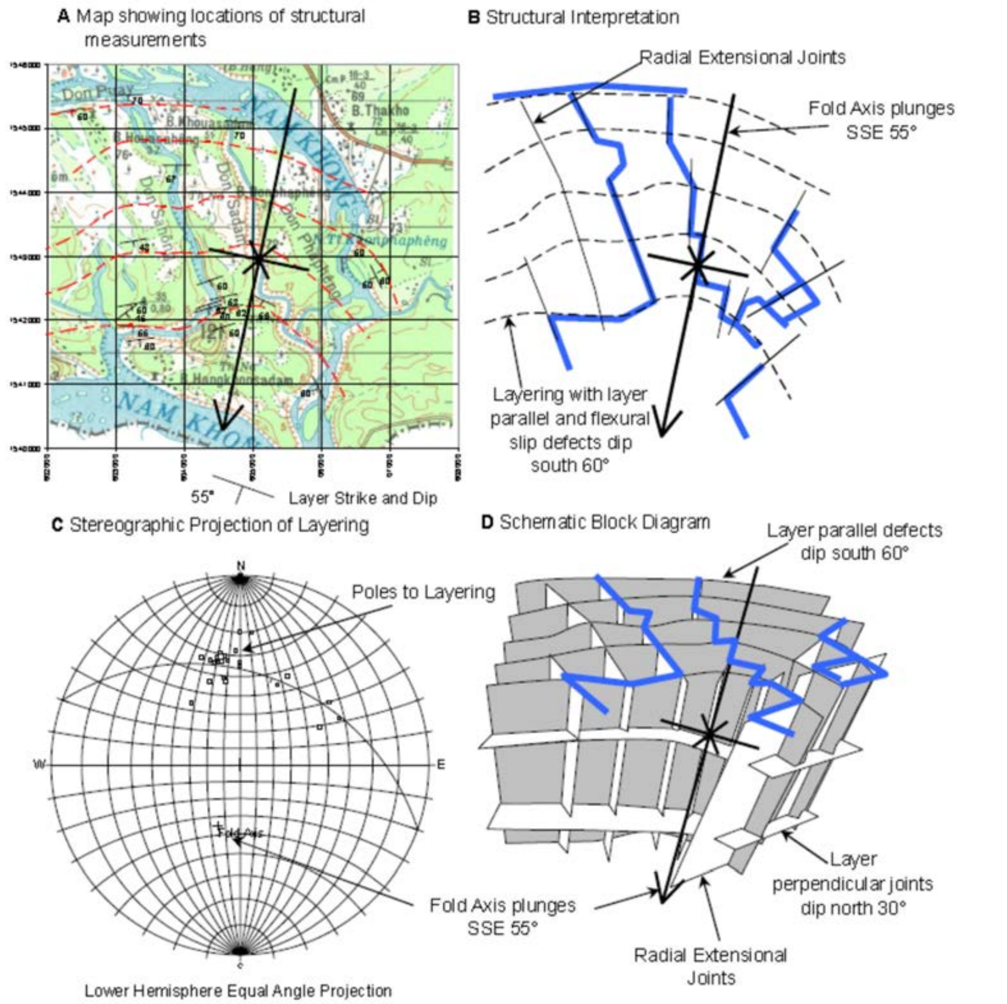


Figure 4.3-2 Dominant Tectonic Trace of Upturning Syncline in Project Area

4.3.2 Earthquake

The PGA of the Modification project is consistent with that of first-phase project. The PGA of operating basic earthquake OBE (with a return period of about 500 yrs) of the project area is 0.05g, and that of MDE_1 (with a return period of about 2,000 yrs) is 0.10g which meets the requirements of LEPTS, and that of MDE_2 (with a return period of about 10,000 yrs) is 0.15g, and corresponding seismic basic intensity is Mag. V.

4.4 Geological description for power facilities's sites

4.4.1 Basic Geological Conditions

The Modification project powerhouse is located in the delta area formed by Hou Sahong River and HouXangpeuk River. Currently the surface is mainly covered by artificial deposit. Except for tailrace, the rest buildings of powerhouse is located on EL.67m platform, and topography is gentle. Below EL.67m platform is formed by excavated materials from first phase project, with a slope between 10° and 25°.

There are 2m-6m deep artificial gravel deposits (Q^{s}) on powerhouse area which are mainly composed of blocks and gravels. Diameter varies from 60cm to 100cm. Quaternary alluvial and residual deposits (Q^{al+el}) are underlain, with a thickness of generally 2m-4m, mainly composed of sandy silt, gravel, clay and sand; under residual deposits, it is shallow metamorphic dacite with tuff of Triassic (T_{1-2}), and its weathered zone is relatively complete; rock mass with a depth of 6.4m-10m is completely weathered, 10m-13m being highly weathered, 13m-16m being moderately weathered, and below 16m being slightly weathered - fresh. Thickness of dacite beds is between 0.1m and 1m, which is rated as medium-thick to thick bed. It is classified as integral - massive structure, while tuff bed is relatively thin, mostly less than 0.3m. Both the uniaxial compressive strengths (UCS) are above 30Mpa; it is dominated by hard rock, with a small portion of medium hard rock, and attitude of bed is N65°-75°E, SE∠50°-70°.

According to geological logs of embankment 1 and powerhouse excavation in first phase and drilling results of this phase, there is no development of above Grade III structural plane in powerhouse area of Modification project, only a crushing zone along bedding planes G2 is exposed (Figure 4.4-1), and its width is less than 1.5m. The zone consists of extruded flaky rock, fractured rock and a small amount of muddy filling, in black color, which is inferred to pass through tailrace.

Rock mass in the vicinity of powerhouse foundation is a slightly - weakly permeable layer, and Lugeon value of water pressure test is generally 1Lu - 2Lu.

Figure 4.4-1 Crushing zone along Bedding Exposed in Excavation of Embankment 1 of first phase (as indicated in red box)

4.4.2 Utilization Criteria for Buildings Foundation

With reference to the foundation utilization criteria of first-phase project, excavation utilization standards and corresponding rock mass structure types with building height of this phase project are shown in Table 4.4-1 and its minimum physical & mechanical parameters required for rock mass are shown in Table 4.4-2. Powerhouse foundation shall be placed on class III slightly weathered - fresh rock mass.

Table 4.4-1 Excavation Utilization Criteria of Building Foundation

Building Height	Excavation utilization criteria (GB50287-2016)	Excavation utilization criteria (Hoke-Brown Criteria)
15 m-20 m	IV_{2B},UMW	Zone③
20 m-25 m	IV_{1B},MW	Zone④
25 m-30 m	IV_{1B}, MW	Zone④
30m-35m	IV_{1B},MW	Zone④
50m-60m	III,(SW-UW)	Zone⑤

Table 4.4-2 Minimum Required Physical & Mechanical Parameters of DSH Modification HPP

Building Height	Hoke-Brown Criteria		GB50287-2016		Characteristic Value of Standard Bearing Capacity
	f'	c'(MPa)	f'	c'(MPa)	
15m	1.10	0.122	0.55	0.25	0.50
20m	1.20	0.195	0.60	0.35	0.60
25m	0.70	0.35	0.75	0.40	0.70
30m	0.75	0.40	0.80	0.45	0.90
55m	1.10	0.45	1.10	0.40	1.65

4.4.3 Engineering Geological Conditions of Powerhouse

New powerhouse annex to be extended is located in the northwest of the first phase powerhouse. The two powerhouses are about 100m apart. The powerhouse is made of reinforced concrete frame structure and color steel roof. A bulb tubular generator unit with 65MW is to be installed.

4.4.3.1 Evaluation of Engineering Geological Conditions of Powerhouse Foundation

(1) Deformation problem of powerhouse foundation

Excavation face of the first phase powerhouse and drilling at this phase revealed that the foundation surface of new powerhouse annex is slightly weathered-fresh dacite, in massive-integral structure, rock mass is intact; according to the monitoring data of first phase powerhouse, there is no deformation problem in powerhouse foundation.

(2) Anti-sliding stability problem of powerhouse foundation

Powerhouse foundation is designed to be placed about 20m below the bottom boundary of moderately weathered. Rock mass is featured with good integrity and high strength. Gently-dipped structural plane is not exposed in boreholes. There is no anti-sliding stability problem in powerhouse foundation.

(3) Powerhouse seepage and anti-seepage recommendations

Water pressure test in borehole revealed that rock mass near powerhouse foundation is slightly-weakly permeable layer. Lugeon value of water pressure test is generally 1Lu-2Lu, and seepage deformation stability of powerhouse foundation is not considerable; however, both banks are dominated by completely and highly weathered rock mass which is rated as medium or higher permeability, so the impervious curtain of powerhouse and both sides embankment dams are to be connected with the first-phase project impervious curtain.

4.4.3.2 Engineering Geological Conditions of Erection Bay

Most parts of erection bay foundation are located in excavation areas. ZK603 did not expose Quaternary and completely weathered layers. Bottom of highly weathered rock is located at EL.55m, and moderately weathered rock is about EL.51m, and below is slightly weathered-fresh rock mass. With reference to first phase geological logs, erection bay foundation is placed at highly weathered bottom, which can meet bearing capacity and deformation requirements.

4.4.4 Engineering Geological Conditions of Dam

Modification project requires two new gravity embankment dams, which are intersected with the first phase embankment 1-4 and embankment 1-1. Dam (right) is a curved dam with total length 94 m and dam (left) is a linear dam with length of 65m; Excavation width of dam foundation is 10.5m, and dam crest is at EL.76.90m. Designed excavation slope ratio is 1:1.2 on downstream side and 1:0.75 on upstream side.

The maximum dam height of first phase embankment 1 is 26m, located in 1-1 section; for 1-1~1-4 section, dam heights are all above 20m. Foundation is placed in moderately weathered. Since impoundment in June 2019, the Owner has continuously monitored deformation of dam and seepage flow, all of which meet requirements.

With reference to the excavation results of embankment 1 in first phase, the dam foundation is to be placed in IV_{1B} moderately weathered rock mass, of which characteristic value of foundation bearing capacity is higher than the design requirement and there is no deformation stability problem in dam foundation.

According to log results of embankment 1, in addition to development of bedding planes in dam foundation, there is also a set of near vertical structural planes, both of which are not gently-dipped joints. Although the other two structural planes are gently dipped, their extension generally does not exceed 1m, and joint surface is mostly closed or slightly open, and detritus filling is dominant, poor connectivity, therefore dam foundation does not have deep or shallow sliding stability problem along gently structural plane; in addition, depth of dam foundation is generally 1/3-1/2 of dam height and highly weathered and moderately weathered rock masses within the embedded depth are dominant, and rock mass has obvious anchoring effect on dam body. In light of above, there is no problem of sliding stability in dam foundation.

Moderately weathered rock mass is generally sub-massive structure, with a small amount of mosaic structure, which is relatively intact. Water pressure test show that moderately weathered zone its Lugeon value mostly 7Lu-12Lu, which is rated as medium permeability. Combined with the water pressure test results this phase, with the 5m depth below bottom of moderately weathered rock mass in the dam foundation, the Lugeon value is less than 5Lu, while within the 10m depth of moderately weathered rock mass, Lugeon value 1Lu-5Lu, which is rated as slightly-weakly permeable layer. Dam height is not high, and anti-seepage treatment measures for dam foundation are relatively simple. With reference to results of dam foundation grouting at first phase, it is recommended that impervious curtain hole be at a certain depth below $q \leq 5Lu$ boundary.

Topography along dam is flat and the slope not more than 10°. After removal top artificial deposits, slope consist of highly weathered rock mass. Design excavation slopes: upstream slope is 1:0.8, basically the same with first phase, and downstream slope is gentler than 1:1.2. 1:0.8 excavation slope ratio is adopted at first-phase, which has experienced three rainy seasons, and no slope instability occurred in construction period. In addition, excavation depth of dam foundation is generally not more than 8m, so slope height is not high, which is a temporary slope. In general, slope instability is low probability.

4.4.5 Engineering Geological Conditions of Excavated Slopes

There is no large-scale fault distributed near Modification powerhouse area. Bedding attitude is N65°-75°E, SE∠50°-70°, and bedding with joints orthogonal bedding are developed. Excavation slope of powerhouse is temporary. For left-bank slope, bedding is obliquely intersected with excavation face, so slope stability is good. Combined with practical experience of slope excavation in first phase powerhouse, it can be excavated with 1:1 slope ratio for above highly weathering layer, and 1:0.3 for moderately weathered and below, after excavation, wire mesh and shotcrete are required. For right-bank slope, below moderately weathered rock mass, dip angle of bedding planes is gentler than excavation slope angle, and some bedding planes are exposed on slope surface. There may be small sliding along the weak interbeds during excavation, but the overall impact is small.

Since the excavation elevation of foundation for Modification project is lower than original impervious curtain elevation of embankment 1, certain drainage measures are required during excavation.

In general, slope of powerhouse area is generally stable, and there may be local block collapse during excavation for which the connection work of excavation and support measures should be done well, and support shall be timely provided after excavating and drainage shall be ensured as well.

4.4.6 Engineering Geological Conditions of Cofferdam

In the Modification project, total length of cofferdam is about 190m. Cofferdam is made of earth and rock. It is located at the front end of delta formed by the intersection of Hou Sahong River and HouXangpeuk River at the outlet of tailrace. The crest is at EL.62m. At the front end of cofferdam, there is an EL.54m platform, and on both sides gradually becomes steeper. To the right end ground is now at EL.65m, and to left end ground is now at EL.62m.

Within the area of recommended cofferdam, ground surface is covered by artificial deposits (Figure 4.4-2), Front section of the deposit is thin, 2m-3m, while both sides is thick, and the thickest part can reach 6m-8m. Main composition is completely weathered materials, gravel mixed with sands and fractured rock and a small amount of construction waste during first phase tailrace excavation. According to geology log of the first-phase tailrace, completely and highly weathered layer is missing near riverside, and moderately weathered rock mass is exposed below Quaternary alluvium. Thickness is about 1m-2m, and the lower part is slightly weathered-fresh rock mass. After transition to banks, completely-highly weathered rock mass gradually develops.

With reference to the D/S cofferdam of first-phase project, it is recommended to excavate Quaternary and completely-highly weathered rock mass for front-end retaining section, and place the foundation on slightly weathered - fresh and moderately weathered rock mass with weak permeability. Bottom of highly weathered rock can be retained for foundation at higher area of banks. Clay core is backfilled with quaternary alluvial, residual layer and completely weathered material. D/S cofferdam of the first-phase adopted above scheme. During construction period, the cofferdam was stable, and seepage amount was very limited even during flood season, therefore the scheme can meet requirements.

Figure 4.4-2 Current Condition for Project Area (red line indicates proposed cofferdam axis)

4.5 Construction materials

For DSH Modification HPP, the required earth material is mainly used for anti-seepage core of cofferdam, and required design demand of cofferdam is 1.1×10^4m^3. Required rock is mainly used for concrete aggregates, and designed demand is about 13.5×10^4m^3.

