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Hydropower potential of municipal water supply schemes in Osun State: Case study of Okinni Dam, Osogbo, Nigeria

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Abstract

Continuous increase in energy demand has been tied to population increase and improved economic well-being of the people. As the world's population continues to grow geometrically, energy supply has been a major concern, especially, since the last two decades. Nigeria is no exception to this and it's even worse affected, because of its lack of adequate planning for its teeming population. From the present predicament of the country, it is obvious that other sources of energy generation mostly renewable - hydro-electric, solar, and wind which are more reliable and environmental friendly be explored as the dependency on the generated power using fossil fuel to the national grid has not helped in anyway. Hence, the need to explore other power alternatives, especially the renewables one. This study was therefore designed to investigate the potential of municipal water supply schemes in Osun State as a means of developing small hydropower plant using Okinni dam as a case study. Field survey was conducted through which key information about Okinni dam was obtained. The dam gives a conversion advantage with its water flow rate ranging between 7.71m3/s and 12.85m3/s based on the season of the year and also a height (head) above ground level of 20m. The collected field parameters were utilised in the standard hydropower equations. The results obtained from the analysis gives a theoretical all year round of 3.1MW of electrical power. Comparing this result with the minimum power demand of 2.1MW and maximum power demand of 3.7MW of the inhabitants of the Okinni town, the Okinni dam services, Ede water works and some residential building at Ede water works, would require a two daily operations whereby the load are carefully selected on 12 hourly bases (Day and Night). This study has thus established the potential and viability of the construction of a small hydropower (SHP) on Okinni dam which will improve the town's commercial and industrial enterprise; hence, this project is recommended for construction.

Keywords: Renewable Energy; Hydropower; Okinni Dam; Municipal Water Supply

1 Introduction

Over two billion people across the globe still are without access to electricity. Unavailability of energy creates an immense barrier to the economic and social development of rural communities. This energy crisis needs to be tackled by the mutual cooperation of global society. In Nigeria epileptic power supply is one of the bottlenecks militating against industrialization. As industrialization of a nation rests on the availability of electric power. Companies, in the process of addressing this challenge resulted into powering their businesses using generators that run on fossil fuels thus increasing the release of green gas into the atmosphere thereby increasing the adverse effect of global warming. In addition, this has also resulted in the continuous increase in the cost of production and hence, reduction in the purchasing power of the people thus making most businesses un-viable and many of them exiting the country. All government's efforts to maintain steady power supply has been futile due to the incessant collapse of the national grid. Hence the need to look into regional/community-based power generation cannot be over emphasized. As this would

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aid industrialization in the country and also make available some basic amenities that will improve the welfare of the citizenry. Small hydropower (SHP) is a viable alternative. It is a renewable energy source, clean and environmentally friendly. 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. This SHP Project is proposed on the Okinni dam which water supply is from the Erinle River, which is one of the Water supply schemes of Ministry of Water Resources and Rural Development of Osun State. The design of this SHP project, if explored, would lead to an increase in employment opportunities, improvement in the ecological environment, and the economic development of the rural areas, more importantly.

1.1 Energy

Energy is the capacity of a physical system to perform work. Energy is stored and is available in different forms and sources. These sources are divided into two groups – Non-Renewable and Renewable as shown in Table1. Non-Renewable energy sources are the ones that are used up and cannot be produced in a short period of time. Their supplies are also limited. Examples are: Fossil fuels (petroleum oil, natural gas and coal), Tar sands, and Nuclear Fission. They are called fossil fuels because they are plants that lived thousands of years ago. They are the predominantly used energy sources today. Another non-renewable energy source is the element Uranium whose atoms we split (through a process called nuclear fission) to create heat and ultimately electricity. These types of energy sources are usually converted into electricity and mechanical energy. We get most of our energy from these non-renewable energy sources. Non-renewable energy sources are used to make electricity, to heat homes, to move our cars and to manufacture products. Renewable energy is one that is derived from natural sources that are continually replenished within the lifetime of humans and are therefore sustainable. Renewable energy sources include Biomass, Biofuel, Geothermal energy, Hydropower, Solar energy and Wind energy. Of all the renewable energy sources, solar, wind, geothermal and hydropower are the cleanest energy sources as they do not require combustion and therefore have no direct greenhouse gases and particles which pollute air and cause climate change. They are therefore considered green and environmentally friendly. All these renewable energy sources also have disadvantages or limitations arising from a factor of how well they can be harnessed considering the energy demand. It can therefore be established that the dependence on an energy source should be considered using several factors varying from its abundance in nature, its ability to be naturally replenished and its sustainability hence the need for renewable energy sources to be more exploited. Water is the most abundant natural resource on earth which makes hydropower the most popular and widely used renewable energy source.

Table 1 Energy Sources [1]

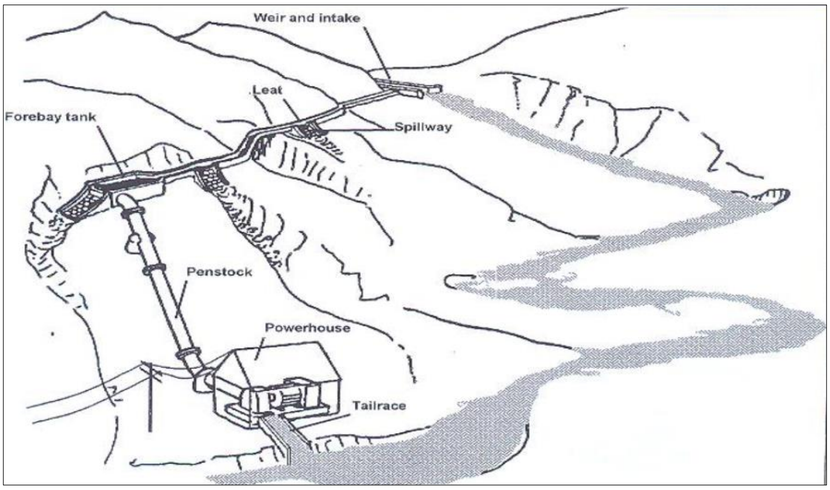
Renewable *Energy derived either directly or indirectly from the sun*	**Nonrenewable** *Energy derived from fossil fuels*
Solar	Coal
Biomass	Oil (petroleum)
Wind	Natural gas
Biofuels	Tar sands
Energy derived from gravity	*Energy derived from the fission of atoms*
Tidal	Nuclear (uranium)
Hydropower	
Energy from the interior of the earth	
Geothermal	

