DETAILED PROJECT REPORT
ON
OKINNI DAM SMALL HYDRO POWER (SHP) PROJECT

Client:
Min. of Water Resources
and Rural Development,
Osun State Government
Oshogbo, Osun State.

Consultant:
UNIDO Regional Centre
for Small Hydro Power in
Africa, Maitama, Abuja,
Nigeria

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- Consultant
- Client

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2.0 SALIENT FEATURES

I. GENERAL

2.1	Name of Project:	Okinni Dam Small Hydro Power Project.
2.2	Location	
2.2.1	State:	Osun
2.2.2	L.G.A:	Egbedore
2.2.3	Access :	Untarred 9km road from Okinni junction.
2.2.4	Nearest Rail:	Oshogbo
2.2.5	Nearest Airstrip/Airport:	Offatedo/Ibadan
2.3	Geographical	
2.3.1	Longitude:	004º 32' 19" – 004º 32' 05" E
2.3.2	Latitude:	07º 53' 32" – 07º 53' 38" N
2.4	Details of Site	
2.4.1	Name of stream:	Erinle
2.4.2	Catchment area:	250km^2
2.4.3	Topography:	A gently-undulating terrain with NE-SW trending ridges to the west and south.
2.4.4	Geology:	Thin Recent alluvial clean gravel deposit over massive pegmatite, belonging to the precambrian crystalline basement complex of southwestern Nigeria. There are Schists and quartzite in the adjoining areas.
2.5	Hydrology	
2.5.1	Min. discharge:	7.71m^3/Sec
2.5.2	Max. flood discharge:	12.85m^3/Sec

II PROJECT FEATURES

2.6	Diversion (New Construction):	Cascade SHP downstream

	2.6.1 Type:	To be determined
	2.6.2 Length of weir:	To be determined
2.7	Headrace Channel (Existing):	N.A
	2.7.1 Shape:	N.A
	2.7.2 Size:	N.A
	2.7.3 Bed slope:	N.A
	2.7.4 Material of lining:	N.A
	2.7.5 Design Discharge:	N.A
	2.7.6 Free Board:	N.A
	2.7.7 Side slope:	N.A
2.8	Desilting Tank	
	2.8.1 Size of Tank:	N.A
	2.8.2 Material:	N.A
	2.8.3 Particle size elimination:	N.A
2.9	Forebay Tank/Dam	
	2.9.1 Capacity:	94.0 Million m^3
	2.9.2 Free board:	5.0m
	2.9.3 Spillway capacity:	2,100m^3/s
	2.9.4 Maximum Dam height:	28.0m
	2.9.5 Flood capacity:	25Million m^3
2.10	Penstock	
	2.10.1 Material:	Mild Steel (MS)
	2.10.2 Diameter:	2000mm / 2 x 1500mm

2.10.3 Nos: 1 / 2

2.10.4 Length : 233m/10m

2.10.5 Design discharge: $5.41m^3/s$

2.10.6 Thickness: 45mm

2.11 Power house

2.11.1 Type: Sandscrete block

2.11.2 Net Head: Bungalow, high roof, 4.6m high.

2.11.3 Power House Dimension: (12 x 6 x 4)m

2.11.4 Installed capacity: 1,900.0/ 3No Turbines.

2.12 Turbine

2.12.1 Type: Kaplan / Kaplan

2.12.2 Nos: 1 / 2

2.12.3 Capacity: 360 / 770 KW

2.13 Generator Type: Synchronous SF320-6 and SF800-11

2.14 Generators Transformers

2.14.5 Nos: N.A

2.14.6 Capacity: N.A

2.15 Annual Energy Generation

2.15.1 At 75% load factor (Million units): 9.87

2.15.2 At 60% load factor (Million units): 7.9

2.16 Estimates of cost

2.16.1.1	Total Cost	-	₦207,620,697.74
2.16.1.2	Civil works	-	₦ 46,626,280.00
2.16.1.3	E & M works	-	₦ 151,842,000.00
2.16.1.4	O & M	-	₦ 9,152,417.74

	2.16.2 Cost of installation per KW	=	₦ 228,810,443.4 / 1,900	
		=	₦ 120,426.55	
2.17	Generation Cost/kWh	=	₦228,810,443.4 / ₦ 13,754,496.0	
		=	₦ 16.6352	
	2.17.1 At 75% load factor			
	2.17.1.1 Without subsidy		NA	
	2.17.1.2 With subsidy		NA	
	2.17.2 At 60% load factor			
	2.17.2.1 Without subsidy		-	NA
	2.17.2.2 With subsidy		-	NA.
2.18	Revenue Generation:			
	Option A Tariff		-	₦ 8.50
	Option B Tariff		-	₦ 6.50
	2.18.1 Energy Generation Cost/year:		-	₦ 105,221,894.40
2.19	Alternative Energy Cost/yr			
	2.19.1 PHCN:		-	₦ 156,118,756.30
	2.19.2 Diesel Generator:		-	₦ 233,644,000.00
2.19	Internal Rate of Return		-	228,810,443.4 / 96,069,476.7
			=	**2.39 yrs.**

3.0 BRIEF SOCIAL CONTEXT OF OKINNI DAM SHP

3.1 Project Background

Over two billion people across the globe still are without access to electricity. Lack of this source of energy creates an immense barrier to the economic and social development of rural communities. This crisis of energy poverty needs to be tackled by the mutual cooperation of global society. Small hydropower (SHP) as a renewable energy source is proven clean and environmentally benign. A considerable amount of power potential remains untapped from SHP and this can offer a major contribution to the pursuit of electrification for rural development. SHP usage leads to an increase in employment opportunities, to an improvement in the ecological environment, and to the economic development of these rural areas.

The SHP Project is proposed on the Okinni dam and built on Erinle River, which is one of the Water supply schemes of Ministry of Water Resources and Rural Development of Osun State

Very recently, due to epileptic power supply and increasing cost of diesel powered generation, the operational and maintenance cost of the water supply scheme has become one of great concern to Osun State. The delivery of potable water to surrounding communities at reduced operational costs has prompted the need for a detailed project report (DPR) of Okinni Dam for the provision of an alternative and cheap energy from SHP.

3.2 Community Brief

The Okinni Dam and Water supply scheme is located in Egbedore local government area of Osun state. The surrounding communities are of diverse tribes like the Ebira and Yoruba speaking people, while the major religions is mainly Christianity and Islamic. Okinni town can easily be accessed by a road from Oshogbo town, while the major rural communities within the project environment can also be accessed by an untarred road.
Osun State is located in South-Western part of Nigeria with an area of approximately 14,875 square kilometers. It lies between longitude 04 00E 05º5 and latitude 05º558N 08º07W and within the tropical rain forest. It is bounded by Ogun, Kwara, Oyo, Ondo and Ekiti State in the south, north, west and east respectively. The state lies within the tropical rain forest.

3.3 Electric Power Access

There is an existing 33KV line that runs from Oshogbo through Okinni junction which is 10km from the Dam site. Two diesel generator of 100KVA, 50KVA sets, are in place as alternative power supply to the Okinni Dam, presently only the 50KVA is serviceable.

The new Ede Waterworks is presently fed by a 33KV line from Oshogbo. The power network consists of 4x2MVA, 33/0.415KV Transformer and 1MVA, 33/0.415KVA Transformer. 2x2MVA transformers are presently unserviceable.

3.4 Socio-Economic Activities

Tradionally, the people engage in agriculture and produce sufficient food and cash crops for domestic consumption as inputs for agro-allied industries and for export. Large proportion segments of the populace are also traders and artisans. Other occupations include hand-weaving, mat-making, dyeing, soap making and wood carving among others.

Yam, maize, cassava, millet, plantain and rice are the major cash crops in the State. Lumbering and growing, marketing of cocoa and cola nut are carried out on a large scale. The mining sector is being activated. The living spring Mineral Promotion Co. Ltd, formed with the backing of the Government of Osun State, is involved in mining activities in various parts of Nigeria.

4.0 PROJECT CONCEPTUALIZATION

4.1 Objectives

Usually, diesel generating sets are supposed to be on standby to compliment any unreliable supply from power utilities. However and sadly enough, the diesel generating sets have become the major energy source for the water supply systems in Nigeria.

The epileptic nature of PHCN has made many industries in the country to fold up, due to the high running cost of maintaining generating plants. Hence, the need for an alternative energy source has arisen, and these sources should be environmentally friendly in view of the current rising climate changes globally. That is, energy source that must not have any adverse effect on the environment on the long run. Therefore, harnessing independent, reliable energy and affordable sources e.g. flowing water – i.e. small hydro power is a win-win option.

By harnessing this energy source, it will bring about development to the surrounding communities, which in turn bring employment, and job opportunities, and which in turn will reduce the poverty level in Osun State.

Therefore, the main objective of this Detailed Project Report (DPR) is;

1. To construct a small hydro power scheme for generating electricity to Okinni community and environs in an environmentally friendly way and at a cheap and affordable price.
2. To provide reliable power (electricity) to the Okinni Dam waterworks, so that it can meet its primary function of supplying treated water to Egbedore Local Government Area of Osun State.

3. The development objective of the project is to improve the quality of life and economic situations of the rural communities, develop cottage industries to provide jobs for rural dwellers by the provision of the electricity to remote communities, and improve the skills of local artisans and technicians in Egdedore, Osun State.
4. To create awareness and knowledge on Mini hydro technology for electricity generation for large cooperative farms, schools, villages and remote communities so as to ensure improved living standards and effective health facilities in rural areas.
5. To seek avenues for partnership and collaboration with the Government of Osun State in the promotion of SHP projects for sustainable development of rural communities in the State. Similarly, for training and capacity building on SHP development in Osun State.
6. To act as a catalyst for large scale use of these technologies in Osun State with special emphasis on stimulating Private Sector Participation (PSP).
7. To promote market development for SHP equipment through support for pilot/commercial project, financing and training of end-users.

4.2 Description

The project is a small hydro power scheme utilizing flow from the Okinni Dam, through the penstock to the power house and thereby generating electricity for the Okinni communities and environs. The layout of Okinni Dam is shown in **Drg Fig 5.1.**

Since there is an existing dam in place, the civil works construction, based on the designed scheme (), consists of:

- Okinni Dam
- Diversion drain penstock
- Siphon-type penstock
- Power House
- Tailrace

while the mechanical / electrical works will consist of the following:

- Turbine
- Governors
- Gate Valves
- Generators
- Control Panels
- Protective device
- Transformers.

Electricity generated from the SHP plant will be evacuated as described in section **10.0.**

4.3 Benefits

The benefits envisaged from the construction of this small hydropower scheme, can be categorized into local and national benefits.

4.3.1 Local Benefits

- Enhances the development of cottage industries and commercial enterprise, which will utilize the electricity generated from the S.H.P. for their operations.

- Job creation and improved standard of living as well as poverty alleviation for the members of the benefiting communities.

- Financial benefits as income realized from the sale of electricity to the consumers.

- Enhancement of agro-allied industries such as processing of cassava, grains, rice – milling etc.

4.3.2 National Benefits

- The creation of awareness for small hydro power schemes as an alternative, effective and more reliable source of power within the communities, state and the country as a whole

- Generation of electricity in eco-friendly way as electricity will be supplied without polluting the environment.

- The hydropower scheme is independent of PHCN, and will not have any problem associated with PHCN as currently experienced in the country.

4.4 Sustainability and Participation

The implementation of the SHP scheme is recommended as a Public Private Sector Participation (PPP) with high-level involvement of the benefiting communities. The management of the scheme will therefore be a collective / co-operative participatory agreement between the private sector organization and the Osun State Government.

The scheme shall be sustained mainly from the revenue generated from collection of tariffs on electricity consumed by the industries and residents. The current domestic tariff charged by PHCN is ₦8.50k/kWh. Members of these communities will be trained to operate, maintain and manage the scheme.

Osun State Government, Ogun-Osun River Basin Development Authority, UNIDO RC-SHP, funding and the benefiting community supplying local labour (unskilled and semi skilled) will all be involved in the implementation.

4.4.1 Operation/In service Support

This will be undertaken as follows:

(i)	Training	-	Osun State Government and Construction Firm
(ii)	Operation	-	Training personnel from the local benefiting community. High school graduates are available in the community
(iii)	Tariff	-	Osun State Government
(iv)	Collection	-	Nominated banks or payment centre
(v)	Maintenance	-	Trained personnel from the community under expert supervision.

5.0 DATA COLLECTION AND ANALYSIS

5.1 Meteorology

Climate is the primary features that contribute to the hydrology of a region and is largely dependent on the geographical position on the earth's surface. Climatic factors of importance are rainfall, its duration, intensity and aerial distribution. Other parameters are temperature, humidity, sunlight hours and wind run. All of these affect hydrological cycle. The climate of the project area can classified into two major seasons, wet (April-Oct) and dry Season (Nov-March). The basic meteorological data for the project area is shown on Tables **9.1 - 9.3.** The average daily temperature in the project area is 28^0 C while annual rainfall amounts to 1130.3mm

5.2 Geology

The project area is situated in the Precambrian basement complex geological province of southwestern Nigeria. The underlying lithology is an extensive and massive pegmatite with impersistent NNW-SSE and N-S trending fractures. There are associated minor lithologies including granite gneisses and biotite granites. These sandy soils covered with patches of alluvial and residual gravel conglomerate occur and along the narrow flood plain to the Erinle River.