In the Modification project, concrete aggregate is recommended to continue to use excavated materials, mainly consisting of the first-phase underwater, river channel excavated materials and powerhouse excavated materials in this phase. Powerhouse is designed to be excavated at about EL.28.60m. Below EL.47.50m, excavated materials are mostly composed of slightly-weathered or fresh rock mass. Rock mechanical test for first phase revealed that slightly weathered - fresh dacite can be used as concrete aggregate, while tuff needs to be removed. According to drilling and engineering geological mapping results, tuff content is about 35%. Reserve of powerhouse excavation is about $1.7\times10^4m^3$. First-phase underwater and river intake excavated materials are mainly stored in disposal area above emergency spillway, with a distance less than 1km from powerhouse. Also there are some materials placed on left and right banks of Hou Sahong river channel, and material on right bank is about 4km away from powerhouse while that on left bank is about 6km. Available material for disposal area is about $6\times10^4m^3$. Available materials for left and right banks of Hou Sahong channel are about 14.5×104m3. In light of above, planned reserve for aggregates required for Modification project is about $21.2\times10^4m^3$, which meets design requirements. Except for excavation material part, there is no need for exploitation and transportation conditions are good.

For clay core materials of cofferdam, it is recommended to use Quaternary alluvial and residual silty clay layer and completely weathered layer excavated in Modification project area. First-phase project provided a successful experience in using such layer of materials, and its quality can meet requirements. The area is about $0.015km^2$, thickness of striped layer is about 1m on average, average thickness is about 3m, average stripping ratio is 1:3, estimated amount is $4.5\times10^4m^3$, and reserves meet design requirements of cofferdam. Excavated material is ideal source of earth materials for cofferdam.

Below the owner's camp and near reservoir area side, there is an alternative borrow area as backup at the foot of $0^\#$ hill with an available area of $0.1km^2$, an available thickness of about 4m on average, and an estimated quantity of $3\times10^4m^3$. The distance from Modification project is less than 1.5km.

5 Hydrological Study

5.1 Meteorological and hydrological investigation methods and their results

Mekong River Basin is subject to control of southwest monsoon and northeast monsoon, with clear distinction of dry and moist seasons. June – November is the wet season, while December– the following May is the dry season. Since the average annual precipitations of Mekong River Basin are subject to the impacts of such factors as geographic location, terrains and landforms, there are great differences between the upper reaches and the lower reaches of the basin. According to statistics of precipitation data from most measured meteorological (hydrological) stations in Mekong River Basin, the average annual precipitations in Mekong River Basin are between 1,240mm – 2,300mm, and the days of average annual precipitation is between 70d – 137d. To be specific, the precipitation during the flood season of June – November is between 1,050mm – 2,100mm, accounting for about 80% of the precipitation all the year round, while the precipitation during the low-flow season of December– the following May accounts for about 20% of precipitation all the year round, and the precipitation is about 130mm - 230mm. The maximum 24h precipitation in Mekong River Basin is between 70mm - 310mm.

The average annual air temperature of the basin is between 24℃– 27℃, the average monthly highest air temperature over the years generally occurs in April, and the average monthly lowest air temperature over the years generally occurs in December.

No meteorological observation station is currently available in complex area of DSHPP. Therefore, its meteorological characteristic values are based on the adjacent Pakse Meteorological Station as the representative station. The two are about 140km apart, with similar elevations, and similar meteorological conditions. The statistics of monthly average meteorological characteristics of Pakse Meteorological Station over the years are shown in Table 5.1-1.

Table 5.1-1 Statistics of Monthly Average Meteorological Characteristic Values of Pakse Meteorological Station over the Years

Station Elev.: 98m

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Precipitation	Average (mm)	1.7	10.2	25.5	64.6	216	353	377	493	318	104	20.9	2.5	1987
	Average rainfall days (d)	0.3	0.7	2.4	6.7	15.3	19.8	21.7	23.7	18.0	10.1	3.4	0.8	122.7
Temperature (℃)	Average temperature	25.0	26.5	28.4	30.2	29.8	28.4	28.0	27.5	27.7	26.5	25.6	24.4	27.3
	Average maximum temperature	34.6	35.7	37.2	37.9	36.4	33.6	33.3	32.3	32.8	32.8	33.3	33.1	34.4
	Average minimum temperature	15.3	17.2	19.7	22.5	23.2	23.2	22.8	22.7	22.6	20.2	18.0	15.8	20.3
	Extreme maximum temperature	43.0	45.0	46.0	45.0	43.0	39.0	38.0	39.0	41.0	38.0	39.0	41.0	46.0
	Extreme minimum temperature	9.0	11.0	7.0	15.0	18.0	19.0	17.0	17.0	19.0	14.0	11.0	10.0	7.0
Relative humidity (%)	Average	78.2	75.1	73.2	76.7	84.8	90.3	92.0	92.7	91.3	87.2	83.1	80.2	83.7
	Average maximum	84.9	83.5	84.4	88.8	95.3	97.8	98.3	98.6	97.9	96.8	93.6	88.6	92.4
	Average minimum	70.8	65.6	61.7	65.9	72.7	81.7	84.2	85.9	83.9	77.5	71.9	71.1	74.4

The area of Lancang – Mekong River Basin is large, and many latitudes are spanned. The statistics of data published by MRC shows the runoff results of all the control sections (main hydrological stations) on mainstream Mekong River are shown in Table 5.1-2.

Table 5.1-2 Runoff Characteristics of Mainstream Mekong River

Mainstream Section	Basin area (km^2)	Percent of basin area in whole basin (%)	Average annual			Percent of runoff in whole basin (%)
			Discharge (m^3/s)	Water volume (100 million m^3)	Runoff depth (mm)	
Chiang Khan	189,000	23.8	2,700	851	450	18.6
Luang Prabang	268,000	33.7	3,900	1,230	460	27.2
Vientiane	299,000	37.6	4,400	1,390	464	30.3
Mukdahan	391,000	49.2	7,600	2,400	610	52.4
Pakse	545,000	68.6	9,890	3,119	572	68.2
Kratie	646,000	81.3	13,200	4,160	640	91.0
Whole basin	795,000	100	14,500	4,570	575	100

There are many branch channels at the Mekong River Section where DSHPP is situated. Its development mode is different from the conventional hydropower projects. The Project is located only on one branch channel from which the water is diverted for electricity generation, with complicated hydrological and hydraulic conditions, and hydrological regime is subject to control of hydrological regime of Pakse Hydrological Station on the main river channel in the upper reaches. According to statistics of annual runoff series of Pakse Hydrological Station (1960 – 2018), runoff during the flood season of June – October accounts for about 80% of the annual runoff. The month with the largest runoff in a year is generally August, and the total runoff is close to 23% of the annual runoff, while the month with the smallest runoff is April, accounting for less than 2% of the total annual runoff. The average monthly discharges of Pakse Hydrological Station over the years are shown in 5.1-3.

Table 5.1-3 Monthly Discharges of Pakse Hydrological Stations over the Years

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Discharge (m^3/s)	2,840	2,250	1,930	1,930	3,050	8,780	16,910	26,820	26,440	15,680	7,810	4,180	9,890
Distribution (%)	2.37	1.85	1.58	1.56	2.51	7.46	14.29	22.57	22.49	13.27	6.54	3.51	100.00

In FS stage, KHIDI entrusted Shanghai Estuarine and Coastal Research Center to make a study on the distribution of discharges of all branch channels in the project area before and after construction of DSH Modification HPP in combination with earlier measured water levels and discharges, by means of hydraulic model for the river channel. The discharges of the Hou Sahong Channel in the locality of hydropower project, and the Khone Phapheng Channel, are shown in Table 5.1-4.

Table 5.1-4 Main Branch Channel Discharges before and after Production of Modification Project

PF	Pakse Hydrological Station (m^3/s)	Natural (m^3/s)		Before production of Modification project (m^3/s)				After production of Modification project (m^3/s)			
		Hou Sahong	Khone Phapheng	Hou Sahong		Khone Phapheng		Hou Sahong		Khone Phapheng	
				Discharge	With Natural Change	Discharge	With Natural Change	Discharge	With Natural Change	Discharge	With Natural Change
Min.	1,236	51	1,060	326	275	800	-260	326	275	800	-260
99%	1,480	83	1,182	488	405	800	-382	488	405	800	-382
95%	1,680	110	1,272	613	503	800	-472	613	503	800	-472
90%	1,881	144	1,347	729	585	800	-547	729	585	800	-547
80%	2,184	180	1,465	897	717	800	-665	897	717	800	-665
70%	2,510	218	1,584	1,063	845	800	-784	1,063	845	800	-784
60%	3,197	278	1,801	1,357	1079	800	-1,001	1,357	1,079	800	-1,001
55%	3,869	323	1,986	1,600	1277	800	-1,186	1,600	1,277	800	-1,186
50%	4,734	382	2,225	1,600	1218	1,048	-1,177	1,863	1,481	800	-1,425
40%	7,797	530	2,909	1,600	1070	1,535	-1,374	2,000	1,470	1,148	-1,761
30%	12,439	710	3,728	1,600	890	2,361	-1,367	2,000	1,290	1,977	-1,751
20%	18,000	892	4,511	1,600	708	3,305	-1,206	2,000	1,108	2,917	-1,594
10%	25,579	1,150	5,420	1,600	450	4,336	-1,084	2,000	850	3,947	-1,473
5%	29,900	1,290	5,897	1,600	310	4,954	-943	2,000	710	4,562	-1,335
1%	37,450	1,561	6,642	1,600	39	5,951	-691	2,000	439	5,558	-1,084
Max.	47,600	1,976	7,519	1,600	-376	7,163	-356	2,000	24	6,763	-756
1/1,000yr	66,000	2,807	8,824	1,120	-1,687	9,731	907	1,120	-1,687	9,427	603

5.2 Inflow design flood analysis for spillway

Floods in Lancang – Mekong River Basin are formed by rainstorm, and floods in the basin correspond to intra-year distribution of rainstorm. According to relevant report of MRC, in Mekong River Basin U/S of Vientiane, the floods in the mainstream Lancang River play a dominant role, with great differences in flood properties D/S and U/S of Vientiane, mainly due to the area locating in the rainstorm center of Mekong River, and feeding of large tributaries. According to hydrological data of hydrological stations on Mekong River, floods in the Lower Mekong River Basin are mainly formed by rainstorms, mostly occur in June – October, and particularly frequent in August and September. According to the measured data of Pakse Hydrological Station for a total of 59 years (1960 – 2018), 52 annual maximum peak flood discharges occurred in August and September, accounting for 88.2% in total, with lower frequencies in the remaining months, as shown in Table 5.2-1. With a long duration, the floods rise and fall slowly. One flood process can basically be controlled in 30 days. Moreover, as spatial distribution of rainfall is uneven, flood process is generally multi-peak type.

Table 5.2-1 Statistics of Months and Frequencies with Annual Maximum Peak Flood Discharges of Pakse Station (1960-2018)

Item	Jun.	Jul.	Aug.	Sep.	Oct.	Yr
Times	1	5	29	23	1	59
Percentage (%)	1.7	8.5	49.2	39.0	1.7	100

The maximum average daily discharges of Pakse Station (1960 – 2018) were corrected and converted as transient discharge series, to which frequency calculation was made, and fitting was conducted with P-III frequency curve. Statistical parameters were determined with curve fitting method based on initial estimation with moment method. The annual peak flood discharge - frequency curve of Pakse Station is shown in Figure 5.2-1, and the designed peak flood discharges are shown in Table 5.2-2.

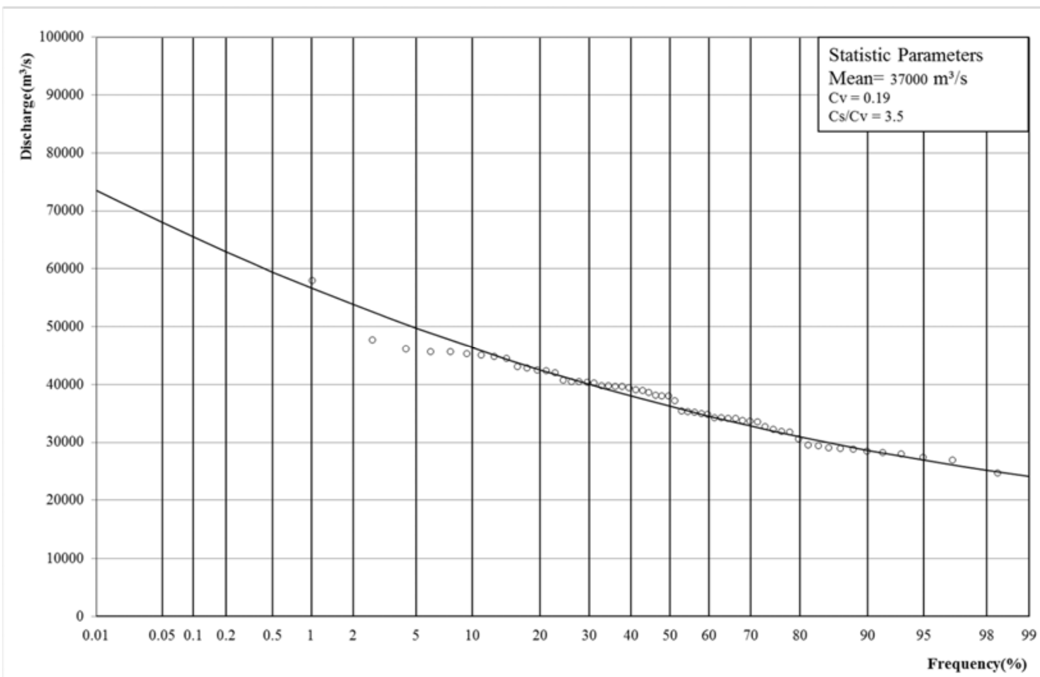


Figure 5.2-1 Annual maximum peak flood discharge - frequency curve of Pakse Hydrological Station

Table 5.2-2 Annual peak flood and frequency calculation results of Pakse Hydrological Station

Frequency (%)	0.01	0.02	0.1	0.2	0.5	1	2	5	10	20	50
Peak flood discharge (m^3/s)	75,700	72,600	65,500	62,500	58,400	55,400	52,300	48,200	45,000	41,700	36,700

The review results are compared with the AECOM's original design results at feasibility study stage of DSHPP (the data series were up to 2010). After series calculation is added, the main frequency design flood results are different within 2%, as shown in Table 5.2-3. Thus, we may judge that the AECOM's original design results are reasonable. At this stage, it is recommended to follow the AECOM's original design results.

Table 5.2-3 Design Flood Comparison of Pakse Hydrological Station

Frequency (%)	Peak flood (m^3/s)								
	0.01%	0.1%	0.2%	1%	2%	5%	10%	20%	50%
Design by A ECOM	77,000	66,000	63000	56,000	53,000	48,000	45,000	42,000	36,000
Review	75,700	65,500	62500	55,400	52,300	48,200	45,000	41,700	36,700
Difference (%)	-1.69	-0.76	-0.79	-1.07	-1.32	0.42	0.00	-0.71	1.94

The flood control standard of DSHPP was against the maximum flood with a 1,000-yr return period (P=0.1%). According to the hydraulic model calculation results of the river channel, under the corresponding flood standards, the discharge results of Hou Sahong Channel in the locality of the Modification project, and Khone Phapheng Branch, are 1,400m^3/s and 9,427m^3/s respectively, and the comparisons with the natural discharge results and pre-extension discharge results are detailed in Table 5.2-3.

