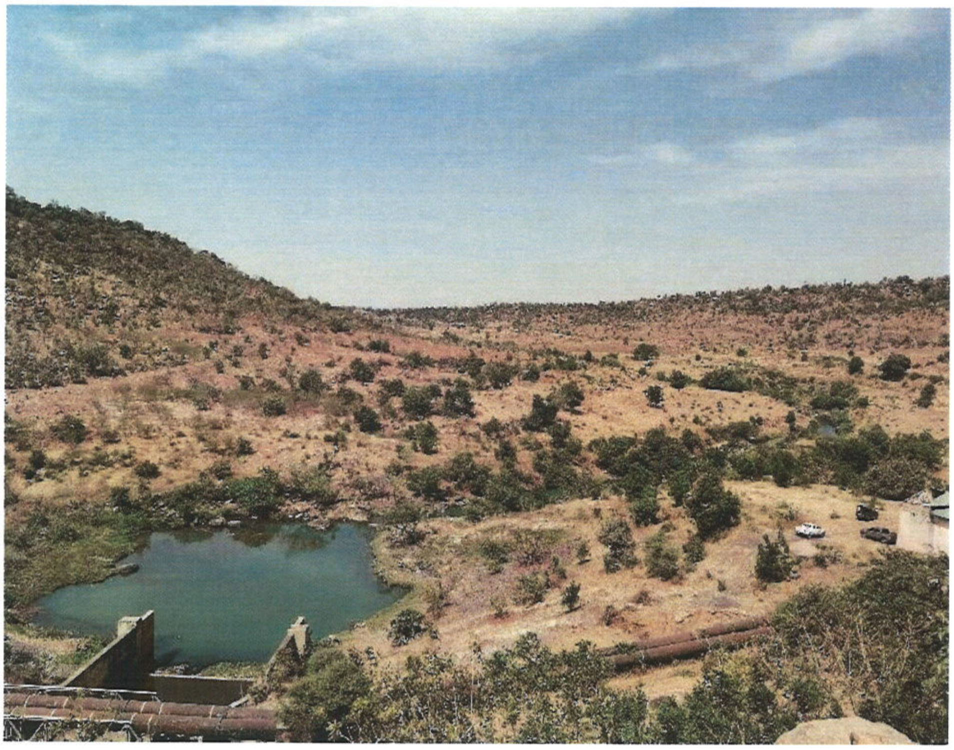
Balanga Dam Small Hydropower (SHP) Project in

Gombe State, Nigeria

Detailed Feasibility Study Report（320KW）



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List of Abbreviations:

B/C	Benefit cost ratio
Cm	Centimeter
m^3/s	Cubic meters per second
DC	Double Circuit
DEM	Digital Elevation Model
EIA	East Environmental Impact Assessment
ESIA	Environmental And Social Impact
E&M	Assessment
FC	Electromechanical
FIRR	Currency
FSR	Financial internal rate of return
FSL	Feasibility Study Report
EL.	Full Supply Level
GWh	Elevation
Ha	Millions of kWh
hr	Hectare-1OOx100 m=0.01 km2 Hour
Hz	Hour
HSSs	Hertz (cycles per second)
HPP	Hydraulic Steel Structures
IEE	Hydraulic Power Plant
Kg	Initial Environmental Examination
Km	Kilogram
Km^2	Kilometer
kV	Square kilometer
kVA	Kilovolt
Kw	Kilovolt ampere
kWh	Kilowatt
LC	kilowatt-hour
LWL	Local currency
M,m	Lower High-Water Level
M^2	Meter
m^3	Square meter
MCM	Cubic meter
Mm	Million cubic meters
MOU	Millimeter
MSL	Memorandum of Understanding
MOL	Mean sea level
Million US＄, M.US＄	Minimum operating level
MVA	Million US dollar
MW	Megavolt-ampere
	Megawatt

N	North
NE	North-East
NW	North-West
NPV	Net present value
NWL	Normal High-Water Level
TWL	Normal Tailwater Level
ONAN	Oil Natural Air Natural
R. Randa	Randa River
RPM	Revolutions per minute
ROD	Rock quality designation
SHP	Small hydropower
SE	South-East
SIA	Social Impact Assessment
Tonne	metric tonne = 1,000 kg
TL	Transmission Line
u/s	Upstream
US＄, USD	US Dollar
Yr.	Year
%	Percent

Engineering Properties of Balanga Dam Project

S.N.	Description	Unit	Qty
I	Reservoir		
1	Basin area upstream of dam site	km^2	313
2	Reservoir level		
	Check flood level	m	323.100
	Design flood level	m	321.600
	Full supply level (FSL)	m	317.150
3	Storage capacity		
	Storage capacity below FSL	10^4m^3	6270
	Regulating storage capacity	10^4m^3	5280
	Dead storage capacity	10^4m^3	990
II	Power generation benefit index		
1	Installed capacity	kW	160×2
2	Guaranteed output (P =90%)	kW	100
3	Average annual energy output	10^4 kW·h	144
4	Annual utilization hours	h	4500
(I)	Main structures		
1	Dam type		Embankment dam
	Crest length	m	210
	Maximum dam height	m	40
2	Spillway		
	Type		Open spillway
	Weir crest width	m	20
	Weir crest elevation	m	317.15
	Energy dissipation mode		Energy dissipation by hydraulic jump
3	Intake gate		
	Type		Intake gate of shaft
	Bottom slab elevation of sluice	m	306.50
4	Waterway structures		

Engineering Properties of Balanga Dam Project

	Design available discharge	m^3/s	5.0
	Approach channel		Buried pipe under dam + exposed pipe
	Length	m	373.59
	Pipe diameter	m	1.2
5	Powerhouse		
	Type		Ground powerhouse
	Dimensions of main and auxiliary powerhouses (L × W × H)	m	27.52×11.0×6.8
	Installation elevation of turbine	m	305.541
(II)	Main E&M equipment		
1	Number of turbines	No.	2
	Model		GD995a-WZ-70
	Rated output	KW	174
	Rated speed	RPM	600
	Maximum working head	m	12.345
	Minimum working head	m	5.507
	Rated head	m	7.832
	Rated discharge	m^3/s	2.47
2	Number of generators	No.	2
	Model		SFW250-10/740
	Unit capacity	kW	160
3	Model of main valve		D941X-6C-1200
	Quantity	No.	2
4	Model of main transformer		SCB13–400/11
	Quantity	No.	1
5	Crane model		3T electric hook bridge
	Span	m	9.0

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1. Executive Summary

1.1 Preface

1.1.1 Project Background

Located in the southern part of Gombe State, the Balanga Dam was built and put into use in 1988. The primary function of the Reservoir is for irrigation. After the repair and maintenance of the water intake tower two years ago, the irrigation function of the reservoir has been restored to normal operation.

Recently, Gombe state government in collaboration with the United Nations Industrial Development Organization (UNIDO) decided to upgrade the Balanga Dam into a multi-purpose dam with both irrigation and power generation capability, in order to provide electricity for small and medium-sized rural enterprises (SMEs) in the surrounding area. The intended small hydropower (SHP) upgrade scheme must also be coordinated in line with the State governments planned secondary water supply project in the irrigation area without affecting the original 4,000 hectares of free-flow irrigation plan.

(The basic data and SHP upgrade tasks of the above reservoir are extracted from relevant materials provided by the State government and UNIDO, including *Executive Summary - Local Government*, *Balanga Dam Micro Hydro Project Report - UNIDO Regional Centre for Small Hydropower (RC-SHP)*, *Validation Report for Balanga Dam SHP Schemes*, etc.

Between 2020 and 2021, based on the request of the United Nations Industrial Development Organization (UNIDO), Kunming Engineering Company Nigeria Limited (KEN) visited the site twice (January 2021 and June 2021) to carry out the necessary investigation and data collection. Some basic topographic surveying and mapping work was completed with the support of the State government. Following the site visit and based on the data collected, KEN considered two options for integrating SHP into the Balanga dam, which are highlighted below:

Scheme 1: Great efforts shall be made not to affect the current irrigation function of the reservoir, to make full use of the original steel pipes, and enable the water used for power generation to be returned/channeled through the existing irrigation canals (i.e. water used for power generation can still be used for irrigation), with a drop of 13.41m and a design water head of 7.83m (according to the field measurement and calculation). In this scenario, an installed capacity of 320kW can be attained.

Scheme 1 has a low impact on the existing irrigation function of the reservoir and has a lower project cost. However, the installed capacity of power generation is less.

Scheme 2: Will make full use of the head, upgrade one of the two irrigation pipelines to the downstream riverbed in order to build a powerhouse for power generation, have a head of 32.57m, and an installed capacity of 500kW can be realized from the FSL (EL.317.15m) of the reservoir to the downstream riverbed (EL.284.58m). However, with this option, the water used for power generation can only be released into the natural river channel. At present, the reservoir only undertakes the irrigation function of 2200ha of cultivated land, and one of its water pipelines carries water with a flow rate of 2.5m3/s, which can meet the irrigation task. In the later period, if the irrigation area of the reservoir increases and the water volume is not enough, a new irrigation channel can be built in the downstream (Phase II project) to irrigate the lower half of the irrigation area.

The water used for power generation in this Scheme is difficult to be used for irrigation at the same time, which has a great influence on the irrigation function of the reservoir. Additionally, the project cost is relatively high, but the installed capacity is larger, and the energy output is relatively large.

The above two schemes were discussed with representatives of the State government and UNIDO for decision-making at the end of the site visit in July 2021. As a result, Scheme 1 was selected as the preferred means of integrating SHP into the Balanga dam. However, upon further review by the state government at the end of 2022, it was concluded that the proposed installed capacity of 320kW was too small to meet the requirements of the area. Therefore, KEC re-organized the design work again in February 2023 according to the installed capacity target of 500KW, and subsequently completed the design of the installation plan of 500KW in September 2023. After repeated weighing by the owners, the first option of 320kW was eventually chosen, necessitating a revision of the detailed feasibility study report.

In February 2024, the preparation of detailed feasibility study report for 320KW installation scheme was completed.

1.1.2 Influence of Construction on the Current Situation of Reservoir

1.1.2.1 Influence of Waterway and Power Generation System Upgrade on Current Function of Reservoir

The Balanga Reservoir has a basin area of 313km^2, with a total storage capacity of 72.6 million m^3, an effective storage capacity is 62.7 million m^3, a dead storage capacity of 9.9 million m^3, and a FSL of 317.15m. The reservoir is intended to irrigate an area of 4,000ha and at present, the reservoir only undertakes the irrigation task of 2,200ha of cultivated land. If the canal system in the irrigation area is improved at a later stage, it will be able to undertake the irrigation task of 6,241 ha of cultivated land. The installed capacity of Balanga Hydropower Project (HPP) to be upgraded is only 320kW, which is a small HPP. It is an additional ancillary works of the Balanga dam, so the main task of the dam after the completion of the project, will still be irrigation.

As confirmed by the Owner, the installed capacity of 320kW is selected for the waterway and power generation system upgrade scheme of Balanga dam. The design scheme is to provide a bifurcated pipe on one of the two culvert pipes for waterway and power generation. The control butterfly valve is arranged on the downstream side of the culvert pipe with a bifurcated pipe, and irrigation can still be carried out without affecting its irrigation function. At present, one culvert pipe has met the irrigation requirements. Under special circumstances, when two culvert pipes are needed for irrigation, the butterfly valve can be opened for irrigation. The power generation water is connected to the current channel through the tail race canal and can be used for downstream water supply. In the construction scheme, a fork is set at the end of the pressure pipeline, which bypasses the workshop to access the irrigation channel, and an irrigation drainage lock is set at the end of the tail channel. When there is no need for power generation and there is water supply demand downstream, the gate valve on the turnout pipe can be opened to supply water downstream. If there is no need for water downstream during power generation, irrigation drainage gates can be opened to discharge power generation water to the downstream river.

Therefore, the main function of the Balanga Reservoir remains irrigation. In the current upgrade scheme, the power generation system is integrated based on the original steel pipe, and the water used for power generation is returned to the built irrigation canal, so that the current function of the reservoir is completely retained, and the project construction has no significant influence on the current function of the reservoir.

1.1.2.2 Influence of Waterway and power generation system upgrade on Main Structures of Reservoir

The main works of the Balanga reservoir are composed of dam, spillway and culvert water intake pipe, among which the dam is an embankment dam with a crest length of 200m, a crest width of 5.0m and a maximum height of 40m. The spillway is arranged on the right bank and is an open spillway, consisting of an overflow weir, a discharge chute and a downstream stilling basin. The overflow weir is 20m wide, and the overflow weir and discharge chute are of reinforced concrete structure. The stilling basin is a deep bedrock pit arising from excavation, and the flood release and energy dissipation are currently in good condition. The culvert pipes are buried under the dam, and there are two parallel ductile iron pipes, each of which is 365m long and 1.2m in diameter. The inlet end is provided with an intake tower (intake gate), which is controlled by a screw opening and closing gate, and the outlet end is provided with a valve and a stilling basin.

The waterway and power generation system upgrade of the Balanga Dam is implemented on the basis of the built Balanga Reservoir, with no change on the main structures of the reservoir. The specific implementation scheme is to use the existing intake sluice and two water conveyance culvert pipes, and erect one bulb tubular T/G unit each at the ends of the two culvert pipes to generate electricity. The main upgrade work includes: 1) upgrading and reinforcement of the penstock at the dam toe; 2) Rebuilding the powerhouse and erecting unit; 3) Rebuilding the tailrace and drainage channel.

The influence of waterway and power generation system upgrade on the current reservoir structures/buildings mainly includes the culvert pipe underneath the dam, pipeline-crossing spillway section and the first section of irrigation canal.

I. Culvert pipe under dam

Theoretically speaking, during the operation of the hydropower project, the frequent opening and closing of valves can change the hydraulic conditions of the current pipes, have adverse effects, increase the risk of pipe leakage, and then threaten the dam safety. However, the maximum head of this project is only 12.35m, and the change of hydraulic conditions has little influence on the pipe. As the pipe has been operating for many years, there is a local aging phenomenon. For the sake of safety, prior and during the construction of the project, great efforts should be made to inspect the pipe to further assess the safety of the pipe. Before operation, water pressure test should be done according to the standard for new pipes, and it cannot be operated until it is confirmed fit for purpose. During the operation of the hydropower project, monitoring facilities should be provided to deal with pipe anomaly in a timely manner.

II. Pipeline-crossing spillway section

At present, the pipe crossing the spillway is a steel framed pipe bridge, and the structure is intact, but the implementation of the SHP upgrade will change its stress conditions to a certain extent. It will therefore be necessary to reinforce the anchor blocks on both sides of the spillway to ensure the safety of the pipe and the spillway in the implementation of the scheme.

III. First section of irrigation canal

In order to meet the requirements of waterway and power generation system and relevant functions of the reservoir, the first section of the irrigation canal needs to be demolished and rebuilt. During the construction period, temporary pipes need to be provided to lead to the downstream irrigation canal. After the completion of the project, the original functions of the channel will be restored without any influence.

1.1.2.3 Influence of Downstream Water Distribution after the Completion of the Project

The construction of the Balanga Dam began in 1985 and was put into use in 1988. The main function of the reservoir is for agricultural irrigation. The planned irrigation area of the first-stage irrigation works is 2,200 hectares, which is irrigated by free flow. After 2011, the government upgraded the irrigation facilities. At present, the reservoir only undertakes the irrigation task of 4,000 hectares of farmland. However, the efficiency of the reservoir has not been fully exerted, far from reaching the designed water supply capacity, and there is still a certain amount of surplus water available for power generation. In accordance with the information provided by the Owner, the reservoir does not drawdown to the minimum operating level (MOL) every year, nonetheless due to the unavailability of relevant operation data and detailed design data of the reservoir, the following is only a qualitative judgment of the impact of the Balanga Dam's additional power generation function on its own irrigation water supply.

According to the survey during the site visit, the local electricity load mainly consists of residents' ordinary lighting and small household and agricultural appliances, but no power grid is available at present, only some small petrol and diesel generators are mainly used for power supply.

Balanga Hydro Power Station is small in scale, after the completion of power generation, it can only supply power to a small range of residents, and the design power supply guarantee rate is low. Due to the lack of data, the demonstration of the installed capacity of the power station temporarily adopts the comprehensive determination of the water transmission capacity of the original water diversion pipeline and the net power generation head, and the demonstration does not fully consider the incoming water conditions, irrigation demand and electricity demand. From the actual intra- annual and intra-daily operation and dispatching of the reservoir, there are time periods when the demand for power generation will not match the demand for irrigation, especially when the peak time-period of daily power consumption corresponds to the lower demand for irrigation. Excess power generation tail water will not be fully utilized when it enters the irrigation canal, which will have a certain impact on the available irrigation water. When there is a contradiction between irrigation water demand and power generation water demand, the principle that irrigation takes precedence over power generation should be adhered to. In addition, because the reservoir capacity is not fully utilized at present, there is still a certain amount of surplus water for power generation. In general, the power generation function may have a certain impact on the irrigation water supply, but the impact is small. During operation, the adverse impact on irrigation water can be avoided through reasonable scheduling.