The pegmatite, an igneous rock, is a quartz feldspar-mica type. There are minor banded gneisses and biotite granites occurring in association. The pegmatite was usefully employed as a construction material for the dam, embankments and reservoir banks stabilization. Areas to the east of dam have occurrences of weakly foliated schist with numerous thin NNW-SSE trending quartz veins and quartz feldspar pegmatite. These are highly fractured and weathered into cobles and pebble-containing undulated laterites and kaolinitised and the fractured quartz veins were exploited at some locations 1km east of the dam for construction purposes. These can be equally utilized for the advantage of the present project. The west end of the embankment and reservoir bank abort on highly fractured, medium-textured quartzites composed dominantly by milky quartz.
The Erinle River, from the dam to over 10km downstream, has crystalline rock channel floor while the adjoining flood plains are narrow, 5-10m wide, and have thin clean gravel deposits.

5.3 <u>Topography</u>

The physiography of the area is generally gently undulating and at 300 – 400m elevations. There are few and scattered ridges which are mostly NNE – SSW elongated. The dominant drainage is the southerly flowing Erinle River and its tributaries diversely flowing northwesterly, northeasterly and southerly. These flow directions are dictated by fracture trends in the crystalline basement rocks underlying the area. The rivers generally are narrow channeled with steep sided valleys.

5.4 <u>Hydrology</u>

The quantity of water contained in surface stream at any given time is of considerable importance in water resources planning, development and management. Hence the knowledge of the quantity and quality of stream flow is crucial in water resource comprehensive management, hydroelectric power generation inclusive.

The Okinni Dam inflow is from the Erinle River. The drainage basin of the river is 250 square km as calculated from topographical map of 1:50,000 and shown in **Fig 5.1**. Flow measurement taken from the Dam underground penstock is shown in **Table 5.1.** Meteorological data obtained from the state meteorological division was used in plotting the run-off hydrograph for the period April-October and is shown in **Fig 5.5**

Table 5.1: Discharge Measurement of River Erinle

S (m)	d(m)	H[m] (x=0.6)	(R)	Time (t)	N	V	V_{av}(m/sec)	ΔQ
1			5	35	0.14	0.10	0.65	0.26
			10	9	1.11	0.76		
	0.4	0.24	15	13	1.15	0.78		
			20	17	1.18	0.80		
			25	21	1.19	0.81		
2			5	6	0.83	0.57	0.66	0.45
			10	11	0.91	0.02		
	0.68	0.41	15	22	0.08	0.47		
			20	21	0.95	0.65		
			25	17	1.47	1.00		
3			5	3	1.67	1.13	0.93	0.78
			10	7	1.43	0.97		
	0.84	0.51	15	10	1.50	1.02		
			20	15	1.33	0.90		
			25	27	0.93	0.63		
4			5	4	1.25	0.85	0.99	0.88
			10	7	1.43	0.96		
	0.89	0.53	15	10	1.50	1.02		
			20	13	1.54	1.04		
			25	16	1.56	1.06		
5			5	9	0.56	0.39	0.39	0.24
			10	13	0.43	0.30		
	0.61	0.37	15	20	0.75	0.51		
			20	25	0.57	0.39		
			25	46	0.54	0.37		

S – Distance from one end of water surface measured.
d – Depth measured
H – Operational depth = x.d; where x =0.6
R – revolution/Sec
N – R/t
V – 0.0086 + 0.6726N
ΔQ – discharge in strip = (b.d) v
Where b = 0.1m
Total discharge= 2.61m^3/sec

5.5 Water Balance

The following reservoir capacity of Okinni Dam was obtained from GAUFF CONSULTANT (NIG) LTD feasibility report:

a. Full supply level capacity – 94 x 10^6 m^3
b. Dead storage - 7 x $10^6 m^3$
c. Live storage - 87 x 10^6 m^3

5.5.1 Water Balance: Wet season (7 months)

Select a firm flow of Q = 12.85m^3/Sec
Total runoff from catchments area = 250 x $10^6 m^3$ - **Fig 5.2**
Volume of water consumed in wet season (7months) using firm flow is given by:

12.85 x 210 x 60 x 60 x 24
= 233.15 x $10^6 m^3$
Balance of water left in reservoir after consumption
= (250 x 10^6 – 233.15 x 10^6) = 16.85 x $10^6 m^3$
Using the hydrograph-Fig **5.5**, runoff monthly distribution for seven wet months were computed and shown in Table **5.2**

Table 5.2 Monthly Runoff/Discharge

Month	Area x10^6 [m]	Rainfall (m)	Volume [x$10^6 m^3$]	Ratio	Runoff /Month [x$10^6 m^3$]	Discharge [m^3/s]	Discharge in descending order	Months available	% Execee dance	Power Potential
Jan	250	0.02	5.0	0.01	2.50	0.93	0.93	12	100	130.2
Feb		0.03	7.5	0.02	5.00	2.07	0.93			
Mar		0.07	17.5	0.06	15.02	5.61	11.92	10	83	254.8
April		0.12	30.0	0.08	20.02	7.72	2.07	9	75	289.80
May		0.16	40.0	0.11	27.53	10.47	5.61	8	67	785.4
June		0.19	47.5	0.12	30.03	11.59	7.72	7	58	1080.8
July		0.33	82.5	0.22	55.06	20.56	8.48	6	50	1180.8
Aug		0.14	35	0.09	22.52	8.40	10.47	5	42	1187.20
Sept		0.21	52.5	0.12	30.03	11.59	11.59	4	33	1465.80
Oct		0.21	52.5	0.14	35.04	13.08	11.59			
Nov		0.03	7.5	0.02	5.01	1.92	13.02	2	17	1622.60
Dec		0.20	5.0	0.01	2.50	0.93	20.56	1	8	2878.40

5.5.1.1 <u>Power Potential</u>: Wet Season (7Months)

Total runoff = $250 \times 10^6 m^3$
Total head = 20m
Power potential = 7QH
= 1,800KW

Total water that can be used = $233.15 \times 10^6 m^3$
Power Potential = 1,799KW
Water Balance = Total runoff less total to be used
= $16.85 \times 10^6 m^3$

5.5.2 <u>Water Balance:</u> Dry Season (5 Months)

Balance brought forward from wet season
= $16.85 \times 10^6 m^3$
Reservoir capacity = $87 \times 10^6 m^3$
Total water available = $103.85 \times 10^6 m^3$

5.5.2.1 <u>Power Potential:</u> Dry Season (5Month)

Balance from runoff of wet season
= $16.85 \times 10^6 m^3$
Reservoir capacity of $94 \times 10^6 m^3$ less dead storage of $7 \times 10^6 m^3 = 87 \times 10^6 m^3$
Total water available = $(87 + 16.85)\ 10^6 m^3$
= $103.85 \times 10^6 m^3$

Total water that can be used = $99.92 \times 10^6 m^3$
Water balance = $3.93 \times 10^6 m^3$
Summary
Q_{max} = $12.85 m^3/s$
Q_{min} = $7.71 m^3/s$
H = 20m
: - Power Potential = 7 x 7.71 x 20 = 1079.4KW
Assume a total number of 3 turbines are used; therefore total volume of water consumed in 5months
= 3x 2.57 x 150 x 60 x 60 x 24
= $99.92 \times 10^6 m^3$
Balance of water in reservoir = $(103.85 – 99.92) \times 10^6 m^3$
= $3.93 \times 10^6 m^3$

5.5.3 <u>Summary</u>

Wet season firm flow = $12.85 m^3/Sec$
Dry Season firm flow = $7.71 m^3/Sec$
Design discharge = $2.57 m^3/Sec$

Wet Season Power = 12.85 x 7 x 20
1,799KW
Dry Season Power = 7.71 x 7 x 20
= 1,080KW

5.6 Proposed Cascade Dam Water Balance

5.6.1 Wet Season

Runoff from Okinni Dam in wet season = 233.15 x 10^6m^3
Runoff from the cascade catchments for seven months = 9.21 x 10^6m^3
Total water available = 242.36 x 10^6m^3
Select a firm flow of Q = $13.20m^3$/Sec
Volume of water consumed for seven months
13.2 x 210 x 60 x 60 x 24
239.5 x 10^6m^3
Balance = 2.86 x 10^6m^3
Power = 7QH
H = 15.5
Therefore, P = 13.20 x 2 x 15.5
= 409.2KW

5.6.2 Dry Season

Runoff from Okinni Dam in dry Season = 103.85 x 10^6m^3
Runoff from the cascade catchments for five months =1.15 x 10^6m^3
Balance brought from wet season = 2.86 x 10^6m^3
Total = 107.86 x 10^6m^3
Select a firm flow of Q = $7.5m^3$/Sec
Volume of water consumed for five months
7.5 x 150 x 60 x 60 x 24
= 104 x 10^6m^3
Balance of water in reservoir
(107.86 – 97.2)10^6m^3
= 10.66 x 10^6m^3
Power = 7QH
= 7 x 7.5 x 15.5
= 813.75KW.

5.6.3 Summary

Wet Season firm flow = $13.20m^3$/Sec
Dry Season firm flow = $7.5m^3$/Sec
Wet Season Power = 1,432.2KW
Dry Season Power = 813.75KW

5.7.1 Analysis of Power Demand

In matching supply with demand, a comprehensive analysis of power demand is important. The load points that could be serviced by the SHP project are:

(i) Okinni Dam services
(ii) New Ede water works
(iii) Residential building at Ede water works
(iv) Okinni village.

The total load consumption for these load centers is estimated at about 3,647.4 KW (maximum) and 2,137.63 KW (minimum) and shown in Appendix **5.7.1**
The summary is shown below for the minimum load.

Table 5.7.1 Summary of Min. Power Demand.

S/N	FACILITY	LOAD (KW)
1	Okinni Dam services	73.43
2	Ede water works	1964.20(40KW off peak load)
3	Okinni village	100
		2137.63

5.7.1 Alternative Sources of Power Supply

The alternative sources of power supply available at Okinni Dam and Ede water works include

(i) Diesel Generators of different sizes (see appendix **5.7.1**)
(ii) PHCN power Supply

The cost of providing electricity to service the load centers above were calculated and shown in **A – 5.7.2**
A summary of the costs calculated are shown in Table **5.7.2** below.

Table 5.7.2 Summary of Alternative Power cost Per Annum

S/N	Power Source	Ede Head works	Residential - Ede Head works	Okinni village	Okinni Dam	Total (₦)
1	PHCN	153,216,093.8	1,442,662.5	1,460,000	---------	156,118,756.3
2	Gen. Set (Diesel)	226,826,200			6,817,800	233,644,000

5.7.3 Matching Demand and Supply

The hydrological potential to supply the power for the services identified give two power generating regimes:

(i) Dry Season from November- March (1138KW)
(ii) Rainy Season from April- October (1916KW)

It is therefore necessary to consider critically the power vis-à-vis supply from the Small Hydro Power Scheme. The generation and demand of electrical power obey the balance equation at time‘t’ given by equation

$P_H = P_{loss\,(t)} = P_{Dj(t)}$ --5.7.1

Where P_H = Output of i^{th} SHP
$P_{loss\,(t)}$ = Total system loss at time‘t’
$Dj(t)$ = Load demand of the j^{th} load demand
t = time interval under construction

The concern is the number of SHP units that can be scheduled or committed to meet the load demand forecast over a time T. The load schedules have been divided into two seasons (Dry and Rainy season generation and divided into two daily operations. Loads are carefully selected on 12 hourly bases (Day and Night) as indicated in load survey **A – 5.7.3**. Demand side management (D.S.M) strategy\methodology, if appropriately applied and utilizing energy efficient systems\ fittings, the magnitude of the load in the load centers can be reduce drastically.

6.0 DESCRIPTION OF THE PROPOSED SCHEME

The Dam type SHP is selected for the Okinni Dam Small Hydro Power Project. The scheme is incorporated to the existing multipurpose Okinni Dam, which was originally designed for irrigation and water supply. The scheme consists of two types of penstock – a siphon type penstock and the existing diversion drain pipe, both with trash rack inlet; vent and priming unit, for the siphon control valves, power house, hydro equipment and tail race. A general layout of the scheme is shown in **Fig 7.1.**

A siphon is primed by allowing water to flow into the penstock while the control valve remains shut. The vent is gradually opened to activate the siphon and allow water to flow through the penstock to the turbine in the power house to generate electricity and then flow out through the tail race canal.

7.0 DESIGN DATA – HYDRO POWER DEVELOPMENT

7.1 Design Parameters

The basic relationship between the Power Potential, flow and Hydraulic head is given by the power equation:

$P = KQH$--eqn 7.1.1

Where P = Power potential in KW
Q = Design flow in m^3/s
Hg = Gross Head in, m
Ho = Net Head in, m
K = Constant (between 6 and 7)

7.1.1 Maximum Power Potential

P = 1800KW
Q = 12.85m^3/s
Hg = 20m
K = 7

7.1.2 Minimum Power Potential

P = 1080KW
Q = 7.71m^3/s
Hg = 20m
K = 7

7.1.3 Head loss (Hloss)

Total head loss = 0.46m (diversion drain pipe)
Total head loss 1.78m (Siphon Pipe)

7.1.4 Surge Pressure

Penstock surge pressure = 206.2 (diversion drain pipe), 364.9m (Siphon pipe)
Penstock design = (206.2 + 20) (diversion drain pipe), (364.9m) (Siphon pipe)
=226.2m (diversion drain pipe), (384.6m) (Siphon

7.1.5 Design thickness

Design penstock thickness = 30mm(Diversion drain pipe)
Design penstock = 45mm (Siphon pipe)

7.1.6 Design Head (Ho)

$H_o = H_g - H_T = 20 - 0.46 = 19.54$m (diversion drain pipe), $20 - 1.78 = 18.22$mm (Siphon pipe)

7.2 DESIGN CALCULATIONS

7.2.1 Civil Works

7.2.1.1 General

General layout of the scheme is shown in fig **7.1.** The civil works planned for the scheme consists of the Diversion drain and the Siphon type penstocks. The two penstocks have the trash rack inlet, vent and priming unit, for the siphon, control valves, power house and tail race

7.2.1.2 Penstock

Two lines of penstock shall be used to convey water from the dam to the power house. One would be from the Diversion drain pipe and the other would be from a water siphon pipe running from the reservoir as shown in figure **7.1**

The pipes would be made of mild steel (MS).