5.3 Design flood analysis during construction

Analyzing the rainstorm properties of Pakse Meteorological Station, Mekong River Basin falls into typical monsoon climate, with clear distinction of the dry season and the wet season. Rainy season generally starts from May and ends in October, while May – September is the main rainy season, with concentrated rainfall.

Scatter diagram of Pakse Station was dot plotted for all the months, as shown in Figure 5.3-1. We may see from the figure that the annual maximum peak flood discharge of Pakse Station emerges in June – October, but mainly concentrates in August – September, and the probability of emergence in June, July and October is low, with relatively low magnitude. Based on above analysis and in combination with construction requirements, frequency maximum discharges of two periods of December – April and November – April are calculated by span-free sampling. Frequency calculations are made according to the maximum discharge series of Pakse Station during the periods of 1960 – 2018.

As the calculated maximum discharge- frequency results of Pakse Station in all time periods during the low-flow season are less than the annual maximum discharge - frequency results, and the maximum discharge - frequency curve of the low-flow season is free of crossing phenomenon, the recommended results are relatively reasonable.

The construction design floods of Pakse Station are shown in Table 5.3-1.

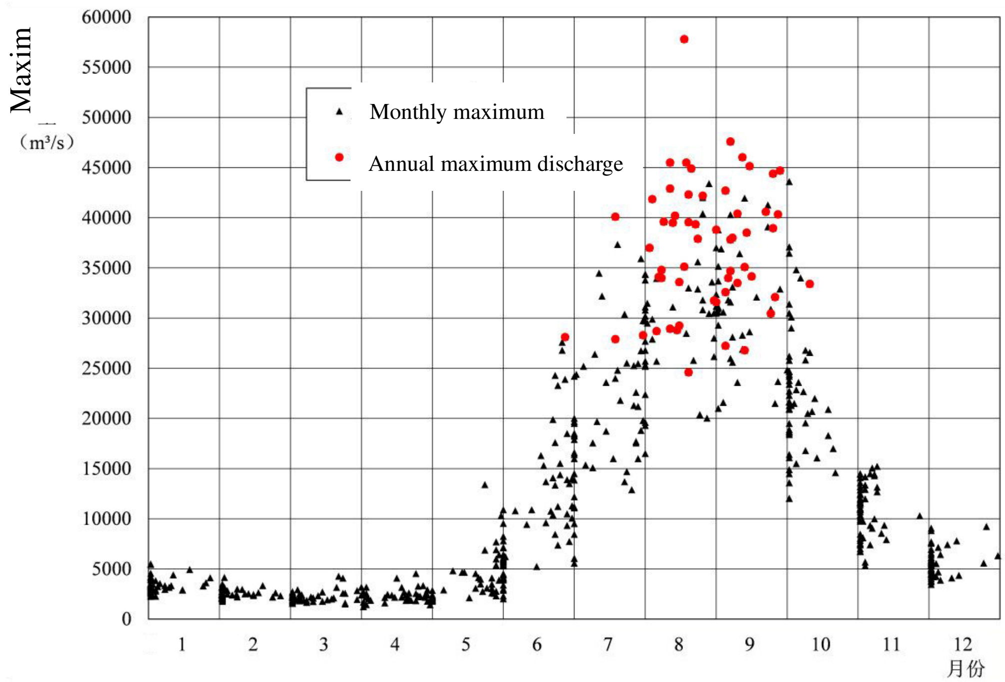


Figure 5.3-1 Scatter diagram of maximum discharge of Pakse Station in all the months over the years

Table 5.3-1 Construction Design Floods of Pakse Station

Item	Design Discharge (m³/s)	
	P=5%	P=10%
Annual maximum discharge	48000	45000
November - April	16800	15100
December - April	8730	7840

5.4 Sedimentation analysis of dam or intake weir

Pakse Station surveyed sediment during 1960 – 1962, 1990, 1997 – 2002 and 2011 – 2013, and a total of 255 groups of measured sediment transport rate data. After deleting part of the plots, correlation of all the measured discharge and sediment transport rates (1960 – 2013) was established, and the correlation diagram is shown in Figure 5.4-1.

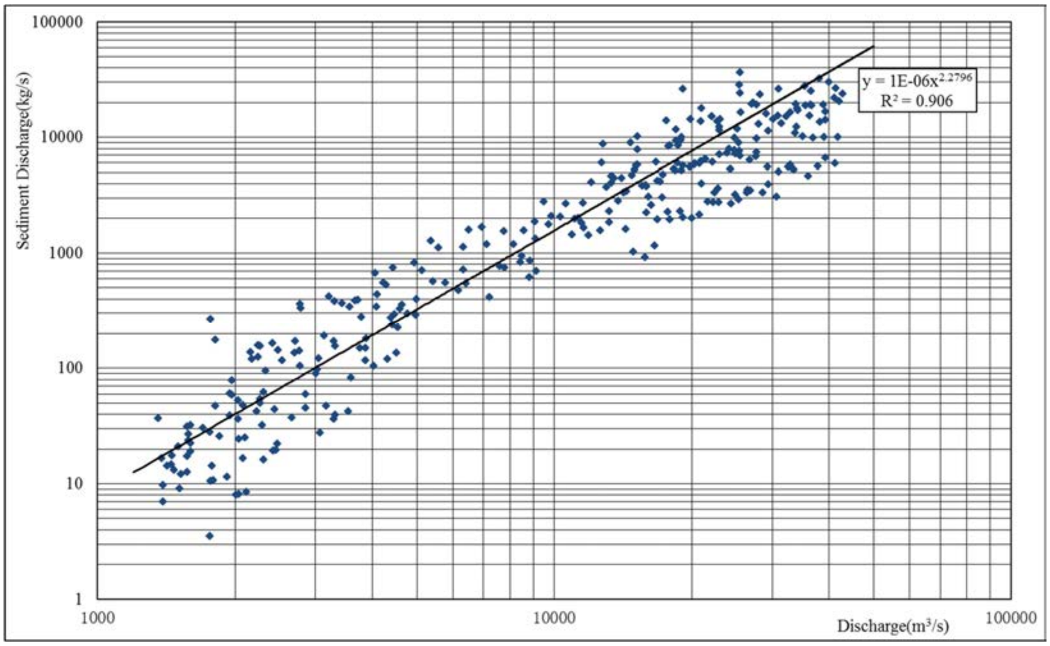


Figure 5.4-1 Correlogram of measured discharge and sediment transport rate of Pakse Hydrological Station (1960 – 2013)

According to measured discharge data, the above correlation is adopted to interpolate and obtain the average annual suspended sediment of Pakse Station (1960 – 2018) as 103.26×10^6t.

5.5 Energy Indicator

The installed capacity of DSHPP after Modification is 325MW. According to the calculation principle, method and related boundary conditions and parameters of runoff regulation, the kinetic energy index of the Modification of DSHPP is calculated, with results shown in Table 5.5-1. After the Modification of the DSHPP, the average energy production will increase by 234GWh after the Modification, and the power generation benefit of the Modification project will be significant.

Table 5.5-1 Kinetic Energy Indexes after Production of DSH Modification HPP

S.N.	Item	Unit	Index	Remark
1	Average annual discharge	m^3/s	9890	Pakse Hydrological Station
2	Regulation performance of reservoir		No regulation	
3	Installed capacity	MW	325/313 (installed capacity/maximum output)	
4	Incl: Modification capacity	MW	65/62 (installed capacity/maximum output)	
5	Maximum head of the Modification project	m	20.3	
6	Minimum head of the Modification project	m	14.0	
7	Rated head of the Modification project	m	17.8	
8	Rated power generation discharge of Modification project	m^3/s	400	
9	Guaranteed output	MW	99.0(P=95%)	
10	Increased average annual energy production	GWh	234	
11	Supplementary annual utilization hours	h	3600	

6 Hydraulic analysis

6.1 Waterway loss, effective head and theoretical of the project

6.1.1 Headloss of the waterway

The Modification project will affect the local topography of the river. The hydrology and hydraulic conditions of the river where the power station is located are also changed to a certain extent compared with the natural condition and the condition of the Modification project before production.

In the process of hydraulic calculation, the inflow of the tributary where the Khon Phapheng Falls are located is limited to not less than 800m^3/s, which guarantees the aesthetic demand of the Khon Phapheng Falls.

According to Table 6.1-1, the process of the water level changes in front of and behind the dam and power generation head of the dam before the commissioning of the DSH Modification HPP is shown in Figures 6.1-1~6.1-3.

Table 6.1-1 Hydraulic Calculation Results (after Production of Modification Project)

PF	Exceeding	Pakse discharge	AR-5 water level	U/S station water level	U/S head loss	D/S station water level	AR-3 water level	D/S head loss	Waterway head loss	Station Discharge
	(%)	(m^3/s)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m3/s)
PF16	Min.	1,236	70.69	70.67	0.02	49.94	49.18	0.76	0.78	326
PF15a	99%	1,357	70.68	70.65	0.03	50.11	49.30	0.81	0.84	400
PF15	98%	1,480	70.66	70.61	0.05	50.28	49.41	0.87	0.92	488
PF14	95%	1,680	70.63	70.54	0.10	50.50	49.60	0.90	1.00	613
PF13	90%	1,881	70.61	70.46	0.15	50.67	49.80	0.87	1.02	729
PF12	80%	2,184	70.57	70.31	0.26	50.91	50.05	0.86	1.12	897
PF11	70%	2,510	70.53	70.13	0.40	51.17	50.27	0.90	1.30	1,063
PF10	60%	3,197	70.46	69.67	0.79	51.46	50.47	0.99	1.78	1,357
PF9a	55%	3,869	70.33	69.38	0.95	51.80	50.86	0.94	1.89	1,600
PF9b	52%	4,429	70.81	70.10	0.71	51.95	51.13	0.82	1.53	1,713
PF9	50%	4,734	70.76	69.75	1.01	52.02	51.31	0.71	1.72	1,863
PF8a	48%	5,340	70.75	69.68	1.07	52.17	51.48	0.69	1.76	1,890
PF8b	46%	5,900	70.77	69.56	1.21	52.30	51.62	0.68	1.89	1,929
PF8c	44%	6,570	70.84	69.64	1.20	52.47	51.81	0.66	1.86	1,976
PF8d	43%	7,035	70.66	69.08	1.58	52.62	51.97	0.65	2.23	2,000
PF8e	42%	7,210	70.97	69.96	1.01	52.69	52.05	0.64	1.65	2,000
PF8	40%	7,797	71.06	70.19	0.87	52.84	52.21	0.63	1.50	2,000
PF7a	38%	8,796	71.33	70.62	0.71	53.22	52.60	0.62	1.33	2,000
PF7b	36%	9,594	71.51	70.91	0.60	53.53	52.91	0.62	1.22	2,000
PF7c	34%	10,500	71.69	71.16	0.53	53.60	52.99	0.61	1.14	2,000
PF7d	32%	11,494	71.88	71.41	0.47	53.95	53.35	0.60	1.07	2,000

PF7	30%	12,439	71.86	71.37	0.49	54.24	53.65	0.59	1.08	2,000
PF6	20%	18,000	72.64	72.30	0.34	55.62	55.07	0.55	0.89	2,000
PF5	10%	25,579	73.35	73.11	0.24	57.38	56.84	0.54	0.78	2,000
PF4	5%	29,900	73.49	73.28	0.21	58.14	57.67	0.47	0.68	2,000
PF3	1%	37,450	74.00	73.83	0.17	58.48	58.05	0.43	0.60	2,000
PF2	Max.	47,600	74.64	74.52	0.12	61.03	60.65	0.38	0.50	2,000

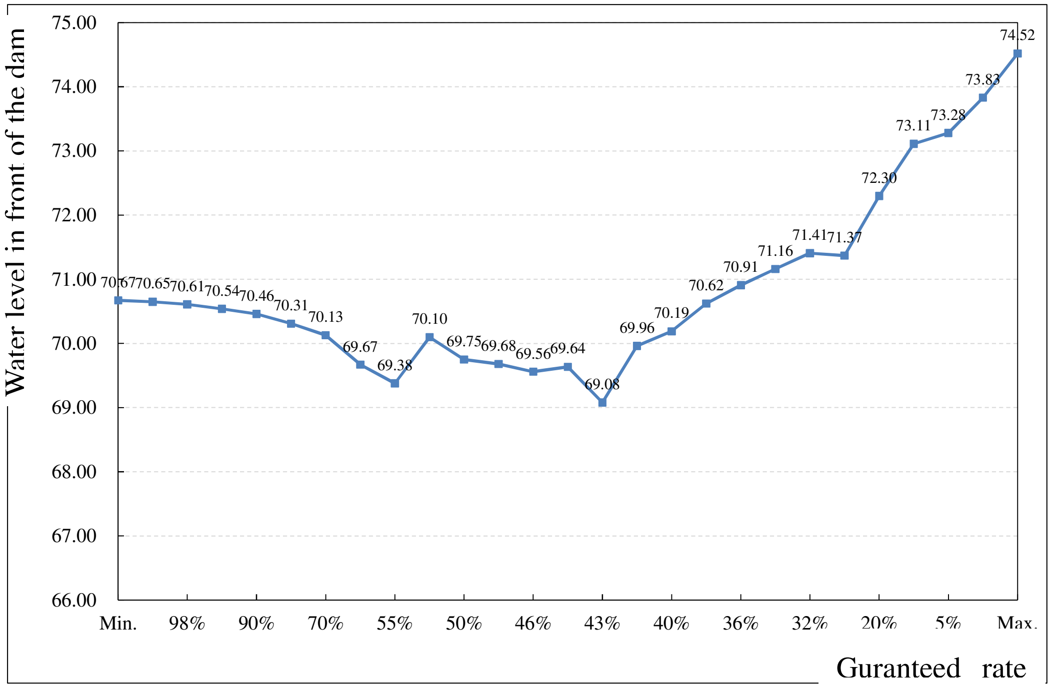


Figure 6.1-1 Process of Water level Changes in front of Dam under Inflows with Different guarantee rates (after the Modification project is put into operation)