1.1.3 Important Statements

1. The design scheme for upgrade works of the waterway and power generation system for Balanga Reservoir has been fully communicated with the Owner, which is based on the premise that the Owner already knows the advantages and disadvantages of the scheme, and the Owner decides to choose the scheme.

2. After going to site three times within two years for collecting the hydrological and meteorological data and operation management data of the reservoir, KEC failed to collect them. The sporadic reservoir design data that was provided by the state belong to the comparison and selection data of a scheme in the original design, which is inconsistent with the current project and basically cannot be used. In addition, the Scheme is a small hydropower upgrade work, so it is unnecessary to carry out systematic demonstration on the original reservoir. Therefore, it is difficult for this feasibility study report (FRS) to make a comprehensive and systematic evaluation and demonstration of hydrological scale and built structures.

3. The dam has been in operation for many years, especially the culvert under the dam is closely related to the operation safety of the dam, but no systematic safety assessment has been carried out for a long time. For the sake of long-term operation safety of HPP, it is suggested that the Owner makes arrangements for a safety evaluation of the built dam to be carried out.

1.2 Upgrade Scheme of Waterway and Power Generation System

After scheme comparison, scheme 1 is selected as the preferred option to carry out the upgrade design of small hydropower generation. The scheme will utilize sluice and water transmission culvert, build a powerhouse at the head of the current irrigation channel to generate electricity, and the power generation water will flow into the irrigation channel for irrigation. The power station is equipped with two 160KW tubular turbine generators with a total installed capacity of 320KW. The project upon completion will provide electricity for productive end users, especially for agri-based MSMEs close to the power plant.

The water intake, water diversion facilities, powerhouse and tailrace works required by the project are arranged on the basis of the existing dam. The upstream water level of the power station is the current water level of the reservoir. Because the downstream is connected to the current irrigation channel, its water level needs to match the current irrigation channel.

The project consists of sluice, pressure pipeline, power generation main and auxiliary building, tail canal, transmission line and so on. Among them, the inlet sluices use the current reservoir sluices, the pressure pipes have conditions to use a single pipe, the current two DN1200 ductile iron pipes, each length is 373.59m, and the downstream pipes are reformed and reinforced, the power plant is rebuilt after the current house is dismantled, the first 40m section of the current channel is dismantled and the drainage channel is rebuilt. The recommended transmission line is 3km.

Fig 1.1. Location of Balanga Dam SHP Project

Fig 1.2. Joint Site Investigation members

Fig 1.3. Photo of the site at the dam crest and along the water conveyance pipe

Fig 1.4. Topographic survey

Fig 1.5. Geotechnical exploration work

Fig 1.6. Soil test pits

Fig 1.7. Dam engineering area

Fig 1.8. Investigation of existing irrigation channel

Fig 1.9. Investigation of surrounding village and farmland

Fig 1.10. Investigation of Site access road

Fig 1.11. Investigation of Existing grid

1.3 Conclusions and Recommendations

1. KEC proposed two schemes for the integration of small hydropower generation system at the Balanga Dam:

Scheme 1: Under the condition of not affecting the current irrigation function of the reservoir, this scheme will make full use of the existing penstock and enable the power generation water to be discharged into the existing irrigation canal, with a head of only 13.41m and a design head of only 7.83m, which can only realize an installed capacity of 320kW. This scheme has a very low impact on the irrigation function of the reservoir as well as lower project cost. However, the installed capacity is relatively low.

Scheme 2: Will be implemented in two phases. ***Phase I*** will make full use of the head, upgrade one of the two irrigation pipelines to the downstream riverbed powerhouse for power generation and enable the power generation water into the riverbed at the dam toe. The head can reach 32.57m, and the installed capacity will be 500kW.

Phase II will commence after the HPP under ***Phase I*** is completed and put into operation. If the irrigation area of the reservoir is further increased (the downstream new irrigation area) and the water quantity is insufficient, the power generation tailwater discharged into the downstream river channel can be reused, and a new retaining dam and an irrigation canal can be built downstream of the tailrace channel of the new power plant (powerhouse).

In Scheme 2, the installed capacity and the energy output is larger. ***Phase I*** has limited impact on the existing irrigation areas, but it is difficult to meet the water demand of the new irrigation areas downstream, so ***Phase II*** needs to be carried out.

2. After our company submitted the second edition of feasibility report (500kW scheme), the state government finally decided to adopt the 320KW scheme, so our institute submitted the feasibility report of 320KW scheme again this time.

The main features of the 320kW scheme are:

The designed waterway and power generation discharge is 5.0m^3/s, the designed head is 7.83m, the installed capacity is 320kW, the average annual utilization hours are 4,500h, and the average annual energy output is 1.44 million kW·h.

The main construction works as follows: 1) Pressure pipeline transformation; 2) Main and Auxiliary Power House; 3) Accessory construction of Power House; 4.) Construction of 11kv transmission lines.

The total construction period of the project is 12 months, and the total estimated cost of the project is $1,167,800. The output line voltage level is 11kV, via a transmission line frame which will be set up next to the power plant.

However, transmission of power beyond the transmission line frame of the power station to the point of use (i.e. agro-processing center/cluster) is not within the scope of the project. This is because the exact location and as a result distance of the agro-processing cluster from the SHP plant is yet to be established.

2. Hydrology and Sediment

2.1 Overview of the Basin

The Gongola River, which serves as the main tributary of the Benue River, originates from the eastern slopes of Jos plateau, running northeasterly to Nafada. It turns south and then southeast to meet its main tributary, River Hawal and then flows south to join the river Benue at Numan. Before reaching Numan, the river is impounded by Kiri Dam, constructed by the government for irrigation purposes and the Dadin Kowa Dam in Gombe State.

Balanga dam is located on the Balanga River, a tributary of the Gongola River. The Balanga Reservoir Project is located on both banks of the Balanga River between Tulla Highway and downstream Balanga Town. It is one of the existing irrigation projects in the country and has the potential for hydropower generation.

The Balanga Reservoir has a basin area of 313km^2, with a total storage capacity of 72.6 million m^3, an effective storage capacity is 62.7 million m^3, a dead storage capacity of 9.9 million m^3, and a FSL of 317.15m. At present, the reservoir only undertakes the irrigation task of 2,200ha of cultivated land and the reservoir potential has not been fully utilized. If the canal system in the irrigation area is improved at a later stage, it will be able to undertake the irrigation task of 6,241 ha of cultivated land.

2.2 Meteorology

Gongola River Basin where Balanga Hydropower Project (HPP) is located has a tropical monsoon climate, with high rainfall (annual rainfall distribution of 1,200-1,400mm) and high temperature (average annual temperature of 24℃-31.4℃). The meteorological reference station of Balanga River Basin is Gombe Meteorological Station which is about 60km northwest of the dam site. See Table 2.2-1 for the summary of the main meteorological indicators of this station.

According to statistics, the average rainfall of Gombe Meteorological Station is 878.1mm, and the average elevation of the basin where Balanga HPP is located is higher than that of Gombe Meteorological Station, and the rainfall has somewhat increased. According to the Nigerian precipitation isoline map, the average annual rainfall of the basin upstream the dam site of the HPP is about 1,200 mm.

The hottest months in the basin where Balanga HPP is located are March and April, and the average monthly temperature over the years is 31.4℃ and 30.2℃ respectively. The coolest months are December and January, and the average monthly temperature over the years is 24℃ and 23.8℃ respectively. Relative humidity is generally highest between July and September, and lowest between January and February. The average monthly maximum relative humidity is 79.1% (August) and the minimum relative humidity is 22.5% (February).

Table 2.1. Statistics of Meteorological Elements of Gombe Meteorological Station

Project\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr.
Average annual temperature (℃)	23.8	26.5	30	31.4	30.2	28.4	26.6	26.1	26.7	27.5	25.8	24	27.3
Average annual rainfall (mm)	0	0.1	2.2	29.4	77.8	122.6	208.2	247.2	156.3	33.8	0.5	0	878.1
Average number of rainy days (days)	0	0	0.3	3.5	7.1	9.4	12.4	13.7	10.8	3	0	0	60.2
Average annual relative humidity (%)	26.1	22.5	27.3	40.8	56.4	66.4	75	79.1	75.5	59.5	37.2	31.3	49.8
Average annual wind speed (m/h)	9.4	10.4	11.2	11.2	11.2	10.8	10.1	9.4	8.3	8.6	9.4	9.4	9.9

2.3 Runoff

Balanga river basin is a typical rain-sourced river in mountainous areas, and its runoff is mainly replenished by precipitation, with little inter-annual change and uneven intra-annual distribution of runoff. Usually, April to October is the flood season, and November to March is the low-flow season. This time, the original design report of the reservoir has not been collected, but the average annual precipitation isoline map of Nigeria has been collected, and it was found that the average annual precipitation in the basin upstream the dam site is 1,200 mm. According to the engineering experience of surrounding basins, the runoff coefficient is taken as 0.5, and the calculated average annual discharge at dam site section is 5.96 m^3 /s.

2.4 Flood

According to the needs of engineering design, it is necessary to calculate the design flood of the section where the powerhouse site of Balanga HPP is located. Because the HPP is at dam toe and the area between the dam and powerhouse sites is small, the flood of the dam site section represents the flood of the powerhouse site section. Because the original design report of reservoir and the measured flood data of surrounding stations have not been collected at this stage, the control basin area at the dam site of Balanga HPP is 313km^2. This time, the inference formula and the local small basin flood calculation formula are used to calculate the peak flood discharge at the dam site.

(1) Calculation principle of reasoning formula

In the reasoning formula, the calculation of the maximum precipitation Ht in the basin period t is generalized as:

H_t=S_{t1}-n formula (2.1)

Where: the value of the rainstorm decline index n is taken as the empirical value of 0.73;

S value is called rain intensity, which is determined by the 24-hour maximum precipitation in the basin.

Because the reasoning formula method is applied to small basins, it is considered that the runoff yield conditions in different parts of the basin are similar, and the infiltration rate of the basin is the same in the whole basin and the whole process. The average infiltration rate μ of the basin is determined according to the empirical flood runoff coefficient and the empirical formula.

According to the calculation of rainstorm and infiltration, the maximum net rainfall ht (flood volume) in a rainstorm period t can be generalized as:

h_t= H_t—μ_t formula (2.2)

The net rain duration tc of rainstorm is calculated as follows:

t_c=((1-n) *S/μ)1/n formula (2.3)

For the peak flood produced by a rainstorm, the reasoning formula method thinks that it is related to the net rainfall process of the rainstorm and the confluence speed of the basin. The formula for calculating peak flood is expressed as:

Qm =0.278(h/τ) Ftc=((1-n) *S/μ)1/n formula (2.4)

Where:

0.278 is the unit conversion coefficient;

H is the net rain of a rainstorm (tc<τ) or the maximum net rain corresponding to τ period (tc>τ);

F is the basin area;

T is the confluence time of basin, which can be expressed as:

τ=0.278(L/(mJ1/3Qm1/4) formula (2.5)

Where:

L is the length of river;

J is the river slope;

M is the confluence parameter.

(2) Determination of basin characteristic parameters and rainstorm parameters

The characteristic parameters of the basin upstream of the dam site is measured by topographic map, mainly including river length, area and elevation, and the river gradient upstream the dam site is calculated by weighted method according to the measurement results. See Table 2.4-1 for the results of characteristic parameters.

Table 2.2. River Characteristic Parameters in the Basin Upstream the Dam Site of Balanga HPP

Name of section/parameter	Area (km^2)	River length (km)	Gradient
Section of dam and powerhouse sites	313	32.1	0.009

The daily rainfall data of Gombe Meteorological Station 60km away from the project area has been collected at this stage. The data series is 40 years, and the measured maximum daily rainfall is 144mm. The maximum daily precipitation of the station is calculated by frequency, and P-3 curve fitting is adopted. Statistical parameters: mean value=86.1mm, Cv=0.31, Cs=3Cv. See Table 2.4-2 for maximum daily precipitation.

Table 2.3. Maximum Daily Precipitation Frequency Fitting at Gombe Station

Frequency (%)	0.5	1	2	3.3	5	10
Designed maximum daily precipitation (mm)	178	166	153	144	136	122

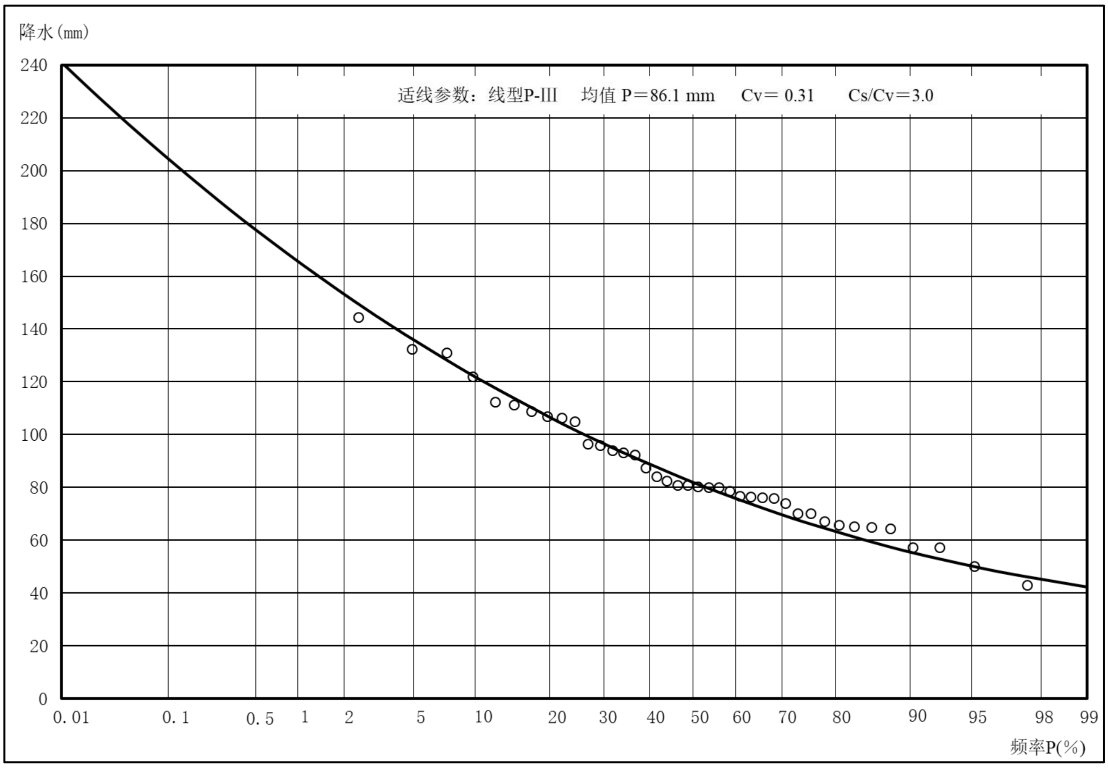

Fig. 2.1. Frequency Curve of Annual Maximum Daily Precipitation at Gombe Station

According to the characteristic values of the basin upstream of the dam site and the maximum daily precipitation parameters, the main frequency design flood of the dam and power sites is calculated by the inference formula. According to the vegetation, terrain and underlying surface in the basin, type III of basin is adopted. See Table 2.4-3 for design flood results of main frequencies under natural conditions of Balanga dam site.

Table 2.4. Peak Design Discharges at Balanga Dam Site

Unit: m^3/s

Frequency (%)	0.5	1	2	3.3	5	10	20
Dam site	657	588	515	465	421	346	272

2.5 Stage-discharge Relations

At this stage, the stage-discharge relations of the downstream site are calculated by Manning formula according to the measured cross section and longitudinal section data of the powerhouse site. When selecting the gradient, the upstream and downstream water surface gradient is comprehensively considered, and the roughness is determined by considering the riverbed composition and riverbank vegetation. The water surface gradient of the reach near the powerhouse site is 45.0 ‰, and the river channel roughness n is 0.025. See Table 2.5-1 for the natural stage-discharge results of the downstream site.

Table 2.5. Stage-discharge Relations at downstream site

Water level (m)	Discharge (m^3/s)	Water level (m)	Discharge (m^3/s)
285	0	287.1	624
285.7	87.9	287.3	731
285.9	136	287.5	847
286.1	194	287.7	972
286.3	263	287.9	1106
284.58	341	288.1	1251
286.7	428	288.3	1407
286.9	523	288.5	1573

3. Engineering Geology

3.1 Overview of Geology Survey

Balanga Dam is located in Balanga Local Government Area, Gombe State, between 9°54'22" north latitude and 11°32'09" east longitude. The reservoir is located opposite the Balanga River, passing through two prominent Strike ridges (canyons). In 1985, the dissolved Bauchi State Government entrusted Balfour Beatty of England to build the dam. As a single-purpose dam, the dam was developed mainly for irrigation, with fishery and navigation as auxiliary purposes.

The total storage capacity of Balanga Reservoir is 72.6 million m^3, and the catchment area of the reservoir is 313km^2. At present, the main function of the reservoir is irrigation. According to the survey data, the dam crest elevation of the reservoir is EL.326.259m, the impoundment elevation is EL.317.15m, the downstream irrigation canal floor elevation is EL.303.74m, and the downstream riverbed floor elevation is EL.284.58m.