1.2 Hydropower

Hydropower is a vital renewable energy source which converts energy in flowing water into electricity. Hydroelectric power plants work on the principle of electric power generation by the use of gravitational force of falling or flowing water. Hydropower is the leading source of renewable energy, providing more than 97% of the total electricity generated by the renewable sources and approximately 22% of the world's electricity production most of which are Small Hydropower Plants (SHP)<10MW (4,5) [2]. Hydropower currently accounts for about 32% of the total installed commercial electric power capacity with an overall large scale potential (exploitable) in excess of 11,000MW (enough to solely power the current electricity demand in the country) [3]. For many years, the hydroelectricity supply in Nigeria has come from the Kainji, Jebba and Shiroro dams with capacities of 760MW, 578.4MW and 600MW respectively [4]. The estimated potential of small hydropower is about 15,000MW in the country. As at February 2017, the installed capacity of small hydro projects in Nigeria (up to 3MW) amounts to 4346.85MW [5].

1.2.1 Small Hydropower Plant

The basic principle of hydropower systems is that if water can be piped from a certain level to a lower level, then the resulting water pressure can be used to perform work. If the water pressure is allowed to move a mechanical component, then that movement involves the conversion of water energy. Hydro - turbines convert water pressure into mechanical shaft power, which can be used to drive an electricity generator, a grain mill or some other useful device. The system requires a sizable flow of water and a proper change in elevation, called effective head, which should be obtained without having to build elaborate and expensive structures Figure 1 shows the main components of a run-of river micro hydro power scheme. Each component has been described briefly below elaborate and expensive structures. Fig 1 shows the main components of a "run-of river" micro hydro power scheme. Each component has been described briefly.



Source: British Hydropower Association, 2005 [6]

Figure 1 Layout and component of a typical small hydropower installation

The source of water is a stream or sometimes an irrigation canal. Small amounts of water can also be diverted from larger flows such as rivers. The most important considerations are that source of water is reliable and not needed by someone else. For example, in Bhutan's Chendebji excellent sources, as they can often be depended on even in dry weather and are usually clean. This less likely to become silted and requires less cleaning. Run of the river schemes require no water storage, the water is instead diverted by the intake weir into small settling basin where the suspended sediment can settle. A grid to prevent the flow of large objects such as logs, which may damage the turbines, usually protects the intake. The diverted water is drawn via a channel into the fore bay tank. The channel is usually a concrete or steel pipe along the side of a valley to maintain its elevation. The fore bay tank holds sufficient water to ensure that the penstock is always submerged to prevent suction of air to the turbine. It also acts as water reservoir during lean season. The water flows from the forebay tank down a closed pipe called the penstock. The penstock is often made of high density materials and exposes the water to pressure; hence the water comes out of the nozzle at the end of the penstock as a high pressure jet. The power in the jet, called hydropower (hydraulic power), is transmitted to a turbine wheel, which changes it into mechanical power. The turbine wheel has blades or buckets, which cause it to rotate when they are struck by the water jet due to momentum transfer. Hydro-turbines convert water pressure into mechanical shaft power, which can be used to drive an electricity generator, a grain mill or some other useful device. The water returns back to the same stream via the tailrace in the powerhouse. The electricity generated is delivered to load centers through a distribution system or power lines connected to the households. Depending on the generation voltage level and distance of the load centers from the power house, distribution transformers can be used for stepping up (at the source) and stepping down (at the end user) voltage.

The capacity and energy output is calculated using standard hydropower equations:

$$P = (Q \times u \times H \times g \times o)/1000$$

Where

P = Power or installed capacity in kilowatts
Q = discharge rate in cubic meter per second
U = density of water in kg per cubic meter
H = effective head in meters
G = acceleration due to gravity and is $9.81 m/s^2$

O = efficiency of hydro turbine generator in %

And Annual Output Energy (kWh) = *P X hr x CF*

Where
P= power or installed capacity in kilowatts
Hr= Annual continuous generating duration (8760 hours in a year)
CF= Plant Capacity Factor (typically 95°/b for run-of-the-river type systems)

According to the international small hydro atlas, there is no international consensus on the definition of small hydropower. In Canada "small" can refer to upper limit capacities of between 20 and 25 MW, in the United States small" can mean 30MW. However, a value of up to 10MW total capacity is becoming generally accepted. Small hydro can be further subdivided into mini hydro, usually defined as < 500 kW and micro hydro < 100 kW. The classification of hydropower is shown in Table 2. What remains the same is that small hydropower is often environmentally benign and makes hydropower a very attractive energy alterative which can make a significant contribution to future energy needs. A well designed small micro hydropower scheme can blend with its surrounding and have minimal negative environmental impacts. It is one of the most environmentally favorable energy conversion options available, because these schemes are run of the river not requiring damming or the creation of water reservoirs. However, there are still some emissions associated with the technology during other life cycle stages. The chain of manufacturing the generating and transmission equipment's and processes are important source of emission [7].

Table 2 Classification of hydropower [8]

Type	Capacity
Large hydro	100MW
Medium hydro	10-100MW
Small hydro	1-10MW
Mini hydro	100KW-1MW
Micro hydro	5 – 100KW
Pico hydro	5 KW

KW (Kilowatt) = 1000 Watts. MW (Megawatt) = 1,000,000 Watts

Over the last few decades there has been a growing realization in developing countries that micro hydropower schemes have an important role to play in the economic development of remote rural areas, specifically in mountainous regions. Depending on the end-use requirement of generated power, the output from the turbine shaft can be used directly as mechanical power or the turbines can be connected to an electrical generator or alternator to produce electricity. For many rural industrial applications such as milling, carpenter workshops or pumping water, shaft power is suitable, but many applications require conversion to electrical power. For domestic applications, like light bulbs, radios, television, rice cookers, heaters, refrigerators, and food processors, electricity is required. This can be achieved by delivering power directly to home via a small electrical distribution system, or by means of batteries which are charged at the power house. This system is commonly used where cost of direct electrification is prohibitive due to scattered and sparsely populated housings.

1.3 Okinni Dam Community Brief

The Okinni Dam shown in figure 2 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 Islam. 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. Traditionally, 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.