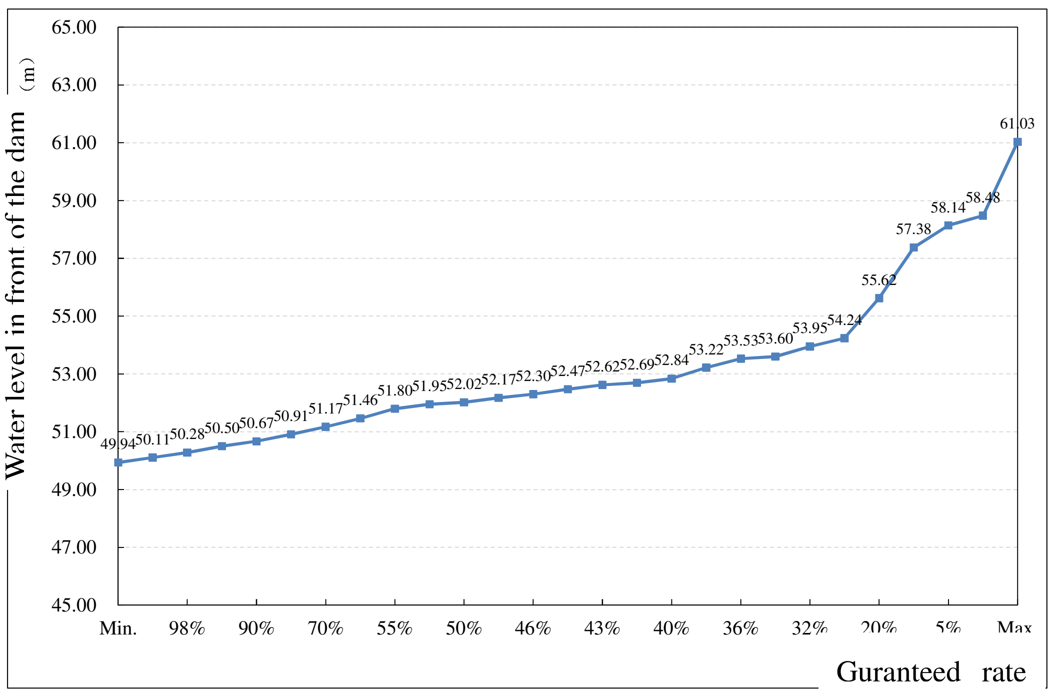


Figure 6.1-2 Process of Water level Changes behind the Dam under Inflows with Different guarantee rates (after the Modification project is put into operation)

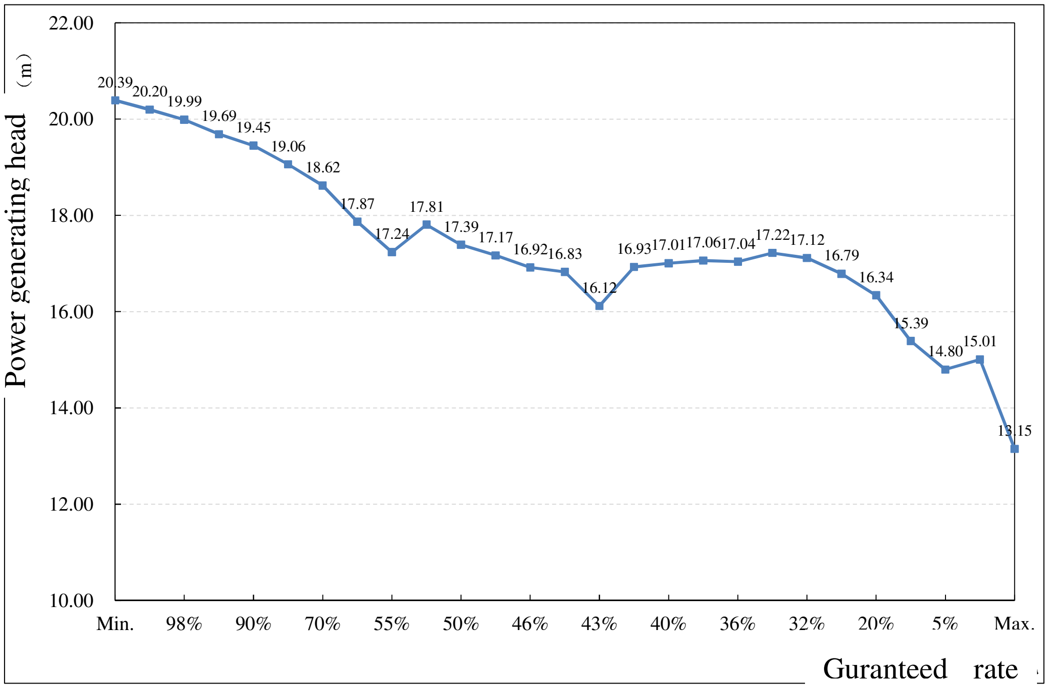


Figure 6.1-3 Process of Power generation head Changes under Inflows with Different guarantee rates (after the Modification project is put into operation)

6.1.2 Headloss of the powerhouse

The head losses along the flow passage of the bulb tubular hydropower plant include the friction head losses and local head losses (before bulkhead gate and after tailrace gate, the headloss through the unit is considered in the unit efficiency). The calculation shall be in accordance with the Employer's Requirements and Specifications.

For the modification project with one unit, the reference flow of the plant is 400 m^3/s.

According to the calculations, the total head losses of the plant (including the friction and local head losses) is about 0.415m.

6.2 Hydraulic calculation of intake and tailwater

6.2.1 Submergence depth of power intake

For avoidance of through-type funnel or power intake, it is recommended to use Gordon’s Formula for estimation purpose.

For this project, maximum water level is EL.75.90m, and dead water level is EL.67.00m. Submergence depth of power intake shall be determined assuming maximum utilizable discharge of the unit is $400m^3/s$. For calculation results, the minimum submergence depth is 3.49m. Therefore the floor elevation of power intake is selected as EL.34.7m, and minimum submergence depth can be well satisfied.

6.2.2 Submergence depth of tailwater outlet

EL.43.10m is selected as the installation elevation to meet the turbine output, efficiency, and maximum cavitation erosion guarantees.

According to Chinese code NB/T 35011-2013, *Design Specification for Powerhouses of Hydropower Station*, for the tubular turbine units, the submerged depth of tailwater outlet shall be larger than the value of $v^2/2g$(v means average flow velocity of cross section of draft tube outlet) and no less than 0.5m.

In order to prevent air from entering the draft tube, the top elevation of the draft tube outlet is set at EL.49.60m, which is 0.51m lower than the minimum tailwater level for one unit operation (EL.50.11m), and larger than the value of $v^2/2g = (400/(13*14.5))^2/(2*9.81) = 0.23m$.

6.3 Hydraulic calculation of backwater in the upstream area

The DSHPP and DSH Modification HPP are located the area where the divergences and convergences are complicated by numerous branches, shoals, and scattered flow paths. The backwater area for the DSH Modification project is between AR5 and the upstream of the hydropower station, see Figure 6.1-4. The distance between AR5 and the upstream hydropower station is about 5km. Based on the mathematical model of Mike 3, the water level value of the backwater area for different discharge can refer to the Table 6.1-2.

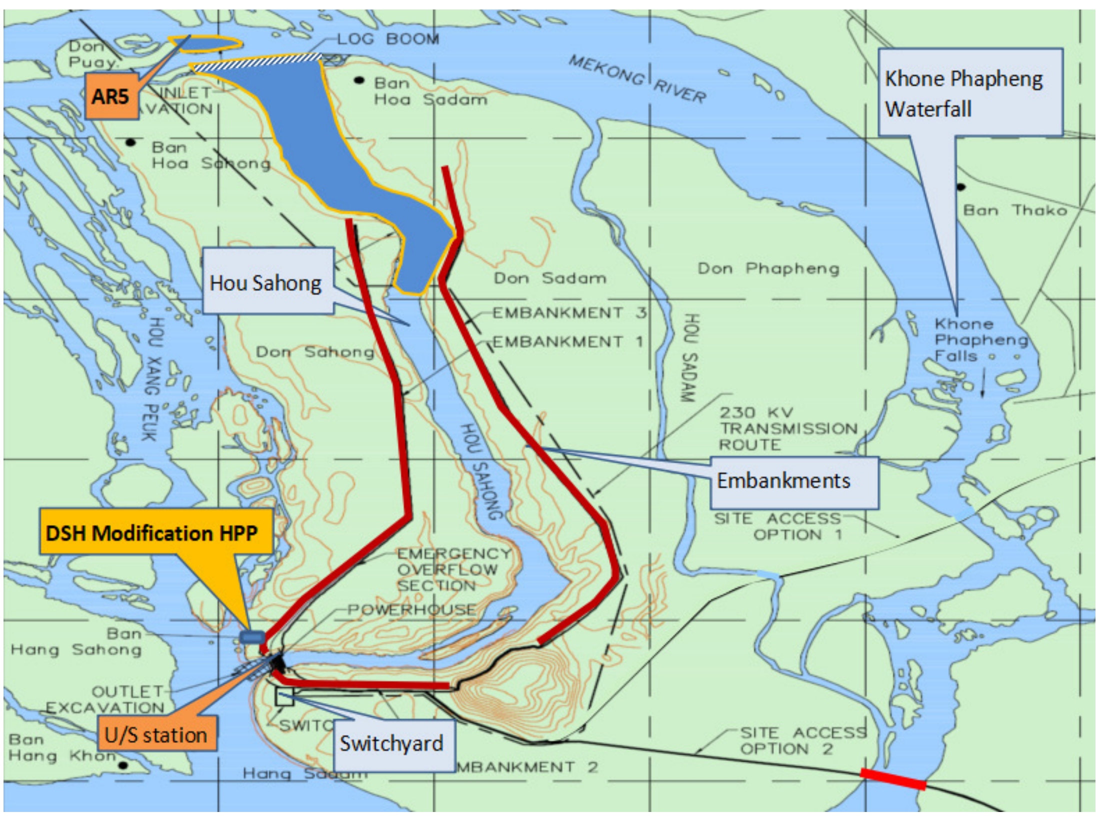


Figure 6.1-4 The location of the DSH Modification HPP

Table 6.1-2 Water Level Calculation Results (after Production of Modification Project)

PF	Exceeding	Pakse discharge	AR-5 water level	U/S station water level
	(%)	(m^3/s)	(m)	(m)
PF16	Min.	1,236	70.69	70.67
PF15a	99%	1,357	70.68	70.65
PF15	98%	1,480	70.66	70.61
PF14	95%	1,680	70.63	70.54
PF13	90%	1,881	70.61	70.46
PF12	80%	2,184	70.57	70.31
PF11	70%	2,510	70.53	70.13
PF10	60%	3,197	70.46	69.67
PF9a	55%	3,869	70.33	69.38
PF9b	52%	4,429	70.81	70.10
PF9	50%	4,734	70.76	69.75
PF8a	48%	5,340	70.75	69.68
PF8b	46%	5,900	70.77	69.56
PF8c	44%	6,570	70.84	69.64
PF8d	43%	7,035	70.66	69.08
PF8e	42%	7,210	70.97	69.96
PF8	40%	7,797	71.06	70.19
PF7a	38%	8,796	71.33	70.62
PF7b	36%	9,594	71.51	70.91
PF7c	34%	10,500	71.69	71.16
PF7d	32%	11,494	71.88	71.41
PF7	30%	12,439	71.86	71.37
PF6	20%	18,000	72.64	72.30
PF5	10%	25,579	73.35	73.11
PF4	5%	29,900	73.49	73.28
PF3	1%	37,450	74.00	73.83
PF2	Max.	47,600	74.64	74.52
PF1a	1/100 yr	56,000	75.11	75.02
PF1b	1/500 yr	63,000	75.42	75.35
PF1	1/1,000 yr	66,000	75.76	75.72

7 Structural analysis for civil engineering facilities

7.1 Dam stability and structural calculation

7.1.1 Dam crest elevation

The Modification project uses the same reservoir with the Don Sahong first-phase project(DSHPP), and the dam crest elevation is 76.90m, same as that of the DSHPP. With reference to the relevant report of DSHPP, the design flood with a 1,000-yr return period is adopted and the freeboard of dam crest is 1.21m which meets the requirements of the Laos power specification.

7.1.2 Dam Stability and Stress Analysis

According to LEPTS, the dam stability and stress analysis is carried out.

7.1.2.1 Calculation Parameters

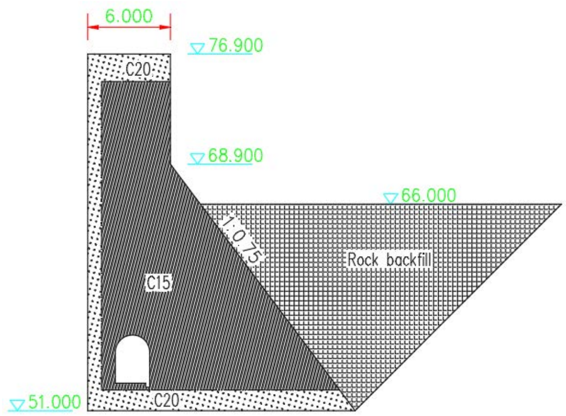
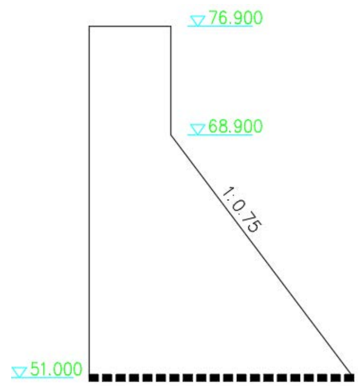
Physical mechanical parameters of rock masses of dam foundation may be referred to Table 7.1-1.

It is to conduct stability and stress analysis about two sections selected for the dam, i.e., left non-overflow monolith and right non-overflow monolith for the Modification project. Simplified diagram of calculations of all the monoliths may refer to Table 7.1-2.

Table 7.1-1: Physical mechanical parameters of rock masses

Anti - Shearing Parameter Value of the Dam Foundation	Bearing Capacity of the Rock Mass for Dam Foundation (MPa)	Rock Mass Density of Dam Foundation (kg/m^3)	Dynamic Elastic Modulus of Dam Foundation Rock (MPa)	Poisson's Ratio
f'=1.36； c'=0.27MPa	3.0	2700	2600	0.28

Table 7.1-2 Calculation Section and Simplified Calculation Diagram

<table>
<tr><td>Geometry of left embankment cross section</td><td>Calculation model of left embankment cross section</td></tr>
<tr><td>
</td><td>
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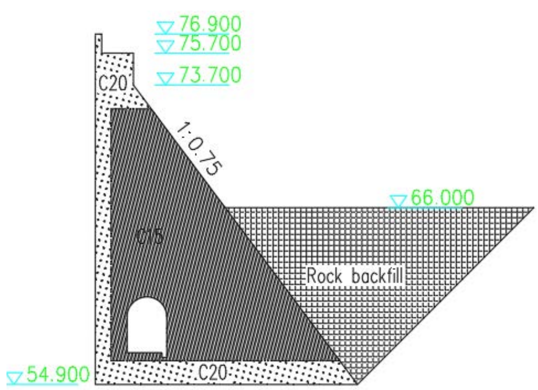
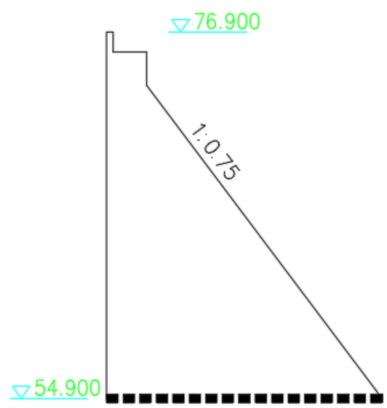
<tr><td>
</td><td>
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7.1.2.2 Calculating Forces and Load Combinations

The calculated forces of the dam, such as gravity, hydrostatic pressure, silt pressure, uplifting force, wave pressure, seismic load, are considered.

Calculation conditions and load combinations may be referred to Table 7.1-3.

Table 7.1-3 Calculation Conditions and Load Combinations

Calculated Operating Conditions	Dead Weight	Hydraulic Pressure	Uplifting Pressure	Wave Pressure	Sediment Pressure	Earthquake Load
FSL Conditions	✓	✓	✓	✓	✓	

Design Flood Operating Conditions	✓	✓	✓	✓	✓	
FSL + Earthquake Operating Conditions	✓	✓	✓	✓	✓	✓

7.1.2.3 Calculation Results of Stability and Stress

Calculation results indicated that under all the operating conditions, the anti-sliding stability and safety coefficient of left dam and right dam cross section can meet the relevant requirements in LEPTS.

