Assessment of Potential of River Lunko, Gidan Kwano (Niger State) for hydropower generation and domestic water supply

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Abstract

In this study, the hydropower potentials of streams in the Gidan Kwano area of the Federal University of Technology, Minna were assessed. The catchment has no stream gauging station. The flow characteristics of the catchment was determined using the flow records 2013 and 2014 from a neighbouring gauging station and discharge area ratio technique. The total estimated water yield is 6 million cubic metres. A development scheme for harnessing the water for hydropower and water supply was proposed. Reservoir analysis showed that 1500m^3 of water per day can be released from Lunko reservoir for power generation. This will generate 8.4 Kwhr for a 4 hour period and provide water to 12,500 persons at consumption rate of 120 liter per capita per day. If these streams are properly harnessed using small hydropower technologies, they can go a long way in solving the water problem in the University as well as boosting the available power supply.

Keywords: *Hydropower Potential, River Lunkko, Gidan Kwano.*

Introduction

Power is a very important tool for the infrastructural development of a nation as power shortage can hinder economic and social development (Okoye, 2007). A functional energy generation system often serves as an effective tool for national economic development (Lawal, 2009). The development of any country is largely dependent on the optimal utilization of the available energy resources (Bashir, 2003). Energy has always been critical for economic growth, social development and poverty reduction. In 1960, Nigeria had a population of about 45.2 million people (PGDA, 2010). Currently, Nigeria has a population of over 177 million people (PRB, 2014). The energy demand was estimated to be about 900MW (Audu and Apere, 2013). The generation potential of the three hydropower plants (Kainji, Jebba and Shiroro) and thermal plants (Egbin, Delta, Sapele, Geregu, Omotosho, Olorunshogo, Afam, Ijora and Orji) is about 7022MW (Titus *et al.*, 2012). The utilization capacity is sometimes less than 10% due to maintenance, lack of gas for the thermal plants and vandalisation (NPBR, 2015). For example, Ilori (2004) reported that total installed capacity of power generation plants in Nigeria was 5,876 MW in 1999 but the available power generation was only 1600 MW. Table 1 shows a summary of plants in the country.

Table 1: Installed Capacity of Power Stations in Nigeria

No	Power station	Installed capacity (MW)	Mode of operation
1	Afam Thermal Power Station	700.9	Gas
2	Delta Thermal Power Station	812	Gas
3	Egbin Thermal Power Station	1320	Steam
4	Ijora Thermal Power Station	66.7	Gas
5	Sapele Thermal Power Station	1020	Steam (6 units) Gas (4 units)
6	Jebba Hydropower Station	540	Water
7	Kainji Hydropower Station	760	Water
8	Shiroro Hydropower Station	600	Water
9	Oji River Power Station	30	Coal
10	Isolated Power Station	10.3	Fuel (Diesel)
11	Geregu Thermal Power Station	434	Gas
12	Omotosho Thermal Power Station	335	Gas
13	Olorunshogo/Papalato Thermal Power Station	335	Gas
14	Okpai Power Station		Gas
15	Omoku Power Station		Gas
16	Ajaokuta Power Station		Gas

(Source: Adeleye, 1997, Obadote, 2009 and Titus *et al.*, 2012)