Figure 2 Landscape view of OKINNI DAM

Table 3 General Features of OKINNI DAM

1.	**Name of Project**	**Okinni Dam Small Hydro Power Project.**
2.	**Location**	
	State	Osun
	L.G.A	Egbedore
	Access	Untarred 9km road from Okinni junction.
	Nearest Rail	Oshogbo
	Nearest Airstrip/Airport	Offatedo/Ibadan
3.	**Geographical**	
	Longitude	004º 32' 19'' – 004º 32' 05'' E
	Latitude	07º 53' 32'' – 07º 53' 38'' N
4.	**Details of Site**	
	Name of stream	Erinle
	Catchment area	250km^2
		A gently-undulating terrain with NE-SW
	Topography	Trending ridges to the west and south.
	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.

Despite all the prospects and potentialities in the hydropower sector in Osun and in Nigeria at large, the sector is still faced with acute challenges which if not overcome, will become impediments to the advancement of the sector and consequently will retard the process of harnessing the whole potentialities of the sector. To establish the potentiality of Hydropower Plant of Okinni Dam, Osogbo, Nigeria by converting the potential energy of a mass of water flowing in a stream with a certain fall into electric energy. The power of the scheme is proportional to the flow and the fall. This paper basically aims at establishing the potentiality of Hydropower Plant of Okinni Dam, Osogbo, Nigeria, this will be done in the following ways; Acquisition and review of relevant existing literature and related studies to ascertain their conformance with National regulations. Relevant literatures include: Okinni Dam engineering designs, Project Implementation Manual, Project Appraisal Document, Dam Inspection Report as well as Inspection and Safety Reports. Evaluation of the engineering and technological attributes of the project as well as other ancillary facilities. These will facilitate good understanding of the potential environmental impacts sources from the project. Assessment of the potential of Hydropower Plant in Okinni Dam.

2 Literature Review

Hydropower is the power derived from the force or energy of moving water, which may be harnessed for useful purposes. Hydropower can be traced back to 250BC when it was recorded that waterpower was used to power the clock [9]. It was then used by the Greeks to turn water wheels for grinding wheat into flour. In the 1700s mechanical hydropower was extensively used for milling and pumping. During the 1700s and 1800s, water turbine development continued and in 1880, a brush arc light dynamo driven by water turbine was used to provide theatre and storefront lighting in Grand Rapids, Michigan. In 1881, a brush dynamo connected to a turbine in a flour mill provided street lighting at Niagara Falls, New York. The breakthrough came when the electric generator was coupled to the turbine, which resulted in the world`s first hydroelectric station, which was commissioned on September 30, 1882 on Fox River at Vulcan Street Plant Appleton, Wisconsin, USA. It however further evolved to generating enough power to supply a large city (Draft, n.d.). Hydroelectric power plants convert the potential energy in water pooled at a higher elevation into electricity by passing the water through a turbine and discharging it at a lower elevation. The water moving downhill turns the turbine to generate electricity. The elevation difference between the upper and lower reservoirs is called the head. Hydroelectricity supplies approximately 19% of the world`s electricity and accounts for over 63% of electricity from renewable sources. Hydroelectric power plants can be categorized into – Large and Small hydropower plants. To distinguish between the categories, the size factor is majorly used. There is no internationally agreed definition for the different sizes of hydropower. A generic distinction between large and small hydropower is that the latter can be seen as installations up to 10MW of installed capacity [10] Department of Energy (DOE) defines large hydropower as power plants having generation capacity of more than 30MW [11].

2.1 Small Hydropower Plants

Small hydropower plants are termed as having a generation capacity of 100kW to 30MW. Within the small hydro range, a distinction can be made between mini hydro (maximum 1MW installed capacity), micro hydro (below 300 or 100kW installed capacity) and pico hydro (below 20, 10 or 5kW installed capacity). Small hydropower plants are sometimes preferable as against the large hydropower plants. Small hydropower development may be installed along with project for flood control, irrigation or other purposes, providing extra revenue for project costs. Few of the advantages of the small hydropower scheme over the large hydropower scheme are as thus:

- Micro hydropower provides low cost solution for remote sites.
- It provides a good solution for energy problems in remote and hilly areas where the extension of grid system is comparatively uneconomical.
- Power from micro hydro power plants can be used in saw mills, carpentry shop, lathe machine, grain grinding, etc.

2.2 Global Small Hydropower Scheme

The globally installed small hydropower plant (SHP) capacity is estimated at 78GW in 2016. The total estimated potential has also increased to 217GW in 2016. Overall, approximately 36% of the total global SHP potential has been developed in 2016. SHP represents approximately 1.9% of the world`s total power capacity, 7% of the total renewable energy capacity and 6.5% of the total hydropower capacity (including pumped storage). SHP is fifth in development with large hydropower having the highest installed capacity to date amongst the renewable energy sources followed by wind and solar power. China is known to dominate the SHP landscape with 51% of the world`s total installed capacity and approximately 29% of the world`s total SHP potential located in China. The top five leading countries in SHP are – China, Japan, Norway, and the USA [12]. These countries account for 67% of the world`s total SHP installed capacity.

2.3 Small Hydropower Scheme in Africa

The total SHP installed capacity for Africa is 580MW and the total estimated potential is 12197MW thus indicating that approximately 5% has so far been developed. This statistic proves the under-utilization of SHP in Africa. To narrow this down to Western Africa, it has a considerable SHP potential with Ghana and Nigeria having estimated potential capacities of 1245MW and 735MW respectively. However only 6% of the potential in Nigeria has so far been developed and there is currently no SHP in Ghana. Nigeria has the highest installed capacity at 45MW [13].

2.4 Small Hydropower scheme in Nigeria

The Nigeria power system is characterized by huge gap between supply and demand; current power demand is estimated at 17,520MW including latent and suppressed demand, against 5,300MW peak generation. As a result, about 90 million Nigerians have been reported to have no access to electricity according to African Progress Report [14]. Out of this non-electrified population, 17 million people live in urban areas, while 73 million live in rural areas. This means majority of the non-electrified live in off-grid areas where grid supply is not economical and may not be sustainable due to high cost of constructing transmission infrastructure. This however points to the need for an off-grid energy generation method that eliminates the high cost of transmission infrastructure construction. Several attempts have been made to tackle the power deficiency in the country [5]. In order to attract required private investment to bridge the huge deficits of electricity demand and supply, the power sector has undergone series of transformation and reforms one of which was the enactment of the 2005 Electricity Power Sector Reform (EPSR) Act which laid a solid foundation for the Federal Government power sector reform and privatization programme.