The maximum compressive stress of dam foundation can satisfy specification requirements.

7.2 Powerhouse stability calculations

According to the provisions of USACE EM1110-2-3001"Planning and Design of Hydroelectric Power Plant Structures", the powerhouse stability calculations have been carried out.

The total powerhouse is selected as calculating and analyzing object.

Normal constraints are applied to the foundation boundary and the bottom of the foundation, other boundaries of the model are considered as free surfaces. Parts of the grid are shown in Fig.7.2-1.

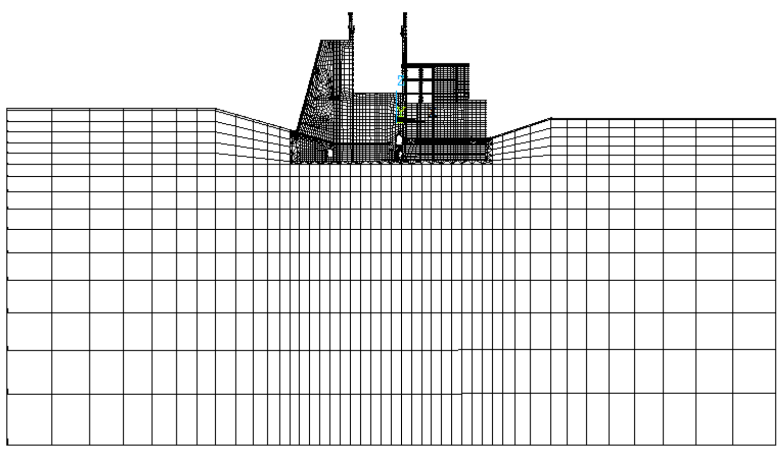

Figure. 7.2-1 Grids of the whole model

According to the calculation results, the anti-sliding and anti-flotation safety factors of the powerhouse under each load case can meet the requirements of ER and USACE, the foundation stresses under each load case meet the requirements of the foundation allowable bearing pressure (5.0MPa).

8 Instrumentation

8.1 Principle of Safety Monitoring Design

Safety monitoring design aims to ensure safety of the Project during construction period and operating period. Instruments, equipment and monitoring point are selected under the principle of “practicality, reliability, excellence and cost-effectiveness”, so as to realize data collection quickly and information feedback without delay, and thus ensure safety of working personnel, equipment and the Project. In addition, monitoring equipment is provided at key locations which are critical to ensure safety of the Project, and this arrangement is target-oriented and facilitates equipment operation and maintenance.

8.2 Monitoring design

8.2.1 Inspection

In accordance with the provisions of this statement and the instructions of the supervisor, the daily inspection, the annual inspection and special inspection of the various parts of the project are carried out.

The main contents of inspections should include:

(1) Inspection of structures

It is mainly included that the deformation, water seepage, and cracks of concrete gravity dam, powerhouse, slope is normal or not.

(2) Inspection of monitoring instrument and equipment

Monitoring equipment, cables, cable joints, stations and their safety protection facilities are damaged or not.

8.2.2 Monitoring Arrangement

(1) Environment monitoring

The water gauge are arranged at the upstream and downstream of the powerhouse, to monitor the dam water level. The meteorological station is shared with the existing Don Sahong project.

(2) Displacement monitoring network

The horizontal displacement and vertical displacement monitoring network are shared with the existing Don Sahong project.

(3) Deformation monitoring

Four surface deformation monitoring points are arranged at the dam and power plant to monitor their plane displacement changes. Four marking points are arranged at the dam and power plant to monitor their vertical displacement changes.

Two Three-Dimention joint meters are arranged to monitor the joints between the dam and powerhouse.

(4) Seepage monitoring

Seven piezometer are arranged at the dam and power plant to monitor the water pressure of their foundation.

Five weirs are arranged at the galleries of powerhouse, left and right dam.

8.3 Type of instruments and quantity

No.	ITEM	UNIT	QUANTITY	REMARKS
1	Stainless Steel Water gauge	m	30	
2	Observation monument	Piece	4	include forced centering plate, Precision≤0.05mm
3	Bench mark	Piece	4	include stainless steel bench mark and protection cover
4	Piezometer	Piece	7	Original installation import, Vibrating wire， standard ranges:0～0.5MPa，resolution:≤0.025％F.S
5	Three-Dimention joint meter	Set	2	Vibrating wire， standard ranges:0～25mm
6	Triangular Weir	Set	5	include weir plate and point gauge
7	Cable protection pipe	m	200	110mm diameter galvanized steel pipe, according to the actual amount measurement
8	switched terminal box	Piece	3	Switching-on 10 pieces of cable for each one
9	Simple observation station	Piece	5	
10	Four core shielded cable	m	300	Estimated amount

9 Electrical and electro-mechanical equipment

9.1 Technical specification of electrical and electro-mechanical equipment at powerhouse and switchyard

9.1.1 Hydraulic Machinery

9.1.1.1 Type Selection of Unit

When considering from the perspective of the head, Kaplan turbines or bulb tubular turbines can be used for the Project. Bulb tubular turbines have following obvious technical advantages in comparison with Kaplan turbines: good flow channel, small size, large energy indexes; small unit size, light in weight, and good operation performance.

In conclusion, bulb tubular turbine is selected for the HPP.

9.1.1.2 Selection of Single Capacity and Number of Units

Taking unit manufacturing, large component transportation and the arrangement of hydraulic complex into consideration, one unit with the single capacity of 65MW will be used for DSH Modification HPP.

9.1.1.3 Selection of Turbine Parameters

The head of the Project is within 13.9-19.8m and the proposed rated head at this stage is 17.8m.

The parameters of the prototype turbine will be as follows based on calculation:

Model:	GZ667-WP-720
Rated output (Pr):	66.34MW
Rated head (Hr):	17.8m
Runner diameter (D1):	7.20m
Rated discharge (Qr):	408.7 m^3/s
Rated efficiency (ηr):	94.02%
Rated speed (nr):	88.2r/min
Runaway speed (on-cam) (nf):	≤200r/min
Runaway speed (off-cam) (nf):	≤240r/min

The parameters of associated generators are as follows:

Rated capacity:	76.47MVA
Rated power:	65MW
Rated voltage:	13.8kV
Rated current:	3052A
Rated power factor:	0.85

Rated frequency:	50Hz
Rated speed:	88.2r/min
Rated efficiency:	≥98%
Cooling way:	Fully air cooled
GD^2:	≥10,000t•m^2

9.1.1.4 Installation elevation

The cavitation coefficient taken for the turbine of this phase is 1.0 and corresponding suction height (Hs) is -6.7m.

The designed tailwater level (TWL) is calculated based on 50.1m when one unit is operating at rated power. There shall be some redundancy on the suction height of the turbine to ensure the safe and stable operation of the project within the full head range. The installation elevation of the turbine is rounded to 43.10m, and corresponding suction height is -7m.

9.1.1.5 Governor and Oil Pressure Device

A microcomputer-based electro-hydraulic governor of self-adaptive control is used. The main distributing valve is 100mm in diameter and 6.3MPa in pressure level.

9.1.1.6 Regulating Guarantee

In the HPP, the rated head is 17.8m, the single capacity is 65MW, and its proportion in the total capacity of the system is not large. It does not require frequency modulation. Based on the characteristics of the HPP, the calculated control value of the hydraulic transient of the HPP is determined as follows in accordance with the principle of "ensuring safety with redundancy reserved":

Relative value of the maximum pressure rise of the turbine spiral case is less than 65% and its absolute value is smaller than 40m in various operating conditions.

The maximum speed increase rate of the unit is less than 60% in various operating conditions.

The maximum vacuum of the draft tube of the turbine is not more than 8m in various operating conditions.

Based on the calculation, when the guide vane closing time is 7s, the closing rule forms a straight line. The highest speed rise of the unit is 53.2%, the maximum water pressure of the spiral case at the end is 29.54m and the minimum pressure at inlet of the draft tube is 6.4m in water column, so the requirements of the specification are met.

9.1.1.7 Bridge Crane of the Main Powerhouse

One 250t/100t bridge crane of 250t/100t with single trolley is selected for the Project.

9.1.1.8 Auxiliary System

9.1.1.8.1 Cooling water system

The technical water supply is water pump supply and the water source is from the upstream passage.

9.1.1.8.2 Dewatering System

Three submersible deep well pumps are selected as service drainage pumps and the drain pipes of the pumps go to the elevation above design flood level behind the tail water gate.

9.1.1.8.3 Leak Drainage System

Three submersible deep well pumps are selected as leak drainage pumps and the drain pipes of the pumps go to the elevation above design flood level behind the tailwater gate.

9.1.1.8.4 7.0MPa Pressure Air System

The system employs the mode of air supply at the first stage pressure. Through calculation, two air compressors with productivity of 1.5m3/min and rated pressure of 7.0MPa are selected for standby for each other; two air reservoirs with rated pressure of 7.0MPa and volume of 4.0m3 are set.

9.1.1.8.5 0.8MPa Pressure Air System

Two air compressors with productivity of 1.8m3/min and rated pressure of 0.85MPa are selected for standby for each other; two air reservoirs with rated pressure of 0.85MPa and volume of 4.0m^3 are set: one is for braking air supply, and the other is for supplying maintenance air. .

9.1.1.8.6 Turbine Oil System

One pressure oil filter, one vacuum oil filter, and two oil pumps (one is fixed and the other is movable) are selected for oil storage, treatment and transportation.

9.1.1.8.7 Hydraulic Measurement System

The contents to be measured by this system include: level of the upstream reservoir, level behind the inlet gate, downstream level, discharge measurement differential pressure, levels of service collecting well, leak collecting well and fire pool, etc.

9.1.1.9 List of Main Equipment

Table 9.1-1 Main Equipment of Hydraulic Machinery

S.N.	Description	Specifications & Parameter	Qty	Unit	Remark
1.	Turbine	GZ667-WP-720, n_r=88.2r/min, H_r=17.8m	1	Nr	single unit≈875t
2.	Generator	SFWG62-68/8800, n=88.2r/min	2	Nr	single unit≈565t
3.	Bridge crane	250t/100t/5t, Lk=21m	1	Nr	single unit≈200t
4.	Governor	WDT-100-6.3	1	set	
5.	Crane	250/100/10t，Lk=21m	1	set	～200t
6.	pump	Q=362m3/h，H=15m	2	set	
7.	strainer	DN250，PN1.6MPa	2	set	
8.	submersible deep well pump	Q=420m^3/h，H=50m	3	set	
9.	submersible deep well	Q=600m^3/h，H=54m	3	set	

S.N.	Description	Specifications & Parameter	Qty	Unit	Remark
	pump				
10.	Air compressor	Q=1.5m^3/min,PN7.0MPa	2	set	
11.	Air container	V=4.0m^3, PN7.0MPa	2	set	
12.	dust removal strainer	Q≥1.5m^3/min, PN7.0MPa	1	set	
13.	Oil removal steainer	Q≥1.5m^3/min, PN7.0MPa	1	set	
14.	Air dryer	Q=1.5m^3/min, PN7.0MPa	1	set	
15.	Air compressor	Q=1.8m^3/min, PN0.85MPa	2	set	
16.	Air container	V=4.0m^3, PN0.85MPa	2	set	
17.	dust removal strainer	Q≥1.8m^3/min, PN0.85MPa	1	set	
18.	Oil removal steainer	Q≥1.8m3/min, PN0.85MPa	1	set	
19.	Air dryer	Q=1.8m^3/min, PN0.85MPa	1	set	
20.	Oil tank	V=30.0m^3	2	piece	
21.	Oil pump	2CY-7.2/3.3-1, N=5.0kW	2	set	
22.	Pressure oil filter	Q＝100L/min, 0～0.3MPa，	1	set	
23.	Vaccum oil filter	Q＝100L/min, N=60kW	1	set	
24.	Hydraulic mmeasurement system		1	set	
25.	turbine oil	LTSA 46#	30	m^3	
26.	Valves&pipes		80	t	

9.1.2 Electrical

9.1.2.1 Interconnection mode of the project

At present, two outgoing lines of 230kV TLs (double circuits on the same tower) of DSHPP are connected to Ban Hat Substation of Lao power grid. The total TL is approx. 28.5km in length and the conductors of the TL are of ACSR 795 MCM model with the cross-sectional area of 402.5mm². The current-carrying capacity at 81℃ will be 917A. The capacity of the TL is 365MVA.

The modification power will be transmitted through the established two circuits of 230kV TLs of the HPP after completion of the modification project. No external TL will be added for the modification project. According to the calculation results, the single circuit TL conductor can carry up to 310MW which is just enough to carry all the 5 units power. Only if prolonged, one unit needs to be shut down.

9.1.2.2 Main electrical scheme

(1) Combination mode of generator and main transformer

G-T block connection is recommended for the generator outlet connection of the modification project.

(2) Installation of generator circuit breaker

A special circuit breakers for the generator will be installed at the outlet of the generator,

(3) Connection at 230kV side

Outdoor switchyard is used for power distribution, where double-bus configuration is adopted. The connection of HV side of the modification project will be directly connected to existing double-bus in outdoor arrangement, and to connect well with existing wiring of the HPP.

9.1.2.3 Connection mode of station service power supply

The power consumers of the plant and dam are centralized within the power supply range of 0.4kV, so the primary power supply voltage of the powerhouse annex and dam area for the power consumers is 0.4kV.

400V single bus connection is recommended for station service power supply. The power is fed from station-service transformer STr5 of unit G5 (modification project) and 22kV external power. The external power supply is in backup state (Not working during normal operation), and one diesel generator is used for security (standby) and black start power. The circuit breakers of the three incoming line circuits are electrically interlocked, and only one of the circuits is allowed to be in operation at any moment. The power of the station-service power system will be fed from unit G5 during normal operation. When unit G5 is shut down, it can obtain power from 230kV system for auxiliary power system. In case of power outage of STr5 circuit, the station-service power system will be fed from 22kV external power supply. However, when there is a power failure of STr5 circuit and the station-service power system cannot be fed from 22kV external power supply, the diesel generator set will be put into operation automatically to be responsible for the power supply of the security load of the HPP when it is sure that both STr5 circuit and 22kV external power supply circuit are in disconnected state.

9.1.2.4 Selection of main electric equipment

(1) Equipment type and arrangement in switchyard

The main transformer of the modification project is located in the plant area. 230kV switchgear is arranged in the outdoor switchyard of DSHPP. The main transformer is connected with the equipment of the outdoor switchyard using 230kV cables. The cable gallery of existing HPP can accommodate the 230kV cable circuits of the modification project, except that both ends of the original gallery need to be extended to be led to the powerhouse and the extended bay of the switchyard of the modification project.

230kV switchyard of DSHPP is located on the mountain top on the left bank of the dam, about 500m away from the powerhouse annex of the modification project. Outdoor open arrangement will be adopted. The extended incoming line bay will be located next to the original bus coupler bay.