From March 2023 to April 2023, KEC conducted two site surveys on the Balanga Dam in Nigeria, and on such basis, this feasibility study report (engineering geology part) has been prepared in combination with geotechnical investigation results prepared by EKOLYSIS DIVINE CONCEPT in Nigeria.

Fig 3.1. Location Map of Project Area

Table 3.1. Quantity of Geological Survey Work at Feasibility Study Stage of Waterway and Power Generation System upgrade of Balanga Reservoir

Survey item		Unit	Feasibility study stage
Geological surveying and mapping	Engineering Geological Surveying and Mapping (1:5000)	km^2	3.11
	Geological surveying and mapping of project area (1:5000)	km^2	1.21
	Geological surveying and mapping of the powerhouse site (1:2000)	km^2	0.67
	Geological surveying and mapping of dam site section (1:1000)	km/No.	1.0/3
	Geological surveying and mapping of new irrigation canal line profile (1:2000)	km/No.	13.4/1
Exploration	Pit and trench exploration	m/No.	9.4/4
Test	SPT	group/ hole	6/3
	Laboratory test of rock (soil)	group	10

3.2 Regional Tectonic Stability

3.2.1 Topography

Nigeria is located in West Africa, between 3°-15° east longitude and 4°-14° north latitude, bordering the Gulf of Guinea and the Atlantic Ocean in the south, Niger in the north, Benin in the west, Cameroon in the east, and Chad across Lake Chad in the northeast. The terrain is high in the north and low in the south. There are plains, valleys, lowlands, hills, basins, depressions, mountains and other terrains in the territory. The coastal strip plain is low and flat, and most places are below EL.50. In the low mountains and hills in the south, except the Niger valley in the middle and east, most areas are located between EL.200m and EL.500m. Niger and Benue valleys in central part of Nigeria have an average elevation below EL.330m. Hausa land in the north, covering more than a quarter of the national area, has an average elevation of about EL.900m.

The study area is located in the Gongola River basin. The basin is generally a lowland area with an elevation between EL.184m and EL.351m (Ikusemoran et al., 2016). Topographic features are undulating plains and gentle river valleys. The water sources in the study area are

Gongola River and its tributaries, Balanga River, Dunbu River and Bagwaria River. Due to the influence of climate, the river water level fluctuates seasonally.

Fig. 3.2. Topography Photo of the Project Area

3.2.1 Stratum and Lithology

Nigeria is located in West Africa, with high terrain in the north and low terrain in the south, which is divided into crystalline basement area and sedimentary cover area. The crystalline basement is mainly distributed in Maru-Kaduna, Bauchi-Upper Ogon-Ibadan-Ifewala and Adamawa-Taraba. The lithology of the crystalline basement is mainly mylonite, gneiss series and schist series of Precambrian-Cambrian. Sedimentary cover is mainly distributed in Birnin Cambi, Chad basin, Niger River basin and its tributaries Benue River basin, and Lagos-Niger Delta region. The sedimentary cover is composed of Cretaceous and Tertiary sand shale, Quaternary alluvial deposits and alluvial proluvial, as shown in Figure 3.2-1.

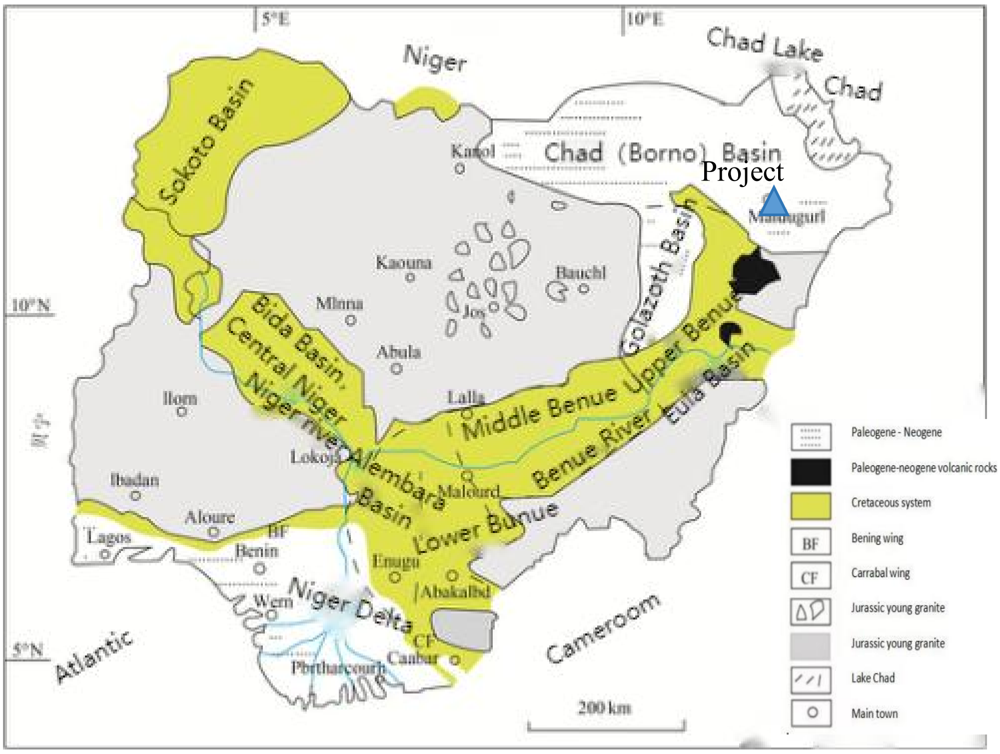

Fig 3.3. Geological Sketch of Nigeria

The Balanga Dam in the study area is located about 10.7 kilometers west of Talasse town, which is the administrative headquarters of Balanga local government in Gombe. The road between Balanga Dam and Mada-Jagali is about 94.3 kilometers south of Gombe Town. It borders the villages of Janjara, Reme, Tula, Dong, Gelengu and Jung. This area belongs to the hydrological zone of Nigeria and is called as Ha-III of Upper Benue Basin (Offodile, 2014). Geologically, this area is located in Muri-Lau basin (Gongola sub-basin) of the North Benue Trough (Nwajide, 2022). The Benue Trough is an intracontinental Cretaceous basin, which is about 1000 kilometers long and 250 kilometers wide at its widest point. It extends along the northeast-southwest direction and is unconformity located on the Precambrian basement. It is a part of the extensive rift system in West and Central Africa, and is believed to be the result of the crustal extension of the African plate after the formation of the former equatorial Atlantic (Fitton,1983; Genik,1992). The Benue Trough is regarded as a slender intra-craton structure developed as a pure rift structure in the pan-African active zone (Kings,1950). The Benkhelil's later research (1982, 1989) shows that the structure is a group of pulled sub-basins or grabens, which is caused by the left displacement of the pre-existing cross-flow fault along the northeast and southwest. Nwajide (2022) emphasized that the cross-flow movement is the main factor for the formation and subsequent evolution of the trough.
The study area is located under the sediments of Gombe Formation (Carter et al., 1963). It is the youngest Cretaceous sediment in the northern Benue Trough. According to Nwojiji et al. (2013), the age of this stratum is from the late Cambrian to the early Maastricht.

Campano-Maastrichtian Gombe sandstone is exposed in the west of Zambuk Ridge, parallel to the north-south strike, so it is called "Kerri-Kerri Basin" (Nwajide, 2022). The Gombe

Formation is considered unconformity because the surface it covers intercepts several older strata, such as Yolde, Pindiga and Fika (Nwajide, 2022). It is usually not as strong fold as the underlying strata. It is eroded and covered by the Keri-Keri Formation and exposed as an inner layer inside the Keri-Keri Formation, for example, in the southwest of Fika on the Gongola River. Ayok and Zaborski (2005) identified the Gombe Formation as the second estuary and delta facies sequence, which covered other sediments in the Zambuku Mountains. Nwajide (2022) pointed out that the main estuary properties of Gombe Formation may indicate that the sediments were mainly transgressive at first, and then turned into regressive sediments. Carter et al. (1963) interpreted the sedimentary environment of Gombe Formation as a river-dominated delta. Hamidu (2012) regarded the red sandstone facies, layered facies and interbedded facies of Zaborski et al., (1997) as alluvial environment, beach environment, coastal environment and submarine sedimentary environment respectively.

Zaborski et al. (1997) divided three main lithofacies in Gombe Formation. The "transition part" at the bottom is a series of thin layers of silty shale alternating rapidly, with some plant remains and fine to medium-sized sandstone interspersed with flaky iron ore. The next major lithofacies is "layered lithofacies", which consists of very regular layered, fine-grained to medium-grained white and gray quartz sandstone, with occasional feldspar sandstone, interbedded siltstone, silty clay, flaky and vesicular iron ore and river channel filling sandstone. The upper part of this formation is "red sandstone facies", which consists of brick red cross-bedded sandstone and coarse-grained and extremely coarse-grained cross-bedded river channel filling sandstone. The "red sandstone facies" of Gombe Formation is well exposed in Balanga dam area (plates 1 and 2), with a local thickness of more than 10m. The occurrence near the dam crest axis is gently inclined to the southeast by 100°.

Fig 3.4. Photo of Representative Rocks in the Project Area

3.2.3 Geological Structure

No large-scale regional fault (fracture) structures have been found in the area.

3.2.4 Regional Tectonic Stability Analysis and Basic Earthquake Intensity

(1) Historical earthquakes and their impacts on the site

According to D.E. Ajakaiye, B.N. Akpati and K.M. Onuoha, Nigeria is located in the west of Africa. In the past few decades, the earthquake activity in Nigeria is general, with the earthquake intensity of Mag. IV. Nigeria, like other mainland areas, can use simple plate tectonic theory to explain the relationship between stress changes and earthquakes.

The mechanism of earthquake change in Nigeria is closely related to the crustal movement, NE-SW deep faults and the weak zone from the Atlantic Ocean to the country (Ajakaiye et al., 1986). Burke (1969) also proposed the relationship with the spreading center of marine fault zone. Table 3.2-1 lists the earthquakes that occurred in Nigeria in the 20^{th} century.

Table 3.2. Earthquakes in Nigeria in the 20th Century

Time	Place	Features
1993.6.22	Warri	-
1939	Lagos	-
1961.7.2	Osaga, Ohafia in the proximity of Omuahia	A crack about 10 meters deep, 5 meters wide and 90 meters long crosses the highway.
1981.7.1	Kunduru Banchi area	-
1984.7.28	Ijebu-Ode	-
1984.8.2	Ejeb-Remo	-
1984.12.8	Ijebu-Ode	-

The recent earthquake occurred in late July and early August, 1984, in Ogun and parts of Ogo, and its influence was not only in Zaria and Lamto, but also in Ivory Coast. Many experienced seismologists believe that it is quite difficult to collect seismic data for a country lacking seismic information. According to previous reports, some major earthquakes mainly include Warri earthquake in 1933 and Lagos earthquake in 1939 (the earthquake had a great impact, and in some areas, many people rushed out of the house in panic). The earthquake may be at the same time as the Accra and Ghana earthquakes (Bacon and Banson, 1979: Bacon and Quaah, 1981). Other earthquakes in Lmo, Kano, Bauchi and Gongola are probably related to crustal movement, but due to lack of funds, they have not attracted enough understanding and research.

From July to August, 1984, the earthquake intensity in the areas of Ibadan-Ijebu Ode and Ajeokuta, north of Lagos, southwest Nigeria, was Mag. V-VI. The investigation shows that the earthquake occurred along the east and west of the boundary of Lagos graben fault system, which has never been discussed before.

Nigeria is a country with no major earthquakes, and its earthquakes mainly occurred in modern times. It is connected with the mid-Atlantic ridge system, and the top of the mid-Atlantic ridge system is just offset by the fault zone. The seismic activity in the fault zone is very strong, but the Balanga Reservoir is located in an area without seismic activity and far away from other reported earthquakes.

In addition, the project area is located on the Precambrian platform of the African Shield, which is considered to be the most stable earthquake-resistant area on the earth. Earthquakes in this area are quite rare, and the intensity is usually quite low. The surrounding mobile platforms, such as Atlas Mountains and the East Africa Rift Valley, are far away from the project area, so their influence on the project can be ignored.

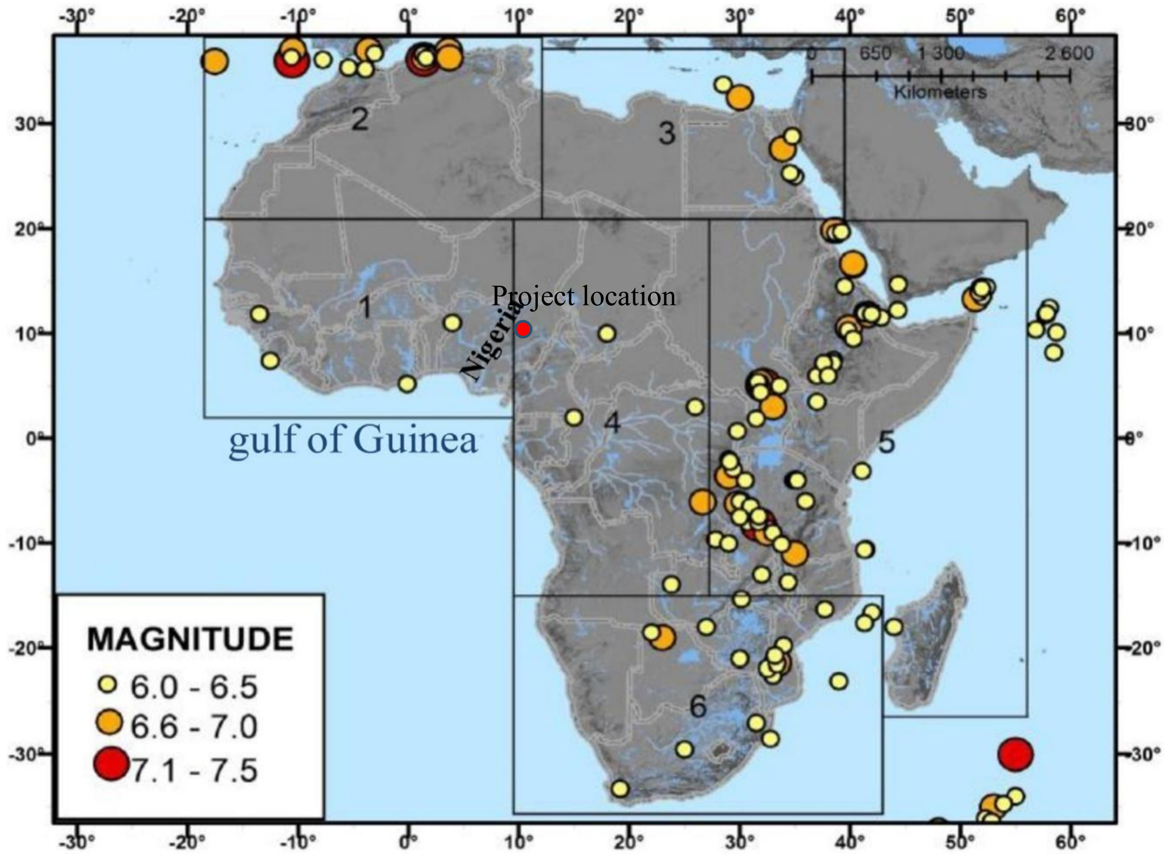

Fig. 3.5. Distribution Map of Earthquake Epicenter in Africa (before 2016)

(2) Design intensity of site earthquake and design ground motion parameters

According to the existing data and considering the incomplete historical earthquake data, the possibility of earthquakes in this area cannot be ruled out, but no destructive earthquakes will occur. It is suggested that the basic intensity of the project site is Mag. IV, and the design earthquake acceleration is 0.05g for horizontal acceleration and 0.03g for vertical acceleration.

(3) Regional structural stability

According to the regional tectonic stability classification table (see Table 3.2- 2), the peak acceleration of ground motion in this area is 0.05g, and the corresponding basic earthquake intensity is Mag. VI. The earthquake intensity is less than Mag. VI, there are no active faults within 25km, and there are no earthquakes and earthquakes with magnitude M>4.7 in the near site of the project. Comprehensive evaluation shows that the regional structural stability of the project area is good.

Table 3.3. Classification of Regional Tectonic Stability

Parameter	Good stability	Slightly good stability	Slightly poor stability	Poor stability
Peak acceleration α of ground motion	α＜0.09g	0.09g≤α＜0.19g	0.19g≤α＜0.38g	≥0.38g
Seismic intensity I	I ＜VII	VII	VIII	I ≥IX
Active fault	No active fault within 25km	No active fault within 5km	Active faults within 5km and seismogenic structures with magnitude less than 5	Active faults within 5km, and seismogenic structures with M≥5
Earthquakes and magnitudes near the project site	Earthquake activity with M<4.7	Earthquake activity with magnitude 4.7≤M<6.	Earthquake activity with magnitude of 6≤M<7 or only once with magnitude of M≥7	Many strong earthquakes with M≥7

Notes:

1. The site conditions of the ground motion parameters in the table are flat and stable Class II sites;
2. The corresponding grade is determined according to satisfying the most unfavorable parameter when judging the stability classification;
3. The applicable scope of regional structural stability classification is the project site area, that is, within 5km around the dam site.