The ever increasing population translates to an increase in the demand for energy and this obviously has economic implications. The rate of growth of GNP depends on the efficiency of energy production and utilization (Igbinovia and Orukpe, 2007). Hydroelectric energy is a renewable energy source which relies on the natural water cycle, and the flow of water due to gravity. It is beneficial to Nigeria and could be harnessed to address the shortage of energy because there are many rivers that are appropriate for HEP dams. Currently, Nigeria develops 23% of her feasible hydropower. This is very low compared to other African countries such as Lesotho (50%); Bukina Faso (46%) and Kenya (34%).About half of the Nigerian population remain literally in the dark without access to electricity. The majority of these numbers are in the rural areas. Nigeria has considerable hydro potential sources exemplified by her large rivers, small rivers and streams and the various river basins being developed. Nigeria has rivers distributed all over the country with potential sites for hydropower schemes which can serve the urban, rural and isolated communities (Zarma, 2006, Adedokun *et al.*, 2013). Small hydropower development continues to be an attractive resource, especially in rural areas (Arthur, 2014). Studies (Okpanefe and Owolabi, 2002 and Zarma, 2006) have shown that SHP potential sites exist in virtually all parts of Nigeria. There are over 278 unexploited sites with total potentials of 734.3 MW. In the light of the above, the aim of this paper therefore, is to assess the suitability of River Lunko for the purpose of power generation and utilize the tail run for water supply to the Federal University of Technology Minna Main Campus Gidan Kwano.

Methodology

The Study Area

The Federal University of Technology Minna Main Campus, Gidan Kwano is located along kilometer10 Minna Bida road, South East of Minna Niger State. It has a land mass of eighteen thousand nine hundred hectares (18,900ha) and is located within the Gidan Kwano Inland Valley East of Minna in Bosso Local Government Area of Niger State. It lies between latitudes 9°15″ to 9°45″ N and Longitudes 6°15″ to 6°45″ E. The study area is classified as part of the tropical climate with alternating but distinct wet and dry seasons, with heavy rainfall in the wet season and little or no rainfall in the dry season. The total annual rainfall in this area is between 1270 mm and 1524 mm, spread over the months of April to October (McCurry, 1973). The average rainfall is about 1400mm. (NIMET, 2014). The town has a mean annual rainfall of 1334 mm (52 inches) taken from an exceptionally long record of 54 years. The highest mean monthly rainfall is in September with almost 300 mm (11.7 inches). The rainy season starts on average around April and lasts about 180-200 days (Ajibade, 1982).The average annual rainfall in the area is 1,200 mm. The river is ephemeral, with flow during rainy season (April to October).

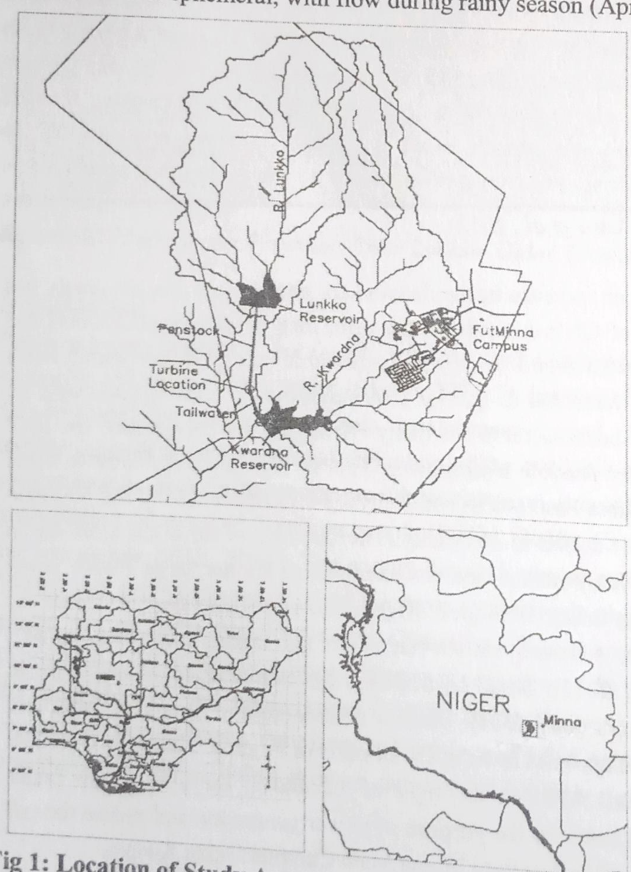

Fig 1: Location of Study Area

The elevation of the basin varies between 190 m and 230 m above sea level in the west and drops slightly to about 220 m in the North-Eastern part. It consists of low-lying terrains and a few gentle hills. The central part is remarkable for its alternating rugged and undulating landscape which is perhaps responsible for the profuse rock outcrop in this part. Most of these outcrops occur as relatively low-hills and ridges with huge masses of fragmented granite boulders. Most of the study area is drained by the Dagga River system flowing in the North East – South West directions. Rivers Kwardna and Lunkko are tributaries of River Dagga. They are seasonal streams. Two right bank tributaries of the rivers Weminafia, Kwardna and