(2) Selection of main electrical equipment

1） Main transformer

Type: Damp-heat type three-phase oil immersed self-cooling/ air-cooling copper coil dual-winding on-load tap changer step-up power transformer

Model: SFZ11-76500/230

Rated capacity: 76500kVA

Rated voltage: $230^{+10\times1.25\%}_{-6\times1.25\%}$/13.8kV

Rated frequency: 50Hz

Wiring group: YN d11

Impedance voltage: Ud=14.1%

Cooling way: ONAN/ONAF

2） 230kV outdoor switchyard equipment

The main components on HV side and the parameters of the equipment requiring replacement in the original switchyard are as follows:

a. HV Power Cable

Type: 230kV XLPE insulated corrugated aluminum sleeve polyethylene sheathed power cable

Nominal voltage of the system (Uo/U): 133/230kV

Maximum operating voltage of the system: 252kV

Conductor cross-sectional area: 400mm²

Rated continuous current-carrying capacity: ≥200A

Rated frequency: 50Hz

Rated short-time withstand current: 31.5kA

b. Outdoor Air Terminal of Cable

Type: Wet-heat type

Nominal voltage of the system: 230kV

Maximum operating voltage of the system: 252kV

Rated current: ≥200A

Rated frequency: 50Hz

Rated short-time withstand current: 31.5kA

c. SF6 Circuit Breaker

Type: Outdoor AC porcelain pole damp-heat type single-fracture SF6 circuit breaker

Model: LW10-252

Nominal voltage of the system: 230kV

Rated voltage: 252kV

Rated current: 3,150A

Rated frequency: 50Hz

Rated short-circuit breaking current: 40kA

d. Disconnector

Type: Three-phase three-pole horizontal dual-fracture damp-heat type disconnector

Model: GW7B-252TH, GW7B-252D1TH and GW7B-252D2TH

Nominal voltage of the system: 230kV

Rated voltage: 252kV

Rated current: 1,600A

Rated frequency: 50Hz

Rated short-time withstand current: 40kA/2s

e. Surge Arrester

Type: Outdoor single-phase damp-heat type metal oxide surge arrester

Model: YH10W-204/532TH

Nominal voltage of the system: 230kV

Rated voltage: 204kV

Peak residual voltage under lightning impulse current: 532kV

Rated frequency: 50Hz

Standard nominal discharge current (8/20μs): 10kA

f. Current Transformer (incoming line bay)

Type: Outdoor single-phase oil immersed damp-heat type current transformer

Model: LCWB7-230TH

Nominal voltage of the system: 230kV

System maximum voltage: 252kV

Rated frequency: 50Hz

Primary rated voltage: $230/\sqrt{3}$ kV

Rated current ratio: 2x400/2x400/2x400/2x400/2x400/2x250/2x250/1A

Rated short-time withstand current: 40kA/3s

g. Current Transformer (outgoing line bay, replace)

Type: Outdoor single-phase oil immersed damp-heat type current transformer

Model: LCWB7-230TH

Nominal voltage of the system: 230kV

System maximum voltage: 252kV

Rated frequency: 50Hz

Primary rated voltage: $230/\sqrt{3}$ kV

Rated current ratio: 2x1000/1A

Rated short-time withstand current: 40kA/3s

h. Current Transformer (bus-coupler bay, replace)

Type: Outdoor single-phase oil immersed damp-heat type current transformer

Model: LCWB7-230TH

Nominal voltage of the system: 230kV

System maximum voltage: 252kV

Rated frequency: 50Hz

Primary rated voltage: $230/\sqrt{3}$ kV

Rated current ratio: 2x1000/1A

Rated short-time withstand current: 40kA/3s

3） Generator Outlet Voltage Equipment

a. Generator Circuit Breaker

Type: special vacuum circuit breaker for the generator

Rated voltage: 17.5kV

Rated current: 4,000A

Effective value of rated short-circuit breaking AC component: 40kA

Rated short-circuit breaking DC component: ≥65%

b. Generator Voltage Switchgear

Type: indoor AC armored metal enclosed switchgear

Rated voltage: 17.5kV

Rated current: 4,000A, 630A

Rated short-time withstand current: 50kA/2s

c. Generator Voltage Busbar

Type: phase-separated whole-section shielded epoxy resin-cast insulated copper tube busbar

Rated voltage (Un): 15kV

Maximum operating voltage (Um): 17.5kV

Rated voltage of conductor to metal shield (Uo): 13.8kV

Rated frequency: 50Hz

Rated current: 4,000A, 1,000A

Rated short-time withstand current: 40kA/2s, 50kA/2s

d. Station-Service Transformer at Generator Terminal

Type: three-phase dual-winding copper coil non-excitation voltage-regulating dry distribution transformer

Model: SCB11-1250/13.8

Rated capacity: 1,250kVA

Rated voltage: 13.8±2×2.5%/0.4kV

Wiring group: D, yn11

Impedance voltage: Ud=6%

e. 22kV Station-Service Transformer

Type: three-phase dual-winding copper coil non-excitation voltage-regulating dry distribution transformer

Model: SCB11-1250/22

Rated capacity: 1250kVA

Rated voltage: 22±2×2.5%/0.4kV

Wiring group: D, yn11

Impedance voltage: Ud=6%

List of main electrical equipment and materials are shown in Table 9.1-2.

9.1.2.5 List of main electrical equipment

Table 9.1-2 List of main electrical equipment

S.N.	Name	Type and Specification	Unit	Qty	Remark
I	Main transformer				
1	230kV main transformer	SFZ11-76500/230,76500kVA,ONAN/ONAF $230^{+10\times1.25\%}_{-6\times1.25\%}$/13.8kV,YNd11,Ud%=14.1%	Nr	1	
II	252kV outdoor equipment				
2	Disconnector	GW7B-252TH,252kV,1600A,40kA/3s,100kA	set	1	

S.N.	Name	Type and Specification	Unit	Qty	Remark
3	Disconnector	GW7B-252D1TH,252kV,1600A, 40kA/3s,100kA	set	1	single earthing switch
4	Disconnector	GW7B-252D2TH,252kV,1600A, 40kA/3s,100kA	set	1	double earthing switch
5	Circuit breaker	LW10-252,SF6,3150A,40kA/3s,100kA	set	1	
6	Current transformer	LCWB7-230TH,230kV, 2x400/2x400/2x400/2x400/2x400/ 2x250/2x250/1A	Nr	3	
7	Current transformer	LCWB7-230TH,230kV,2x1000/1A	Nr	6	
8	Current transformer	LCWB7-230TH,230kV,2x1000/1A	Nr	3	
9	Surge arrester	YH10W-204/532TH	Nr	3	
10	230kV post insulator	ZS-252/8	Nr	2	
11	Outdoor single-phase cable terminal	230kV 400mm²	Nr	6	
12	230kV HV cable	XLPE-1×400mm²,133/230kV	single-phase meter	1650	
13	ACSR	LGJ-300/25	m	920	
14	Galvanized steel strand	GJ-70	m	135	
III	Generator voltage equipment				
15	VT cabinet	DS: GN19-17.5/630,17.5kV,630A,50kA/2s FU: XRNP-20,20kV,0.5A,1000MVA VT: JDZX-15,15kV	Nr	1	
16	VT-LA cabinet	DS: GN19-17.5/630,17.5kV,630A,50kA/2s FU: XRNP-20,20kV,0.5A,1000MVA LA: YH5WD-17.5/40TH,13.8kV VT: JDZX-15,15kV	Nr	1	
17	GCB cabinet	DS: GN22-17.5/4000,17.5kV,4000A,50kA/2s GCB: vacuum type, 17.5kV,4000A,40kA/2s,DC≥65% ES: JN15F-17.5/40,17.5kV,40kA/2s CT: LZZBJ9-15,15kV,4000/1A	Nr	1	
18	VT-LA cabinet	VT: JDZX-15,15kV LA: YH5WD-20/45TH,15.8kV FU: XRNP-20,20kV,0.5A,1000MVA DS: GN19-17.5/630,17.5kV,630A,50kA/2s	Nr	1	

S.N.	Name	Type and Specification	Unit	Qty	Remark
		ES: JN15F-17.5/40,17.5kV,40kA/2s			
19	Combined current limit fuse cabinet	DS: GN19-17.5/630,17.5kV,630A,50kA/2s FUR: FUR-15/160,15kV,160A,50kA(tentative) CB: 17.5kV,630A,25kA/2s CT: LZZBJ-15,15kV,150/1A CT: LZZBJ-15,15kV,4000/1A	Nr	1	
20	Insulated copper tube bus	13.8kV,4000A,40kA/4s	single-phase meter	200	
21	Insulated copper tube bus	13.8kV,1000A,50kA/4s	single-phase meter	40	
22	Excitation transformer	ZSCB11-1300/13.8,1300kVA, 13.8/0.54kV,Yd11,Ud=6%	Nr	1	
23	Station-service transformer at generator terminal	SCB11-1250/13.8,1250kVA 13.8±2×2.5%/0.4kV, D,yn11,Ud=6%	Nr	1	
24	Generator neutral-point earthing transformer cabinet	transformer: 80kVA,13.8/0.22kV (provisional) LA: Y1.5W-10.5/23,13.8kV	Nr	1	
IV	24kV equipment				
25	22kV station-service transformer	SCB11-1250/22,1250kVA 22±2×2.5%/0.4kV, D,yn11,Ud=6%	Nr	1	
26	circuit breaker cabinet	CB: 24kV,630A, 25kA/2s CT: LMZZB8-20, 24kV,50/1A	Nr	1	
27	VT-LA cabinet	LA: YH5WS-26/63TH,22kV VT: JDZX11-20,24kV FU: XRNP-24,24kV,0.5A,1000MVA	Nr	1	
28	22kV outdoor surge arrester	YH5WS-30/87TH	Nr	3	
29	22kV outdoor drop fuse	RW-22,100/80A	Nr	3	
V	Station-service power equipment				
30	Diesel generator	800kW,400/230V,cosΦ＝0.8,50Hz	Nr	1	
31	Station-service 0.4kV switchboard	MNS, 400V, withdrawable type	Nr	24	
VI	Other				
32	Lighting equipment		set	1	
33	Power cable	0.6/1kV， 12.7/22kV， 21/35kV	km	20	

S.N.	Name	Type and Specification	Unit	Qty	Remark
34	Cable tray		t	30	
35	Installing material	section steel	t	20	
36	Earthing material	50x5 flat copper	t	20	
37	Elevator	speed≥1.5m/s, load=1,000kg	Nr	1	

9.1.2.6 Overvoltage protection

A zinc oxide arrester is installed on HV and LV sides of the main transformer respectively. Overhead earth lines are erected for the whole 230kV outgoing lines constructed for existing HPP as the direct lightning protection of 230kV outgoing lines.

A group of motor zinc oxide arresters are installed at the outlet of each generator. In addition, a microcomputer harmonic elimination device is installed on the opening triangular winding of the voltage transformer.

9.1.2.7 Lighting system

Normal lighting and emergency lighting are provided for the DSHMP. Emergency lighting and evacuation indication lighting are provided at important passageways, staircase and exits. 380/220V three-phase five-wire system is used for normal lighting of the whole DSHMP. The power supply is fed from 400V power distribution board. AC380V is used for emergency lighting of the DSHMP and the power is taken from inverter power supply board.

9.1.3 Control and Protection

The secondary electrical system of DSH Modification HPP is designed based on unattended operation (fewer personnel on duty) in accordance with the principle of safety, reliability and advanced technology.

9.1.3.1 Automatic Control

9.1.3.1.1 Dispatching in the HPP

After the construction of the HPP, it will accept the remote dispatching of Laos power grid, and relevant interfaces for remote dispatching will be reserved in the computer monitoring system of the HPP.

9.1.3.1.2 Overall Design Scheme of the Computer Monitoring System

An independent control system will be provided for the Project. The host computer will be located in the original central control room for monitoring the new equipment putting into operation in the HPP, i.e. centralized monitoring method based on computer monitoring will be adopted for the monitoring system. The computer monitoring and control system of the HPP is divided into the HPP control level and local unit control level. Star redundant fiber optic Ethernet will be used.

The master control level will complete the monitoring of the whole plant and be responsible for the communication with the computer system of the dispatching center. In addition, it will provide management service for the whole plant of the HPP.

One unit LCU, one switchyard LCU, and one common LCU will be provided respectively according to each unit, switchyard and common equipment of the whole plant in the local unit control level. The level will be mainly responsible for the monitoring and control of the equipment of each area under its control.

PLC-based intelligent local control devices are used for the control of the common equipment of the whole plant and the auxiliary equipment of units.

9.1.3.1.3 DC Control Power Supply

One set of 110V DC power system will be provided for the operation of the monitoring, protection, excitation and other equipment of the Modification project.

9.1.3.1.4 Excitation System

Self-excited thyristor static excitation is used for the generator. The excitation regulator is microcomputer type with double automatic regulating channels with a manual regulating channel and the channels are used for hot standby for each other. The regulator has PID regulating rule and PSS function.

9.1.3.2 Relay Protection

The microcomputer-based relay protection devices are used for the relay protection system of the HPP.

Main equipment protection to be provided for the HPP will be as follows:

Generator protection; Main transformer protection; 230kV cable protection.

The electrical laboratory equipment of the DSHPP will be shared in the Modification project.

Table 9.1-3 List of Main Equipment for Control and Protection

S.N.	Description	Model	Unit	Qty	Remark
1	Computer monitoring host computer system		Set	1	
2	Computer monitoring local control unit (LCU)		Set	3	one set each for unit/switchyard/common
3	Generator protection system (including excitation transformer)	Microcomputer-based, double configuration	Set	1	
4	Main transformer protection system (including HV station-service transformer)	Microcomputer-based, double configuration	Set	1	including one set of non-electrical protection
5	230kV cable protection	Microcomputer-based, double configuration	Set	1	
6	110V DC system		Set	1	2 sets of 1200Ah batteries

S.N.	Description	Model	Unit	Qty	Remark
7	Excitation system	Microcomputer-based regulator	Set	1	
8	On-line monitoring system of unit		Set	1	
9	Auxiliary and common equipment control system		Set	1	
10	Electric energy metering and acquiring system		Set	1	
11	Auxiliary panel and control box		Nr	15	
12	Automatic fire alarm system		Set	1	
13	Control cable		km	50	
14	Transformation of interface with equipment of Phase I		LS	1	

9.2 Electrical calculation on 3-phase short circuit for generator, main transformer and circuit breaker and condenser operation machine of the powerstation and switchyard

To select electrical equipment, short-circuit current calculation is carried out for 13.8kV busbar at generator outlet, 230kV HV busbar and 0.4kV LV busbar of the modification project. The outgoing line of the modification project will be connected to the two circuits of 230kV TLs of existing HPP. The access system and the system parameters are the same as those used for the original four units. The short-circuit currents of 230kV Ban Hat Substation furnished by the Owner are 5.23kA (three-phase) and 3.94kA (single phase).

The electrical single line of short-circuit current calculation system is shown in Figure 9.2-1.

The calculated results of short-circuit current are shown in Table 9.2-1.