The reform saw the liberalization and commercialization of the national utility company leading to the unbundling of the National Electric Power Authority (NEPA), which became Power Holding Company of Nigeria (PHCN) consisting of 18 new successor companies including 6 generation companies, 1 transmission company and 11 distribution companies. So far both the generation and distribution assets are privatized and have been handed over to private owners. The EPSR Act of 2005 established the National Electricity Regulatory Commission (NERC), Nigeria Bulk Electricity Trading (NBET), the Rural Electrification Agency (REA) and other agencies as key institutional tools to drive the core objectives of the reform program [15]. Despite the reforms, investment in hydropower appears to be most feasible. According to Energy Commission of Nigeria (ECN) and Transmission Company of Nigeria (TCN), the hydro power potential of Nigeria as shown in Table 4 stands at about 14,000MW. This comprises of large, medium and small scheme hydropower across the length and breadth of the country. Small hydropower schemes have been identified to be the surest solution to rural unavailability which is where the majority of the non-electrified population is contained [16]. The fastest way to investing in small hydropower in Nigeria lies with converting existing dams to hydropower stations. There are already over 25 small dams distributed across Nigeria capable of generating about 30MW if converted into hydropower plants. These plants have the capability to feed into the embedded generation methodology, providing additional power to the distribution companies within their locations.

Table 4 Identified Small Hydropower Potential Sites in Nigeria [17]

S/n	Dam	Capacity (mw)	State	Population
1	Oyan	10	Oyo	7,840,864
2	Ikere Gorge	6	Oyo	7,840,864
3	Bakobri	3	Zamfara	4,515,427
4	Kampe	3	Kogi	4,473,490
5	Owena	0.45	Ondo	4,671,695
6	Doma	1	Nassarawa	2,523,395
7	Jibia	4	Katsina	7,831,319
8	Gimi	1.7	Kaduna	8,252,366
9	Ile-Ife	2	Osun	4,705,589
10	Ogbese	1	Ondo	4,671,695
11	Ogwashi-uku	2	Delta	5.663,362
12	AunaKontagora	2.4	Niger	5,556,247
13	Kila	11	Taraba	3,066,834
14	Karamti	20	Taraba	3,066,834

15	Bali	11	Taraba	3,066,834
16	Sardauna	11	Taraba	3,066,834
17	Tella	27	Taraba	3,066,834
18	Ankwe	19	Benue	5,741,815
19	Gongola	16	Taraba	3,066,834
20	Rafin Soja	0.5	Taraba	3,066,834
21	Sulma	0.07	Katsina	7,831,319
22	Balanga	0.69	Gombe	3,256,962
23	Ishapa	0.067	Kwara	3,192,893
24	Onipanu	0.045	Oyo	7,840,864
25	Mangu	0.075	Plateau	4,200,442
26	Ogbese	0.1	Ekiti	3,270,798
27	Adada	0.109	Enugu	4,411,119
28	Ivo	0.056	Enugu	4,411,119
29	River Nun	6	Bayelsa	2,277,961
30	Otukpo	1.9	Benue	5,741,815
31	Asejire	0.177	Oyo	7,840,864
32	Fikyu	0.304	Taraba	3,066,834

Table 5 Small hydro scheme in existence in Nigeria [18]

River	State	Installed capacity(MW)
Bagel I	Plateau	1
Bagel II	Plateau	2
Ouree	Plateau	2
Kurra	Plateau	8
Lere	Plateau	4
Lere	Plateau	4
Bakalori	Sokoto	3
Tiga	Kano	6
Challawa	Kano	7.5
Zobe	Katsina	0.30
Jibla	Katsina	4
Owena	Ondo	0.45
Ikere Gorge	Oyo	6
Doma	Nasarawa	1
Kampe	Kogi	3
Oyan	Ogun	10

One of the notable ongoing SHP development projects in Nigeria is that of the United Nations Industrial Development Organization (UNIDO) in collaboration with the Energy Commission of Nigeria and the Federal Ministry of Environment. The project aims to help the government of Nigeria achieve inclusive and sustainable industrial development by building human and institutional capacity for the development of small hydropower projects across the country. A regional centre for SHP has also been established in addition to developing local capacity for the fabrication of small hydropower turbines to reduce project cost. Over 200 potential SHP sites have been identified across the country (a few of which was listed above in Table 4 while 19 feasibility studies with detailed project reports and bankable documents have been carried out. Presently, three of the proposed SHP projects have been completed in Taraba, Bauchi and Enugu states, while there are ongoing projects in Ogun, Osun and Benue states [15].

2.5 Small Hydropower scheme in Osun State

In the course of feasibility study of municipal water schemes in Osun state, a visitation to some other identified potential sites that can be used for SHP generation was conducted. The identified sites visited are ss shown in Table 6:

Table 6 Potential Hydropower sites in Osun state, Nigeria

Name	Potential power
Okinni dam	3,054KW
EDE	Not feasible
Eko- Ende (Owalla dam)	65.7kW
Old Iwo Dam	Not feasible
Aiyekungba water fall (Oke Ila)	Not feasible
Esa-Odo dam	51.0kW
Ekeji-Ile Ijesha Weir	11.3kW
Erin Ijesha Waterfall	867.0kW

3 Methodology

As mentioned earlier, the dam selected for this study is Okinni dam. The potential power of the dam was derived from the field parameters. Also, the energy requirement of this community was determined. The following steps were taken to achieve success in the design process:

3.1 Collection of data

For the determination of the potential power of the dam, two major parameters were collected: water flow- rate and water fall head, both parameters were used to determine the system`s pipeline size, turbine type, rotational speed, and generator size. The energy requirement of the communities was also obtained from the power distribution company in the location.

3.2 Obtaining the water balance document to obtain the design flow rate

This document was pivotal to the calculation of the power generated by the hydropower scheme. In view of this, it is very important to determine as precisely as possible the water flow-rate and water fall head. For the Okinni dam, the document was obtained from the Osun State Water Corporation (Mechanical and Electrical section).