(i). Design.

- Diversion Drain pipe.
  Assume D = 1,000m
  $Q = 2.57m^3/s$
- Determine average velocity i.e. V = Q/A
  $V = 2.57/ D^2\pi$
- Calculate head loss in system H
  Assume roughness 'K' = 0.06
  $k/d = 0.06/1000 = 6x10^{-5}$
  1.2Q/d = 1.2 x 2.57/ 1000 = 3.084m
  From Moody chart diagram, using $k/d = 6 \times 10^{-5}$ and 3.084
  f = 0.0135
  $h_{losswall} = fLQ^2/12d^5$
  Where: L = 92m
  $Q = 2.57m^3/s$
  d = 1.0m
  f = 0.0135
  $hloss = 0.0135 \times 92 \times 2.57^2/12 \times (1)^5$
  = 0.27m
- Minor losses
  $K_{valve} = 0.2$
  $K_{expansion} = 0.15$
  $K_v + K_e = 0.35$, $h_{min} = v^2/ (k_v + k_e) = 3.29^2/2 \times 9.81 (0.35)$
  = 0.19m
  Total head loss = $h_{losswall} + h_{min}$
  = 0.27 + 0.19
  = <u>0.46m</u>

(ii) Surge pressure

Wave velocity, $a = 1440/ \sqrt{1 + 2150 \times 1000/ 2 \times 10^5 \times 10}$
= 1441

- Calculate critical time - Tc
  $T_c = (2L/a) = 2 \times 92/1441 = 0.13Sec$
  Choose closure time such that
  $T > 2T_c$
  T > 2 x 0.13 = 0.26

  Choose T = 0.5 > 0.26
- Calculate K
  K = {<u>L x V}</u>

$\{g \times h_g T\}$
$92 \times 3.27 / 9.8 \times 20 \times 0.5 = 9.4$

- Determine Surge pressure

$$h_{surge} = h_{gross}\{K/2 \pm \sqrt{K + K^2/4}\}$$
$$20(4.7 \pm 5.61)$$
$$\text{Take } h_{surge} = 20(4.7 + 5.61)$$
$$= 206.23m$$
$$h_{total} = h_{surge} + h_a$$
$$= 206.23 + 20$$
$$= 226.23m$$

(iii) Determine pipe wall thickness

$t_{eff}. = 3/ 1.1 \times 1.2 – 1 = 1.27$

$$\text{Safety Factor, SF} = \frac{200 \times 1.27 \times 320N/mm^2}{h_{total}}$$
$$\frac{200 \times 1.27 \times 320}{226.23 \times 1000}$$

SF = 0.40 < 3.5 reject

Select t = 30mm

$t_{effective} = 30 / 1.1 \times 1.2 – 1 = 21.73$

$$SF = \frac{200 \times 21.73 \times 320}{226.23 \times 1000} = \frac{1390720}{226230} = 6.15 > 3.5 \text{ ok.}$$

adopt t_{eff} = <u>30mm</u>

7.2.1.3 <u>Siphon System</u>

(i) Design

$Q = 10.28m^3/s$
Assume velocity, $v = 3.5m^3/Sec$
$Q = AV = [\pi d^2/4]\ v$
$d = \sqrt{4Q/\pi v}$
$d = 1.93m$
Select, d = 2m and L =**<u>233m</u>**

(ii) Calculate head loss in system,

$H_t = h_{loss} + h_{turbulence}$
$H_{losswall} = f(LQ/12d^5)$
Assume roughness 'IL' = 0.06
Therefore, $k/d = 0.06/2000 = 3 \times 10^{-5}$
$1.2Q/d = 1.2 \times 10.28/2 = 6.17$ for Moody chart using $k/d = 3 \times 10^{-5}$ and 6.17
$f = 0.01$, $h_{losswall} = fLQ^2/12d^5$ = **<u>0.64m</u>**

(iii) <u>Minor $h_{losseswall}$, Turbulence</u>

- Entrance losses

  Kentr = 0.3

  hentr = $V^2/2_g$ (0.3) = 0.19m

- Value losses, K = 0.3

  - foot value loss, K = 0.3

$h_{footvalue} = kv^2/2g = 0.3 \times 3.5^2/ 2 \times 9.81 = 0.19$m

- Gate valves – 2No i.e. $(k_1 + k_2)V^2/2g$

$k_1 = k_2 = 0.1$

We have, $0.2 \times V^2/2g = 0.2 \times 3.5/2 \times 9.81 = 0.124$

- Losses in bends, for 4 bends;

  k_1, k_2, k_3 and k_4

  $k_1 = 0.25$, $k_2 = 0.25$, $k_3 = 0.12$ and $k_4 = 0.40$

$= (k1 + k2 + k3 + k4)V^2/ 2g = 1002 \times 3.5^2/2 \times 9.81 = 0.64$

$h_{turbulence} = 0.19 + 0.19 + 0.12 + 0.64 = 1.14$m

$h_T = 0.64 + 1.4 = 1.78$

$h_{net} = 20 – 1.78 =$ **<u>18.22m.</u>**

(iv) Surge Pressure

Wave velocity, a = 1440/ √1 + (2150d/Et)

a = 1440/ √ 1 + 2150 x 2000/ 2 x 10^5 x 20 = 1000

- Calculate critical time, $T_c = 2L/a = 2 \times 233/1000 = 0.47$
- Choose closure time such that $T > 2T_c$

  $T > 2 \times 0.47 = 0.943$

  Take T = 1Sec.

- Calculate K ; $K = \left\{\frac{LV}{g \times h_{gross} \times T}\right\}^2 = \left\{\frac{233 \times 3.5}{9.81 \times 20 \times 1}\right\}$

  = 17.28

$h_{surge} = \{k/2 \pm \sqrt{k + k^2/4}\}h_{gross}$

$\{17.28/2 + - \sqrt{17.28 + (17.28)^2/4} = 20$

= 20(8.64 + - 9.59)

= 364.6m

Total headloss = $h_{gross} + h_{surge}$

= 20 + 364.6m

= **<u>384.6m</u>**

(v) Determine pipe wall thickness; try D = 20mm

$t_{effective} = 20/1.1 \times 1.2 – 2 = 13.5$

- Calculate safety factor, SF

SF = 200 x 13.5 x 320 x 320/ 384.6 x 2000 = 1.37 < 2.5 [reject]

Try D = 45mm; $t_{effective} = 45/1.1 + 1.2 – 2 = 32.09$

SF = 200 x 32.09 x 320 / 384.6 x 2000 = 2.67 > 2.5

Therefore adopt pipe thickness of 45mm

(vi) Bifurcation pipes - (Fig 7.2)

$Q = 10.28m^3/s$
$Q_F = 10.28 / 2 = 5.14m^3/s$
Q = AV, Let v = 3.5m/s
A = Q.v = 5.14/3.5 = 1.47mction
$D^2 = \frac{4\,(1.47)}{\pi} = 1.87$
$D = \sqrt{1.87} = 1.37m$
Adopt, D = **1500mm**

7.3 Equipment Selection

7.3.1 Unit Selection

Okinni Dam, with the integration of an SHP project, demands equipment selection that is flexible enough to accommodate the varying power demand and supply schedules. 3 units of 2 x 778 KW and 1 x 360 KW are selected. This selection is informed by:

i. Available potential of 1,800 KW
ii. Operational mode of the power station
iii. Investment for electro-mechanical equipment
iv. Ease of operation and maintenance
v. Ease of transportation and installation of equipment

7.3.2 Type of Turbine

Based on the hydrology for the site, a discharge of $2.57m^3/s$ for the existing penstock and 10.28m3/s for the Siphon penstock of 5.14m3/s after bifurcation with the head of 19.54m and using the application range of turbines, the reaction (Kaplan) turbine is the most suitable for the Okinni dam SHP Scheme and hence selected.

Therefore, one number 360KW Kaplan turbine, ZD560 – LH – 60 and two (2) numbers 778KW Kaplan turbines model ZD500 – LH – 100 are recommended respectively.

7.3.3 Turbine Parameters

By considering the design parameters of the site: the head, discharge and power potential, different type of turbines from manufacturers catalogue are available. Two (2) units of Kaplan turbines with adjustable blades; ZD560 and ZD500 were selected from the manufacturer's catalogue. From turbines calculation, the following under listed parameters were obtained.

A. ZD560

1. Runner diameter (Δ_1) = 0.6078m or 61cm
2. Turbine speed (η) = 930.918rpm
3. Specific Speed (N_s) = 429.939
4. Guide vane height (b) = 0.243m or 24cm

5. Hub diameter (d_n) = 0.252m or 25cm
6. Number of blades (Z_1) = 5 Numbers
7. Sunction head (H_s) = 2.6m
8. Installed altitude (Δ) = 377.5m

Therefore, the turbine calculated is ZD560-LH-61

When computed with that of the manufacturer's catalogue (ZD560 – LH - 60)

With; Head = 19.54m
Discharge = 2.57m3/s
Power rating = 360KW

Where; ZΔ = Kaplan turbine with adjustable scale
560 = runner type
L = Vertical shaft
H = Concrete spiral case
61cm = runner diameter.

B. ZD500

1. Runner diameter (D1) = 0.89m or 89m
2. Turbine speed (η) = 633.6rpm
3. Specific speed (Ns) = 430.2
4. Guide vane height (b) = 0.3572m or 36m
5. Hub diameter (d_n) = 0.3714m or 37cm
6. Number of blades (Z_1) = 5 Numbers
7. Suction head (Hs) = -2.6
8. Installed altitude = 377.6m

Therefore, the turbine calculated is ZD500 – LH – 89

When compared with that of the manufacturers catalogue (ZD500 – LH – 100)

With; Head = 19.54m
Discharge = 2.57m^3/s
Power rated = 778.36KW

Where; ZΔ = Kaplan turbine with adjustable blade
500 = runner type
L = Vertical shaft
H = Concrete spiral case
89 = runner diameter

7.3.4 RETSCREEN Simulation

The RETSCREEN Energy Model for Small Hydro Project NRCan. / CEBRL, Version 2002 – Release 2 was used in simulating the Okinni Dam site conditions.

A printout of the simulation is attached (**A-7.3.1).**

The turbine characteristics as per simulation are Kaplan and same model as above.

7.3.5 <u>Generator:</u>

The manufacturer's catalogue for Kaplan turbines has corresponding generators for rated power of 360KW for existing penstock-SF 320 – 6 selected and SF 800 – 14 for the siphon penstock.

7.3.6 <u>Governor:</u>

Speed governor is to monitor the speed deviation and convert it to displacement deviation of the servomotor. Size of Governor is determined by the nature of the servomotor (w). The governor selected is model DST – 300 and YT – 300 for existing and TY – 1000 for the Siphon from the manufacturers catalogue.

7.3.7 <u>Valve</u>:

Considering the head, which is a low head and the nominal diameter (D_1) which ranges from 15 – 320cm butterfly valve of type Δ and nominal diameter selected for both existing and Siphon turbines.

7.4 <u>Energy Generation</u>

The load centres can be grouped into two, namely

(a) Okinni Dam power demand
(b) Ede water works power demand

The power potential of the project can be summarized as follows.

- 1138KW for Dry season (Nov-March) 5 months
- 1916KW for Rainy season (April-Oct) 7 months

To achieve this power generations, 3 Nos turbines with corresponding Synchronous generators and auxiliary equipment were selected for the Small Hydro Power Scheme as in **7.3**

The operating schedule is as follows

- 1 Nos x 360KW and 1No x 778KW units operating for 5 months (Nov-March) at full load.
- 1 No x 360KW unit and 2 Nos x 778KW units operating for 7 months (April-Oct) at full load.

The expected yearly energy revenue from this project using a tariff of ₦ 8.5/ KWH is ₦105,221,894.4

7.4.1 <u>Energy Calculations</u>

Installed capacity – 3 units of total capacity = 1916KW
3 Nos turbine to run for 5 months (Nov-March)

3 Nos turbines to run for 7 months (April-Oct)
Operating time – 24 hours
Energy produced for 5 months
= 1080KW x 24hrs x 151 days
= 3,913,920 KWH
Energy produced for 7 months
= 1916KW x 24hrs x 214 days
= 9,840,576 KWH
Total energy produced in a year
= (3,913,920 + 9840576) KWH
= 13,754,496.0Kwh
Expected net production= 90% of total energy produced
= 13,754,496.0x 0.9
= 12,379,046.4 KWH
Revenue for the year = 12,379,046.4 x ₦8.5
= ₦105,221,894.4

8.0 COST ESTIMATES

8.1 General

Cost of the scheme has been worked out in great details so as to arrive at a realistic cost estimates.

8.2 Basics

The material cost component of the scheme was estimated using the current market prices of the relevant materials.