Lunkko drain most of the Northern and the entire middle area into the main river. These run predominantly North-South. Two other left bank tributaries drain the Southern part in a general East-West direction.

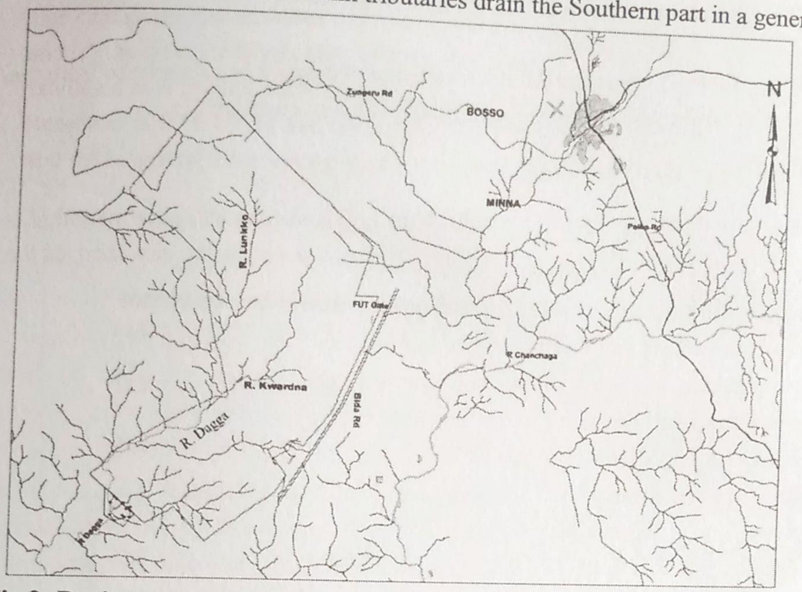

Fig 2: Drainage system of Dagga Area

Data Collection

In assessing the available hydropower potential of river Lunko, rainfall and evaporation data was collected from Nigeria Meteorological Agency (NIMET) Minna station (9.65167°N, 6.46194°E), Upper Niger River Basin Development Authority (UNRBA) Minna station (9.3700°N, 6.3200°E) and Geography Department of the Federal University of Technology Minna station (9.63778°N, 6.5200°E). Stream flow records from a gauging station on River Dagga at Latitude 9.462537°N and Longitude 6.37437°E were collected for analysis. Topographical maps were collected from the office of the Surveyor General of the Federation (2010 and 2012).The topographic maps collected were Minna Sheet 164 NE on a scale of 1:100,000 and parts sheets 163 Zungeru South East and 184 Bida North East on a scale of 1:50,000. ASTER30 DEM data covering the area was sourced from the Land Processes Distributed Active Archive Center (LP DAAC) and J-space systems (ASTER GDEM page). The DEM gives contour at 30m interval. Reconnaissance survey of river Lunko was carried out to access a suitable site for the reservoir. During the survey, the site characteristics as well as the surrounding environmental and land-use constraints were taken into account. Ground-truth of the elevation was carried out. A contour map of the reservoir area was developed. The capacity of the reservoir was assessed for varying dam heights. Then, a depth-capacity curve was drawn to choose the optimum full supply level. The power potential was calculated using a development scheme that will allow the tailwater to fill a water supply reservoir (Kwardna Reservoir) downstream of the Lunko Reservoir (Fig. 3). The potential pipeline route from Lunko Reservoir to Kwardna Reservoir was selected to optimize power potential and avoid significant environmental impact. The monthly water yield of the Lunko catchment was assessed using drainage area ratio method (Sule and Jimoh, 1992, Smakhtin and Masse, 2000) to transfer stream flow records from River Dagga to River Lunko. It was based on the assumption that the ratio of streamflows of the gauged and the ungauged sites are equal to the ratios of their drainage areas. River Lunko is a tributary of River Dagga. The catchment area of Lunko catchment at the proposed dam site is 19.81 km^2, while that of Dagga at the gauging point is 100 km^2.