3.3 Engineering Geological Conditions of the Proposed Penstock and Powerhouse Area

The proposed penstock and powerhouse are located on the hillside about 150m northeast of Balanga Dam and about 45m east of the stilling basin, as shown in Figure 3.3-1 satellite image.

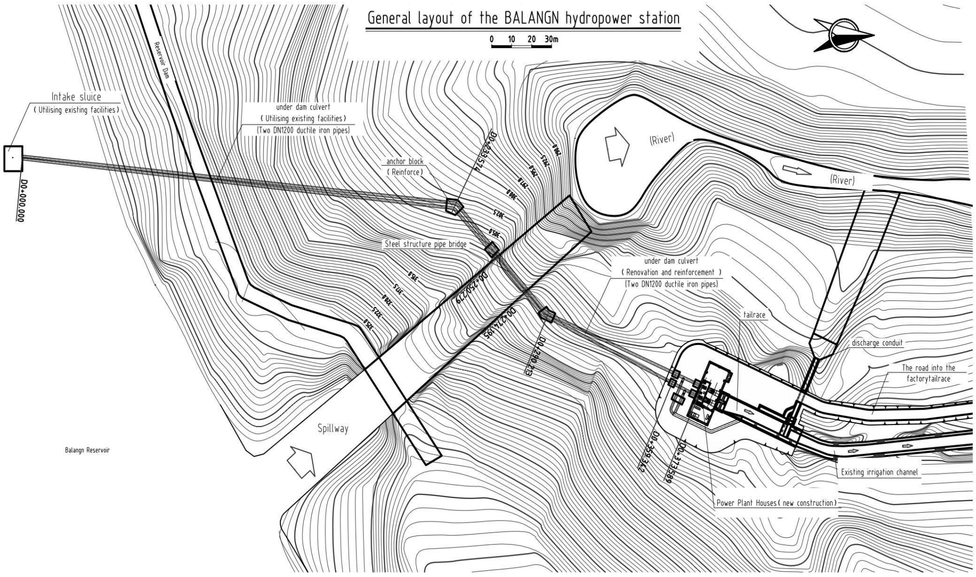

Figure 3.6. Proposed Penstock and Powerhouse Layout/location

The terrain of the site is relatively gentle, with a slope of 8°-20°, and the plants are mainly shrubs. The surface is mostly Quaternary eluvial deposits (Qedl), with an estimated thickness of 0.5m-1.0m. It is mainly composed of sub-angular blocks and gravel mixed with a small amount of gravel and silt, and the composition is mainly sandstone, with loose structure and poor cementation. It is inferred that the underlying highly weathered sandstone generally has an embedded depth of 5m. It is suggested that the foundation of each structure should be placed in highly weathered sandstone, and the foundation should be properly treated when it is placed on residual slope.

Figure 3.7. Topography of the Proposed Penstock and Powerhouse

The excavated back slope of the powerhouse is about 5m-8m. The excavated surface of the stratum is mainly residual slope, and the underlying is highly weathered sandstone. It is suggested that the excavated slope ratio is 1:1.75-1:2, and the sections with relatively poor local geological conditions should be supported by wire mesh and shotcrete.

According to the engineering geological analogy method, the suggested physical and mechanical parameters of residual slope deposits and highly weathered sandstone layers in the site are shown in Table 3.2-3.

Table 3.4. Recommended physical and mechanical parameters of main rock and soil layers

Lithology	Unit weight (kN/m^3)	Poisson's ratio (μ)	Modulus of compressibility E(MPa)	Shear strength		Eigenvalue of standard bearing capacity (Mpa)
				f	c (Mpa)	
Residual slope deposit	19-20	0.30	20-23	0.45-0.50	0.01-0.02	0.18-0.25
Highly weathered sandstone	22-24	0.27	30-35	0.50-0.55	0.15-0.20	0.40-0.50

3.4 Natural Building Materials

The natural building materials of the Project mainly include earth, rock, etc.

1. Earth Material

The project area is rich in earth materials. Weathered earth materials of sandstone are distributed on both banks of the dam site, which are composed of reddish brown, brown-yellow, brown silty clay with gravel mixed with fractured blocks, sandy loam, sandy loam with gravel, etc. It is mainly distributed in hillside areas. The inferred thickness is generally 0m-3.0m. According to the engineering geological analogy method, similar weathered soil materials can meet the anti-seepage requirements;

2. Rock Material

The project area is a sandstone area with good rock quality. At this stage, it is considered to select a quarry within 15km of the project area to exploit and process aggregate.

In addition, the large blocks and boulders distributed in the river valleys in the project area can be considered to use natural sand gravel as the source of concrete aggregate. Due to the large particle size, the grading cannot meet the requirements for direct use, and they can only be used after processing. It is estimated that their reserves and quality can meet the needs of the project. It is recommended to conduct site review and selection during construction.

The dam foundation rock to be excavated near the dam site area is mainly weakly weathered - fresh sandstone. The rock is hard, and the preliminary strength can meet the quality requirements of concrete aggregate. It is suggested that it can be used as concrete coarse aggregate after processing during construction.

3.5 Conclusions and Recommendations

3.5.1. Conclusions

(1) The project area belongs to the Benue Trough in Nigeria, which is an intracontinental Cretaceous basin. According to the regional tectonic stability classification table, the seismic peak acceleration in this area is 0.05g, the corresponding basic seismic intensity is Mag. IV, and the seismic intensity is less than Mag. VII. The regional tectonic stability in the project area is good.

(2) Southwest side of the stilling basin downstream of the existing Balanga Dam. It is recommended that the foundation be placed on the highly weathered sandstone. If it is required to be placed on the residual deluvial layer, the foundation should be treated.

3.5.2 Recommendations

In engineering construction, it is necessary to strengthen the protection of geological environment conditions, strengthen the survey, design and construction management, minimize the disturbance and damage to the natural environment, avoid triggering new geological disasters and adverse engineering geological problems, and timely block and protect the artificial slopes generated by such engineering activities as artificial filling, slope cutting and waste storage/disposal area, to avoid the occurrence of artificial fill landslide and fill debris flow.

It is suggested to pay attention to the construction geological work at the next stage to fully avoid geological risks and provide geological basis for design optimization and construction safety in time.

4. Project Task and Scale

4.1 Project tasks

4.1.1. Development Tasks

1. Power generation

The full supply level (FSL) of Balanga Reservoir is EL.317.15m, the elevation of the downstream riverbed is EL.303.74m, and the head is13.41m. The proposed HPP is upgraded on the basis of the completed Balanga Reservoir, with an installed capacity of 320kW.

4.1.2 Power Supply Range

The installed capacity of the HPP is 320kW, which aims to provide power productive uses, especially for agro-processing.

4.2 Necessity of Project Construction

(1) The construction of the HPP is conducive to the local economic and social development
In Gombe State, agriculture is the main pillar industry of the state's economy. Except for food processing industries, there are few manufacturing industries and the living standard of local residents is low. The construction of HPP will improve local water supply, sanitation, transportation and other public infrastructures, bring benefits and welfare to residents, and promote local economic and social development.

(2) Being beneficial to reduce fossil fuel consumption and harmful gas emissions The construction of Balanga HPP is conducive to reducing the construction scale of coal-fired power plants and gas-fired power plants, preserving oil and natural gas resources for Nigeria, reducing environmental pollution and improving the eco-environment. It can reduce emissions of sulfur dioxide, carbon dioxide, ash and nitrogen oxides.

4.3 Installed Capacity and Number of Units

4.3.1 Selection of Installed Capacity

The Balanga Reservoir has a basin area of 313km^2, a total reservoir capacity of 72.6 million m^3, an effective reservoir capacity of 62.7 million m^3, a dead reservoir capacity of 9.9 million m^3 and a FSL of EL.317.15m, and the planned irrigation area of the reservoir is 4,000ha. At present, the reservoir only undertakes the irrigation task of 2,200ha cultivated land. The main function of Balanga Reservoir is still irrigation. The irrigation function of the reservoir must be considered in the waterway and power generation system upgrade scheme to minimize the impact.

The proposed HPP is upgraded on the basis of the completed Balanga Reservoir. The FSL of the reservoir is EL.317.15m, the elevation of the downstream riverbed is EL.284.58m, and the design head is 32.57m, which can achieve an installed capacity of 320kW.

According to field visit and survey, we initially proposed the 320kW and 500kW schemes for comparison. The 320kW scheme is to build a powerhouse at the end of the existing pipeline, and the water for power generation is channeled in the current irrigation canal. The 500kW scheme is to set a bifurcated pipe on one of the two culvert pipes to divert water to the downstream riverbed for power generation, and the upgraded culvert pipe retains the current irrigation function of the reservoir. At this stage, power generation will not affect reservoir irrigation. When irrigation water volume increases at the next stage, irrigation intake dam and irrigation canal will be built downstream of the river, and power generation water will be used to irrigate the irrigation area in the lower reach.

After discussing with state representatives, it was agreed that the installed capacity of the power station will be 320KW.

4.3.2 Selection of Number of Units

The power supply objective of the Balanga HPP is mainly to power agro-based MSMEs. Considering the operation mode of the HPP, the convenience of unit equipment cost and maintenance, it is proposed to use two tubular-turbine generators at this stage, with a unit capacity of 160kW each.

4.4 Capacity Index of HPP

The basin area of Balanga Reservoir is 313km^2 and the effective storage capacity is 62.7 million m^3. With good regulation performance, the HPP has an annual utilization of 4,500 hours for the time being, and the annual average energy output is 1.44 million kWh.

Table 4.4 Energy Indices of Waterway and Power Generation System upgrade of Balanga Reservoir

Item	Unit	Value
Full supply level (FSL)	m	317.15
Minimum operating level (MOL)	m	312.5
Installed capacity	KW	320
Number of units		2
Unit capacity	KW	160
Average annual energy output	10^4kWh	144
Annual utilization hours	h	4500
Rated available discharge	m^3/s	5
Rated head	m	7.83

5. Project Layout and Structures

5.1 Design Basis and Basic Data

5.1.1 Project Rank and Design Safety Standards The upgrade works
The upgrade works of waterway and power generation system for Balanga Reservoir is based on the existing reservoir. The HPP has an installed capacity of 320kW, an available discharge of 5.0m^3/s, a design head of 7.83m, and an annual energy output of 1.44 million kW·h. After the completion of the HPP, it will provide power supply for productive activities such as agro-processing facilities in the surrounding area.

The Project rank is Grade V, and the project scale is small (2). Main structures/buildings include Grade 5 for water retaining buildings, flood releasing buildings, waterway and power generation buildings, Grade 5 for secondary buildings, and Grade 5 for temporary buildings.

5.1.2 Design Basis

5.1.2.1 Flood Standard
Design flood standard for powerhouse: 30-yr return period
Flood check standard for powerhouse: 100-yr return period
Standard for downstream energy dissipation flood: 10-yr return period.

5.1.2.2 Seismic Fortification Standard
According to the seismic and geological data in this area, the designed seismic acceleration in this area is 0.05g for horizontal acceleration and 0.03g for vertical acceleration. The basic earthquake intensity is Mag. IV, and the earthquake intensity is less than Mag. VII. There is no active fault within 25km, and there is no earthquake and earthquake activity with magnitude M>4.7 near the project site. Comprehensive evaluation shows that the regional structural stability of the project area is good.

5.1.3 Technical Specifications Adopted in the Design

(1) SHP/TG 001:2019 Technical Guidelines for the Development of Small Hydropower houses

(2) DL/T 5020-2007 Specification for Compiling of Pre-feasibility Study Report of Water Resources and HPPs

(3) GB50071-2002 Design Code for Small HPP

(4) SL252-2017 Standard for Rank Classification and Flood Protection Criteria of Water and HPPs

(5) GB 50201-2014 Standard for Flood Control

(6) DL5108-1999 Code for Design of Roller-Compacted Concrete Gravity Dams

(7) SL25-2006 Design Specification for Stone Masonry Dam

(8) SL253-2018 Design Code for Spillway

(9) SL74-2019 Specification for Design of Steel Gate in Hydraulic and Hydroelectric Engineering

(10) SL285-2003 Design Code for Intake of Hydraulic and Hydroelectric Engineering

(11) NB/T10391-020 Code for Design of Hydraulic Tunnel

(12) SL205-2015 Design Specification for Hydropower Headrace and Forebay

(13) SL281-2003 Design Specification for Steel Penstock of Hydroelectric Stations

(14) SL266-2014 Design Code for Hydro powerhouse

(15) GB51247-2018 Specification for Seismic Design of Hydraulic Structures

(16) SL744-2016 Specification for Load Design of Hydraulic Structures

(17) SL191-2008 Design Code for Hydraulic Concrete Structures

(18) SL328-2005 Rule on Calculation of Quantity of Work in Hydropower and Water Conservancy Project

(19) Other relevant technical specifications and standards.

5.1.4 Basic Data

5.1.4.1 Geographical Location of the Project

Balanga Reservoir is located in the southeast of Gombe State, 70km away from Gombe (highway length), of which 60km is asphalt road and the last 10km is unsurfaced road, so the traffic is relatively convenient.

5.1.4.2 Hydrology and Meteorology

Gongola River Basin where Balanga HPP is located has a tropical monsoon climate, with high rainfall (annual rainfall distribution of 1,200-1,400mm) and high temperature (annual average temperature of 24℃-31.4℃).

According to statistics, the average rainfall of Gombe Meteorological Station is 878.1mm, and the average elevation of the basin where Balanga HPP is located is higher than that of Gombe Meteorological Station, and the rainfall somewhat increases. According to the Nigerian precipitation isoline map, the average annual rainfall of the basin upstream the dam site is about 1,200 mm.

The hottest months in the basin where Balanga HPP is located are March and April, and the average monthly temperature over the years is 31.4℃ and 30.2℃ respectively. The lowest months are December and January, and the average monthly temperature over the years is 24℃ and 23.8℃ respectively. Relative humidity is generally the highest between July and September, and the lowest between January and February. The average monthly maximum relative humidity is 79.1% (August) and the minimum relative humidity is 22.5% (February).

5.1.4.3 Geological Parameters

Table 5.1. Suggested Geological Parameters

Lithology	Unit weight (kN/m^3)	Poisson's ratio (μ)	Modulus of compressibility E(MPa)	Shear strength		Eigenvalue of standard bearing capacity (Mpa)
				f	c (Mpa)	
Residual slope deposit	19-20	0.30	20-23	0.45-0.50	0.01-0.02	0.18-0.25
Highly weathered sandstone	22-24	0.27	30-35	0.50-0.55	0.15-0.20	0.40-0.50

5.1.4.4 Geological Parameters

Table 5.2. Energy Index Results of Balanga HPP

Item	Unit	Value
Full supply level (FSL)	m	317.15
Minimum operating level (MOL)	m	312.5
Installed capacity	KW	320
Number of units		2
Unit capacity	KW	160
Average annual energy output	10^4kWh	144
Annual utilization hours	h	4500
Rated available discharge	m^3/s	5.0
Rated head	m	7.83

5.2 Comparison and Selection of Technical Upgrade Schemes for HPP

Balanga Reservoir has a basin area of 313km^2, a total reservoir capacity of 72.6 million m^3, an effective storage capacity of 62.7 million m^3, a dead storage capacity of 9.9 million m^3 and a FSL of EL.317.15m. At present, the reservoir only undertakes the irrigation task of 2,200 ha of cultivated land, and the reservoir has not been fully utilized. It can undertake the irrigation task of 6,241 ha of cultivated land if the associated canal system in the later irrigation area is improved.

The proposed HPP is upgraded on the basis of the completed Balanga Reservoir. The FSL of the reservoir is EL.317.15m the elevation of the existing channel head is EL.303.74m. The head is 13.41m, the design head is only 7.83m, and only 320kW of installed capacity can be achieved.

5.2.2 Development and Comparison of Construction Schemes (Proposals)

Balanga Reservoir is a medium-sized reservoir, and its main function is agricultural irrigation. The existing dams, spillways and culvert pipes are basically in normal operation. Due to such factors as dam stability and safety against sliding, leakage safety, inundation problem and cost control, it is not suitable to increase the water level of the reservoir, and the water head can only be calculated according to the FSL.

After repeated study, based on the principle of "safety, reliability, economy and rationality, overall consideration", two design schemes are proposed for comparison.

Scheme I: Utilizing the current intake sluice and culvert pipe to build the powerhouse at the headwork of the current irrigation canal to generate electricity with an installed capacity of 320KW.

The scheme will utilize the current intake sluice and culvert pipe to build the powerhouse at the headwork of the current irrigation canal to generate electricity, and the water used for power generation will flow back to the irrigation canal for irrigation purpose. The FSL of the reservoir is EL.317.15m, and the longitudinal slope of the irrigation canal is 0.5‰. At present, the flow capacity is only 5.0m^3/s and the normal tail water level (TWL) is EL.304.70m when the headwork is at EL.303.74m. According to the statistics of water energy parameters, this scheme will have a total installed capacity of 320kW.