Labour cost as obtained in the construction industry in Nigeria have been used in calculating the labour component of the rates.

i. Unskilled = 1,000 / day
ii. Semi-skilled = 1,500 / day
iii. Skilled = 2,000 / day.

8.3 BILL OF ENGINEERING MEASUREMENT AND EVALUATION

8.3.1 Civil

S/NO.	DESCRIPTION	QTY	UNIT	RATE	AMOUNT
1.00	**Plant**				
1.11	Maintaining on site all plant required for this section	Item	Sum		250,000.00
1.12	Site Clearance - Clear site of all shrub, debris and trees and remove away from site.	Item	Sum		200,000.00
1.13	Excavate to remove vegetable soil average 150mm deep, spread and level as directed by consultant	Item	Sum		150,000.00
1.20	**Setting Out**				
1.21	Provide material and set out the building on site as on the working drawing	Item	Sum		50,000.00
	Total for Bill No. 1 carried to summary				650,000.00

S/NO.	DESCRIPTION	QTY	UNIT	RATE	AMOUNT
2.00	**<u>EXCAVATION</u>**				
2.10	Excavate for foundation and penstock pipeline starting from stripped level and not exceeding 2.0 metres deep.	730	m^3	850	620,500.00
2.12	Excavate pit for foundation bed starting from stripped level and exceeding 2.0m deep.	80	m^3	650	52,000.00
2.13	Select excavated material for back filling around foundation	75	m^3	250	18,750.00
2.14	Re-use surplus excavated material to make up level at site	150	m^3	250	37,500.00
2.15	Approved laterite filling	100	m^3	650	65,000.00
2.16	300mm approved rock granite hardcore	69	m^2	6,500	448,500.00
	Total for Excavation and Earthworks carried to summary				1,242,250.00

3.00	**<u>CONCRETE WORKS Reinforced in-situ concrete (1:1$^{1/2}$:3 – 38mm aggregate) developing minimum 21N/mm2 work strength at 28 days as described:</u>**				
3.1	Foundation and pit strip	10	m^3	24,000	240,000.00
3.2	Over site	111	m^3	24,000	2,664,000.00
	Total c/f				2,904,000.00

S/NO.	DESCRIPTION	QTY	UNIT	RATE	AMOUNT
	Total b/f				2,904,000.00
3.30	**High tensile bar reinforcement in foundation bed**				
3.3.1	12mm diameter bars	2	Tonnes	180,000	360,000.00
3.3.2	10mm diameter bars	1.5	Tonnes	180,000	270,000.00
3.4.0	**Sawn formwork to:**				
3.4.1	Edge of bed 150mm high	40	m	475	19,000.00
	Total for Concrete works carried to summary				3,553,000.00
3.5.0	**Blockwork**				
3.5.1	225 x 225 x 425mm hollow sandcrete block wall filled solid with weak concrete	150	m^2	1,250	187,500.00
	Total for Block work carried to summary				187,500.00

S/NO.	DESCRIPTION	QTY	UNIT	RATE	AMOUNT
4.00	**SUPER STRUCTURE**				
4.1.0	**CONCRETE WORK**				
	Reinforced in-situ concrete				
	(1:1$^1/_2$:3-20mm aggregate) developing minimum 21N/mm^2 work strength at 28 days as described:				
4.1.1	Columns	5	m^3	24,000	120,000.00
4.1.2	Beams Lintel	7	m^3	24,000	168,000.00
	High tensile bar reinforcement in columns and beams				
4.1.3	12mm diameter bars	2.5	Tonnes	180,000	450,000.00
4.1.4	10mm diameter bars	1	Tonnes	180000	180,000.00
4.20	**Sawn formwork to:**				
4.2.1	Sides of columns	60	m^2	475	28,500.00
4.2.2	Sides and soffit of lintel	24	m^2	475	11,400.00
	Total for concrete works carried to summarry				957,900.00
4.3.0	**BLOCKWORK**				
	Hollow sandcrete block wall bedded with cement and sand mortar (1.6) as:				
4.3.1	225mm walls	180	m^2	1,250	225,000.00
	Total for Block work carried to summary.				**225,000.00**

S/NO.	DESCRIPTION	QTY	UNIT	RATE	AMOUNT
4.4.0	**ROOF COVERING**				
4.4.1	Corrugated Aluminum roofing sheets laid on treated hardwood timber carcass (including purlins, rafters, struts, tie beams, wall plates) and fixed with screw nails, plus scaffolding	120	m^2	8,500	1,020,000.00
4.4.2	**CEILING**				
4.4.3	1.2m x 1.2m x 0.06m thick flat asbestos cement ceiling/celotex sheet to the building including noggins and batten	90	m^2	1000	90,000.00
	Total for roof works caried to summary				**1,110,000.00**
4.5.0	**WINDOW AND DOORS**				
	WINDOWS				
4.5.1	1050 x 1500mm double panel, wooden frame, wooden louver windows (single control, 7-blade carrier)	2	Nr	15,000	30,000.00
	DOORS				
4.5.2	2400 X 2100mm high metal roller stutter door, plus installation	1	Nr	100,000	100,000.00

4.5.3	1000 x 2100mm high, purpose made metal swing door, including ironmongery.	1	Nr.	78,000	78,000.00
	Total for doors and windows carried to summary.				**208,000.00**

S/NO.	DESCRIPTION	QTY	UNIT	RATE	AMOUNT
5.00	**FINISHING**				
	FLOOR, WALL AND CEILING FINISHES				
	Internal				
5.1.0	50 mm thick screeded bed	72	m^2	875	63,000.00
5.1.2	12mm rendering to:				
	Walls	180	m^2	875	157,500.00
	External				
5.1.3	12mm thick cement and sand rendering (1:6) on walls	180	m^2	875	157,500.00
5.00	**PAINTING AND DECORATING**				
5.1.0	**Internal**				
	Prepare and apply coat of and one finishing coat of Portland Emulsion paint on:				
5.1.1	Walls	180	m^2	500	90,000.00
5.1.2	Soffit of asbestos ceiling sheet	90	m^2	500	45,000.00
5.2.0	**External**				
5.2.1	Walls	180	m^2	500	90,000.00
5.2.2	Soffit of asbestos ceiling sheet	90	m^2	500	45,000.00
	Total for finishings carried to summary				648,000.00

6.00	**ELECTRICAL AND MECHANICAL WORKS**				
6.10	Allow provisional sum for all the electrical work to be executed completely		Sum		600,000.00
6.11	Provide 10 tons gantry crane with horizontal travel, manually operated with hoist cable capable of lifting up to a maximum height of 7.5 M		Sum		500,000.00
	Total for Electrical work carried tosummary				1,100,000.00
S/NO	**DESCRIPTION**	**QTY**	**UNIT**	**RATE**	**AMOUNT**
7.00	**PIPE WORKS**				
7.1.0	Provide,weld together end to end to form penstock and fix in place mild steel pipes:				
7.1.1	i 1000 dia.	100	m.	23,000	2,300,000.00
7.1.2	ii. 1500 dia.	20	m.	35,000	700,000.00
7.1.3	Iii 2000 dia	250	M	50,000	12,500,000.00
7.20	Provide and place 1:2:4 concrete mix in saddle support for penstock.	50	M^3	24,000	1,200,000.00
7.30	Provide and place in position appurtenances.(control valves, bends etc). as specified in the drawing.				
7.3.1	i. Sluice valves-1000mm dia	1	Nr.	750,000	750,000.00
7.3.2	ii. Sluice valves- 1500mm dia	2	Nr.	800,000	1,600,000.00

7.3.3	iii Sluice valves- 2000mm dia	1	Nr.	950,000	950,000.00
7.3.4	iv. Foot valves - 2000mm dia	1	Nr.	850,000	850,000.00
7.3.5	v. Air vent with release valves - 75mm dia.	4	Nr.	15,000	60,000.00
7.3.6	vi. Flanged expander 600 x 1000.	1	Nr.	650,000	650,000.00
7.3.7	vii Flanged – Y 2000 x 1500 x 1500	1	Nr.	600,000	600,000
7.3.8	vi. Intake Trash rack and structure as specified in the drawings.	1	Nr.	250,000	250,000.00
7.3.9	vii. Primming tank complete with fittings as specified.	1	Nr.	15,000,000	15,000,000.00
	TOTAL FOR PIPE WORKS CARRIED TO SUMMARY				**37,410,000.00**

8.3.2 Electromechanical

S/N	Description of Item	Unit	Qty	Unit Rate	USD	Naira @ ₦120/$
1	Kaplan Turbine; ZD 560-LH-60	Set	1	46,800	46,800	5,616,000.00
2	Kaplan Turbine; ZD 500-LH-100	Set	2	112,500	225,000	27,000,000.00
3	3Phase Synchronous generator 415V,0.8PF,50Hz, SF 320-6	Set	1	52,000	52,000	6,240,000.00
4	3Phase Synchronous generator 415V,0.8PF,50Hz SF 800-14	Set	2	126,500	253,000	30,360,000.00
5	Butter Fly Valve Dia 1000mm	Set	1	9,950	9,950	1,194,000.00
6	Butter Fly Valve Dia 1500mm	Set	2	24,090	48,180	5,781,600.00
7	Speed Regulatory Governor model DST-300,YT-300	Set	1	15,220	15,220	1,826,400.00
8	Speed Regulatory Governor model TY 1000	Set	2	36,900	73,800	8,856,000.00
9	Excitation System (360KW)	Set	1	10,600	10,600	1,272,000.00
10	Excitation System (872KW)	Set	2	25,900	51,800	6,216,000.00
11	Automatic Component for 360 KW	Set	1	6,900	6,900	828,000.00
12	Automatic Component for 872 KW	Set	2	16,800	33,600	4,032,000.00
13	Provide for Earthing of all Electrical System in the Power house and switch yard	Lump	Sum	1500	1,500	180,000.00
14	Provision for 2 x 2.5MVA TX including HT Breakers, Switch Fuses Isolators and other civil works in the Switch yard	Lump	Sum	165,000	165,000	19,800,000.00
15	33KV overhead line with 120 mm^2 Alluminium Bare Conductor (ACSR) and concrete poles	Spans	25	3,500	87,500	10,500,000.00
16	Metering Panels to include Ammeters, Voltmeters,	Nos	3	1,500	4,500	540,000.00

	KW meters, pf meters, frequency meters, tri – vector meters, speed indicators, Temperature indicators,Gate valve opening position					
17	Synchronization panel to include relevant meters	Nos	1	120,000	120,000	14,400,000.00
18	4 x 500mm^2 PVC/SWA/PVC (armoured cable)	M	200	200	40,000	4,800,000.00
19	1 x 150mm^2 XLPE Cable(33KV)	M	100	80	8,000	960,000.00
20	Freight Cost	Lump	Sum	10,000	10,000	1,200,000.00
21	Insurance and duty	Lump	Sum	2,000	2,000	240,000.00
	Sub Total				1,265,350	151,842,000.00

8.4	**SUMMARY**	
S/No	**DESCRIPTION**	**AMOUNT**
1.0	SETTING OUT AND PLANT	650,000.00
	SUB-STRUCTURE	
2.0	Excavation and Earth Works	1,242,250.00
3.0	Concrete Works	3,553,000.00
4.0	Block Work	187,500.00
	SUPER- STRUCTURE	
5.0	Concrete works	957,900.00
6.0	Block Works	225,000.00
7.0	Roof Works	1,110,000.00
8.0	Doors and Windows	208,000.00
9.0	Finishing	648,000.00
10.0	Electrical Works	1,100,000.00
11.0	Pipe Works	37,410,000.00
12.0	**Subtotal civil works**	47,291,650.00
13.0	**Electro-Mechanical works**	151,842,000.00
14.0	**SUB - TOTAL**	199,133,650.00
15.0	10% Contigency	19,913,365.00
16.0	**Total**	219,047,015.00
17.0	5% VAT	10,952,350.75
18.0	**Sub-Grand Total**	229,999,365.75

19.0	Supervision	29,899,917.54
20.0	Project vehicle + Running cost	16,191,360.28
	GRAND TOTAL	**276,090,643.58**

9.0 ENVIRONMNENT IMPACT ASSESSEMENT

9.1 Introduction:

The statutory provision of the Federal ministry of environment and other relevant laws of Nigeria makes it mandatory to carry-out environmental impact assessment on all projects that are not friendly t o the environment.

However the present small hydropower project proposed for Okinni Dam will produce clean electricity in an environmentally friendly manner to old Oshogbo/Ede headworks and the surrounding community.

The SHP project is proposed to be sited at existing Okinni – dam (Completed 1988) which is replenished yearly by runoff from river Erinle and other smaller streams in the catchments area.

The environmental assessment was conducted to determine the baseline data conditions of the environment in the project location and surrounding by giving a description of the physical and social component of the environment. In addition the EIA will determine the possible impacts (Positive or Negative) of the proposed Okinni Dam small hydropower project will have on its immediate vicinity. More importantly the sources and characteristics of environmental impact will be identified and highlighted. Mitigation measures for envisaged impact shall be given. An environmental management plan will be recommended that will ensure the sustainability of the SHP project and its environment.

9.2 Justification for the Project:

The old Oshogbo/Ede water works has been operating at its lowest ebb for some time now, due to electrical power availability problems. The water works is the backbone of the water supply to Osun state as a whole.

The present State Government considers water supply to its citizens a priority for healthy living, therefore it has considered using some of its existing raw water supply dams for small hydropower generating stations integration to supply the much needed power and addition to its primary design function.