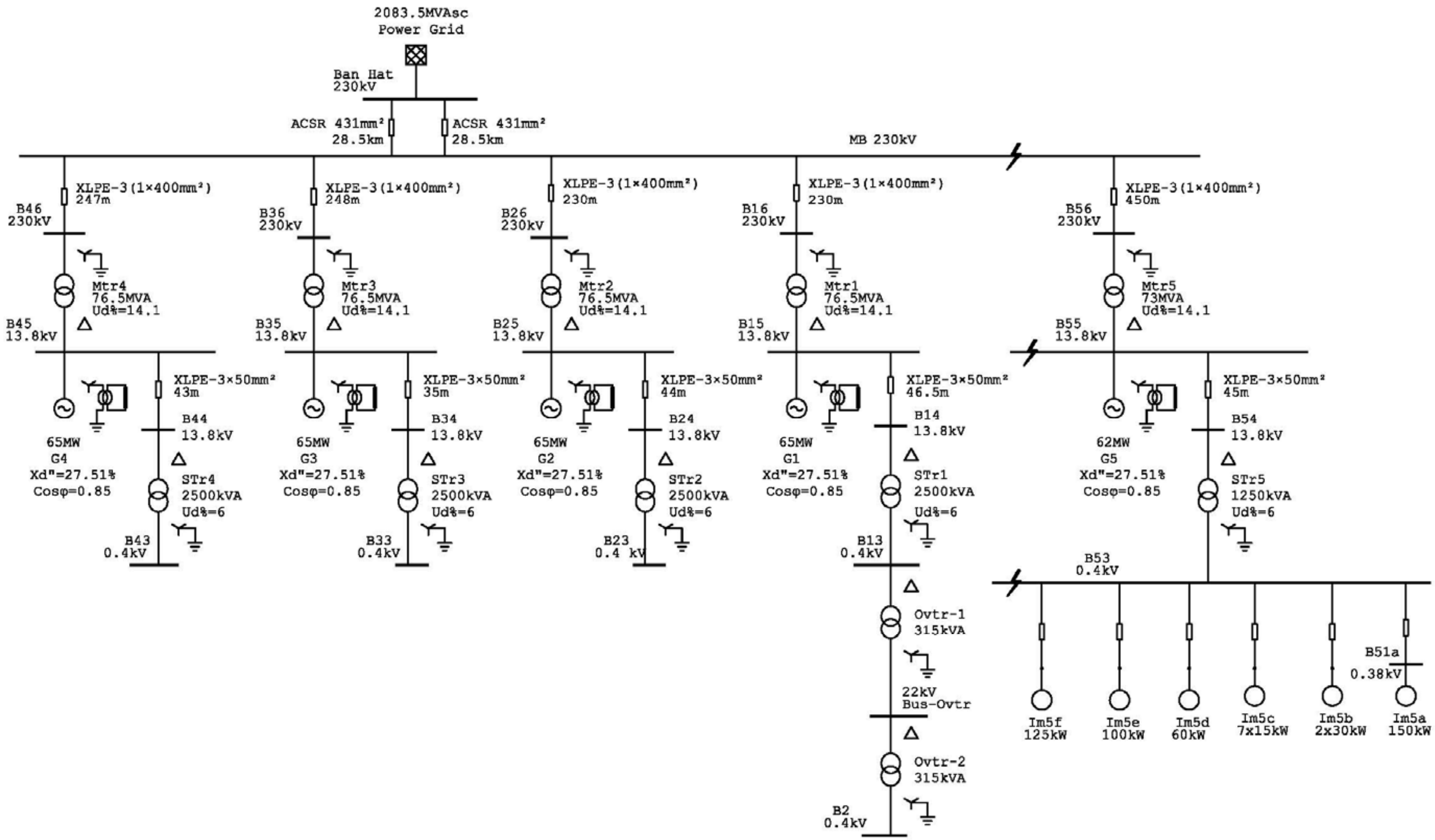

Figure 9.2-1 Electrical Single Line Diagram

Table 9.2-1 Calculated Results of Short-circuit Current

Voltage at short-circuit point (kV)	Name of branch name	Three-phase short circuit (S-C)				Single-phase short circuit (S-C)			Two-phase short circuit	Two-phase short circuit to ground
		Initial symmetrical S-C current Ik"(kA)	Peak S-C current ip(kA)	Steady S-C current Ik(kA)	0.05s DC component idc(kA)	Initial symmetrical S-C current Ik"(kA)	Peak S-C current ip(kA)	Steady S-C current Ik(kA)	Initial symmetrical S-C current Ik"(kA)	Initial symmetrical S-C current Ik"(kA)
230 (MB)	G1	0.542	-	-	-	0.786	-	-	-	-
	G2	0.542	-	-	-	0.786	-	-	-	-
	G3	0.542	-	-	-	0.786	-	-	-	-
	G4	0.542	-	-	-	0.786	-	-	-	-
	G5	0.546	-	-	-	0.789	-	-	-	-
	Power grid	4.444	-	-	-	3.774	-	-	-	-
	Total	7.155	18.720	7.151	-	7.705	20.160	7.705	6.054	7.589
13.8 (B55)	STr5	0.174	-	-	0.149	-	-	-	-	-
	Mtr5	20.975	-	-	18.998	-	-	-	-	-
	G5	13.859	-	-	12.156	-	-	-	-	-
	Total	34.999	94.790	34.834	31.303	-	-	-	29.150	29.150
0.4 (B53)	Feedback Im5a-Im5f	6.697	-	-	-	3.755	-	-	-	-
	STr5	31.847	-	-	-	32.165	-	-	-	-
	Total	38.544	88.563	31.847	-	35.920	82.534	35.920	32.663	37.496

9.3 Electrical calculation on grounding system

A high current earthing system is used for the HPP. Short-circuit current calculation is carried out according to the power grid information furnished by the Owner.

In accordance with IEEE Std 80, The maximum grid current is: $I_G=S_f\ C_p\ D_f\ (3I_0)=4.3$ kA.

It is required for that the ground resistance R of the HPP is not more than 0.45Ω.

It is proposed that the ground grid is arranged in the lower excavation layer of the powerhouse annex and dam area and on the excavation face of the tailrace area. Equipotential ground grid is laid in the main transformer platform and the outdoor switchyard. The powerhouse annex and dam area of the modification project is connected with the ground grid of existing HPP by laying ground conductors on the 230kV HV cable gallery, the access road between the modification project and existing HPP and the intake stoplog transportation road. The ground grid of the modification project is connected with the taps reserved in the ground grid of the existing switchyard.

To further improve the reliability of the ground grid, the steel bars in hydraulic structure, metal pipes, gate slot and other metal conductors are taken full use of as natural earthing bodies in the design of ground grid, so as to reduce the ground resistance, and to ensure safe operation of the HPP.

10 Hydro-mechanical equipment

Based on current hydraulic layout, the steel structural equipment is divided into two parts as follow: power generation system and stoplog transferring system. The whole project consists of 2 sets of gates, 3 sets of trash racks, 2 sets of various hoists,1 set of transferring vehicle. The basic material of gate and trashrack shall be Q345B and Q235B. The total weight of hydraulic steel structures is 1,303 t. Detailed design parameters shall be shown in table 10.1-1 as follow.

Table 9.3-1 Hydraulic Steel Structures/Equipment for DSH Modification HPP

S.N.	Item	Type of Gate	Opening size (W×H) (m)	Nr of Gates/ Openings	Design Head (m)	Type of Support	Single Gate Wt / Total Gate Wt (t)	Wt of single slot/ total gate slot (t)	Way of Operation	Name and Type of Hoist	Capacity (kN)	Nr (set)	Stroke (m)	Unit Wt (t)	Total Wt (t)	Gate Counterweight(t)	Remark (t) rail, balance beam, grabbing beam, lock, gate storage
1	Intake trash rack	Vertical	5.1×41.2	3/3	4/6	fixed roller	50/150	25/75	trash cleaner	Shared gantry crane with trash cleaner	50	/	48	share	share		dogging device: 6 grabbing beam 4
2	Intake maintenance gate	Stoplogs	15.36×17.77	1/1	41.2	slider	351/351	60/60	opened & closed in static water	gantry crane	2×800	1	48	170	170		dogging device: 6, grabbing beam 12,rail 12 storage slot 22
3	Tailrace emergency gate	Plain gate	13.194×11.437	1/1	26.129	fixed roller+slider	230/230	55/55	closed in dynamic water & opened in static water	wire rope hoist	2×2500	1	35	100	100		dogging device 4
4	Transfer vehicle	Track trolley	6×3×0.85	1		wheel	10/10			turntable		2		14	28		rail 8 ;
	total (t)						741	190							298		74

11 Construction plan and schedule

11.1 Preparatory works

11.1.1 Construction Access and Transport

11.1.1.1 Site Access and Transport

(1) Current situation of site access

1) Road

Road 13# on left bank is connected to Pakse, the third biggest city of Laos and Vientiane, the capital of Laos. The Project site is about 150km away from U/S Pakse City, about 839km away from Vientiane, the capital of Laos, about 270km away from Ubon, Thailand, about 897km away from Bangkok, the capital of Thailand, and about 450km away from Phnom Penh, the capital of Cambodia. The Project has a northern route and a western route as its site access.

The northern route is from Kunming, China, to the dam site as follows: Kunming-Yuxi-Yuanjiang-Mohei-Puer-Mohan-Mengsai-Luang Prabang- Vientiane-

Taqu-Base- powerhouse site. The dam site is 2,233 km away from Kunming, China, in highway mileage. The existing roads are as follows: The roads from Kunming to Mohan in China are all freeways; the roads of Mohan–Vientiane-dam site in Laos all belong to the national road 13 which is the south-north national trunk highway in Laos, with a bituminous concrete pavement having a width of 6.5 m~ 7 m.

The western route is all in Thailand as follow, Bangkok –Sarawuli–Sloin–Uwen–Base–

project site.

2) Railway

The goods can be transported by railway from China to Vientiane City, and then by road in Laos to the construction site. Alternatively, goods can be transported by railway from Bangkok to Nong Khai in Thailand, and then by road in Laos to the construction site.

3) Sea transport

The middle reaches of the Mekong River is unnavigable. In case of sea transport, goods can be transported to the Bangkok Port in Bangkok, Thailand, and then transported by road to Nong Khai (Thailand), and then Vientiane - Phou Khoun - Muang Souy - project area, namely, transported to the dam site by road.

(2) Means and routes of site access

The combination of road and railway or the combination of road and sea is used for the site access. The Project has a northern route and a western route as its site access.

(3) Transport of heavy-big piece

In the Project, the heaviest equipment is main transformer with a single transportation weight of 70 t, while the biggest equipment is bridge crane beam with a single section dimension of 21m×2.0m×1.6 m(L×W×H).

The heavy-big pieces are transported by sea to LEAM Chebang of Thailand and then by road to the site.

11.1.1.2 On-site Access

The built on-site roads of DSHPP may be used, and only construction accesses are required to be built. The new building on-site temporary branch road is of the Hydropower engineering level 3. Such construction branch roads with Slag stone pavement width is 6.0 m and a total length of 1.0 km. See Table 11.1-1 for road will be utilized.

Table 11.1-1 Technical parameters of on-site roads

Classification	Name	Grade	Pavement properties	Width of pavement(m)	Width of roadbed(m)	Length (km)	Remark
Approach race		Hydropower project dedicated III level	Asphalt table place	6.0	7.0	7.37	Completed
On-site road	R1	Hydropower engineering level 3	Mud and rubble	6.0	7.0	0.4	Completed
	R2			6.0	7.0	3.3	Completed
	R3			5.0	6.0	2.85	Completed
	R4			5.0	6.0	1.1	Completed
	L1			6.0	7.0	3.7	Completed
	L2			6.0	7.0	0.3	Completed
	L3			5.0	6.0	0.7	Completed
	L4			6.0	7.0	4.2	Completed
	L5			5.0	6.0	0.22	Completed
	L6			3.5	4.5	1.2	Completed
	L7			3.5	4.5	0.35	Completed
	Construction road		Slag stone pavement	6.0	7.0	1.0	New-bulit/Temporary
East Sahong bridge		The bridge is 330m long and 8.3m wide. It is reinforced concrete bridge with designed load of steam-50 and hang-120					Completed

11.1.2 General Construction Layout

11.1.2.1 Plan of construction zoning and layout scheme

(1) Layout of public production facilities

The explosive magazine, oil depot, Contractor's camp, E&M equipment store, Owner's camp and warehouse are set at the same place as Don Sahong HPP. They are all set along the access road.

The oil depot is laid out at the inner side of access road, with an occupied area of 1,000 m^2. The M&E equipment warehouse is used to store permanent M&E equipment, electrical equipment, gate and hoist. The field assembly of metal structure is laid next to camps, with an occupied area of 4,000 m^2.

In addition, the explosive depot also belongs to warehouse facilities. Because it will cause relatively severe danger in case of explosion, the explosive depot is laid out on a gentle slope on the left bank, which is far away from the construction area. This explosive depot covers an area of about1,200 m^2.

(2) Living camp

The administrative personnel are calculated as 10% of constructors at peak hours, namely, considered as 75 persons. The floor area of living and welfare facilities is calculated based on the per capita total floor area and the index (16 m^2/person). Specifically, the floor area is about 1,200 m^2 and the occupied area is about 2,500 m^2.

The peak labor force for construction is about 762 persons, Such structures as office, dormitory and welfare facility are configured based on the per capita comprehensive floor area of 7.21m^2/person. About 5500 m^2 of temporary building (self-build) is needed. The administrative staff camp and the labor camp are independently laid out in zones. The camp mainly includes dormitory, office, canteen, sanitary and recreational facilities, medical room, and relevant auxiliary facilities.

(3) Layout of construction site

The project mainly includes civil works, concrete pouring and installation of metal structure for powerhouse. The production areas mainly include integrated warehouse, steel and wood factory, compressor station, and machinery repair workshop. In combination with road layout and elevation distribution, the construction area is set on gentle vacant land of new powerhouse and 4# channel. Machinery repair plant, steel and wood factory are set next to the Switchyard.

11.1.2.2 Layout of slag yard

Earth and rock excavation volume of main works in the Project is $25.18\times10^4m^3$ (incl. cofferdam excavation volume of 2.38×10^4 m^3), and dam demolition volume is 9878 m^3, totaling $26.16\times10^4m^3$. The excavated material for direct filling of cofferdam is $3.38\times10^4m^3$, volume of $17.21\times10^4m^3$ will be reclaimed to use, only volume of $5.57\times10^4m^3$ will be disposed.

If such spoils are not rationally planned and placed without plans, soil erosion and water loss will occur. Therefore, the spoil area of the Project must be planned rationally.

According to the allocation planning of earth-rock, 1 spoil areas and 2 stockpile area in total are planned in the whole project area at this stage. In combination with topographic and site conditions of the Project and considering project zone and construction progress, one disposal yard is planned between 3# and 4# channels, with a stockpile top elevation of 68m, average stockpile height of 5m, and stockpile capacity of $7.96\times10^4m^3$.

Storage yard 1# is planned between 2# and 3# channels, with a stockpile top elevation of 73m, average stockpile height of 5m, and stockpile capacity of $12.65\times10^4m^3$. Storage yard 2# is planned upstream of the $1^{\#}$ channel, with a stockpile top elevation of 75.5m, average stockpile height of 5.5m, and stockpile capacity of $12.2\times10^4m^3$.