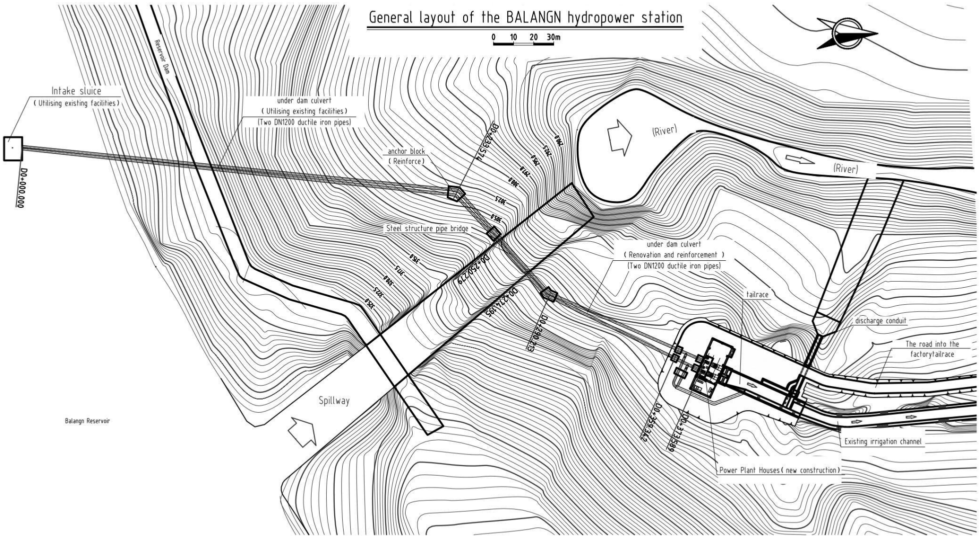

Fig 5.1. General Layout of Scheme 1

Table 5.3. Scheme 1 hydraulic energy parameters

Basic data	Total storage capacity	10^4m^3	7260	
	Effective storage capacity	10^4m^3	6270	
	Dead storage capacity of reservoir	10^4m^3	990	
	Check flood level of reservoir	m	323.1	
	Design flood level of reservoir	m	321.6	
	Full supply level	m	317.15	
	Minimum water level for power generation	m	312.5	Consider as per favorable working depth
	Inlet elevation of penstock	m	306.5	Provisional
	Downstream canal floor elevation	m	303.74	
	Minimum TWL	m	304.1	TWL of half unit
	Normal TWL	m	304.7	Water level of two units at full capacity
	Maximum TWL	m	305.143	Maximum water level for downstream water consumption
Head loss calculation	Frictional head loss at full capacity	m	1.279	
	Local head loss at full capacity	m	1.014	(inlet 0.146 + 2 elbow 0.174+ main valve 0.221+turbine inlet 0.307+other comprehensive 0.165)

	Frictional head loss of half a unit	m	0.379	
	Local head loss of half a unit	m	0.326	(inlet 0.039+2 elbow 0.047+main valve 0.114+turbine inlet 0.082+ other comprehensive 0.044)
Head calculated result	Maximum head	m	12.345	
	Design head	m	7.832	Average reservoir level - FSL of canal – head loss at full capacity
	Minimum head	m	5.507	

Advantages of Scheme I: 1) The power generation water flows into the existing irrigation channels and farmlands can be irrigated. Also, the construction of the power station has little impact on the irrigation function of the reservoir; 2) The existing buildings can be utilized to the maximum extent, and the investment of the power station construction is 1.1678 million US dollars, which is relatively small.

Disadvantages of Scheme I: 1) The power generation available head is only 13.41m, only 320KW installed capacity can be achieved, the installed capacity is small; 2) The annual average power generation is 1.44 million KW·h, with less power generation.

Scheme II: (500kW HPP +new low-level irrigation canal)
There is still a head of nearly 17m between the irrigation canal and the downstream riverbed. If no irrigation is considered, the installed capacity of the reservoir can achieve 500kW. Due to the large inflow of the reservoir, the impoundment is not fully utilized. At this stage, it is considered to divert excess water to the riverbed powerhouse for power generation. After the irrigation water demand is further increased at the later stage, a low-level irrigation canal will be built downstream to divert power generation water for irrigation. The irrigation intake dam and irrigation canal at the later stage are phase II works.

(1) 500kW HPP
Now, one of the two irrigation pipelines will be rebuilt/upgraded to the downstream riverbed powerhouse for power generation. The FSL of the reservoir is EL.317.15m, and the elevation of the downstream riverbed is EL.284.58m. After considering the downstream water level, when the normal tail water level (TWL) is taken as EL.285.71m and the available discharge is taken as 2.5m^3/s, the installed capacity of the HPP is 500kW. After the upgraded water pipeline is provided with bifurcated pipes to divert water for power generation, a control butterfly valve is installed at the downstream end of the water pipeline, which can still be used for irrigation without affecting the irrigation function of the reservoir.

(2) Phase II works (new low-level irrigation intake dam and irrigation canal)

The new low-level irrigation intake dam and irrigation canal are construction works of later stage. Due to the low utilization rate of reservoir impoundment volume at present, the excess impoundment of the reservoir can be used to generate electricity in a short time, which has little conflict with irrigation. When there is a big contradiction between the increase of irrigation water consumption and power generation, a new low-level irrigation canal will be built downstream, and the upper and lower irrigation areas will be irrigated by section.

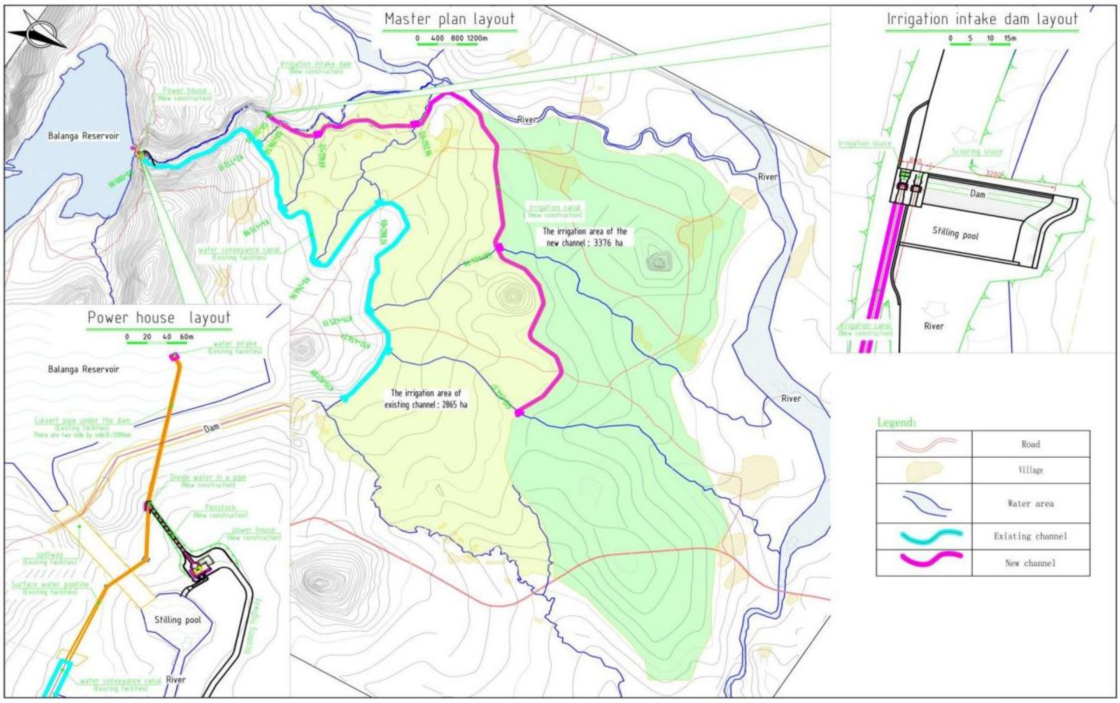

Fig 5.2. General Layout of Scheme 2

Table 5.4. Scheme 2 Hydraulic Energy Parameters

Basic data	Total storage capacity	10^4m^3	7260	
	Effective storage capacity	10^4m^3	6270	
	Dead storage capacity of reservoir	10^4m^3	990	
	Check flood level of reservoir	m	323.1	
	Design flood level of reservoir	m	321.6	
	FSL of reservoir	m	317.15	
	Minimum water level of power generation	m	312.5	Consider as per favorable working depth
	Inlet elevation of penstock	m	306.5	Provisional
	Downstream riverbed	m	284.58	

	elevation			
	Minimum TWL	m	285.42	TWL of half a unit
	Normal TWL	m	285.71	Water level of two units at full capacity
	Maximum TWL	m	286.61	Maximum water level for downstream water consumption
Head loss calculation	Frictional head loss at full capacity	m	0.98	
	Local head loss of half a unit	m	1.139	(inlet 0.146 + 2 elbow 0.174+ bifurcated pipe 0.125+main valve 0.221+turbine inlet 0.307+other comprehensive 0.165)
	Frictional head loss of half a unit	m	0.379	
	Local head loss of half a unit	m	0.326	(inlet 0.039+2 elbow 0.047+bifurcated pipe 0.033+ main valve 0.114+ turbine inlet 0.082+ other comprehensive 0.044)
Head calculation result	Maximum head	m	30.53	
	Design head	m	26.50	Average reservoir level - FSL of canal - head loss at full capacity
	Minimum head	m	24.17	

Advantages of Scheme 2:

1) Fully utilize the head of the reservoir, realize the installed capacity of 500kW, and "high water level for high irrigation, low water level for low irrigation" also takes into account the irrigation function of the reservoir.

2) A culvert pipe is left to supply water to the built high-level irrigation canal, which has met the irrigation requirements at the current stage. The construction of a new low-level irrigation canal at the later stage depends on the substantial increase of irrigation water consumption. If the irrigation water consumption increases slowly, the power generation benefit of the reservoir can be realized ahead of schedule.

Disadvantages of Scheme 2:

1) The construction of hydropower station in the first phase of the project requires 1.1678 million US dollars. and a low -level irrigation canal of 13.24km in length needs to be built in the second phase. The new low-level irrigation canal will increase the project cost by about 4.8 million USD. Hence the cost of the project will be higher.

2) The new low-level irrigation canal will occupy a certain amount of cultivated land, and the 13.24km irrigation canal will occupy nearly 6 ha of cultivated land.

5.2.3 Selection of Construction Schemes (Proposals)

The above two power station construction schemes are feasible, but at the same time they have advantages and disadvantages. The scheme 1 has low influence on the irrigation function of the reservoir and saves on project cost, but at the same time, the installed capacity of power generation is lower. For Scheme 2, power generation requires a second phase project to be built in order to cater for the irrigation requirements of the lower section of the canal, which has a great impact on the irrigation function of the reservoir, and the project cost is relatively high, but the installed capacity of the power station and the power generation is large.

Finally, with the consent of the Owner, the scheme 1 is recommended.

5.3. General Layout of the Project

Based on the comparison of schemes, Scheme I was selected for the design of power generation system integration. The concept is to utilize the current intake sluice and culvert pipe, build the powerhouse for power generation at the headwork of the existing irrigation canal, and the water used for power generation will flow back to the irrigation canal for irrigation purposes. The powerhouse is provided with two 160kW bulb tubular T/G units with a total installed capacity of 320kW.

One bifurcated pipe is set on the upgraded culvert pipe for water diversion, and a control butterfly valve is set on the downstream side of the culvert pipe. For general irrigation tasks, the irrigation requirements can be met by using another culvert pipe. This control butterfly valve is closed and the HPP generates electricity normally. When the water quantity is insufficient under special circumstances, the power generation will be suspended, the control butterfly valve will be opened, and two water culvert pipes will deliver water at the same time. The irrigation function of Balanga Reservoir will not be changed by upgrade waterway and power generation system.

The water diversion power generation upgrade project combined with the current layout of the building, the addition of hydropower generation system. The water intake, water diversion facilities, powerhouse and tailwater buildings required by the project are arranged on the basis of the current project. The upstream water level of the power station is the current water level of the reservoir, because the downstream is connected to the current irrigation channel, its water level needs to match the current irrigation channel.

This project consists of intake sluice, penstock, main and auxiliary powerhouses, tailrace, transmission lines (TLs), production and living quarters, etc. The intake sluice uses the release sluice of the current reservoir, and the penstock uses a single pipe for a single unit. The project will use the current two DN1200 ductile iron pipes with a length of 373.59m each, to upgrade and reinforce the downstream pipe. The powerhouse will be rebuilt after dismantling the existing house, and the tailrace will be built after dismantling the first 40m of the existing irrigation channel and drainage channel. The transmission line (TL) is planned as 3km.

5.4 Structures of Phase I Works

The structures/buildings of phase I works include the existing intake gate, the culvert pipe under the dam, the new penstock upgrade works, the main and auxiliary powerhouses, etc.

5.4.1 Intake Gate

The existing intake gate is built in the reservoir area upstream of the dam of Balanga Reservoir, which is a reinforced concrete shaft gate (sluice) body. There are two 1.8m×1.8m flat cast iron gates in the gate (sluice) body, which are opened and closed by a manual screw hoist. The gate body is connected with two DN1200 culvert pipes (ductile iron pipes) under the dam. At present, the sluice body of the intake gate is in good condition, and the gate/sluice and hoisting equipment have just been overhauled, and the opening and closing are normal.

5.4.2 Culvert Pipe Under Dam

Balanga Reservoir is provided with two parallel culvert pipes, with a length of 373.59m each. The upstream section of 175m is a culvert pipe buried under the dam and connected to the intake gate. The lower section of the dam is protected by reinforced concrete, which is reliable in structure and good in safety. The downstream section (198.59m) is an exposed pipe laid on the ground, which crosses the spillway and connects with the irrigation canal, and a control valve and stilling basin are arranged at the outlet end of the culvert pipe. Two culvert pipes are both ductile iron pipes with a diameter of 1.2m. At present, the culvert pipes are in good structure and operate normally.

5.4.3 Penstock Upgrade Works

The design scheme of the pressure pipeline upgrade and reinforcement project is that the culvert pipe under the dam in the upstream section is not treated, and the current pipe bridge across the spillway in the downstream is a steel frame pipe bridge. The structure is intact at present, but the upgrade construction of water diversion and power generation will change its force conditions to a certain extent. According to the site situation, the existing piers on both sides of the spillway are to be reinforced to ensure the safety of the pipeline and spillway. In the downstream section of the pipeline after crossing the spillway, the existing pipeline is to be dismantled and reinstalled according to the spacing requirement of the units arranged in the diversion power plant. Specific measures are:

1) Remove the 75m pipe in the downstream section;
2) Each pipe adds 15m long steel pipe to connect the main valve of the unit;
3) The removed ductile iron pipe shall be reinstalled after replacing the water sealing material, connecting the downstream pipe, and re-setting the anchor pier and support pier;
4) A turnout pipe is set on each steel pipe upstream of the main valve, and a gate valve (which can be removed by the current situation) is installed. After the two pipes are combined, a

DN1500 precast concrete pipe is used to bypass the right end of the plant to access the tailrace channel and the reservoir can supply water to the downstream when there is no power generation.

5.4.4 Main and Auxiliary Powerhouses

The main and auxiliary powerhouses are arranged at the end of the pressure pipeline, and the existing buildings such as houses need to be demolished and rebuilt. The installed capacity of the power station is 320KW, consisting of 2 sets of 160KW bulb tubular T/G units, which are downstream of the powerhouse in the direction of access road and outlet line. The tail water of the power generation needs to be discharged into the irrigation channel, so the construction elevation of the main and auxiliary powerhouses of the power station is determined by calculating the head elevation of the irrigation channel.

The floor elevation of the main and auxiliary powerhouses is EL.304.981m, which is 0.3m higher than the outdoor floor elevation. It is composed of an erection bay, main generator hall and electrical auxiliary powerhouse, which are arranged in a single floor. The foundation is a reinforced concrete strip foundation, and the foundation and superstructure are designed with C30 reinforced concrete frame structure.

The main powerhouse (erection bay and main generator hall) is arranged at the left end of the powerhouse, and the erection bay and main generator hall are connected into a whole, with the same width and height, of which the width is 11.0m and the total height is 6.8m. The erection bay is 7.7m long, and the entrance gate is arranged on the downstream side, which is 4.5m wide and 4.0m high. There are two 160kW bulb tubular T/G units in the main generator hall, with a length of 12.8m and a spacing of 5.0m. The upstream side is provided with auxiliary equipment of hydraulic machinery such as governor.

The electrical auxiliary powerhouse is arranged at the left upstream end of the powerhouse, with a total length of 7.0m, a total width of 11.0m and a height of 5.5m. The upstream side is a High voltage (HV) room and the downstream side is a central control room.