3.3 Design calculation

3.3.1 Civil Works

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

3.3.2 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.

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

3.3.2.1 Design

- Diversion Drain pipe

$$D = 1m$$

$$Q = 2.57m3/s$$

- Determine average velocity i.e.

$$V = Q/A$$

$$V = 4 \times 2.57/ D^2\pi = 3.27m/s^2$$

- Calculate head loss in system H

Assuming roughness 'K' = 0.06

$$k/d = 0.06/1000 = 6x10^{-5}$$

Calculating Reynolds' Number = 3.6×10^5

From Moody chart diagram, using k/d = 6 x 10-5 and Re= 3.6×10^5

The F was calculated as;

$$f = 0.0135$$

$$h_{losswall} = fLV^2/2gd$$

Where:

L = 92m
V = $3.27m/s^2$
d = 1.0m
f = 0.0135
g= $9.81m/s^2$

$$h_{loss} = 0.0135 \times 92 \times 3.27^2/2 \times 9.81x1$$

$$= 0.67m$$

- Minor losses

$$K_{valve} = 0.2$$

$$K_{expansion} = 0.15$$

$$K_v + K_e = 0.35$$

$$h_{min} = (k_v + k_e)\, V^2/ 2g = (0.35\ )\, 3.27^2/2 \times 9.81$$

$$= 0.19m$$

$$\text{Total head loss} = h_{losswall} + h_{min}$$

$$= 0.67 + 0.19$$

= 0.86m

Surge pressure

$$a_w = \frac{a}{\sqrt{1 + \frac{D}{\delta}\frac{B}{E}}}$$ …………………………………….(3.1)

Table 7 Wave velocity analysis

Liquid	**B [N/m²]**	ρ **[kg/m³]**	**Pipe material**	**E [N/m²]**	$\frac{D}{\delta}$	a_w **[m/s]**
Water 20°C, 1.25 bar	$2.105 x 10^9$	998	steel	$2 x 10^{11}$	100	1012
			cast iron	$1.1 x 10^{11}$	20	
			lead	$1.9 x 10^{10}$	5	
Crude oil	$1.594 x 10^9$	805	steel	$2 x 10^{11}$	100	
Gasoline	$1.092 x 10^9$	690	steel	$2 x 10^{11}$	100	

Wave velocity, a = 1449.8

Calculate critical time – Tc

$$Tc = (2L/a) = 2 x 92/1441 = 0.13Sec$$

Since valve or pump closure should be greater than critical time, closure time is selected such that;

$$T > 2T_c$$

$$T > 2 x 0.13 = 0.26$$

$$\text{Choose } T = 0.5 > 0.26$$

- Calculate K , K = (L xV)/(g x hgT)

$$92 x 3.27/ 9.8 x 20 x 0.5 = 3.07$$

- Determine Surge pressure

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

$$20(1.54 \pm 2.33)$$

$$\text{Take } h_{surge} = 20(1.54 + 2.33)$$

$$= 77.4m$$

$$h_{total} = h_{surge} + ha$$

$$= 77.4 + 20$$

$$= 97.4m$$

- Determine pipe wall thickness, tp

$$t_p = \mathbf{P * r / \sigma}$$

$$P = P_h + P_s$$

Where

P = total pressure
P_h = pressure due to water hammer
P_s = static water pressure

σ = stress

$$P_h = \rho_w * C_p * V$$

For water under ordinary conditions, C_p= 1120

So

$$_h= 1000 * 1120 * 3.27$$

$$P_h = 3.66 \text{ MPa}$$

Static pressure, P_s

$$P_s = \boldsymbol{\rho}_w * g * H$$

$$P_s = 1000 * 9.81 * 20$$

$$P_s = 0.1962 \text{ MPa}$$

Factor of safety, n = 4

$$\boldsymbol{\sigma}_{yp} = 957 \text{MPa}$$

But

$$P = P_h + P_s$$

$$P = 3.66 + 0.1962$$

$$P = 3.8562 \text{ MPa}$$

$$\boldsymbol{\sigma}\text{allowable} = \boldsymbol{\sigma}\text{yp} / n$$

$$= 957 * 10^6 / 4$$

$$\boldsymbol{\sigma}_{allowable} = 239.25 \text{ MPa}$$

Hence

$$= \mathbf{P * r} / \boldsymbol{\sigma}\text{allowable}$$

$$= 3.8562 * 10^6 * (1 / 2) / (239.25 * 10^6)$$

$$t_p = 8.05893 * 10^{-3} \text{ m} = 8.06 \text{ mm}$$

3.3.3 Siphon System

3.3.3.1 Design

$Q = 10.28 m^3/s$

Assume velocity, $v = 3.5 m^3/Sec$

$Q = AV = [\pi d^2/4]\ v\ d = \sqrt{4Q/\pi v}$

$d = 1.93$ m

Select, d = 2m and L =233 m

Calculate head loss in system,

Ht = hloss + hturbulence

- Calculate head loss in system H

Assume roughness 'K' = 0.06

$K/d = 0.06/2000 = 3x10^{-5}$

Calculating Reynolds' Number = $7.8\ x10^6$

From Moody chart diagram, using $k/d = 3\ x\ 10^{-5}$ and $Re= 7.8\ x10^6$

f = 0.01

$H_{losswall} = fLV^2/2gd$

$H_{losswall} = 0.01\ x\ 233\ x\ 3.5^2/2\ x\ 9.81x2$ **=0.69 m6**

Minor hlosseswall, Turbulence

Entrance losses

$K_{entr} = 0.3$

$h_{entr} = V^2/2_g\ (0.3) = 0.19$ m

Valve losses, K = 0.3

foot value loss, K = 0.3

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

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

$k_1 = k_2 = 0.1$

We have, $0.2\ x\ V^2/2g = 0.2\ x\ 3.5^2/2\ x\ 9.81 = 0.12$

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 $k_4 = 0.40$

$= (k1 + k2 + k3 + k4)V^2/\ 2g = 1.02\ x\ 3.5^2/2\ x\ 9.81 = 0.64$

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

$$h_T = 0.69 + 1.14 = 1.83$$

$$h_{net} = 20 - 1.83 = 18.17\text{m}$$

Surge Pressure

Using equation (3.1) and parameters of Table 3.1

Wave velocity, $a = 1012/ \sqrt{1} + (2150d/ET)$

$a = 1012/ \sqrt{} 1 + 2150 \times 2000/ 2 \times 10^5 \times 20 = 1457.7$

Calculate critical time, $T_c = 2L/a = 2 \times 233/1457.7 = 0.32s$

Choose closure time such that $T > 2T_c$

$T > 2 \times 0.32 = 0.64$

Take T = 1Sec.