The slope ratio of stockpile of all the slag yard are considered as per 1:2, and the steel gabions are set at stockpile toe for retaining purpose.

11.1.3 Facilities of the Construction Plants

11.1.3.1 Aggregate processing system

The aggregate system is set on the vacant land between 1# and 2# channels, to supply all aggregate necessary for the concrete, cofferdam filter and transition material of the Project. Total concrete volume of the Project is about 12.02×10^4 m^3, and total shotcrete is 800 m^3. The Plant is necessary to process aggregate of approximately 27.55×10^4t for concrete (incl. coarse aggregate of 17.84×10^4t, and fine aggregate of 9.71×10^4t).

As per a monthly peak concrete placement intensity of 0.96×10^4 m^3/mon, the designed treatment capacity of the Plant is 76 t/h, and production capacity of aggregate is 65t/h.

11.1.3.2 Concrete system

Adjacent to aggregate system, the system mainly undertakes concrete production for the Project. With a total concrete supply volume of 12.02×10^4 m^3, and a total shotcrete supply volume of 800 m^3, the Plant mainly supplies secondary and tertiary grading. As per a monthly peak concrete placement intensity of $0.96\times10^4m^3$/mon, the designed treatment capacity of the Plant is $30m^3$/h. The aggregate necessary for production of concrete is sourced from aggregate system.

One concrete batching plant (HZS75-1Q500) is provided, together with such associated facilities as cement and additive storage/conveyance system, aggregate supply system, admixture system and air compressor house. Bulk transportation is dominant for cementing materials.

11.2 Construction materials

11.2.1 Selection of raw materials

(1) Cement

According to the actual situation of the Project, grade 42.5 Portland cement is used for concrete. Considering the cement source of Don Sahong HPP, it is preliminarily planned to select Thakhet Cement Plant or Khammouan Cement Plant in Laos as the Project cement supplier.

Thakhet Cement Plant is located in Thakhet with distance of about 513km from the project. Khammouan Cement Plant is located in the south of Vientiane with distance of 1139km.

(2) Aggregate

In this modification project, concrete aggregate is recommended to continue to use excavated materials, mainly consisting of the first-phase underwater, river channel excavated materials and powerhouse excavated materials.

(3) Admixture

Admixture adding in concrete can improve the workability of concrete and reduce heat of hydration. Fly ash is the most widely used auxiliary cementitious material. The fly ash is to be purchased from Rayong, Thailand, with a haul distance of 1,129km.

In feasibility study stage of first phase, the fly ash quality had been tested. In this modification project, fly ash from Rayong is recommended to continue to use.

11.2.2 Other materials supply

Planning on procurement and transportation of construction materials, construction machinery, M&E equipment, living materials and others required for HPP construction is as follows:

1) Steel is mainly supplied by enterprises in Thailand through road transportation;

2) Wood is supplied by local enterprises through road transportation;

3) Oils and explosive materials may be purchased in Laos, but the guarantee rate is not high. Necessary storage is necessary by warehouse.

4) The E&M equipment and heavy and large components are purchased in China, shipped to LEAM Chebang and followed by road transportation;

5) The construction equipment may utilize the available equipment for DSHPP as much as possible, and the insufficient equipment may be purchased or leased in Vientiane and Thailand.

6) Production materials such as bricks, tiles, small hardware and office supplies are purchased in Pakse of Laos and transported through roads;

7) Living materials are purchased in Laos and transported by roads.

11.3 Civil engineering facilities

11.3.1 Construction Cofferdam

11.3.1.1 Design criteria

Dam is applied to retain water at intake. According to layout of new powerhouse, operating water level of reservoir and topographic and geological conditions, it is required to retain water with earth and rock cofferdam in D/S of powerhouse. The main hydraulic structures of the Project are grade II, and the cofferdam height is less than 15m, but the service years of cofferdam are 2.5 years. Therefore, the diversion structures are determined as grade IV, the cofferdam retaining standard is taken as P=5%, Q=48,000m^3/s (Annual), and the corresponding water level in front of the cofferdam is 61.09m. The discharges and water levels in front of the cofferdams corresponding to different standard floods are shown in Table 11.3-1.

Table 11.3-1 Discharges and Water Levels Corresponding to Different Standards

Standard (P=%)	Time Period	Corresponding Pakse Flood Discharge (m^3/s)	Water level in Front of Cofferdam (m)
10%	Annual	45000	60.38
5%	Annual	48000	61.09
1%	Annual	56000	62.23
10%	Dec.- Apr.	7840	52.86
10%	Average Nov.	10760	53.69
10%	Average Dec.	5470	52.20
10%	Average Jan.	3610	51.67

11.3.1.2 Structure Design

The cofferdam axis is arranged at the edge of the lowest level platform in the downstream. The specific location is shown in the Figure 11.3-1.

Figure 11.3-1 The axis position of cofferdam

In construction operation of DSHPP, the clay cores are well applied. Annual earth and rock cofferdam with cores is adopted again.

The cofferdams is featured as follows: U/S slope ratio of 1:1.8, the D/S slope ratio of 1:1.6, crest width of 5m, crest elevation of 63.0m, and maximum height of 13m. Core crest elevation and width of cofferdam are 62m and 3m respectively and the slope ratios on both sides of cores are both 1:0.15. The U/S and D/S sides of cores are each set with filter and transition material, with a horizontal thickness of one meter each. For the sake of guaranteeing seepage control of cofferdam, the cofferdam core foundation is 0.5m below the top boundary of strongly weathered rock stratum, and the core elevation of foundation plane is 51.5m. Furthermore, the cofferdam U/S slope is provided with 40cm-thick block stones for slope protection and anti-scour.

It is proposed to start cofferdam excavation in early January in 2022. The retaining standard for cofferdam filling excavation adopts average monthly discharge of P=10%, and the corresponding water is 52.20m. Therefore, the cofferdam excavation can be carried out on dry land. For the sake of not affecting power generation of DSHPP, C15 concrete retaining wall is set in this part which nearby the tailrace of DSHPP, to control the scope of cofferdam slope toe. C15 concrete retaining wall is 2.5m high (incl. lower 0.5m-thick enlarged foundation cushion), the top is 0.5m wide, and the slope ratio is 1:0.5. The typical section of cofferdam is shown in Figure 11.3-2.

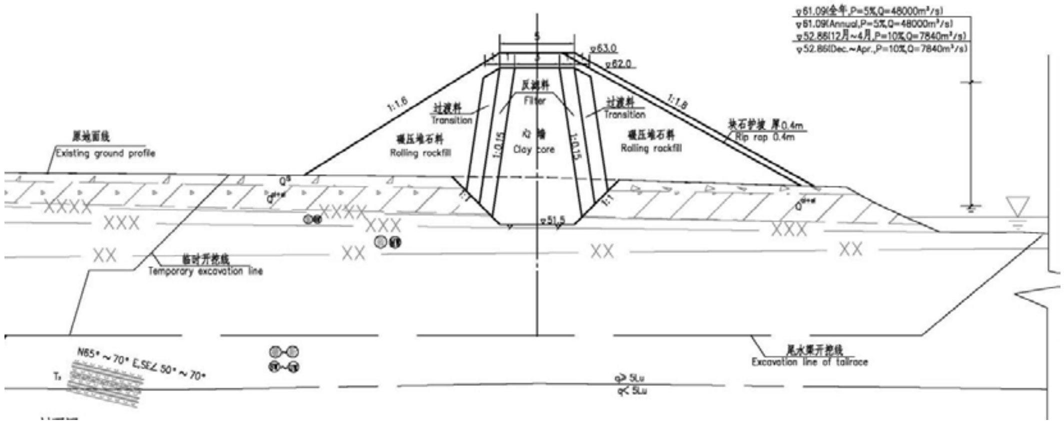

Figure 11.3-2 Typical Section of Cofferdam

Calculation of cofferdam has been carried out and it shows that the overall anti-sliding, stability and safety factors of upstream and downstream cofferdam slopes meet specifications and the upstream and downstream cofferdam slopes are stable.

11.3.2 Drainage of Foundation Ditch

Drainage of foundation ditch includes initial drainage and regular drainage. Regular drainage of foundation ditch includes rainfall, water leakage from foundation and cofferdam, waste water of construction. According to the meteorological data, the maximum rainfall is 450.3mm, with water-collecting area of the foundation ditch being 21162m^2. Considering the seepage of cofferdam, the maximum drainage intensity is about 422m^3/h according to the one-day discharge. For regular drainage of foundation ditch, volume of drainage equipment is designed to be 450 m^3/h. 4 units (one for standby) of submersible pumps (lift: 30m; flow: 150m^3/h) are proposed to be selected in preliminary stage.

11.4 Electrical and electro-mechanical equipment

11.4.1 Compressed Air Supply for Construction

The compressor stations will be provided according to the project, which mainly includes compressor station of dam works, compressor station of powerhouse works and compressor station of tailrace. The compressed air supply for construction of main works is relatively centralized. Three compressed air stations are respectively set in powerhouse construction area, with a total air supply of $100m^3/min$.

11.4.2 Water Supply for Construction

Just one water supply system is proposed to be provided. The water supply system with water supply quantity of $370m^3/h$, mainly supplies water for the aggregate processing system, concrete production supply system, production area of powerhouse works and Contractor's Camp, Employer's Camp. The water is from Hou SaHong River.

The supply system proposed in the proximity of U/S river channel below the permanent operator's village, with a two-stage pump station for lifting water.

In an attempt to meet the requirements of different users for water quality. Domestic water will be supplied after purification treatment. The water for production and construction can directly flow into elevated water tanks, without treatment.

11.4.3 Power Supply for Construction

Installed capacity of electric equipment for the project construction is 3,600kW and peak load of construction electricity is calculated to be 2,660kW according to the demand coefficient method.

The power supply for construction operation is proposed from diesel power plant. One diesel power plant is proposed for the whole project on the right bank in the D/S, with a rated installed capacity of 6×450KW.

In addition, one diesel power plant is separately set, with one set of diesel generator set, with a rated installed capacity of 250KW, to serve as emergency standby power supply.

11.5 Environmental safe-guard measures during construction

Risk Analysis and related safety precautions for Construction Period has been carried out, which includes fire and explosion hazard, transportation risk, electrical damage, slope instability, falling from high place, welding injury, mechanical injury, flood risk, debris flow, vehicle damage, lifting injury, object strike, drowning hazard, abandoned slag field, reservoir impounding, safety sign defects, dust hazard, harmful gas, major hazards of dangerous chemicals, and etc.

Meanwhile, the blasting productive test should be carried out before the excavation blasting to determine the various blasting parameters. In order to ensure the construction safety, measures of control blasting are required for excavation blasting. Requirements for control particle vibration speed are shown in Table 11.5-1.

Table 11.5-1 Allowable vibration velocity of Blasting Particle(Unit：cm/s)

item	age(day)		
	3	3~7	7 above
Concrete	1	1.5	4.5
Dam Foundation Grouting	1	1.2	2
Prestressed anchorage cable	1	1.2	4.0
Mechanical and electrical equipment of powerhouse	0.75		

12 Monitoring plan of power facilities during operation

DSH Modification HPP is designed according to the mode of "unattended operation" (operation with a few watchers).

An independent control system will be provided for the Project. The host computer will be located in the original central control room for monitoring the new equipment putting into operation in the HPP, i.e. centralized monitoring method based on computer monitoring will be adopted for the monitoring system. The computer monitoring and control system of the HPP is divided into the HPP control level and local unit control level. Star redundant fiber optic Ethernet will be used.

Operation personnel conduct centralized control and monitoring for the main M&E equipment of the whole plant through the operator workstation in the central control room.

All the real-time information related to supervision and control in the station level computer is directly collected from the local control unit (LCU). In this way, even though the entire host computer system fails, the supervision and control of the HPP's equipment will not be affected.

PLC-based intelligent local control devices are used for the control of the common equipment of the whole plant and the auxiliary equipment of units. Relevant information content of each equipment is transmitted to the computer monitoring and control system of the HPP.

The HPP is equipped with one set unit on-line monitoring device for the on-line monitoring of physical quantities (e.g., vibration, runout and pressure pulsation) of the Hydro-generator unit.

13 Manuals for reservoir operation and operation & Maintenance of equipment

13.1 Manuals for reservoir operation

The production schedule of cascades U/S of the DSHPP is uncertain, and these cascades are basically designed without regulation capability. It can be seen that the compensation benefits of the U/S cascades to the DSHPP are very limited. The DSHPP adopts run-of-river development. The reservoir is designed without regulation capacity. The operation of the reservoir is mainly based on the inflow. The actual operation for the water level of the reservoir shall be adjusted according to the daily discharge of the Pakse station to ensure that sufficient water is diverted to generate electricity.

13.2 Manuals for operation & maintenance of equipment

13.2.1 M&E equipment

1) The operation rules for equipment shall be prepared as per the operation needs of such equipment. Such rules shall be strictly followed during actual operation of the HPP, and the work concerning routine maintenance and service of such equipment shall be done well.

2) Manuals for equipment operation and maintenance are provided by corresponding equipment manufacturers.

13.2.2 Metal structure

(1) According to requirement of various equipment, an operating handbook for gates and hoists should be written. Workers should strictly comply with this handbook and keep good maintenance for these equipments.

(2) Some equipments such as main wheel of emergency gate, hinge of radial gate, rotating parts of hoist need regular lubrication and maintenance.

(3) Some emergency gates use self lubricating composite slider with low friction efficient. These slider need appropriate protection measures.

14 Construction cost of the project

Total investment of power station is composed of investment on hydraulic complex works and independent expenses and contingency and interest during construction period.

Based on the reference below:

(1) Design drawings, quantities and list of equipment and materials, etc.

(2) Supply conditions and market prices of materials, equipment, etc of third quarter of 2021 in Laos and Thailand.

The investment is calculated as per price levels of third quarter of 2021 and The static total investment of the project is 84688.27×10^3USD.

15 Implementation schedule of the project

Construction of the Project will start from December in 2021 and complete in June 2024, with a total construction period of 31 months, including 29 months for power generation period of the first unit, and 2 months for completion period.

The critical construction item of the Project is construction of powerhouse. The construction critical path is: open excavation of ground powerhouse→powerhouse concrete placement→bridge crane installation→T/G unit installation→water filling and commissioning of the units→power generation of the units→completion of the works.

The construction items of main works in the Project include cofferdam works for powerhouse, powerhouse works, dam and intake works, and tailrace, etc. The progress schedule is as follows:

(1) Dam and intake works

The earth and rock foundation excavation of intake will be performed between December in 2021 and March in 2022, and dam concrete placement will be performed between April in 2022 and August in 2023. The demolition of non-overflow dam section is arranged between October and November in 2023.

(2) Powerhouse works

Powerhouse excavation will be performed from December in 2021, and concrete placement will be conducted from April in 2022 to July in 2023. Bridge crane will be installed from May to June in 2023, while unit will be installed from July in 2023 to March in 2024. The unit will put into production by the end of the April in 2024.

(3) Tailrace works

Foundation excavation of tailrace will be performed from December in 2021 to March in 2022, and concrete placement will be conducted from October to November in 2023. Tailrace emergency gate will be installed in September and completed in November in 2023.

(4) Completion works

Such outstanding works such as site clearing will be completed from May to June in 2024.