5.4.5 Tailrace Channel Work

The tailrace channel shall be rebuilt after the first 40m section of the current channel and the drainage canal are dismantled. According to the current requirements of the project, the tailrace channel shall have the following functions: 1) to connect the power generation water to the downstream irrigation channel; 2) According to the flow capacity of irrigation channels, the excess water is discharged; 3) Discharge power generation water when there is no supply requirement downstream. According to the functional requirements of the tailrace channel the tailrace channel is equipped with the connecting section of the channel, the overflow side weir, the irrigation drainage lock and the irrigation drainage channel. The first end of the connecting section of the channel is the tail sluice body, which is provided with two holes, and the sluice body is provided with a stacked beam door groove, which can be easily blocked when one generator is repaired by one machine. The downstream end of the channel connection section is equipped with a 14.5m long overflow side weir, which can discharge excess water. The end of the connecting section of the channel is provided with a drainage tank and a gate. The gate is opened when there is no water supply requirement downstream, and the water is discharged into the downstream river through the drainage tank and drainage channel.

6. E & M Equipment Installation Works

6.1 General

According to the hydro energy planning, the proposed installed capacity of the HPP is 320kW.

(1) Water level

Check flood level of reservoir 323.10m

Design flood level of reservoir 321.60m

FSL of reservoir 317.15m

MOL of reservoir 312.50m

Downstream normal TWL 304.7 m

Downstream check TWL 305.143 m

(2) Discharge

Available discharge for power generation 5.0m³/s

(3) Head

Maximum net head 12.34m

Weighted average head 7.83m

Minimum net head 5.51m

(4) Meteorology

Extreme minimum temperature 23.8 ℃

Extreme maximum temperature 31.4 ℃

Average annual temperature 24 ℃

(5) Humidity

Maximum relative humidity 79.1%

Minimum relative humidity 22.5%

(6) Basic earthquake intensity

Seismic peak acceleration IV

(7) Hydroenergy index of HPP

Installed capacity of HPP 320kW

Average annual energy output 1.44 million kW·h

Guaranteed output 100kW

Annual utilization hours 4500h

6.2 Hydraulic Machinery

6.2.1 Turbine and Its Auxiliary Equipment

The main parameters of the T/G unit are:

a) Turbine

Type: GD995a-WZ-70

Rated head 7.83 m

Rated discharge 2.47 m^3/s

Rated output 174 kW

Rated speed 600 r/min

Quantity 2.

b) Generator

Type SFW160-10/740

Rated output 160kW

Rated voltage 400V

Quantity 2.

6.2.2 Main E & M Equipment

1) Governor

According to the current manufacturing level of the governor and oil pressure device of the HPP, the HPP adopts the associated high oil pressure digital microcomputer-based electro-hydraulic governor (GYT-300-16) the tubular-turbine generator, and the oil pressure level is 16MPa.

2) Main Inlet Valve

The HPP adopts the water supply mode of one penstock for one unit, the inlet valve is provided at the inlet of the turbine. The FSL in the upstream of the HPP is EL.317.15m, the normal TWL is EL.304.7m, and the maximum water pressure borne by the inlet valve is13.41m. According to the experience of similar HPPs and manufacturers both at home and abroad, the electric butterfly valve with a nominal diameter of 1.2m and the model of D941X-6C-1200. is preliminarily selected.

3) Travelling Crane

The heaviest component of the unit is the overall weight of the generator. The lifting weight is about 2.0t. One 3t electric single-beam bridge crane with a span of 9.0m is used for the installation and maintenance of the unit.

6.3 Electrical Component

Connection of the HPP with Power System

Two 160kW T/G units with a total installed capacity of 320kW are installed in the waterway and power generation system upgrade of Balanga Reservoir. The HPP operates in an isolated network after it is completed, and the electricity generated is supplied for local consumers. There is one circuit of 11kV outgoing line in the HPP, and the size of the conductor used is LGJ-70 with the transmission distance of approximately 3km.

6.3.2 Primary Electrical Wiring

Two feasible primary electrical wiring schemes are drawn up for technical and economic comparison in accordance with the power supply requirements, the number of units installed and the scale of the HPP:

Scheme I: Two units are connected with a main transformer in a way of single-bus wiring, and the voltage step-up side is wired using the transformer line group. In this scheme it has the least equipment investment, the smallest floor space, and simple secondary protection configuration. However, not all the electric energy can be transmitted out in case the main transformer and 0.4kV bus equipment fail or when they are under maintenance. The frequency of failure or maintenance of this component is very low.

Scheme II: A unit is connected with a main transformer in a way of single-bus wiring, and the voltage step-up side is in single-bus wiring way. In this scheme it is flexible, convenient and reliable, and the secondary protection configuration is simple. In addition, the failure or maintenance of any main transformer and the 0.4kV equipment will not affect the transmission of electric energy by another unit. However, the equipment investment and floor space of the scheme are the largest.

The installed capacity of this HPP is small. There is one circuit of 11kV overhead outgoing line. Considering the plant layout of the HPP, scheme I is more suitable, so it is recommended to adopt scheme I, that is, two units are connected with a main transformer in single-bus wiring manner, and the voltage step-up side is connected using the transformer line group.

6.3.3 Power Consumption in Powerhouse Area

The power of the powerhouse area is supplied in the mixed manner of the auxiliary power supply of the units and the diesel generator. A 50 kVA step-down transformer is selected, and the power is fed from the 11kV line side. In addition, a 400V diesel generator of 30kVA is provided. The power of the powerhouse area is supplied in primary voltage class with the rated voltage of 400V. The power is mainly supplied from powerhouse area transformer during normal operation, and the power supply of the diesel generator works for standby. The standby power supply will be manually put into operation in case the power supply of powerhouse area transformer fails.

6.3.4 Selection of Main Electrical Equipment

The hydropower project is located at an elevation of lower than 500m. All electrical equipment is considered based on the altitude of 1,000m and the seismic fortification intensity of 4 degrees.

The main electrical equipment is selected according to the principles of advanced technology, economy and rationality, safety and reliability, and convenient operation and maintenance, and shall meet the requirements of relevant regulations and specifications of China. The technical parameters of electrical equipment are selected based on normal working conditions and checked according to the short-circuit current of different short-circuit points, both of which must meet requirements.

6.3.4.1 Generator

Two 160kW horizontal T/G units are selected for the HPP. For the generator, the rated frequency is 50Hz, the rated voltage is 0.4kV, the rated power factor is 0.8 (lag) and the rated current is 289A.

6.3.4.2 Main Transformer

A dry type three-phase double-winding copper-core step-up power transformer with no-load tap-changer is used as the main transformer based on the wiring mode and the generator capacity of the HPP according to the principle of capacity matching. The specific parameters of the transformer are as below: model: SCB13-500/10.5, rated transformation ratio: 10.5±2×2.5%/6.3 kV, wiring group: D.y11, impedance voltage: 4%, cooling mode: ONAN.

6.3.4.3 HV Cabinet Equipment

A complete set of 11kV switch cabinet with the model of KYN28-12 is selected. There are 3 cabinets in total. Five-prevention system is provided for the cabinets. All 11kV equipment is installed in the cabinets except cables, and oil-free equipment is used.

ZN65A-12/T1250-25 vacuum circuit breakers with rated voltage of 12kV, rated current of 1,250A and rated breaking current of 25kA are used.

JDZXF-10 type 11kV voltage transformer with rated voltage of 11kV, transformation ratio of $\frac{10.5}{\sqrt{3}} / \frac{0.1}{\sqrt{3}} / \frac{0.1}{\sqrt{3}} / \frac{0.1}{3}$, accuracy grade of 0.2/0.5/3P and secondary load capacity of 30/50/50VA is used.

LZZBJ-10 type current transformer with rated voltage of 11kV is used. Refer to *Main Electrical Wiring* for its rated transformation ratio and secondary capacity.

Gapless zinc oxide surge arresters are selected. HY5WZ-17/45 type surge arresters are used for HV side of main transformer, while HY5WZ-17/51 type arresters are selected for 11kV line side.

6.3.4.4 Station-Service Transformer and switchboard

One station-service transformer with model S13-50/10.5, rated transformation ratio of 10.5±5%/0.4kV, and wiring group of D, yn11 is provided.

A complete LV switch cabinet of GCS model is used for station service, and cables will enter in the switch cabinet from the bottom.

6.3.4.5 Cables

The cables are flame-retardant. The model of HV cables is ZC-YJV22-8.7/10, that of LV power cables is ZC-YJV22-0.6/1, and control cables is ZC-KVVP-0.45/0.75.
Cables are mainly laid in cable trenches and buried pipes, etc.

6.3.5 Overvoltage Protection

Zinc oxide arresters of model HY5WZ-17/51 are installed at the incoming line of 11kV line for protection, so as to prevent lightning waves from invading the HPP along the transmission line and causing damage to electrical equipment.

6.3.6 Grounding

The grounding grids of the powerhouse and step-up station in the plant area are reliably connected to form a unified grounding network of the whole plant. The grounding resistance of the unified grounding network is required to be not more than 1ohm. The grounding electrode shall be used, or electrolytic grounding electrode should be provided in the place with good soil quality and out of the grounding network until the requirements are met in case the grounding resistance requirements cannot be met.

The natural grounding body in the powerhouse area shall be made full use of when laying the grounding network and the artificial grounding materials shall be galvanized. The outdoor grounding trunk line and the top of grounding electrode shall be buried underground with a depth of 0.8m. Clay shall be backfilled around the grounding belt to reduce the grounding resistance. The enclosures of all electrical equipment, cable trays, cabinet and panel foundations and protective net frames shall be reliably grounded. The framework and main electrical equipment (transformers, circuit breakers and surge arresters) shall be reliably connected to the main grounding network at two different grounding points.

6.4 Control, Protection and Communication

6.4.1 Control

The HPP is designed according to the principle of "unattended (few people are on duty)", and adopts a hierarchical distributed computer monitoring system, which is divided into two levels, i.e. HPP level and local control unit level (LCU). There are two hot standby operator workstations and one communication workstation at HPP level, where there are 2 sets of integrated unit control panels and 1 set of utilities LCU at LCU level. The whole system is interconnected by single fiber Ethernet. (It can only be realized if the basic implementation of the power station network is available).

The monitoring system mainly has the following functions: data acquisition and processing, control and adjustment, AGC/AVC, HPP operation safety monitoring, operation guidance, equipment operation statistics and production management, data communication, HMIs, remote control, etc. The local control unit (LCU) of the unit receives the operation instructions from the upper computer system or the operating equipment of the LCU to realize sequential control, synchronization, active/reactive power regulation, emergency shutdown, data acquisition and processing of the unit. The LCU shall be able to run independently in case the upper computer fails.

6.4.2 Relay Protection and Automation Device

Corresponding relay protection and automatic safety protection devices are installed in the HPP for generators, transformers and 11kV lines, and the function configuration is as below:

(1) Generator Protection

Over-current protection, stator winding grounding protection, stator winding overload protection, rotor one-point grounding protection, over-voltage protection, loss of excitation protection and other functions.

(2) Main Transformer Protection
The devices for overcurrent protection, overload protection and temperature protection are started, if necessary, by the composite voltage at HV and LV sides.

(3)11kV Line Protection
Three-stage overcurrent protection, three-phase primary reclosing and other functions.

(4) Powerhouse Transformer Protection
Fuses are used for protection.

6.4.3 Secondary Wiring
The primary electrical equipment and LCU are hardwired. The measuring circuits of current and voltage are provided separately from the protection circuit and are connected to different secondary windings. The rated current of AC current circuit is 1A, and the AC voltage is 100V.

(a) Measurement
A computer monitoring system is used in the HPP, and gateway metering points are provided at 11kV line outgoing side of the HPP. One-way electronic type electric energy meters with active accuracy of 0.2s are used, and the accuracy level of corresponding voltage transformer is 0.2 and that of current transformer is 0.2s.

In addition to the gateway metering points, meters are also installed at the generator outlet for internal assessment of the HPP. One-way electronic type electric energy meters with active accuracy of 0.5 are used at generate outlet, and the accuracy level of corresponding voltage transformer is 0.2 and that of current transformer is 0.5S.

(b) Synchronization
Automatic quasi-synchronization mode is adopted in the HPP as the normal synchronization way. The outlet circuit breakers of No. 1 and No. 2 generators, the LV side circuit breakers of main transformers and 11kV line circuit breakers are used for synchronization. The synchronization devices are installed in the LCU panel of corresponding unit. Another set of manual quasi-synchronization equipment is provided for backup in the HPP.

6.4.4 DC System
There are two panels for DC system. A complete set of DC maintenance-free lead-acid batteries is selected to work as the DC power supply of the HPP, with rated voltage of 220V and rated capacity of 100Ah. It is used to provide DC power for control, protection, automatic safety protection device, circuit breaker operation and emergency lighting of the whole plant.

A high frequency switching rectifier is used for 220V DC system as the charging and floating charging device of the battery. The module used for closing and battery charging is in N+1 hot backup mode, which can be replaced in live manner. In addition, it is provided with an automatic voltage regulator. 18 single lead-acid batteries of 12V are used in one panel. It is no need to replenish electrolyte under normal use during the service life. A set of insulation monitoring devices is provided for the system, with 8 circuits for closing feeder and 24 circuits for control circuits, and its power is supplied in radiation manner.

6.4.5 Communication System

It is temporarily determined to use walkie-talkies for internal communication and optical fiber for external communication due to the lack of information on communication requirements of the HPP at this stage, which may be revised as required after the communication information is finalized.

6.4.6 Electrical Equipment Layout

Two 160kW T/G units and their auxiliary equipment are installed in the main powerhouse, and the auxiliary equipment and the operation boxes of and utility devices are arranged near corresponding equipment. The HV room and central control room are arranged in the auxiliary powerhouse. It includes three KYN28-12 HV cabinets, one dry-type main transformer, two integrated unit control panels, one main transformer LV side line incoming panel and one 400V powerhouse panel in the HV room. The monitoring system panel, relay protection panel, DC device panel, video monitoring panel and console are located in the central control room.

7 Method Statement

7.1 Construction Transportation

7.1.1 Off-Site (External Transportation

According to the actual situation of the Project and the off-site (external) traffic conditions, the transportation mode of external materials is mainly via highway. According to the E&M design data, the local permanent bridge along the line for the supply of large components of the Project can basically meet the transportation requirements of heavy and large components.

Balanga Reservoir is located in Balanga Town, Gombe State. According to the site and existing highway conditions, the external transportation route of the HPP can be: Gombe State - Balanga Town - project area, with a total highway length of about 110km, of which 70km is the Nigerian A345 trunk highway, with good road conditions; 35km-long village road to Balanga Town has ordinary road conditions, but it can meet the construction needs; and 5km-long unsurfaced road from Balanga to the reservoir, with poor road conditions, needs simple renovation to meet the construction requirements.

7.1.2 On-Site Transportation

The Project is characterized by small quantities, relatively concentrated structures/buildings, low transportation intensity and gentle terrain in the project area. Therefore, low-standard unsurfaced roads are adopted as the construction accesses on site, and the road sections with high local traffic density need to be paved with macadam.

7.2 Construction Plant/Facilities (Workshops)

According to the characteristics of the project, a fixed concrete mixing station is provided in the production area of the powerhouse, and one $0.5m^3$ mixer is provided in the fixed mixing station. One $300m^2$ cement store is provided on the side of the concrete mixing station, and one steel processing plant is provided on the tailrace channel side.

7.3 Master Construction Programme

The whole construction duration can be divided into four construction periods: start-up period, preparatory period, construction period of main works and completion period of works. The total construction period of the works is the sum of the last three periods. The construction milestone (progress schedule) of this project is arranged in accordance with the current average advanced construction level of the same type of hydropower project and the same construction conditions.

The planned construction period of this project is 12 months. The construction period is mainly from March of the first year to February of the second year. Two units generate electricity at the same time. In addition, a 3-month start-up period is arranged, which is not included in the total construction period.

I. Progress during the start-up period

The start-up period of the project mainly includes the renovation of off-site roads, the erection of construction power supply and communication system, land acquisition, project bidding, bid evaluation and contract signing, etc. According to the characteristics of the project, the preliminary start-up period of the project is 3 months.

II. Progress of preparatory period

The construction items during preparatory period include on-site road construction, site leveling, water supply, on-site power supply system and construction communication, concrete batching plant, comprehensive processing plant/workshop, temporary house construction, etc., which are scheduled for construction from March to May of the first year.

III. Construction period of main works

After analyzing and studying the construction procedure and construction period of the main buildings in the main works of this scheme, the critical construction path of this project is the construction of the main and auxiliary powerhouses and installation works.

After the completion of the preparatory work, the construction period of the main works will commence and will include: carrying out the upgrade and reinforcement of penstock, the construction of main and auxiliary powerhouses, the installation of turbine units, the construction of tailrace, the construction of production and living quarters, the construction of powerhouse appurtenances and other items in an all-round manner. The construction period of main works is from April to December of the first year. The construction period of main works is 8 months.

IV. Completion period of the works

A two-month completion period is arranged for this project. At the end of December of the first year, the T/G unit will be erected and put into operation, and the pending work will be completed in February of the following year and the works of the hydropower project will be completed.