$$Q_U = (A_u/A_g)^b Q_g \qquad (1)$$

where Q_U is the estimated daily stream flow at the ungauged site, Q_g is daily stream flow at the gauged site, A_g is the drainage area of the gauged site, A_u is the drainage area of the ungauged sites, b is an exponent which varies widely ranges from 0.5 to 0.85. The exponent (b=0.5) was adopted based on the work of Sule and Jimoh (1992) in Gurara River Basin at Jere Kaduna State.

A monthly water balance analysis (Table 2) was carried out to determine the monthly safe release from the reservoir for power generation. The power potential was then calculated using equation (2).

$$P = \eta \gamma Q H \quad (2)$$

Where *P is the* Power (KW), η is efficiency, γ = Specific weight (N/m^3), *Q is the* discharge (m^3/s) and *H is the head* (m) available for power generation (this is equal to the difference between the elevation of the outlet at Lunko and the turbine at Kwardna).

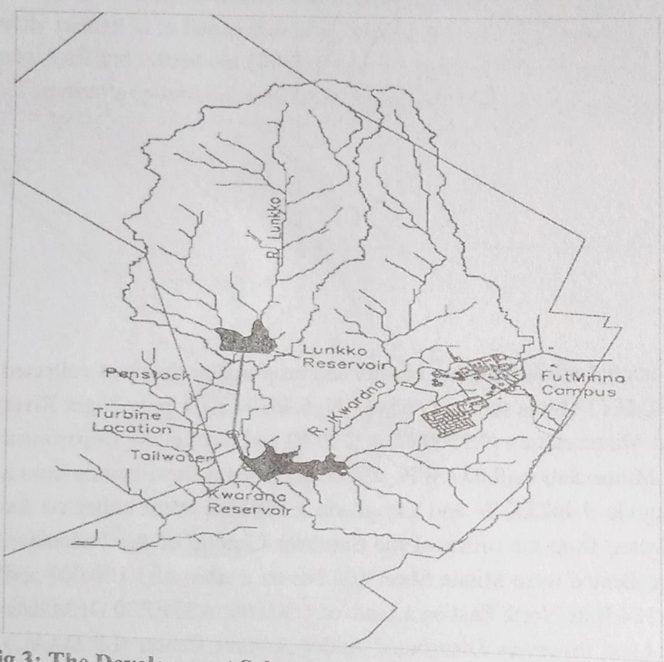

Fig 3: The Development Scheme

Table 2: Water Balance Analysis (Miloradov, 1995)

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6
Month	Capacity at beginning of month	Surface area	Evaporation and other losses	Monthly release for power generation and water supply	Capacity at end of month
October	Full reservoir				
November					Col 2 – Col 4 – Col 5
December					

Col 2 surface area of reservoir equivalent to the capacity
Col 3 determined based on average daily rate of evapotranspiration in the area

Results and Discussion

The catchment characteristics of Lunko are: (a) area is 19.81 km^2, (b) length of longest river is 8.711 km and (c) the distance from outlet to the centroid along the river is 3.6 km. The yield of Lunko catchment was estimated as 6 million cubic metres. The area-capacity curve (Fig. 4) shows that the capacity of the Lunko Reservoir is 0.58 MCM and the height of the dam is 7 m. The surface area of the reservoir is 310,000 m^2 and the length of the reservoir is 953 m. A monthly water balance for the reservoir is presented in Table 3.