 Calculate K ; K = { LV } = {233 x 3.5}

{g x h_{gross} x T} {9.81 x 20 x 1}

= 4.16

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

$$\{4.16/2 + - \sqrt{} 4.16 + (4.16)^2/4\}*20$$

$$20(2.08 + 6.37)$$

169 m

Total head = hgross + hsurge

=20 + 169 m

= 189 m

Determine pipe wall thickness, tp

$$t_p = P * r / \sigma$$

$$P = P_h + P_s$$

Where

P = total pressure
Ph = pressure due to water hammer
Ps = static water pressure
σ = stress

$$P_h = \rho_w * C_p * V$$

For water under ordinary conditions, C_p= 1120

So;

$$P_h = 1000 * 1120 * 3.5$$

$$P_h = 3.92 \text{ MPa}$$

Static pressure, P_s

$P_s = \boldsymbol{\rho}_w * g * H$

$$P_s = 1000 * 9.81 * 20$$

$$P_s = 0.1962 \text{ MPa}$$

Factor of safety, n = 4

$$\boldsymbol{\sigma}_{yp} = 957 \text{MPa}$$

But

$$P = P_h + P_s$$

$$P = 3.92 + 0.1962$$

$$P = 4.1162 \text{ MPa}$$

$$\boldsymbol{\sigma}\text{allowable} = \boldsymbol{\sigma}\text{yp} / n$$

$$= 957 * 10^6 / 4$$

$$\boldsymbol{\sigma}_{allowable} = 239.25 \text{ MPa}$$

Hence

$$= P * r / \sigma \text{ allowable}$$

$$4.1162 * 10^6 * (2/ 2) / (239.25 * 10^6)$$

$$t_p = 0.0172\text{m} = 17.20 \text{ mm}$$

Bifurcation Pipes

$$Q = 10.28\text{m}^3/\text{s}$$

$$Q_F = 10.28 / 2 = 5.14 \text{ m}^3/\text{s}$$

$$Q = AV, \text{ Let } v = 3.5 \text{ m/s}$$

$$A = Q.v = 5.14/3.5 = 1.47 \text{ m}^2$$

$$D^2 = \frac{4\,(1.47)}{\pi} = 1.87$$

$$D = \sqrt{1.87} = 1.37 \text{ m}$$

Adopt, D = 1500 mm

3.4 Electromechanical Equipment Selection

3.4.1 Turbine 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:

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

3.4.2 Generator Selection

The basic parameters to be considered in the selection of a suitable type of electrical generator are;

Type of desired output: A.C or D.C constant frequency or variable frequency.

Hydraulic turbine operations mode.

Type of electrical load: Interconnection with the national grid, storage in batteries or an isolated system supplying variety of household or industrial loads.

3.4.3 Governor Selection

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).

3.4.4 Valve Selection

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.

3.5 Energy Generation

This was done to explore how the energy demand of the load centres would be generated. The load centres can be grouped into two, namely

- Okinni Dam power demand
- Ede water works power demand

3.6 Energy Calculation

This was done to calculate the energy generated and the expected yearly revenue.

Installed capacity – 3 units of total capacity = 1916KW 2 turbines to run for 5 months (Nov-March)

3 turbines to run for 7 months (April-Oct)

Operating time – 20 hours (This was used to allow for downtimes, maintenance and unforeseen circumstances.)

3.7 Cost Estimates

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

3.8 Environmental Impact Assessment (EIA)

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 to 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.

4 Results and discussion

4.1 Identification of existing structures and site survey

The SHP 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 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. A Power House can also be sited on the site. Below are the dimensions of the existing component at the dam. While the mechanical / electrical components would need to be purchased they consist of the following:

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

4.2 Collection of data

The data was obtained at the Osun State Water Corporation. The data obtained are listed below:

4.2.1 Meteorology

Table 8 Baseline Climatic data year 2016

Month	Rainfall	Temperature (ºC)			Evaporation	Wind	Sunshine
	(mm)	Max	Min	Mean	(mm)	(knot)	(hr)
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

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) which gives a total of 7 months and dry Season (Nov-March) which gives a total of 5 month with average daily temperature in the project area as 28^0 C while annual rainfall amounts to 1130.3mm. The climatological data presented in Table 8 – 10 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 from November through March.

Table 9 Baseline Climatic data year 2017

Month	Rainfall	Temperature (ºC)			Evaporation	Wind	Sunshine
	(mm)	Max	Min	Mean	(mm)	(knot)	(hr)
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 10 Baseline Climatic data year 2018

Month	Rainfall	Temperature (ºC)			Evaporation	Wind	Sunshine
	(mm)	Max	Min	Mean	(mm)		(mm)
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

4.2.2 Geology

The project area is situated in the Precambrian basement complex geological province of south-western 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.

4.2.3 Topography

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.

4.2.4 Hydrology

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.

4.3 Water Balance

The following reservoir capacity of Okinni Dam was obtained from the consultant's feasibility report:

a. Full supply level capacity – 94 x 106 m3

b. Dead storage=7 x 106m3

c Live storage=87 x 106 m3

4.3.1 Water Balance: Wet season (7 months)

Select a firm flow of Q = 12.85 m^3/Sec

Total runoff from catchments area = 250 x $10^6 m^3$

Volume of water consumed in wet season (7months) using firm flow is given by:

$$12.85 \times 210 \times 60 \times 60 \times 24$$

$$= 233.15 \times 10^6 m^3$$

Balance of water left in reservoir after consumption

$$= (250 \times 10^6 - 233.15 \times 10^6) = 16.85 \times 10^6 m^3$$

- Power Potential: Wet Season (7Months)