The Okinni dam which was completed in 1988 was selected as a starting point for a Small hydropower programme in Osun State. The basic infrastructure available includes a dam with a capacity to store 94 x $10^6 m^3$ of water, a 3,500mm diameter bottom outlet conduit pipe and other basic dam infrastructures.

The integration of a small hydropower project into the Okinni dam will transform it into a multipurpose dam. Since it will generate electricity while supplying raw water to Old Erinle dam for municipal water demand in an ecologically friendly manner.

9.3 Sustainability

The Okinni dam small hydropower project will be supplied by water to run its turbines through the yearly runoff flow from river Erinle that originates from surrounding hills and other smaller tributaries. Hence the sustainability of the Okinni dam small hydropower project is assured.

9.4 Project Options/Alternatives:

The options and alternatives considered below took into considerations the sustainability and protection of the environment.

(a) Option 1: No project at all:

This option implies that the SHP project will not be implemented and Okinni dam will continue to supply raw water downstream wastefully that may never be fully utilized due to lack of adequate power for the operations of the Ede/Oshogbo headworks. However for adequate water supply to Osun State, the no project option is rejected.

(b) Option 2: Siphon type + Bottom outlet conduit.

The above scheme entails supply of water to the penstock mechanism from the storage reservoir and through existing bottom outlet conduit, to ensure that no structural aspect of the existing dam is altered. This scheme ensures that no environmental damage is done to the existing structures and environment by the introduction of the small hydropower project to the system. The siphon system pipes will be laid across the top of the dam into the reservoir and into the power house. This option is thereby selected for the following reasons:

i. The stored water behind Okinni – dam that was hitherto released downstream as raw water alone, will now in addition be utilized for electricity generation without damaging or altering the existing system.
ii. The flood water and live storage of the dam will now be effectively utilized
iii. Energy produced in the raining season is 1,900KW while dry season will be 1,076KW

(c) Option 3: Siphon system + Bottom outlet conduit + Cascade system.

The cascade system to be located 10km downstream of Erinle – Dam will temporarily store the water being released upstream of Erinle – dam.

It is expected that a head of about 15.5m will be developed by the impoundment which may be used to produce additional 1,400KW of energy during the raining season and another 813.8KW during the dry season downstream of Erinle-dam. The above energy scenario is in addition to the one produced upstream from the Okinni dam. It will be useful in the future to include this cascade system; however option 2 without the cascade is the selected option for the Detailed Project Report (DPR).

9.5 Description of the Environment:

9.5.1 Introduction:

The baseline environmental data is presented in Tables **9.1**, **9.2** and **9.3**

9.5.2 Agricultural land and soil

The predominant soil at site could be classified as loamy soil with some patches of lateritic soil. There is excellent land for the cropping of Yam, Maize, Cassava e.t.c

9.5.3 Flora and Fauna:

The vegetation type is the rainforest type. The climatological data presented in Table **9.1** – **9.3** show that there is a distinct raining season and dry season. The rainy season starts in April and ends in October while the dry season is between November through March. These features affect the type of vegetation and with an annual rainfall of about 1,396.8mm

Table 9.1 Baseline Climatic data year 2005

Month	Rainfall (mm)	Temperature (ºC)			Evaporation (mm)	Wind (knot)	Sunshine (hr)
		Max	Min	Mean			
Jan	0.0	34.1	17.5	25.80	7.0	2.77	-
Feb	18.5	36.0	23.6	29.80	4.9	2.89	-
Mar	101.6	34.3	22.9	28.60	3.5	3.81	-
April	93.1	33.4	23.7	28.55	3.0	4.46	-
May	226.2	31.2	22.8	27.00	1.7	3.06	-
Jun	156.4	29.7	22.5	26.10	1.4	2.93	-
Jul	107.6	28.0	22.1	25.05	1.1	1.87	-
Aug	59.1	27.2	20.9	24.05	1.3	1.74	1.81
Sept	223.7	29.6	21.8	25.70	1.3	2.93	4.4
Oct	120.6	30.8	21.9	26.35	1.7	2.45	5.6
Nov	5.9	33.7	21.9	27.80	3.0	2.53	7.9
Dec	17.6	35.5	21.7	28.60	3.1	2.10	7.4

Table 9.2 Baseline Climatic data year 2006

Month	Rainfall (mm)	Temperature (ºC)			Evaporation (mm)	Wind (knot)	Sunshine (hr)
		Max	Min	Mean			
Jan	30.90	33.0	23.6	28.3	2.90	-	5.5
Feb	23.30	35.0	24.3	29.65	4.00	3.36	7.3
Mar	104.20	33.2	23.0	28.10	3.20	2.61	6.1
April	156.00	33.7	23.4	28.55	2.70	3.40	7.3
May	129.40	31.0	22.6	26.80	1.90	3.00	5.8
Jun	164.30	30.4	22.1	26.25	1.90	2.77	5.3
Jul	238.40	29.0	22.0	25.50	1.30	2.42	3.5
Aug	111.50	27.5	21.6	24.55	1.20	2.74	1.9
Sept	212.50	28.7	21.8	25.25	1.20	2.86	3.6
Oct	204.20	30.5	21.9	26.20	1.40	2.90	5.0
Nov	94.70	33.1	18.6	25.85	3.50	2.20	7.7
Dec	0.00	34.3	17.0	25.65	4.70	2.32	7.5

Table 9.3 Baseline Climatic data year 2007

Month	Rainfall (mm)	Temperature (ºC)			Evaporation (mm)	Wind (knot)	Sunshine (hr)
		Max	Min	Mean			
Jan	0.0	35.0	18	26.5	8.15	2.77	3.33
Feb	0.50	36.2	22.6	29.4	6.30	2.79	6.04
Mar	59.0	35.9	23.1	29.5	5.80	3.16	4.60
April	116.1	32.8	23.1	27.95	3.30	3.07	6.50
May	165.3	31.4	22.4	26.90	2.30	2.67	6.50
Jun	221.8	29.9	21.9	25.90	1.90	2.93	4.80
Jul	182.6	28.3	21.8	25.10	1.40	2.55	3.87
Aug	188.2	28.1	21.7	24.90	1.40	2.70	3.10
Sept	207.7	29.2	21.5	25.35	1.50	2.60	4.30
Oct	218.9	30.2	21.6	25.90	1.70	1.90	5.60
Nov	36.3	31.9	22.4	27.15	2.20	1.80	7.10
Dec	24.7	32.7	19.8	26.25	3.40	2.58	6.90

9.5.4 Health:

Primary health Care is available in Okinni which is the hosting community of the Okinni – dam small hydro-power project. There are hospitals and clinics in Oshogbo, the state capital which is about 20min drive from Okinni town.

9.5.5 Social services:

Water supply to Okinni and other villages around the small hydro-power project is pipe borne water which is supplied from the old Ede – water supply scheme. However due to poor power supply, the water supply could be assessed as about 20% efficient. Stream and boreholes are the alternative supplies for drinking water to the villages. There are secondary schools and numerous primary schools in the environment.

9.5.6 Community organization:

There is an Oba who is the town paramount leader, who is a traditional ruler at Okinni and has chiefs who support his rulership. The Community has organized associations for youth and women development.

9.6 Associated and potential environmental impact and their mitigation.

9.6.1 The impact of this small hydropower project on the community and its environment can be categorized into two main phases of the project life viz:

- Construction phase
- Operational phase.

The system presented for environmental analysis divides the human environment into four major categories viz:

- Physical and chemical
- The ecological
- Aesthetic
- Social factor.

9.6.2 Construction Phase:

9.6.2.1 Physical and Chemical Impact:

The major element that constitute, physical and chemical environmental impacts includes, waters, land, air and noise.

However out of these four elements only air will be impacted upon during construction, as a result of the fugitive dust that will be generated during construction and installation of the power house and other infrastructure. However, this is a temporary situation and no serious consequences on population because of the distance of Erinle- dam from the villages.

9.6.2.2 Ecological impacts:

The Okinni dam was completed in 1988 and the addition of the small hydropower plant will not modify or alter the existing infrastructure or the ecosystem. Therefore the project will not have any effect on the basic ecological parameters such as species and population, the communities and habitat and the ecosystem.

9.6.2.3 Social Impacts

There is no detrimental impacts expected from the project on the following basic social parameters e.g. Individual interest, individual wellbeing and no social intercession will be disrupted.

9.6.3 Operational Phase:

During the operational phase of the small hydropower project there wouldn't be any adverse effect on the environment, rather the production of electrical energy will bring positive impacts to the community. The production of electricity at Okinni dam small hydropower plant will improve the operation of the water treatment and supply facilities at Old Ede-water works.

The three major load centres that will benefit from the SHP projects are:

- water treatment /supply works
- staff quarters around the scheme
- Some villages around the dam site as may be considered by the state government.

The availability of power to these load centres is discussed in details in Chapter 5

9.7.0 Environmental Management Plan:

The small-hydropower plant is ecofriendly with its measurable parameters and the positive effects on the community. The Osun state ministry of water resources should be empowered to take up the responsibility of managing the scheme.

9.7.1 Environmental Monitoring:

The schedule of monitoring shall be every two years. The scope of monitoring will cover the following:

- Socio – economics
- Occupational health
- River flow down stream to the proposed cascade system
- Ecological effects on fishes and fauna

9.7.2 Environmental Management Plan:

The appointed officer who will control the SHP plant should work in conjunction with the state ministry of water resources to control and enforce regular action on the environmental plan.

9.8.0 Decommissioning and Abandonment:

The small hydropower plant with a capacity of 1,900KW (2NO x 770KW and 1NO x 360KW) that was designed for Okinni dam will have a life expectancy of about 50years. At the expiration of the useful life of the project, adequate arrangements will be made to remove all movable infrastructures.

9.9.0 Conclusion:

The environmental aspect of the proposed small hydropower project was conducted alongside the detail project report studies.

The small hydropower project is friendly to the environment and has a net positive benefit to the people of Osun State and Nigeria people as a whole.

The positive socio – economic impact can be stated as follows:

- Most convenient regular energy source devoid of epileptic supply
- The power supply to the old Oshogbo/Ede Headworks will be regular and steady.
- The concomitant effect of regular drinkable water supply is excellent health to the people of Osun State.
- The site being one of the epoch – making project on small hydro power plant, will be a tourist center that could be considered by the state government.

10.0 POWER EVACUATION / DISTRIBUTION

The power generated is at 415V, 50Hz, 0.8pf a common busbar through a synchronizing panel. 2Nos x 2.5 MVA transformers is to be provided to step up the output voltage to 33KV one of the transformer to serve as spare.

A 33 KV dedicated line is to be constructed to connect the Ede water works for a total distance of 17Km. The Okinni dam will be fed directly from the common bus bar within the generating station

10.1 Switch Yard and Protective Facilities

The switch yard comprised of 2 Nos 2.5MVA 415/33KV transformers. HT switch gears are installed to protect the out going HT line. The system will be adequately protected.

$$P\ (w) = \sqrt{3}\ IV\ COS\ \Theta$$

Where $COS\ \Theta = 0.8$

$$\text{Therefore } I = P\ (w)/\sqrt{3} \times V\ COS\ \Theta$$
$$= 2000000/\sqrt{3} \times 33000 \times 0.8$$
$$= 43.7A$$

The 43.7 a protection is provided at switchyard. Appropriate No of 33KV, SF6 Breakers CTs, Isolators etc are to be provided in the switchyard.

Cable Choice

$120mm^2$ Aluminum bar Conductor (ACSR) is used for the overhead line. This will provide minimum power loss on the line.

Peak power (Rainy season) = 1916KW

$$P_{KVA} = \frac{P_{kw}}{P_f} = 1916/\ 0.8 = 2395KVA = 2.3MVA$$

The closest available transform to this figure is 2.5Mva. The 2.5Mva is therefore recommended.

11.0 PROJECT IMPLEMENTATION

The implementation of the project will require approximately six months (excluding tendering, contract awarding, if required, it will need maximum 2 months). The critical path will be the civil works, that is to say the building of the conveyance structures. The period from the awarding of the contracts to installation and commissioning is in the order of five to six months.

Project implementation cost summary is shown in **A-11.1.**

12.0 OPERATION AND MAINTENANCE

The micro hydro power scheme will be operated during the day and night according to the recommended load scheduling. The plant will occasionally be shut down in order to carry out necessary maintenance or repair work at the plant.

12.1 Training of Local Personnel

Two employees, preferably skilled people in SHP will be assigned the responsibility of operating the hydro power scheme. They will be instructed in the operation and maintenance of the new electro – mechanical equipment.