7.4 Bill of Quantities

No.	Item	Unit	Quantity
I	Temporary works and camp		
	Compressed air, water, power and communication works	LS	1
	Construction warehouse	m^2	200
	Contractor’s camp	m^2	200
	Road maintenance	LS	1
	Other temporary works (workshop and drainage etc.)	LS	1
II	Upgrading works of penstock		
(I)	Building works		
	Open earth excavation	m^3	299.16
	Open rock excavation	m^3	199.44
	Concrete C20	m^3	470.66
	Concrete C25	m^3	22.68
	Steel bar	t	10.36
	Formwork	m^2	403.20
	Removal of ductile iron pipe	LS	1.00
(II)	Hydraulic steel structures (HSSs) and installation works		
	Installation of ductile iron pipe	m	150.00
	Fabrication and installation of ordinary pipes	t	20.85
	Gate valve DN1000	set	2.00
	Expansion joint	No.	4.00
III	Main and auxiliary powerhouses		
(I)	Building works		
	Demolition of existing houses and structures/buildings	LS	1.00
	Open earth excavation	m^3	794.79
	Open rock excavation	m^3	650.28
	Earth and rock backfill	m^3	458.15
	Lower concrete of powerhouse C25	m^3	308.53
	Upper concrete of powerhouse C30	m^3	235.09
	Second-stage concrete of powerhouse C30	m^3	16.00
	Steel bar	t	46.04

No.	Item	Unit	Quantity
	Formwork	m^2	1058.29
	Brick laying	m^3	92.40
	Mortar plastering M10	m^2	1047.20
	Coating of interior and exterior walls	m^2	1047.20
	Floor paint	m^2	256.93
	Window	m^2	162.00
	Door	No.	4.00
	651 rubber water stop	m	64.00
	PE closed-cell foam plastic board (L-600)	m^2	76.80
	Light steel roof	m^2	305.50
	Traveling steel beam	t	8.00
	Waterproofing of roofs	m^2	100.40
(II)	E&M equipment and installation works		
1	Hydraulic machinery		
	Turbine and generator	set	2
	Inlet valve	set	2
	Bridge crane	set	1
	Auxiliary system	set	1
	Firefighting and alarm system	set	1
	Erection materials	lot	1
2	Primary electrical		
	Main transformer	set	1
	Lightning arrester	pcs	3
	Power cable 10kV	km	0.15
	Power cable 1kV	km	2
	Switchgear (with CB)	lot	1
	Switchgear (without CB)	lot	2
	Auxiliary transformer	set	1
	LV distribution cabinet	lot	1
	Diesel generator	No.	1

No.	Item	Unit	Quantity
	Power transfer case	No.	1
	Lighting system	lot	1
	Earthing system	lot	1
	Cable tray	t	1.5
	Integrated unit control panel	No.	2
	Incoming line panel of main transformer on LV side	No.	1
3	Secondary electrical		
	Computer monitoring system	set	1
	Generator protection device microcomputer-based	set	2
	Main transformer protection devise micro computer-based	set	1
	11Kv line protection device microcomputer-based	set	1
	220V DC system	set	1
	Metering system	set	1
	Video monitoring system	set	1
	Control cables	km	5
4	E&M equipment installation cost	LS	1
5	Communication	LS	1
IV	Tailrace works		
(I)	Building works		
	Open earth excavation	m^3	371.69
	Open rock excavation	m^3	304.11
	Concrete C20	m^3	533.53
	Steel bar	t	16.01
	Formwork	m^2	1008.38
	651 rubber water stop	m	86.28
(II)	Hydraulic steel structures (HSSs) and installation works		
1	Tailrace gate equipment and installation works		
	Service plat gate leaf of drainage sluice at irrigation canal 1.6t/No.	t	1.20
	Service plat gate slot of drainage sluice at irrigation canal 2.5t/ No.	t	1.50

No.	Item	Unit	Quantity
2	Hoist		
	Screw hoist dead weight 0.8t	set	1.00
	Track and accessories	t	1.00
V	Auxiliary structures of powerhouse area		
	Grouted rubble M7.5	m^3	132.00
	Concrete C20	m^3	150.50
	Steel bar	t	1.51
	Formwork	m^2	79.00
	Handrail	m	80.00
	Precast concrete pipe DN1500	m	38.00
VI	Transmission line		
	11kV transmission line (TL)	km	3

8 Environmental and Social Impact Assessment (ESIA)

This project involves the integration of SHP in the already existing Balanga Dam and reservoir. There is no significant new construction and construction area, no new construction land acquisition requirement and the tailwater from power generation will be drained through the existing irrigation canal and river. There will therefore be no serious change to the current environmental conditions of the dam's project area.

However, the project will still need to undertake an Environmental and Social Impact Assessment (ESIA) in accordance with relevant environmental laws in Nigeria. In addition to the ESIA, a complementary Environmental and Social Management Plan (ESMP) will be developed on the basis of the ESIA's findings. The ESMP will focus on the specific environmental or social risks that will have been identified in the ESIA and will propose related mitigation and/or offsetting measures. The latter will ensure that the project activities during construction and operation do not result in any adverse environmental or social impacts. In addition, as the Balanga SHP project is based on the existing Balanga Dam, it may reasonably be assumed that an ESIA was carried out prior to its construction. As a result, it may therefore only be necessary to update/revise the existing ESIA. The Gombe State government, with the support of UNIDO will be responsible for conducting the ESIA.

9. Cost Estimate (Estimated Cost)

9.1 Overview of the Project

Total construction period is 12 months. Total cost of the implementation scheme is 1.1678 million USD. The transmission line voltage is 11 kV, which is only transmitted to the transmission line frame next to the power station. The transmission of power to the agro-processing cluster beyond the transmission line frame of the power station is not within the scope of the project.

9.2 Basis of Compilation

Refer to the latest cost estimate, valuation, measurement and accounting standards issued and collected by China and Nigeria. According to the price levels and relevant provisions in the second quarter of 2023 in Gombe, Nigeria. All kinds of relevant labor, materials and other market price investigation materials on the project site. Design drawings, quantities, list of equipment and materials at the design variation stage of the feasibility study of the Project.

9.3 Basic Unit Prices

9.3.1 Budget Unit Prices and Labors

Project complex: Foreman 2.94 USD/hour, Senior Worker 2.45 USD/hour, Intermediate Worker 1.27 USD/hour and Junior Worker 0.98 USD/hour.

9.3.2 Budget Unit of Materials

Gasoline: 650.17 USD/t Diesel: 778.37 USD/t

Cement: 183.69 USD/t Log: 524.76 USD/m^3

Steel bar: 866.44 USD/t Explosive: 4334.35 USD/t

9.3.3 Budget Prices of Electricity, Compressed Air and Water

Electric power: 0.246 USD/kW.h

Compressed air: 0.042 USD/m^3

Water: 0.31 USD/m^3

9.3.4 Budget Prices of Sand and Aggregate

Sand: 10.16 USD/m^3

Aggregate: 24.55 USD/m^3

Rock block: 22.85USD/m^3

9.4 Compilation of Cost Estimate for Works

9.4.1 Quota, Cost, Planned Profits, Taxes and Price difference

Table 9.4-1 Quota Rates of Construction Works

No.	Description	Quota number						
		Earth works	Rock works	Concrete works	Formwork	Foundation and anchoring	Dredging works	Other works
1	Other direct cost	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%
2	Indirect cost	8.5%	12.5%	9.5%	9.5%	10.5%	7.25%	10.5%
3	Corporate profit	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%	7.0%

Table 9.4-2 Quota Rates of Installation Works

S.N.	Description	Quota number
		Equipment and HSSs (hydraulic steel structures) installation works
1	Other direct cost	4.0%
2	Indirect cost	75%
3	Corporate profit	7%

9.4.2 Compilation of Cost Estimate for Construction work

The main construction works are compiled according to the design quantity multiplied by unit price. The traffic works are compiled according to the designed quantity multiplied by the expanded unit index. Housing construction works are compiled according to the design floor area multiplied by the cost index. Other permanent construction works are listed as per 2% of cost of the main construction works.

9.4.3 Compilation of Cost estimate for E & M HSSs and Installation Works

1. Original price of equipment

Determine the original price of the equipment according to the inquiry data of the manufacturer.

Water turbine GD006-WZ-70 **36801 USD/No.**

Generator SFW160-10/740 **18792 USD/No.**

Bridge crane 3t **10962 USD/No.**

2. Equipment freight and miscellaneous charges

The rate of comprehensive freight and miscellaneous charges for equipment is 25%.

9.5 Cost Estimate of the Project

9.5.1 Summary of Cost Estimate

Table 9.5-1 Summary of Cost Estimate

No.	Description	Unit	Quantities	Total (Yuan)	Total (USD)
I	Construction auxiliary works and camp	LS	1	960000.00	150336.00
II	Penstock pipeline reconstruction project	LS	1	455902.81	71394.33
（I）	Construction works	LS	1	253180.07	39648.48
（II）	Metal structures and installation works	LS	1	202722.74	31745.85
III	Main and auxiliary powerhouses	LS	1	4326750.93	677581.08
（I）	Construction works	LS	1	1157429.90	181265.40
（II）	E&M equipment and installation works	LS	1	3169321.03	496315.68
1	Mechanical equipment	LS	1	1704003.00	266846.86
2	Electrical Primary	LS	1	727430.53	113915.63
3	Electric Secondary	LS	1	624808.50	97845.02
4	Installation cost of E&M equipment	LS	1	104358.00	16342.46
5	Communication	LS	1	8721.00	1365.71
IV	Tailrace channel	LS	1	485763.70	76070.81
（I）	Construction works	LS	1	427559.96	66956.09
（II）	Metal structure and installation works	LS	1	58203.74	9114.72
V	Plant ancillary works	LS	1	78720.19	12327.78
VI	Transmission line	LS	1	100000.00	15660.00
VII	Other cost	LS	1	1050000.00	164430.00
	Total			7457137.63	1167800.00

9.5.2 Quantities and Cost Estimates

Table 9.5-2 Quantities and Cost Estimate

No.	Description	Unit	Quantities	Unit price （Yuan）	Total (Yuan)	Unit price (USD)	Total USD
I	**Construction auxiliary works and camp**				**960000.00**		**150336.00**
	Water, electric power and communication works	**LS**	1	10000.00	10000.00	1566.00	1566.00
	Construction warehouse	**m2**	200	2000.00	400000.00	313.20	62640.00
	Contractor's camp	**m2**	200	2000.00	400000.00	313.20	62640.00
	Road maintenance	**LS**	1	50000.00	50000.00	7830.00	7830.00
	Other temporary works (processing plant/workshop, drainage, etc.)	**LS**	1	100000.00	100000.00	15660.00	15660.00
II	**Penstock pipeline reconstruction project**				**455902.81**		**71394.33**
(I)	**Construction works**				**253180.07**		**39648.48**
	Open earth excavation	m^3	299.16	15.24	4559.20	2.39	714.99
	Open rock excavation	m^3	199.44	65.46	13055.34	10.25	2044.26
	Concrete C20	m^3	210.50	689.55	145150.28	107.98	22729.79
	Concrete C25	m^3	22.68	717.28	16267.91	112.33	2547.64
	Steel bar	t	4.97	8011.72	39818.25	1254.64	6235.56
	Formwork	m^2	403.20	60.34	24329.09	9.45	3810.24
	Removal of ductile iron pipe	LS	1.00	10000.00	10000.00	1566.00	1566.00
(II)	**Metal structures and installation works**				202722.74		31745.85
	Installation of ductile iron pipe	m	150.00	108.77	16315.50	17.03	2554.50
	General steel pipe production and installation	t	8.10	14124.35	114407.24	2211.87	17916.15
	Butterfly valve DN1000	set	2.00	20000.00	40000.00	3132.00	6264.00
	Expansion joint	t	4.00	8000.00	32000.00	1252.80	5011.20
III	**Main and auxiliary powerhouses**				**4326750.93**		**677581.08**
(I)	**Construction works**				**1157429.90**		**181265.40**
	Demolition of original houses and buildings	LS	1.00	10000.00	10000.00	1566.00	1566.00
	Open earth excavation	m^3	1094.79	15.24	16684.60	2.39	2616.55

	Open rock excavation	m^3	350.28	65.46	22929.33	10.25	3590.37
	Earth and rock backfill	m^3	458.15	14.47	6629.43	2.27	1040.00
	Substructure concrete of powerhouse C25	m^3	205.33	752.41	154492.35	117.83	24194.03
	Superstructure concrete of powerhouse C30	m^3	183.25	890.37	163160.30	139.43	25550.55
	Second-stage concrete of powerhouse C30	m^3	16.00	977.44	15639.04	153.07	2449.12
	Steel bar	t	32.26	8011.72	258458.09	1254.64	40474.69
	Formwork	m^2	1058.29	60.34	63857.22	9.45	10000.84
	Bricklaying	m^3	92.40	452.65	41824.86	70.88	6549.31
	Mortar plastering M10	m^2	1047.20	18.70	19582.64	2.93	3068.30
	Interior and exterior wall coatings	m^2	1047.20	45.00	47124.00	7.05	7382.76
	Floor paint	m^2	256.93	60.00	15415.80	9.40	2415.14
	Window	m^2	162.00	380.00	61560.00	59.51	9640.62
	Door	set	4.00	2500.00	10000.00	391.50	1566.00
	651 rubber water stop	m	64.00	121.16	7754.24	18.97	1214.08
	PE closed-cell foam plastic board (L-600)	m^2	76.80	20.00	1536.00	3.13	240.38
	Light steel roof	m^2	305.50	500.00	152750.00	78.30	23920.65
	Travelling steel girder	t	8.00	10000.00	80000.00	1566.00	12528.00
	Waterproofing of roof	m^2	100.40	80.00	8032.00	12.53	1258.01
（II）	**E&M equipment and installation works**				**3169321.03**		**496315.68**
1	**Mechanical equipment**				**1704003.00**		**266846.86**
	Turbine and generator	set	2	624787.50	1249575.00	97841.72	195683.44
	Inlet valve	set	2	151547.00	303094.00	23732.26	47464.52
	Bridge crane	set	1	98305.00	98305.00	15394.56	15394.56
	Auxiliary system	set	1	43029.00	43029.00	6738.34	6738.34
	Firefighting and alarm equipment	set	1	10000.00	10000.00	1566.00	1566.00
	Erection materials	lot	1	0.00	0.00	0.00	0.00
2	**Electrical Primary**				**727430.53**		**113915.63**
	Main transformer11kv	set	1	110598.40	110598.40	17319.71	17319.71
	Lightning arrester	pcs	3	500.00	1500.00	78.30	234.90
	Power cables 10kv	km	0.15	212083.31	31812.50	33212.25	4981.84
	Power cables1kv	km	2	13174.86	26349.72	2063.18	4126.36
	Switchgear (with circuit breaker)	lot	1	40000.00	40000.00	6264.00	6264.00
	Switchgear (without circuit breaker)	lot	2	35000.00	70000.00	5481.00	10962.00

	Auxiliary transformer	set	1	45000.00	45000.00	7047.00	7047.00
	Low voltage switch box	lot	1	40000.00	40000.00	6264.00	6264.00
	Diesel generator	platform	1	28000.00	28000.00	4384.80	4384.80
	Power transfer box	piece	1	5000.00	5000.00	783.00	783.00
	Lighting system	lot	1	25000.00	25000.00	3915.00	3915.00
	Earthing system	lot	1	41130.00	41130.00	6440.96	6440.96
	Cable Tray	t	1.5	8693.27	13039.91	1361.37	2042.06
	Integrated unit control panel	No.	2	100000.00	200000.00	15660.00	31320.00
	Incoming screen of main transformer on LV side	No.	1	50000.00	50000.00	7830.00	7830.00
3	**Electric Secondary**				**624808.50**		**97845.02**
	Computer supervisory control system	set	1	160000.00	160000.00	25056.00	25056.00
	Generator protection device Microcomputer-based	set	2	45000.00	90000.00	7047.00	14094.00
	Main transformer protection device Microcomputer-based	set	1	20000.00	20000.00	3132.00	3132.00
	11kV line protection device Microcomputer-based	set	1	20000.00	20000.00	3132.00	3132.00
	220V DC system	set	1	142050.00	142050.00	22245.03	22245.03
	Metering system	set	1	30000.00	30000.00	4698.00	4698.00
	Video surveillance system	set	1	52968.00	52968.00	8294.79	8294.79
	Control cables	km	5	21958.10	109790.50	3438.64	17193.20
4	**Installation cost of E&M equipment**	LS	1	104358.00	**104358.00**	16342.46	**16342.46**
5	**Communication**	LS	1	8721.00	**8721.00**	1365.71	**1365.71**
IV	**Tailrace channel**				**485763.70**		**76070.81**
（I）	**Construction works**				**427559.96**		**66956.09**
	Open earth excavation	m^3	371.69	15.24	5664.56	2.39	888.34
	Open rock excavation	m^3	304.11	65.46	19907.04	10.25	3117.13
	Concrete C20	m^3	355.60	689.55	245203.98	107.98	38397.69
	Steel bar	t	10.67	8011.72	85485.05	1254.64	13387.01
	Formwork	m^2	1008.38	60.34	60845.65	9.45	9529.19
	651Rubber water stop	m	86.28	121.16	10453.68	18.97	1636.73
（II）	**Metal structure and installation works**				**58203.74**		**9114.72**