Total runoff = 250 x 106m3
Total head = 20m
Power potential = 7QH = 1,800KW

Total water that can be used = 233.15 x 10^6m^3

Water Balance= Total runoff – Total to be used

= 250 x 10^6m^3 – 233.15 x 10^6m^3

= 16.85 x 10^6m^3

Qmax = Total water to be used / Total Run off Time

= 233.15 x 10^6/ 7 x 30 x 24x 60 x60

= **12.85m^3/s**

4.3.2 Water Balance: Dry Season (5 Months)

Balance brought forward from wet season

	= 16.85 x 10^6m^3
Reservoir capacity	= 87 x 10^6m^3
Total water available	= 103.85 x 106m^3

4.3.3 Power Potential: Dry Season (5Month)

Balance from runoff of wet season

= 16.85 x 10^6m^3

Reservoir capacity of 94 x 10^6m^3 less dead storage of 7 x 10^6m^3 = 87 x 10^6m^3 Total water available = (87 + 16.85) 10^6m^3

= 103.85 x 10^6m^3

Total water that can be used = 99.92 x 10^6m^3

Qmin = Total water to be used / Total Run off Time

= 99.92 x 10^6/ 5 x 30 x 24x 60 x60

= 7.71m^3/s

Water balance = 3.93 x 10^6m^3

4.3.4 Summary

Qmax = 12.85m3/s

Qmin = 7.71m3/s

H = 20m

Power Potential Dry season = 7 x 12.85 x 20 = 1799KW

Power Potential Dry season = 7 x 7.71 x 20 = 1079.4kW approximately 1,080kW

4.3.5 Summary

Wet season firm flow = 12.85m^3/Sec

Dry Season firm flow = 7.71m^3/Sec

Design discharge = $2.57m^3/Sec$

Wet Season Power = 12.85 x 7 x 20

1,799kW

Dry Season Power = 7.71 x 7 x 20

= 1,080kW

The climatological data presented in Table 8 – 10 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 from November through March. This explains the varying firm flow in the two seasons and definitely affected the power generated in the seasons too. It is only wise to design using the dry season.

4.4 Load Analysis and Survey

The load points that could be serviced by the SHP project are:

- Okinni Dam services
- New Ede water works
- Residential building at Ede water works
- Okinni village.

The total load consumption for these load centres is estimated at about 3,647.4 KW (maximum) and 2,137.63 KW (minimum) and shown in Appendix 4.4.

The summary is shown below for the minimum load.

Table 11 Summary of Minimum 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
	TOTAL	2137.63

4.4.1 Alternative Sources of Power Supply

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

Diesel Generators of different sizes

PHCN power Supply

The cost of providing electricity to service the load centres above were calculated

A summary of the costs calculated are shown in Table 12 below.

Table 12 Summary of Alternative Power cost Per Annum

S/N	Power	Ede	Head	Residential-	Okinni	Okinni	Total (₦)
	Source	works		Ede Head works	village	Dam	__
1	PHCN	581,500,139.5		6,393,770.7	11,774,900	---------	599,668,810.2
2	Gen. Set	341,634,200				13,807,800	355,442,000
	(Diesel)						

4.4.2 Matching Demand and Supply

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

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

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 below.

Table 13 Okinni dam shp load schedule

A. Dry season operation			
Available Power (KW)	**Recommended Usage**		**Consumption**
1 x 360	12 hrs Operation		
1 x 778	1.	Okinni Dam	89.0
= 1138KW	2.	Okinni Village	-
	3.	Ede Head Works	
	i.	Auxillary Pumps	79.0
	ii.	Osogbo (1 Nos pump)	406.0
	iii.	Oloki (1 Nos Pump)	273.0
	iv.	Ede work low lift (1 Nos)	175.0
	v.	Alarasan (1 Nos pump)	115.5
	12 hrs Operation		
	i.	Auxillary Pumps	79.0
	ii.	Osogbo (1 Nos pump)	406.0
	iii.	Ede low lift (1 Nos)	175.0
	iv.	Ede (1 Nos Pump)	175.0
	v.	Ifon/ilobu (1 Nos pump)	203.0
	vi.	Okinni Dam	100.0
B. Rain season			
Available Power (KW)	**Recommended Usage**		**Consumption**
1 x 360	12 hrs Operation		
2 x 778	Ede Head Works		
= 1916KW	i.	Auxillary Pumps	78.0
	ii.	Ede low lift (2 Nos)	350.0
	iii.	Osogbo (2 Nos pump)	812.0
	iv.	Oloki (1 Nos Pump)	273.0
	v.	Ede (1 Nos)	175.0
	vi.	Alarasan (1 Nos pump)	115.5
	vii.	Okinni Dam	52.5

	viii.	Okinni village	60.0
	12 hrs Operation		
	i.	Okinni Dam	100.0
	Ede Head Works		
	i.	Auxillary Pumps	78.0
	ii.	Osogbo (2 Nos pump)	812.0
	iii.	Ede low lift (2Nos)	350.0
	iv.	Ifon/ilobu (1 Nos pump)	203.0
	v.	Okinni Village	100.0
	vi.	Oloki (1 Nos Pump)	273.0

4.5 Design Calculation

Head loss (H loss)

Total head loss = 0.86m (diversion drain pipe)

Total head loss 1.83m (Siphon Pipe)

4.5.1 Surge Pressure

Penstock surge pressure = 77.4 (diversion drain pipe),

169m (Siphon pipe)

Penstock design = (77.4 + 20) (diversion drain pipe)

(169+ 20) (Siphon pipe)

=97.4m (diversion drain pipe),

189m (Siphon pipe)

4.5.2 Design thickness

Design penstock thickness = 8.06mm (Diversion drain pipe)

Design penstock = 17.20mm (Siphon pipe)

4.5.3 Design Head (Ho)

$H_o = H_g - H_T = 20 - 0.86 = 19.14$m (diversion drain pipe),

$20 - 1.83 = 18.17$mm (Siphon pipe)

4.6 Electromechanical Equipment Selection

4.6.1 Type of Turbine Selected

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.