12.2 Maintenance of Micro Hydro Scheme

The main duties of the operators of the scheme will be:

- Starting and closing down the scheme as required
- Switching the power supply to the different consumer groups on or off according to schedule.
- Observing the operation of the plant on a regular basis by controlling all relevant parts of the scheme.
- Cleaning the intake, the sand trap, the head race and the Forebay from floating debris and sediments.
- Keeping the power house clean at all times

- Carrying out maintenance activities in accordance with defined procedure
- Trouble shooting in case of minor problems with the generation or the transmission of electricity
- Carrying out necessary maintenance works on the civil structures of the scheme.
- Reading the Kwh – meters at the power house daily and reducing same.
- Maintenaning accurate records of the power generation and operation (log box)

In addition to his duties directly related to the operation of the scheme, the operator should also assist the village administrator in leading interested visitors / tourists to the MHP facility

12.3 Spare Parts for Facility

12.3.1 Recommended Spare parts for Turbine/Generator

1. Bearings
2. Lubricants like multipurpose grease and oils in dust free containers
3. Instruments (voltmeter, pressure gauge, (etc)
4. Bolts and nuts
5. Fusess, MCBs and ELCBs
6. Cable conductors
7. Lightning arrestors
8. Ballast heaters
9. AVR
10. Gaskets, O rings for all flange joints
11. Two lengths of penstock
12. V-belts and couplings
13. Oil seals, rubber packing, gland ropes(one set)
14. One type each of pipe fitting, connector, ferrules washer etc of hydraulic and water pipe lines
15. One card of each type of electronic controller/governor//protection if applicable
16. One set of indicating lamps and LEDS

12.3.2 Recommended tools

a) A set of open-ended spanners
b) Flat and cross-head screwdrivers
c) Grease gun
d) Bearing puller
e) Tool rack to neatly place the tools
f) Emergency rechargeable lights
g) Digital Multimeter, Tong Tester
h) Special tools like chain-pulleys, slings, nylon rope etc
i) Test lamp and Tester
j) Special tools required to dismantle and assemble turbine parts

k) Tap and dice set
l) Feeler gauges
m) Bench vice, hammer, hacksaw and 1m x 2m Table
n) Dial gauge
o) Spirit level

13.0 ECONOMIC AND FINANCIAL ANALYSIS

13.1 Financial Analysis:

A Ten-Year Financial Report made up of The Profit and Loss Account, Balance Sheet and the Cash Flow Statement was prepared. We have also prepared a 30-Year financial and economic analysis report using the Net Present Value (NPV) method. Also included is a detailed fixed asset schedule for your information and use.

Below are some of the basic assumptions used to prepare the Net Present Value of the project:

- Discount Rate: 17%
- Inflation Rate: 8%

The detailed input and the result of the financial analysis is equally attached. Please find below the extract of the Hydro Power Plant Financial Analysis:

13.1 Financial Analysis								
Total Project Cost	233,225,746	NGN	**Selling Condition**					
Capital Cost per kW installed capacity	109,105	NGN	Tarrif (HH)	820	NGN/month	(assumed for 0.7A)		
	909	US$	Tarrif (WW)	4,179,147	NGN/month			
1 US$ =	120	NGN	Increase	8%	Per Annum	(based on inflation rate		
Plant Capacity	2,138	kW	Number HH	500	units			
Annual Demand Growth	3%	%	Number WW	2	units			
Average Annual Inflation	8%	%	Tarrif	8.50	NGN/kwh			
Average Interest/Discount rate	17%	%						
Service Life	30	Years	NPV	**737,254,483**	NGN	(at end of year 0)		
O&M Hydro	9,176,817	NGN/a	FIRR	47.19%				

<u>Interpretation</u>:

With a discount rate of 17% and a span of 30 years, our projected cash flows are worth NGN 970.5M today, which is higher than the initial NGN233.2M paid in order to start the project.

The resulting NPV of the above project is NGN737.3M, which means the project will receive the required return at the end of the project. Since the project as returned a significant positive NPV, we therefore recommended the project for acceptance. As we already know that projects with positive are expected to increase the value of the firm. Thus, the NPV decision rule specifies that all independent projects with positive NPV should be accepted.

The project is expected to be acceptable even at an interest rate as high as 49% having recorded an IRR of 49.17%.

Financial Analysis

Total Project Cost	233,225,746	NGN	**Selling Condition**			
Capital Cost per kW installed capacity	109,105	NGN	Tarrif (HH)	820	NGN/month	(assumed for 0.7A)
	909	US$	Tarrif (WW)	4,179,147	NGN/month	
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Plant Capacity	2,138	kW	Number HH	500	units	
Annual Demand Growth	3%	%	Number WW	2	units	
Average Annual Inflation	8%	%	Tarrif	8.50	NGN/kwh	
Average Interest/Discount rate	17%	%				
Service Life	30	years	NPV	**737,254,483**	NGN	(at end of year 0)
O&M Hydro	9,176,817	NGN/a	FIRR	49.18%		

Year		Demand total	Investment (as a grant)	O&M Cost Hydro	Net Revenue house	Unit Cost	sub-total	Commercial	Unit Cost	sub-total	total	Net Cash-flow
		Kwh/a	NGN	NGN/a	unit	NGN/kWH	NGN/a(h/h)	Units	NGN/kWH	NGN/a (w/w)	NGN/a (w/w)	NGN/a
2008	0		233,225,746									**233,225,746**
2009	1	12,379,046		(9,176,817)	500	820	4,922,362	2	4,179,147	100,299,532	105,221,894	96,045,077
2010	2	12,699,814		(9,910,963)	500	886	5,316,151	2	4,513,479	108,323,495	113,639,646	103,728,683
2011	3	13,028,892		(10,703,840)	500	957	5,741,443	2	4,874,557	116,989,374	122,730,818	112,026,978
2012	4	13,366,499		(11,560,147)	500	1,033	6,200,759	2	5,264,522	126,348,524	132,549,283	120,989,136
2013	5	13,712,853		(12,484,958)	500	1,116	6,696,820	2	5,685,684	136,456,406	143,153,226	130,668,267
2014	6	13,754,496		(13,483,755)	500	1,205	7,232,565	2	6,140,538	147,372,919	154,605,484	141,121,729
2015	7	13,754,496		(14,562,455)	500	1,302	7,811,170	2	6,631,781	159,162,752	166,973,922	152,411,467
2016	8	13,754,496		(15,727,452)	500	1,406	8,436,064	2	7,162,324	171,895,772	180,331,836	164,604,384
2017	9	13,754,496		(16,985,648)	500	1,518	9,110,949	2	7,735,310	185,647,434	194,758,383	177,772,735
2018	10	13,754,496		(18,344,500)	500	1,640	9,839,825	2	8,354,135	200,499,229	210,339,054	191,994,554
2019	11	13,754,496		(19,812,060)	500	1,771	10,627,011	2	9,022,465	216,539,167	227,166,178	207,354,118

2020	12	13,754,496		(21,397,025)	500	1,913	11,477,172	2	9,744,263	233,862,300	245,339,472	223,942,448
2021	13	13,754,496		(23,108,787)	500	2,066	12,395,346	2	10,523,804	252,571,284	264,966,630	241,857,843
2022	14	13,754,496		(24,957,490)	500	2,231	13,386,973	2	11,365,708	272,776,987	286,163,961	261,206,471
2023	15	13,754,496		(26,954,089)	500	2,410	14,457,931	2	12,274,964	294,599,146	309,057,077	282,102,989
2024	16	13,754,496		(29,110,416)	500	2,602	15,614,566	2	13,256,962	318,167,078	333,781,644	304,671,228
2025	17	13,754,496		(31,439,249)	500	2,811	16,863,731	2	14,317,518	343,620,444	360,484,175	329,044,926
2026	18	13,754,496		(33,954,389)	500	3,035	18,212,830	2	15,462,920	371,110,079	389,322,909	355,368,520
2027	19	13,754,496		(36,670,740)	500	3,278	19,669,856	2	16,699,954	400,798,886	420,468,742	383,798,002
2028	20	13,754,496		(39,604,399)	500	3,541	21,243,444	2	18,035,950	432,862,797	454,106,241	414,501,842
2029	21	13,754,496		(42,772,751)	500	3,824	22,942,920	2	19,478,826	467,491,820	490,434,740	447,661,989
2030	22	13,754,496		(46,194,572)	500	4,130	24,778,354	2	21,037,132	504,891,166	529,669,520	483,474,948
2031	23	13,754,496		(49,890,137)	500	4,460	26,760,622	2	22,720,102	545,282,459	572,043,081	522,152,944
2032	24	13,754,496		(53,881,348)	500	4,817	28,901,472	2	24,537,711	588,905,056	617,806,528	563,925,179
2033	25	13,754,496		(58,191,856)	500	5,202	31,213,589	2	26,500,728	636,017,461	667,231,050	609,039,194
2034	26	13,754,496		(62,847,205)	500	5,618	33,710,676	2	28,620,786	686,898,857	720,609,534	657,762,329
2035	27	13,754,496		(67,874,981)	500	6,068	36,407,531	2	30,910,449	741,850,766	778,258,297	710,383,316
2036	28	13,754,496		(73,304,979)	500	6,553	39,320,133	2	33,383,284	801,198,827	840,518,960	767,213,981
2037	29	13,754,496		(79,169,378)	500	7,078	42,465,744	2	36,053,947	865,294,733	907,760,477	828,591,099
2038	30	13,754,496		(85,502,928)	500	7,644	45,863,003	2	38,938,263	934,518,312	980,381,315	894,878,387

NPV = Net Present Value of Investment

FIRR = Internet Rate of Return of Investment

13.2 Economic Analysis

Hydo Power

Tota Project cost:	233,225,746	NGN
Total E-M cost:	151,842,000	NGN
Total Project Cost:	1,943,548	US$
Annual Demand Growth:	3%	
Annual Enegy Production MHP:	12,379,046	kWh
Average Annual Inflation rate:	8%	
Average interest/discount rate:	17%	
Inflaion corrected rate:	9%	
O&M E&M:	2.0%	% of t E&M Cost
O&M civil & transmission:	1.5%	% of total costs
Basic Cost Wages Operator:	62,165	NGN/Month
No of Operators 2:	1,491,967	NGN/a
Administration & Overhead:	2,537,441	NGN/a

Year	Year of Operation MHP	General Price index	Annual Enrgy Production MHP Scheme	Annuity of Investment for MHP Scheme over 30 years	Operation and Maintenance E&M MHP	Operation and Maintenance Civil Works & Transmission	Wages MHP Operators & Administration	Total Cost Hydro Power	Energy Cost 'HYDRO'	Unit Energy Cost
			kWh	NGN	NGN	NGN	NGN	NGN	NGN/kWh	Cent S$/kWh
2009	1	115%	12,379,046	7,774,192	3,036,840	2,110,569	4,029,408	16,951,009	1.37	0.01
2010	2	130%	12,379,046	7,774,192	3,279,787	2,279,414	4,351,761	17,685,154	1.43	0.01
2011	3	145%	12,379,046	7,774,192	3,542,170	2,461,768	4,699,902	18,478,031	1.49	0.01
2012	4	162%	12,379,046	7,774,192	3,825,544	2,658,709	5,075,894	19,334,338	1.56	0.01
2013	5	179%	12,379,046	7,774,192	4,131,587	2,871,406	5,481,965	20,259,150	1.64	0.01
2014	6	197%	12,379,046	7,774,192	4,462,114	3,101,118	5,920,523	21,257,947	1.72	0.01
2015	7	215%	12,379,046	7,774,192	4,819,083	3,349,208	6,394,164	22,336,647	1.80	0.02
2016	8	234%	12,379,046	7,774,192	5,204,610	3,617,144	6,905,698	23,501,643	1.90	0.02
2017	9	253%	12,379,046	7,774,192	5,620,979	3,906,516	7,458,153	24,759,840	2.00	0.02
2018	10	273%	12,379,046	7,774,192	6,070,657	4,219,037	8,054,806	26,118,691	2.11	0.02
2019	11	294%	12,379,046	7,774,192	6,556,310	4,556,560	8,699,190	27,586,251	2.23	0.02
2020	12	316%	12,379,046	7,774,192	7,080,815	4,921,085	9,395,125	29,171,216	2.36	0.02

2021	13	340%	12,379,046	7,774,192	7,647,280	5,314,772	10,146,735	30,882,978	2.49	0.02
2022	14	365%	12,379,046	7,774,192	8,259,062	5,739,953	10,958,474	32,731,681	2.64	0.02
2023	15	392%	12,379,046	7,774,192	8,919,787	6,199,150	11,835,152	34,728,280	2.81	0.02
2024	16	420%	12,379,046	7,774,192	9,633,370	6,695,082	12,781,964	36,884,607	2.98	0.02
2025	17	449%	12,379,046	7,774,192	10,404,040	7,230,688	13,804,521	39,213,441	3.17	0.03
2026	18	479%	12,379,046	7,774,192	11,236,363	7,809,143	14,908,883	41,728,581	3.37	0.03
2027	19	509%	12,379,046	7,774,192	12,135,272	8,433,875	16,101,594	44,444,932	3.59	0.03
2028	20	542%	12,379,046	7,774,192	13,106,094	9,108,585	17,389,721	47,378,591	3.83	0.03
2029	21	579%	12,379,046	7,774,192	14,154,581	9,837,271	18,780,899	50,546,943	4.08	0.03
2030	22	619%	12,379,046	7,774,192	15,286,948	10,624,253	20,283,371	53,968,763	4.36	0.04
2031	23	661%	12,379,046	7,774,192	16,509,903	11,474,193	21,906,041	57,664,329	4.66	0.04
2032	24	706%	12,379,046	7,774,192	17,830,696	12,392,129	23,658,524	61,655,540	4.98	0.04
2033	25	783%	12,379,046	7,774,192	19,257,151	13,383,499	25,551,206	65,966,048	5.33	0.04
2034	26	862%	12,379,046	7,774,192	20,797,723	14,454,179	27,595,302	70,621,396	5.70	0.05
2035	27	943%	12,379,046	7,774,192	22,461,541	15,610,513	29,802,926	75,649,172	6.11	0.05
2036	28	1026%	12,379,046	7,774,192	24,258,465	16,859,354	32,187,160	81,079,171	6.55	0.05
2037	29	1111%	12,379,046	7,774,192	26,199,142	18,208,103	34,762,133	86,943,569	7.02	0.06
2038	30	1198%	12,379,046	7,774,192	28,295,073	19,664,751	37,543,104	93,277,120	7.54	0.06
								Average 2009-2038	**3.43**	**NGN/kWh**