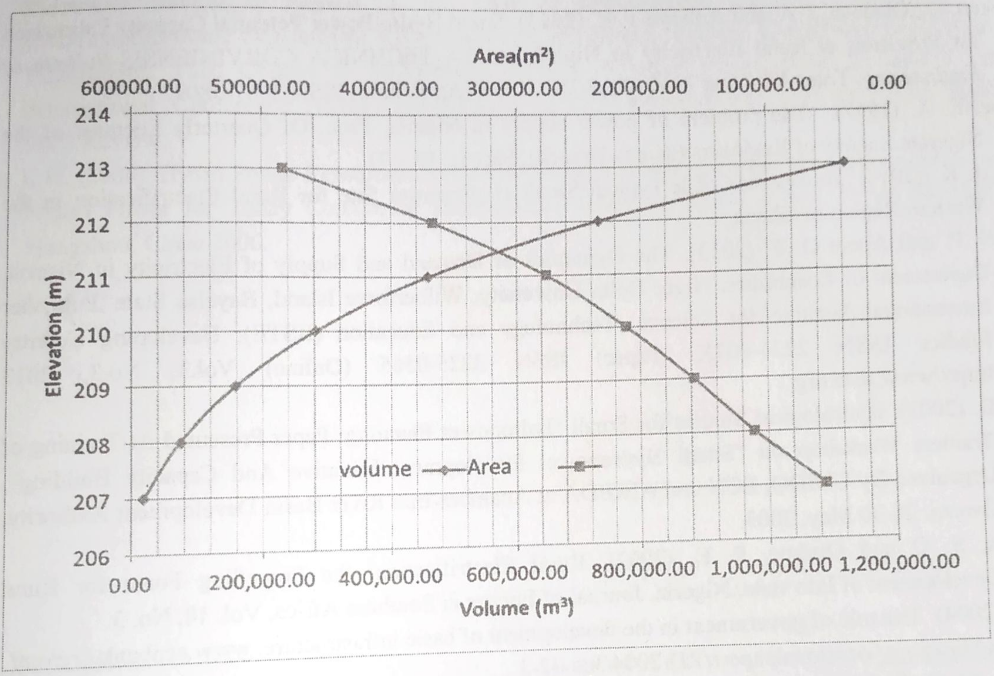

Fig. 4: Elevation Area Capacity Curve for Lunkko Catchment

A monthly discharge of 46,500 m^3/day equivalent to 1,500m^3/day of water would be released between October and March from the reservoir, and from April to September during the rainy season as the reservoir is filled. This discharge can satisfy the water demand of 12,500 people in the Gidan Kwano campus of the university, with a daily consumption rate of 120 litres per capita per day. It was however, observed that the evaporation loss is high because it is a shallow reservoir, with a low capacity to area ratio. This is due to the high temperatures and incoming solar radiations in the months of March to September (Dry season). The release is equivalent to 0.42 m^3/s for a 24-hr plant and 2.5 m^3/s for 4-hr plant. Power generation should be based on 4-hr run. The power potential is equivalent to 8.4KWhr for a 4 hour period.

Table 3: Monthly water balance for Lunko Reservoir

Month	Volume at beginning of month (m^3)	Surface Area (m^2)	Evaporation and Other Losses (m^3/month)	Release for Economic Use (m^3)/month	Volume at the end of month (m^3)
October	580,000	310,000	42,284	46,500	491,216
November	491,216	290,000	43,500	45,000	402,716
December	402,716	255,000	43,478	46,500	312,739
January	312,739	220,000	47,740	46,500	218,499
February	218,499	180,000	36,288	42,000	140,211
March	140.211	150,000	41,850	46,500	51,861

Conclusion

The study has shown that river Lunko can be harnessed to generate 8.4 Kw/hr of power for a 4 hour period and supply 12500 people with a daily consumption rate of 120 l/c/d water. Therefore, it is recommended that the economic potentials of the river and other rivers within the university should be harnessed to address the inadequate water and power supply to the university.

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