1	**Tailgate equipment and installation works**				**36546.83**		**5723.25**
	Irrigation channel drainage lock working flat door leaf 1.6t/ fan	t	1.20	13030.84	15637.01	2040.63	2448.76
	Irrigation channel drainage lock working flat door leaf 2.5t/ fan	t	1.50	13939.88	20909.82	2182.99	3274.49
2	**Hoist**				**21656.91**		**3391.47**
	Screw hoist dead weight 0.8t	platform	1.00	15552.12	15552.12	2435.46	2435.46
	Track and accessories	t	1.00	6104.79	6104.79	956.01	956.01
V	**Plant ancillary works**				**78720.19**		**12327.78**
	Grouted rubble M7.5	m^3	45.00	403.88	18174.60	63.25	2846.25
	Concrete C20	m^3	24.00	752.41	18057.84	117.83	2827.92
	Steel bars	t	1.12	8011.72	8973.13	1254.64	1405.20
	Formwork	m^2	79.00	60.34	4766.86	9.45	746.55
	Precast concrete pipe DN1500	m	38.00	756.52	28747.76	118.47	4501.86
VI	**Transmission line(Connect only to the power station cable rack)**				**100000.00**		**15660.00**
	Power station cable tray	LS	1	100000.00	100000.00	15660.00	15660.00
VII	**Other cost**				**1050000.00**		**164430.00**
	Overheads of the Contractor	LS	1	100000.00	100000.00	15660.00	15660.00
	Site security cost	LS	1	100000.00	100000.00	15660.00	15660.00
	Commuting cost	LS	1	200000.00	200000.00	31320.00	31320.00
	Operation test cost	platform	2	50000.00	100000.00	7830.00	15660.00
	Investigation and design cost	LS	1	450000.00	450000.00	70470.00	70470.00
	Training cost for HPP operators	LS	1	100000.00	100000.00	15660.00	15660.00
	Total				**7457137.63**		**1167800.00**

9.5.3 Summary of Unit Prices of Construction Works

Table 9.5-3 Summary of Unit Prices of Construction Works

Unit: RMB

No.	Description of item	Unit	Unit price	Including								
				Direct engineering cost					Indirect cost	Corporate fee	Difference in price	Tax
				Direct cost for charging			Other direct cost					
				Labor	Material	Mechanical utilization						
1	Open earth excavation	m^3	15.24	0.44	0.47	11.35	0.49	1.08	0.97	0.44		
2	Open rock excavation	m^3	65.46	5.22	9.10	27.58	1.68	5.45	3.43	13.00		
3	Earth and rock backfill	m^3	14.47	1.45	0.33	10.18	0.48	1.06	0.95	0.02		
4	Slope protection with grouted rubble M7.5	m^3	403.88	62.86	131.43	3.68	7.92	21.62	15.93	160.44		
5	Channel concrete C20	m^3	865.35	61.81	229.54	74.02	14.61	36.10	29.13	420.14		
6	Mortar plastering	m^2	18.70	6.98	3.88	0.19	0.44	1.21	0.89	5.11		
7	Fabrication and fixing of steel bar	t	8011.72	799.56	3212.80	578.48	183.63	262.60	352.59	2622.06		
8	651 rubber water stop	m	121.16	18.47	81.41		4.00	9.35	7.93			
9	Brick laying	m^3	452.65	60.63	246.58	2.97	12.41	29.03	24.61	76.42		
10	Penstock concrete C20	m^3	689.55	32.70	194.01	47.22	10.96	27.06	21.84	355.76		
11	Penstock concrete C25	m^3	717.28	32.70	199.87	47.22	11.19	27.64	22.30	376.36		
12	Lower concrete of powerhouse C25	m^3	752.41	41.08	219.89	47.65	12.34	30.49	24.60	376.36		
13	Upper concrete of powerhouse C30	m^3	890.37	114.72	231.95	48.60	15.81	39.05	31.51	408.73		
14	Second-stage concrete of powerhouse C30	m^3	977.44	186.59	233.72	46.41	18.67	46.11	37.21	408.73		
15	Formwork	m^2	60.34	21.02	18.48	9.57	1.96	5.36	3.95			
16	Precast concrete pipe	m^3	756.52	69.53	189.78	72.11	13.26	36.19	26.66	348.99		

9.5.4 Summary of Unit Prices of Installation Works

Table 9.5-4 Summary of Unit Prices of Installation Works

Unit: RMB

No.	Description of work	Unit	Unit price	Including

				Direct engineering cost					Indirect cost	Planned profile
				DC cost				Other direct cost		
				Labor	Material	Mechanical utilization	Installing material			
1	Turbine installation	No.	20569.04	7220.18	4539.63	1517.36		531.09	5415.14	1345.64
2	Generator installation	No.	24480.17	8511.87	5236.45	2112.03		634.41	6383.90	1601.51
3	Governor installation	No.	6988.52	2528.16	1470.00	458.77		178.28	1896.12	457.19
4	Butterfly valve installation	No.	4046.75	1355.42	892.61	411.05		106.36	1016.57	264.74
5	Bridge crane	No.	11355.01	4734.73	844.06	1210.74		271.58	3551.05	742.85
6	installation of oil system	System	10.06	3.10	2.30	1.40		0.27	2.33	0.66
7	Installation of compressed air system	System	6.47	2.10	1.30	0.90		0.17	1.58	0.42
8	Installation of water system	System	18.43	6.60	4.10	1.10		0.47	4.95	1.21
9	Pipeline of oil system	t	12082.12	4297.20	2148.25	1313.01		310.34	3222.90	790.42
10	Pipeline of compressed air system	t	14122.14	5336.46	2192.75	1313.01		353.69	4002.35	923.88
11	Pipeline of water system	t	9813.98	3544.52	1405.50	1313.01		250.52	2658.39	642.04
12	Installation of generation equipment	LS	18.47	5.40	2.60	1.40	3.30	0.51	4.05	1.21
13	Installation of control and protection equipment	LS	11.38	3.50	1.00	1.00	2.20	0.31	2.63	0.74
14	Installation of computer monitoring equipment	LS	7.42	3.00	0.50	0.60	0.40	0.18	2.25	0.49

No.	Description of works	Unit	Unit price	Including							
				Direct engineering cost						Indirect cost	Planned profile
				DC cost					Other direct cost		
				Labor	Material	Mechanical utilization	Installing material				
15	Installation of DC equipment	LS	17.05	2.10	6.90	0.50	4.30	0.55	1.58	1.12
16	Installation of auxiliary equipment	LS	15.78	3.30	2.20	1.60	4.70	0.47	2.48	1.03
17	Power cable 10kV	km	353472.19	3268.20	3311.27	902.90	307802.91	12611.41	2451.15	23124.35
18	Power cable 1kV	km	61219.18	3268.20	3311.27	902.90	45174.40	2106.27	2451.15	4004.99
19	Control cable	km	21958.10	4474.45	1140.73	613.50	10276.85	660.22	3355.84	1436.51
20	Cable tray	t	8693.27	1432.98	380.24	233.84	4731.60	271.15	1074.74	568.72
21	Installation of earthing system	t	10282.49	1935.52	683.85	1174.51	4050.50	313.78	1451.64	672.69
22	Installation of production dispatching and communication equipment	set	6845.75	2930.02	902.14	206.67		161.55	2197.52	447.85
23	Installation of air conditioner	LS	8.08	2.30	2.40	0.90		0.22	1.73	0.53
24	Installation of mechanical repair/workshop equipment	LS	7.28	2.00	2.50	0.60		0.20	1.50	0.48
25	Installation of power transformer 11kV	set	13247.72	3654.30	3464.16	2151.08		370.78	2740.73	866.67
26	Installation of mechanical repair/workshop equipment	LS	7.28	2.00	2.50	0.60		0.20	1.50	0.48
27	Installation of HV electrical equipment	LS	7.44	2.20	1.20	1.10	0.60	0.20	1.65	0.49

No.	Description of works	Unit	Unit price	Including							
				Direct engineering cost						Indirect cost	Planned profile
				DC cost				Other direct cost			
				Labor	Material	Mechanical utilization	Installing material				
28	Installation of flat steel gate dead weight of each set 10t	t	2030.84	899.68	130.56	145.93		47.05		674.76	132.86
29	Installation of embedded parts of gate dead weight of each set ≤10t	t	3939.88	1381.94	436.51	725.46		101.76		1036.46	257.75
30	Installation of screw hoist dead weight of equipment 1t	No.	5552.12	2291.23	392.86	652.91		133.48		1718.42	363.22
31	Installation of ductile iron pipe	m	108.77	52.82	4.24	2.58		2.39		39.62	7.12
31	Fabrication and installation of ordinary steel pipe Q235	t	14124.35	1396.50	1209.16	1279.87	7800.00	467.42		1047.38	924.02
32	Installation of track type P43	pair 10m	13080.27	1578.80	493.15	385.71	8158.16	424.63		1184.10	855.72

9.5.5 Summary of hourly rates for Construction Machinery

Table 9.5-5 Summary of Hourly Rates of Construction Machinery

Quota number	Description and specification	Cost Composition											Total hourly rate (RMB)
		I			II								
		Depreciation cost (RMB)	Equipment repair and replacement cost (RMB)	Installation and disassembly cost (RMB)	Labor and power/fuel cost								
					Quota							Cost (RMB)	
					Labor (man-hour)	Gasoline (kg)	Diesel (kg)	Electric power (kW·h)	Compressed air (m^3)	Water (m^3)			
1	Single bucket hydraulic	35.63	25.46	2.18	2.7		14.9					74.10	137.37

Quota number	Description and specification	Cost Composition										Total hourly rate (RMB)
		I			II							
		Depreciation cost (RMB)	Equipment repair and replacement cost (RMB)	Installation and disassembly cost (RMB)	Labor and power/fuel cost							
					Quota						Cost (RMB)	
					Labor (man-hour)	Gasoline (kg)	Diesel (kg)	Electric power (kW·h)	Compressed air (m^3)	Water (m^3)		
	excavator 1.0m³											
2	Bulldozer 59kw	10.8	13.02	0.49	2.4		8.4				48.91	73.22
3	Bulldozer 74kw	19	22.81	0.86	2.4		10.6				56.61	99.28
4	Tractor 74kw	9.65	11.38	0.54	2.4		9.9				54.16	75.73
5	Wheel roller 9-16t	13.51	15.76									29.27
6	Debristling machine	8.36	10.87	0.39	2.4		7.4				45.41	65.03
7	Frog rammer 2.8kw	0.17	1.01		2			2.5			20.19	21.37
8	Pneumatic drill handheld	0.54	1.89						180.1	0.3	49.22	51.65
9	Pneumatic drill air-legged	0.82	2.46						248.4	0.4	67.86	71.14
10	Down-the-hole drill type 80	15.11	22.67	0.46	1.3			25.7	72.6		70.52	108.76
11	5t dump truck	10.73	5.37		1.3		9.1				42.42	58.52
12	Concrete mixer 0.4m³	3.29	5.34	1.07	1.3			8.6			24.07	33.77
13	Concrete mixer 0.8m³	4.39	6.3	1.35	1.3			18			38.83	50.87
14	Vibrator (plug-in) 1.1kw	0.32	1.22					0.8			1.26	2.80
15	Frequency changer set 8.5kva	3.48	7.96					6.4			10.05	21.49
16	Air (sand)-water gun 6m³/min	0.24	0.42						202.5	4.1	62.79	63.45
17	Truck 5t	7.77	10.86		1.3	7.2					36.49	55.12
18	Rubber-tyred vehicle	0.26	0.64									0.90

Quota number	Description and specification	Cost Composition										Total hourly rate (RMB)
		I			II							
		Depreciation cost (RMB)	Equipment repair and replacement cost (RMB)	Installation and disassembly cost (RMB)	Labor and power/fuel cost							
					Quota						Cost (RMB)	
					Labor (man-hour)	Gasoline (kg)	Diesel (kg)	Electric power (kW·h)	Compressed air (m^3)	Water (m^3)		
19	Tower crane 10t	41.37	16.89	3.1	2.7			36.7			79.57	140.93
20	Gantry crane 10t	20.42	5.96	0.99	2.4			17.5			46.99	74.36
21	Bridge crane 5t	8.44	3.26	0.39	1.3			8.8			24.39	36.48
22	Crawler crane 15t	37.88	22.29	1.41	2.4		11.9				61.16	122.74
23	Truck crane 8t	20.9	14.66		2.7		7.7				48.90	84.46
24	Oil operated air compressor $6m^3$/min	3.98	7.14	1.05	1.3		12				52.57	64.74
25	Diesel generator 160kW	6.53	9.7	1.72	3.9		33.7				149.66	167.61
26	Centrifugal pump 30kW	0.64	3.6	1.05	1.3			27.4			53.59	58.88
27	Centrifugal pump 55kW	1.08	4.36	1.24	1.3			50.2			89.38	96.06
28	DC welder 30kVA	1.03	0.68	0.19				30			47.10	49.00
29	DC welder 25kVA	0.33	0.3	0.09				14.5			22.77	23.49
30	Electric arc butt welder type 150	1.69	2.56	0.76	1.3			80.1	8.1	3.2	144.85	149.86
31	Steel bar bender φ6-40	0.53	1.45	0.24	1.3			6			19.99	22.21
32	Steel bar cutter 20kW	1.18	1.71	0.28	1.3			17.2			37.57	40.74
33	Steel bar straightener	1.6	2.69	0.44	1.3			7.2			21.87	26.60
34	Pipe bender	5.17	1.77	0.12	1.3			5.5			19.20	26.26
35	Veneer reeling machine 22*3500mm	72.84	13.31	1.2	2.4			22.2			54.37	141.72

Quota number	Description and specification	Cost Composition										Total hourly rate (RMB)
		I			II							
		Depreciation cost (RMB)	Equipment repair and replacement cost (RMB)	Installation and disassembly cost (RMB)	Labor and power/fuel cost							
					Quota						Cost (RMB)	
					Labor (man-hour)	Gasoline (kg)	Diesel (kg)	Electric power (kW·h)	Compressed air (m^3)	Water (m^3)		
36	Lathe φ400-600	5.88	4.91	0.05	1.3			8			23.13	33.97
37	Radial drilling machine φ50	4.45	2.71	0.03	1.3			4.7			17.95	25.14
38	Planer B650	2.26	2.09	0.15	1.3			2.3			14.18	18.68
39	Pressure oil filter type 150	1.04	0.34	0.1	1.3			0.9			11.98	13.46
40	X-ray detector	3.26	5.21	0.07	1			1.7			10.80	

9.5.6 Calculation of Material Budget Prices

Table 9.5-6 Calculation of Material Budget Prices

No.	Description and specification of materials	Unit price	Price (RMB)					
			Original price	Insurance premium	freight and miscellaneous charges	Site warehouse price	Purchase and safekeeping cost	Budgetary price
1	Steel bar comprehensive	t	4864.86	19.46	540.00	5424.32	108.49	5532.81
2	Steel bar mesh	t	20000.00	80.00	864.86	20944.86	418.90	21363.76
3	Cement 425	t	918.92	3.68	216.22	1138.82	34.16	1172.98
4	Explosive (comprehensive)	t	27027.03	108.11		27135.14	542.70	27677.84
5	Log	m^3	3003.00	12.01	270.27	3285.28	65.71	3350.99
6	Gasoline	t	2160.00	8.64	1620.00	3788.64	75.77	3864.41
7	Diesel	t	3240.00	12.96	1620.00	4872.96	97.46	4970.42
8	Sand	m^3	54.05					54.05
9	Aggregate	m^3	108.11					108.11
10	Rubble	m^3	97.30					97.30
11	Electric power	kWh	1.57					1.57
12	Compressed air	m^3	0.27					0.27
13	Water	m^3	1.98					1.98

10. Conclusion and Recommendations

The proposed 320kW design scheme for the integration of small hydropower generation system at the Balanga Dam shall be carried out without affecting the current irrigation function of the reservoir. This scheme will make full use of the existing penstock at the dam and enable the power generation water to be discharged into the existing irrigation canal, thereby having a very low impact on the irrigation function of the reservoir. The project will have a power generation discharge of $5.0m^3/s$, the designed head is 7.83m, the installed capacity is 320kW, the average annual utilization hours are 4,500h, and the average annual energy output is 1.44 million kW·h.

The total construction period of the project is 12 months, and the total estimated cost of the project is $1,167,800. The output line voltage level is 11kV, via a transmission line frame which will be set up next to the power plant.
Transmission of power beyond the transmission line frame of the power station to the point of use (i.e. agro-processing center/cluster) is not within the scope of the project.
The construction conditions of the Balanga hydropower project are suitable.

The implementation of this project can provide reliable and sufficient power supply for productive uses in the surrounding communities, thereby greatly enhancing people's livelihood, ensure food security and create jobs, with obvious social and economic benefits.

In light of the above, the Balanga Dam SHP project has good development conditions and should be developed as soon as possible. At the next stage, it is necessary to strive for the support of the Gombe State Government with regard to providing convenient conditions for the construction of the project. At the construction stage, it is necessary to strengthen security measures and pay attention to the safety of construction personnel to ensure the smooth execution of the project.