13.3 The Projected Profit and Loss

		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
As at December 31		('000)	('000)	('000)	('000)	('000)	('000)	('000)	('000)	('000)	('000)	('000)
Turnover	Revenue from electricity		105,222	113,640	122,731	132,549	143,153	154,605	166,974	180,332	194,758	210,339
	Other income											
	Total Rent		**105,222**	**113,640**	**122,731**	**132,549**	**143,153**	**154,605**	**166,974**	**180,332**	**194,758**	**210,339**
Operating Expenses:												
	Repairs and maintenance		3,037	3,280	3,542	3,826	4,132	4,462	4,819	5,205	5,621	6,071
	Insurance cost		1,151	1,243	1,342	1,449	1,565	1,691	1,826	1,972	2,130	2,300
	General Expenses		2,452	2,648	2,860	3,089	3,336	3,603	3,891	4,202	4,538	4,901
	Salaries and wages		2,537	2,740	2,960	3,196	3,452	3,728	4,027	4,349	4,697	5,072
	Total Operating Expenses		9,177	9,911	10,704	11,560	12,485	13,484	14,562	15,727	16,986	18,344
Operating Profit			**96,045**	**103,729**	**112,027**	**120,989**	**130,668**	**141,122**	**152,411**	**164,604**	**177,773**	**191,995**
Depreciation			16,375	16,375	16,375	16,375	16,375	16,375	16,375	16,375	16,375	16,375
Preoperating costs expensed		4,946										
PROFIT BEFORE FINANCE CHARGES		(4,946)	79,670	87,354	95,652	104,614	114,293	124,747	136,036	148,229	161,398	175,620
INTEREST												
PROFIT BEFORE TAXATION		(4,946)	79,670	87,354	95,652	104,614	114,293	124,747	136,036	148,229	161,398	175,620
TAXATION												
PROFIT BEFORE DIVIDENDS		(4,946)	79,670	87,354	95,652	104,614	114,293	124,747	136,036	148,229	161,398	175,620
DIVIDENDS												
NET PROFIT/(LOSS) FOR THE YEAR		(4,946)	79,670	87,354	95,652	104,614	114,293	124,747	136,036	148,229	161,398	175,620

ACCUMULATED PROFIT/(LOSS)	**(4,946)**	**74,724**	**162,078**	**257,730**	**362,344**	**476,637**	**601,384**	**737,421**	**885,650**	**1,047,048**	**1,222,667**

13.4 The Projected Balance Sheet	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]
CAPITAL EMPLOYED											
Share Capital	233,226	233,226	233,226	233,226	233,226	233,226	233,226	233,226	233,226	233,226	233,226
Retained Profit/Loss	(4,946)	74,724	162,078	257,730	362,344	476,637	601,384	737,421	885,650	1,047,048	1,222,667
Total Shareholders' Funds	228,280	307,950	395,304	490,956	595,570	709,863	834,610	970,646	1,118,876	1,280,273	1,455,893
Long-term Loan											
Deferred Tax											
TOTAL CAPITAL EMPLOYED	**228,280**	**307,950**	**395,304**	**490,956**	**595,570**	**709,863**	**834,610**	**970,646**	**1,118,876**	**1,280,273**	**1,455,893**
EMPLOYMENT OF CAPITAL											
Fixed Assets	181,618	165,243	148,868	132,493	116,118	99,743	83,368	66,993	50,618	34,243	17,868
Current Assets:											
Stocks											
Debtors											
Cash and Bank Balance	46,662	142,707	246,436	358,463	479,451	610,120	751,242	903,654	1,068,258	1,246,030	1,438,025
Total Current Assets	**46,662**	**142,707**	**246,436**	**358,463**	**479,451**	**610,120**	**751,242**	**903,654**	**1,068,258**	**1,246,030**	**1,438,025**
Current Liabilities:											
Creditors											
Current Portion of Loan											
Taxation											
Dividends											
Total Current Liabilities											

Net Current Assets	46,662	142,707	246,436	358,463	479,451	610,120	751,242	903,654	1,068,258	1,246,030	1,438,024
TOTAL EMPLOYMENT OF CAPITAL	**228,280**	**307,950**	**395,304**	**490,956**	**595,569**	**709,863**	**834,610**	**970,647**	**1,118,876**	**1,280,273**	**1,455,892**

13.5 The Projected Cashflows

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
CASH INFLOWS	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]	[N ' 000]
ELA DAM Electricity Project	233,226										
Other Investors											
Long-Term Loan											
Operating Profit		96,045	103,729	112,027	120,989	130,668	141,122	152,411	164,604	177,773	191,995
TOTAL CASH INFLOWS	**233,226**	**96,045**	**103,729**	**112,027**	**120,989**	**130,668**	**141,122**	**152,411**	**164,604**	**177,773**	**191,995**
CASH OUTFLOWS											
Capital expenditure	181,618										
Pre-operating costs	4,946										
Change in working capital											
Long-term loan principal repayment											
Interest payment on loan											
Tax payment											
Dividend remittance											
	186,563										
NET CASH FLOW	46,662	96,045	103,729	112,027	120,989	130,668	141,122	152,411	164,604	177,773	191,995
OPENING CASH BALANCE		46,662	142,707	246,436	358,463	479,452	610,120	751,242	903,654	1,068,258	1,246,031
CLOSING CASH BALANCE	**46,662**	**142,707**	**246,436**	**358,463**	**479,452**	**610,120**	**751,242**	**903,654**	**1,068,258**	**1,246,031**	**1,438,025**

13.6 Fixed Asset Schedule

Electro-Mechanical Component

Description	Unit	Qty	UC (NGN)	Total NGN	Total (US$)
Turbine - Kaplan ZD 560-LH-60	-	1	5,616,000	5,616,000	46,800
Turbine - Kaplan ZD 500-LH-100	No	2	13,500,000	27,000,000	225,000
3 Phase Syncronization Generator SF 320-6	No	1	6,240,000	6,240,000	52,000
3 Phase Syncronization Generator SF 800-14	No	2	15,180,000	30,360,000	253,000
Butter fly valve Dia 1,000mm		1	1,194,000	1,194,000	9,950
Butter fly valve Dia 1,500mm		2	2,890,800	5,781,600	48,180
Speed Regulator Governor TY 10000	No	2	4,428,000	8,856,000	73,800
Provision for 2x2.5 MVA (HT Breaker etc)	No	1	19,800,000	19,800,000	165,000
33 Kv Overhead line (120 mm2 Allum cond.)	No	25	420,000	10,500,000	87,500
Automatic Component (872 Kw)		2	2,016,000	4,032,000	33,600
Excitation System		2	3,108,000	6,216,000	51,800
Syncroniztion panel		1	14,400,000	14,400,000	120,000
Other Miscellaneous		1	10,406,400	10,406,400	86,720
Freight		1		1,200,000	10,000
Insurance & duty	%	1		240,000	2,000
vat	%			0	0
Sub-total-Electro-Mechanical Component				**151,842,000**	**1,265,350**

Power House Civilworks

Description	Unit	Qty	UC (NGN)	Total NGN	Total (US$)
				FOB	FOB
Setting out and Plant	m^3	1.0	650,000	650,000	5,417
Sub-structure		1.0	4,353,380	4,353,380	36,278
Pipe works	m^3	1.0	37,410,000	37,410,000	311,750
Concrete works, blocks etc	m^3	1.0	3,148,900	3,148,900	26,241
Electrical works		1.0	1,100,000	1,100,000	9,167
Sub-total -Power House Civilworks				**46,662,280**	**388,852**

Other Costs

10% Contingency				19,850,428	165,420

5% VAT				9,925,214	82,710
				29,775,642	**248,130**
Total Assets				**228,279,922**	**1,902,333**

14.0 CONCLUSIONS AND RECOMMENDATIONS

14.1 Conclusions

1. The Okinni Dam is suitable for the development of Small Hydro Power (SHP)
2. The installation of 1x 360 KW and 2x 778 KW turbines is considered appropriate taking into consideration the design data/parameters.
3. The SHP scheme, a diversion drain pipe and a siphon-penstock and power house has minimum and very simple civil engineering works and can be completed in a period of 4-6 months.
4. Natural occurring construction materials are available within the environment of Okinni Dam
5. The proposed scheme has minimum interface with the environment and hence would not affect the ecology of the area.
6. The SHP scheme shall generate electricity throughout the year. Thus, it would help in generating employment and improvement of quality of life in the communities around Okinni Dam.
7. The SHP scheme will further clean the environment by avoiding the burning of 515 litres of diesel oil per hour, with its attendant polluting effect.

14.2 Recommendations

8. In the process of data gathering and analysis, the inadequacy of data was very obvious. It is therefore recommended for the sustainability of the SHP project that meteorological and hydrographic station be established.
9. Capacity building in SHP project in areas such as civil work, water management, Electro-mechanical etc is recommended for the sustainability of the project.
10. The Okinni Dam SHP project can easily and readily enhance the tourism activities in the state.
11 The Okinni Dam is overgrown with weeds, even at the dry season. It is recommended that the Okinni Dam environment and the access road, overgrown with weeds be regularly maintained –cutting of overgrown grasses/weeds. It is equally recommended that a staff of the ministry be assigned the responsibility of periodic monitoring of the Okinni dam structure and facilities.
12. Large losses of stored water at Okinni Dam and old Ede head works needs to reduced. It is recommended that the leakage at the diversion drain pipe (Okinni) and the electromechanical devices at old Ede head works be urgently rehabilitated.
13. A profile survey is recommended between new Erinle dam and old Ede head works to identify all infrastructure close to the river.
14. Considering the total run-off at Okinni Dam, the distance and topography between Okinni dam and new Erinle dam, as well as the power demand as estimated, introduction of a cascade SHP is recommended. The upper and lower dam is recommended which can produce additional power of about 1,400.0 KW

15.0 RECOMMENDED BUSINESS MODEL

Any business model to be considered should also accommodate the ownership of the power plant, which is crucial for the long term sustainability of the whole scheme.

In this regard, it is recommended that a Management Committee be formed / put in place to discuss and decide on the various issues pertaining to the ownership and day to day operation of the whole scheme.

There are many models available for ownership and some of these are:

- Cooperative
- Individual
- Private Limited Company
- Public Limited Company
- Public Private Partnership

The Management Committee should have a focus on capacity building, in-built monitoring and evaluation processes, dispute redressal, mechanisms, etc to ensure smooth operation of the scheme.

The statutory / legal issues associated with the project should also be addressed by this committee. All the clearances required, like environmental, water regulatory agencies etc should be sought and obtained.

The Management Committee should provide support for the maintenance and the transmission and distribution networks; powerhouse maintenance, as well as water regulation measure, when necessary.

Tariff design and collection should be implemented based on an economic and financial analysis study of the scheme as designed. This is to ensure that the power plant become self-sustaining. Punitive measures for non-payment of tariff should also be developed and agreed upon.

All stakeholders will enter into a mutually binding agreement committing their obligation to the scheme.

A-5.7.1

LOAD SURVEY

EQUIP/FITTING	TOTAL NO OF EQUIP	KW	NO OPERATIONAL ON AT A TIME	TOTAL POWER KW
A Okinni Dam				
Gantry crane	1	6	1	6.0
Rotonk Actuator	1	15	1	15.0
Radial Gates	3	15	2	30.0
Gallery Pump	2	7.5	2	30.0
Street Light	47	0.125	47	5.9
Residential (14 Nos) (consumption /flatusing load (4B/R))	4	4.5	4	18.0
Sub Total				104.9

EQUIP/FITTING	TOTAL NO OF EQUIP	KW	NO OPERATIONAL ON AT A TIME		TOTAL POWER KW	
B Low Lift Pump	4	250	Min 2	Max 3	Min 500.0	Max 750.0
High Lift Pumps Back wash pumps	2	22		1	22	22.0
Ifon//lobu pump	3	290	1	2	290.0	580
Alarasan	2	165	1	1	165	165.0
Oloki	4	390	1	3	390	1170.0
Ede	3	250	1	2	250	500
Oshogbo	4	580	2	3	1160	1740.0
Dozing Pumps	11	1	3	4	3.0	4.0
Allum mixer	2	4	2	2	8	8.0
Lime pupms	4	0.75	4	4	3	3.0
Blower	3	11	1	2	11	22.0
Compressor	2	7.5	1	1	7.5	7.5
Booter pump	3	4	1	1	4	4.0
Street light	255	0.250	255	255	63.75	63.75
SubTotal					2877.25	5039.25

A. 5.7.2

ALTERNATIVE POWER SOURCES

Alternative power sources within the Okinni dam and Ede head works are

A. PHCN Power Source
B. Diesel generators of different capacities
- 2 No x 1.5 MVA Generating sets (Serviceable)
- 1 Nos 500 KVA Generating set (Serviceable)
- 1 Nos 680KVA Generating set (Unserviceable)
- 1 Nos 100KVA Generating set (Unserviceable)
- 1 Nos 50KVA Generating set (Serviceable)

A. PHCN Power Source

PHCN supply the water works at a rate of ₦ 8.50/KWH
Total load at Ede- 5039.25KW with 0.7 DF
=(5039.25 x 0.7) KW = 3527.48KWH
Residential = 77.5 x 0.76 = 46.5

S/N	FACILITY	LOAD (KW)	OPERATING HOURS	CONSUMPTION	COST(₦)
1	Ede Head works	3527.48	14 x 365 = 5110	18,025,422.8	153,216,093.8
2	Residential (Ede works)	46.5	10 x 365 = 3650	237,615	1,442,662.5
					154,658,756.3

B Diesel Generator Source

B.1 2 x 1.5MVA Generating set
Average operating hours- 8hrs/day= 2920hrs
Diesel Consumption 2 x 200/hr = 400/hr
Cost of Diesel/ litre = ₦ 110/ ltr
Cost of Oil/ litre = ₦ 260
Oil required / service- 200 litre

(i) Diesel Cost

- 2920hrs x 400L/hr x ₦ 110 /L = ₦ 128,480,000.00

(ii) Maintenance cost

Engine oil replacement: 2 Nos x 200L x 4 times x ₦ 260 /L
= ₦ 208,000.00
Topping 2 No x 20L x 50 times x ₦ 260/L = ₦ 520,000.00
Servicing materials N 150,000 x 2 Nos x 4 times = ₦ 1,200,000.00
Spare parts replacement/ work materials = ₦1,500,000.00
Personnel cost ₦ 25,000 x 2 x 12month = ₦ 600,000.00
₦ 32,508,000.00

Sub Total (i) + (ii) = 128,480,000 + 32,508,000 = ₦ 160,988,000.