4.6.2 Turbine Parameters

By considering the design parameters of the site: the head, discharge and power potential, different type of turbines from manufacturer's 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

- Runner diameter (Δ1) = 0.6078m or 61cm
- Turbine speed (η) = 930.918rpm
- Specific Speed (Ns) = 429.939
- Guide vane height (b) = 0.243m or 24cm
- Hub diameter (dn) = 0.252m or 25cm
- Number of blades (Z1) = 5 Numbers
- Sunction head (Hs) = 2.6m8. Installed altitude (Δ) = 377.5m
- 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 = 19.14m

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

- Runner diameter (D1) = 0.89m or 89m
- Turbine speed (η) = 633.6rpm
- Specific speed (Ns) = 430.2
- Guide vane height (b) = 0.3572m or 36m
- Hub diameter (dn) = 0.3714m or 37cm
- Number of blades (Z1) = 5 Numbers
- Suction head (Hs) = -2.6
- 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 = 19.14m

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

4.6.3 Generator Selection

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.

4.6.4 Governor Selection

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.

4.6.5 Valve Selection

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.

4.7 Energy Generation

The load centres can be grouped into two, namely

- Okinni Dam power demand
- 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

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.

4.8 Energy Calculation

Energy produced for 5 months = 1138kW x 20hrs x 151 day = 3,436,760 kWh

Energy produced for 7 months = 1916kW x 20hrs x 214 days = 8,200,480 kWh

Total energy produced in a year = (3,436,760 + 8,200,480) kWh = 11,637,240Kwh

Revenue for the year = 11,637,240 x ₦ 32.26 = ₦ 375,417,362.4

4.9 Cost Estimates

4.9.1 Basics

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

Table 14 Bill of Engineering Measurement and Evaluation

S/N	Description of Item	Unit	Qty	Unit Rate	USD	Naira @ N 360/$
1	Kaplan Turbine; ZD 560-LH-60	Set	1	46,800	46,800	16,848,000.00
2	Kaplan Turbine; ZD 500-LH-100	Set	2	112,500	225,000	81,000,000.00
3	3Phase Synchronous generator 415V,0.8PF,50Hz, SF 320-6	Set	1	52,000	52,000	18,720,000.00
4	3Phase Synchronous generator 415V,0.8PF,50Hz SF 800-14	Set	2	126,500	253,000	91,080,000.00
5	Butter Fly Valve Dia 1000mm	Set	1	9,950	9,950	3,582,000.00
6	Butter Fly Valve Dia 1500mm	Set	2	24,090	48,180	17,344,800.00
7	Speed Regulatory Governor model DST-300,YT-300	Set	1	15,220	15,220	5,479,200.00
8	Speed Regulatory Governor model TY 1000	Set	2	36,900	73,800	26,568,000.00
9	Excitation System (360KW)	Set	1	10,600	10,600	3,816,000.00
10	Excitation System (872KW)	Set	2	25,900	51,800	18,648,000.00
11	Automatic Component for 360 KW	Set	1	6,900	6,900	2,484,000.00
12	Automatic Component for 872 KW	Set	2	16,800	33,600	12,096,000.00
13	Provide for Earthing of all Electrical System in the Power house and switch yard	Lump	Sum	1500	1,500	540,000.00
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	59,400,000.00
15	33KV overhead line with 120 mm2 Alluminium Bare Conductor (ACSR) and concrete poles	Spans	25	3,500	87,500	31,500,000.00
16	Metering Panels to include Ammeters, Voltmeters, KW meters, pf meters, frequency meters, tri – vector meters, speed indicators, Temperature indicators,Gate valve opening position	Nos	3	1,500	4,500	1,620,000.00
17	Synchronization panel to include relevant meters	Nos	1	120,000	120,000	43,200,000.00
18	4 x 500mm2 PVC/SWA/PVC (armoured cable)	M	200	200	40,000	14,400,000.00
19	1 x 150mm2 XLPE Cable(33KV)	M	100	80	8,000	2,880,000.00
20	Freight Cost	Lump	Sum	10,000	10,000	3,600,000.00
21	Insurance and duty	Lump	Sum	2,000	2,000	720,000.00
	Sub Total				1,265,350	455,526,000.00

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

Unskilled=2,000 / day
Semi-skilled=3,000/ day
Skilled=4,000 / day.

Table 15 Summary of the total cost (Civil, Electromechanical, Administrative, Labour etc)

Summary		
S/no	**Description**	**Amount**
1.	SETTING OUT AND PLANT	650,000.00
Sub-structure		
2.	Excavation and Earth Works	1,242,250.00
3.	Concrete Works	3,553,000.00
4.	Block Work	187,500.00
Super- structure		
5.	Concrete works	957,900.00
6.	Block Works	225,000.00
7.	Roof Works	1,110,000.00
8.	Doors and Windows	208,000.00
9.	Finishing	648,000.00
10.	Electrical Works	1,100,000.00
11.	Pipe Works	37,410,000.00
12.	Subtotal civil works	47,291,650.00
13.	Electro-Mechanical works	455,526,000.00
14.	SUB – TOTAL	502,817,650.00
15.	10% Contigency	50,281,765.00
16.	Total	553,099,415.00
17.	5% VAT	27,654,970.75
18.	Sub-Grand Total	580,754,385.75
19.	Supervision	29,899,917.54
20.	Project vehicle + Running cost	16,191,360.28
	GRAND TOTAL	626,845,663.57

4.10 Environmental Impact Assessment

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 via:

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

4.10.1 Construction Phase

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 Okinni- dam from the villages.

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.

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.

4.10.2 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 methodology.

4.10.3 Environmental Management Plan:

The small-hydropower plant is eco-friendly 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.

4.10.4 Environmental Monitoring:

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

- Socio – economics
- Occupational health
- Ecological effects on fishes and fauna

4.10.5 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.

4.10.6 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.

4.10.7 Completion

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 Headwork 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 centre that could be considered by the state government.

4.10.8 Power Evacuation/ Distribution

The power generated is at 415V, 50Hz, 0.8pf a common bus bar 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

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

4.10.10 Cable Size

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

Peak power (Rainy season) = 1916KW

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

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

5 Conclusion

The Okinni Dam is suitable for the development of Small Hydro Power (SHP). The installation of 1x 360 KW and 2x 778 KW turbines is considered appropriate taken into consideration the design data/parameters. 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. Natural occurring construction materials are available within the environment of Okinni Dam. The proposed scheme has minimum interface with the environment and hence would not affect the ecology of the area. 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. The SHP scheme will further clean the environment by avoiding the burning of 515 litres of diesel oil per hour, with its attendant pollution effect.

Recommendations

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. Also, capacity building in SHP project in areas such as civil work, water management, Electro-mechanical etc is recommended for the sustainability of the project.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest.

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