B.2 1 x 500 KVA Generating Set

Average operating hours – 8hrs/day = 2920hrs
Diesel Consumption – 100L/hr
Cost of oil - ₦ 260 / L
Oil required for service – 80 L

(i) Diesel Cost

- 2920hrs x 100L/hr x ₦ 110 /L = ₦ 32,120,000.00

(ii) Maintenance cost

Engine oil replacement: 80L x 4 times x ₦ 260 /L	=	₦ 83,200.00
Topping -10L x 25 times x ₦ 260/L	=	₦ 65,000.00
Servicing materials ₦100,000 x 4 times	=	₦ 400,000.00
Spare parts replacement/ work materials	=	₦ 450,000.00
Personnel cost ₦ 25,000 x 2 x 12month	=	₦ 600,000.00
		₦ 33,718,200.00

Sub total = (i) + (ii) = 32,120,000 + 33,718.200 = ₦ 65, 022,500.00

B.3 1 No x 50 KVA

Average operating hours – 10hrs/day = 3650hrs

Diesel Consumption	–	15L/hr
Cost of Diesel	-	₦ 110 / L
Cost of Oil	-	₦260/L
Oil required for service	–	35 L

(i) Diesel Cost

- 3650hrs x 15L/hr x ₦ 110 /L = ₦ 6,022,500.00

(ii) Maintenance cost

Engine oil replacement: 35Lx 8 tines x ₦ 260 /L	=	₦ 72,800.00
Topping -5L x 25 tines x ₦ 260/L	=	₦ 32,500.00
Servicing materials ₦ 25,000 x 8 tines	=	₦ 200,000.00
Spare parts replacement/ work materials	=	₦ 250,000.00
Personnel cost ₦ 25,000x 12month	=	₦ 240,000.00
		₦ 6,817,800.00

Subtotal = (i) + (ii) 6022500 + 6817800 = ₦ 12,840,300.00

Total cost on Diesel Generating sets = B.1 + B.2 + B.3
= 160,988,000 + 65,838,200, + 12,840,300
= ₦ 239,666,500

C Okinni Village ₦4/KWH

S/N	FACILITY	LOAD (KW)	OPERATING HOURS	CONSUMPTION	COST(₦)
1	500	0.20	10 x 365 = 3650	365,000	365,000 x ₦ 4 = ₦1,460,000

A.5.7.3

<u>OKINNI DAM SHP LOAD SCHEDULE</u>

A DRY SEASON OPERATION

Available Power (KW)	Recommended Usage	Consumption
1 x 360 1 x 778 = 1138KW	<u>12 hrs Operation</u> (1) Okinni Dam (2) Okinni Village	 89.0 -
	(3) Ede Head Works (i) Auxillary Pumps (ii) Osogbo (1 Nos pump) (iii) Oloki (1 Nos Pump) (iv)Ede work low lift (1 Nos) (v) Alarasan (1 Nos pump) <u>12 hrs Operation</u> (i) Auxillary Pumps (ii) Osogbo (1 Nos pump) (iii) Ede low lift (1 Nos) (iv) Ede (1 Nos Pump) (v) Ifon/ilobu (1 Nos pump) (vi) Okinni Dam	 79.0 406.0 273.0 175.0 115.5 79.0 406.0 175.0 175.0 203.0 100.0

B RAIN SEASON

Available Power (KW)	Recommended Usage	Consumption
1 x 360 2 x 778 = 1916KW	<u>12 hrs Operation</u> Ede Head Works (i) Auxillary Pumps (ii) Ede low lift (2 Nos) (iii) Osogbo (2 Nos pump) (iv) Oloki (1 Nos Pump) (v)Ede (1 Nos) (vi) Alarasan (1 Nos pump) (Vii) Okinni Dam (Viii) Okinni village <u>12 hrs Operation</u> (i) Okinni Dam <u>Ede Head Works</u> (i) Auxillary Pumps (ii) Osogbo (2 Nos pump) (iii) Ede low lift (2Nos) (iv) Ifon/ilobu (1 Nos pump) (v) Okinni Village (vi) Oloki (1 Nos Pump)	 78.0 350.0 812.0 273.0 175.0 115.5 52.5 60.0 100.0 78.0 812.0 350.0 203.0 100.0 273.0

A.7.1

Design Parameters

The power potential is given by, P = KQH

Where P = Power potential in KW

Q = Design flow in m^3/s

Hg = Gross Head in, m

Ho = Net Head in, m

K = Constant (between 6 and 7)

- Maximum Power Potential
  P = 1800KW
  Q = $12.85m^3/s$
  Hg = 20m
  Minimum Power Potential
  P = 1080KW
  Q = $7.71m^3/s$
  Hg = 20m

- Head loss
  Total head loss = 0.46m (diversion drain pipe)
  Total head loss 1.78m (Siphon Pipe)
  Surge Pressure
  Penstock surge pressure = 206.2 (diversion drain pipe), 364.9m (Siphon pipe)
  Penstock design = (206.2 + 20) (diversion drain pipe), (364.9m) (Siphon pipe)
  = 226.2m (diversion drain pipe), (384.6m) (Siphon pipe)
- Design thickness
  design penstock thickness = 30mm(Diversion drain pipe)
  design penstock = 45mm (Siphon pipe)
- Design Head
  $H_o = H_g - H_T = 20 - 0.46 = 19.54m$ (diversion drain pipe), $20 - 1.78 = 18.22mm$ (Siphon pipe)

7.2 Design Calculations

7.2.1 Civil Works

(A) Penstock

Two lines of penstock shall be used to convey water from the dam to the power house. One would be from the Diversion drain pipe and the other would be from a water siphon pipe running from the reservoir as shown on figure **7.1**
The pipes would be made of mild steel.

i. Design.

- Diversion Drain pipe.

Assume D = 1000m
Q = $2.57m^3/s$

- Determine average velocity i.e. V = Q/A

$V = 2.57/ D^2$ח

- Calculate head loss in system H_t

Assume roughness ‘K’ = 0.06
$k/d = 0.06/1000 = 6x10^{-5}$
$1.2Q/d = 1.2 \times 2.57/ 1000 = 3.084m$
From moody chart diagram using $k/d = 6 \times 10^{-5}$ and 3.084
    $f = 0.0135$
$h_{losswall} = flLQ^2/12d^5$
Where: L = 92m
    $Q = 2.57m^3/s$
    d = 1.0m
    f = 0.0135
$hloss = 0.0135 \times 92 \times 2.57/12 \times (1)^5$
    = 0.27m

- Minor losses

$K_{valve} = 0.2$
$K_{expansion} = 0.15$
$K_v + K_e = 0.35$, $h_{min} = v^2/ (k_v + k_e) = 3.29^2/2 \times 9.81 (0.35) = 0.19m$
Total head loss = $h_{losswall} + h_{min}$
    = 0.27 + 0.19
    = 0.46m

- Surge pressure

    Wave velocity, $a = 1440/ \sqrt{} 1 + 2150 \times 1000/ 2 \times 10^5 \times 10 = 1441$

- Calculate critical time

    $T_c = (2L/a) = 2 \times 92/1441 = 0.13Sec$
Choose closure time such that
$T > 2T_c$
$T > 2 \times 0.13 = 0.26$
Choose T = 0.5 > 0.26

- Calculate K

$$K = \frac{\{L \times V\}}{\{g \times h_g T\}}$$
$92 \times 3.27/ 9.8 \times 20 \times 0.5 = 9.4$

- Determine Surge pressure

$$h_{surge} = h_{gross} \{K/2 \pm \sqrt{}K + K^2/4\}$$
    $20(4.7 \pm 5.61)$
Take $h_{surge} = 20(4.7 + 5.61)$
    = 206.23m
$h_{total} = h_{surge} + h_a$
    = 206.23 + 20

= 226.23m

- Determine pipe wall thickness
  t_{eff}. = 3/ 1.1 x 1.2 – 1 = 1.27

Safety Factor, SF = $\frac{200 \times 1.27 \times 320 N/mm^2}{h_{total}}$

$\frac{200 \times 1.27 \times 320}{226.23 \times 1000}$

SF = 0.40 < 3.5 reject

Select t = 30mm

$t_{effective}$ = 30 / 1.1 x 1.2 – 1 = 21.73

SF = $\frac{200 \times 21.73 \times 320}{226.23 \times 1000} = \frac{1390720}{226230}$ = 6.15 > 3.5 ok.

adopt t = 30mm

(ii) Design – Siphon System.

Q = 10.28m^3/s

Assume velocity, v = 3.5m^3/Sec

Q = AV = [πd²/4] v → Q = AV = $[\pi d^2/4]$ v

d = √ 4Q/πv

d = 1.93m

Select, d = 2m and L =233m

- Calculate head loss in system,

$H_t = h_{loss} + h_{turbulence}$

$H_{losswall} = f(LQ/12d^5)$

Assume roughness 'IL' = 0.06

Therefore, k/d = 0.06/2000 = 3 x 10^{-5}

1.2Q/d = 1.2 x 10.28/2 = 6.17 for moody chart using k/d = 3 x 10^{-5} and 6.17

f = 0.01, $h_{losswall} = fLQ^2/12d^5$ = 0.64m

<u>Minor $h_{losseswall}$, Turbulence.</u>

- Entrance losses
  Kentrane = 0.3
  hentrance = $V^2/2_g$ (0.3) = 0.19m
- Value losses, K = 0.3
  - foot value loss, K = 0.3

  $h_{footvalue} = kv^2/2g = 0.3 \times 3.5^2/ 2 \times 9.81$ = 0.19m
- Gate valves – 2No i.e. $(k_1 + k_2)V^2/2g$

  $k_1 = k_2 = 0.1$

We have, 0.2 x V2/2g = 0.2 x 3.5/2 x 9.81 = 0.124

- Losses in bends, for 4 bends;
  k_1, k_2, k_3 and k_4
  $k_1 = 0.25$, $k_2 = 0.25$, $k_3 = 0.12$ and $k_4 = 0.40$

  = $(k1 + k2 + k3 + k4)V^2/ 2g = 1002 \times 3.5^2/2 \times 9.81$ = 0.64

$h_{turbulence} = 0.19 + 0.19 + 0.12 + 0.64 = 1.14m$
$h_T = 0.64 + 1.4 = 1.78$
$h_{net} = 20 – 1.78 = 18.22m.$

- Surge Pressure

Wave velocity, $a = 1440/ \sqrt{1} + (2150d/Et)$
$a = 1440/ \sqrt{1} + 2150 \times 2000/ 2 \times 10^5 \times 20 = 1000$

- Calculate critical time, $T_c = 2L/a = 2 \times 233/1000 = 0.47$

- Choose closure time such that $T > 2T_c$
  $T > 2 \times 0.47 = 0.943$
  Take T = 1Sec.

- Calculate K ; $K = \left\{\frac{LV}{g \times h_{gross} \times T}\right\}^2 = \left\{\frac{233 \times 3.5}{9.81 \times 20 \times 1}\right\} = 17.28$

$h_{surge} = \{k/2 \pm \sqrt{k} + k^2/4\}h_{gross}$
$\{17.28/2 + - \sqrt{17.28} + (17.28)^2/4 = 20$
$= 20(8.64 + - 9.59)$
$= 364.6m$

Total $head_{loss} = h_{gross} + h_{surge}$
$= 20 + 364.6m$
$= 384.6m$

- Determine pipe wall thickness; try D = 20mm
  $t_{effective} = 20/1.1 \times 1.2 – 2 = 13.5$

- Calculate safety factor, SF
  $SF = 200 \times 13.5 \times 320 \times 320/ 384.6 \times 2000 = 1.37 < 2.5$ [reject]

Try D = 45mm; $t_{effective} = 45/1.1 + 1.2 – 2 = 32.09$
$SF = 200 \times 32.09 \times 320 / 384.6 \times 2000 = 2.67 > 2.5$
Therefore adopt pipe thickness of 45mm.

- Bifurcation pipes

$Q = 10.28m^3/s$
$Q_F = 10.28 / 2 = 5.14m^3/s$
Q = AV, Let v = 3.5m/s
A = Q.v = 5.14/3.5 = 1.47m
$D^2 = \frac{4 (1.47)}{\pi} = 1.87$
$D = \sqrt{1.87} = 1.37m$
Adopt, D = 1500mm