FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

HYDROMETEOROLOGY: ENHANCING THE CAPACITY FOR HYDROELECTRICITY GENERATION IN OUR HOMES AND INDUSTRIES

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BTech, MTech, PhD (Minna)
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INAUGURAL LECTURE SERIES 36

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This 36th Inaugural Lecture was delivered under the Chairmanship of:

Professor M. A. Akanji, FNSMBM
Vice-Chancellor
Federal University of Technology, Minna

Published by:
University Seminar and Colloquium Committee,
Federal University of Technology, Minna.

27th August, 2015

Design + Print:
Global Links Communications, Nigeria
✆: 08056074844, 07036446818

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1.0 INTRODUCTION

Nigeria is endowed with sufficient energy resources to meet its present and future development requirements. The country possesses the world's sixth largest reserve of crude oil. It is increasingly an important gas province with proven reserves of nearly 5,000 billion cubic meters. Identified hydroelectricity sites have an estimated capacity of about 14,250MW. Nigeria has significant biomass resources to meet both traditional and modern energy uses, including electricity generation. The country is exposed to a high solar radiation level with an annual average of 3.5 to 7.0 $kWh/m^2/day$. Wind resources in Nigeria are however poor to moderate and efforts are yet to be made to test their commercial competitiveness. Hydropower is one of the leading sources of electricity production in many countries, including Nigeria. It is clean and renewable (Mohammed, 2013).

Slogan for Sustainability:

> *"You can't always get what you want,*
> *But if you try sometimes, you just might find*
> *You get what you need."*

Surface water is the main natural source of water for hydropower generation. Nigeria is blessed with a number of rivers and streams which are either seasonal or perennial. The Rivers Niger and Benue with several tributaries such as Sokoto, Gurara, Gongola and Kaduna constitute the Nigeria river systems which offer some potential renewable sources of energy for economically viable large hydropower development. The total potential surface water resources of Nigeria from these rivers and streams are estimated at 240,464 m^3/sec (Mohammed, 2013).

In the glorious Qur'an, Surah, Al-Anbiya, 21:30 that every living thing has been made from water. Allah said *"We made from water every living thing."*

There are many problems associated with hydropower generation in Nigeria; the current infrastructure of the hydropower plants are in dire need of rehabilitation and the actual energy output of the plants are far below their projected capacity. The current installed capacity of grid electricity is about 6,000MW, of which about 67 percent is thermal and the balance is hydro-based. The combined installed capacity of the three major hydropower dams (Kainji, Jebba and Shiroro) is 1,900MW. The systems have been performing below expectation and could be as low as 30 percent. For example, power output in Nigeria in recent times has been erratic despite the fact that electricity came to Nigeria in 1896; 15 years after it was introduced in England. However, to date, the total electric energy generated in Nigeria has been lingering between 3,000 megawatts and 4,000 megawatts. Climate form a significant part of this problem. Other causes include maintenance, financial and political problems. Generating plant capability is low and the demand and supply gap is crippling. This poor performance has negatively affected the industrial, commercial and domestic sub-sectors of our national economic lives.

Adequate preparations to forestall the adverse impact of hydrology and meteorology on hydroelectric power generation in Nigeria can only be meaningful if they are backed by proper scientific research (Mohammed, 2013).

2.0 HYDROMETEOROLOGY

Hydrometeorology is the science that studies the cycle of water. It is intimately related to the science of meteorology, hydrology and climatology. The hydrometeorology studies the processes of the hydrological cycle that occur in the atmosphere (evaporation, condensation and precipitation) and in the ground (rainfall interception, infiltration and surface runoff) and their interactions. The science of hydrometeorology studies the behaviour of hydrologic elements, such as rivers, ponds and dams. It also concerns the physics, mathematics, and statistics of processes and phenomena involved in exchanges between the atmosphere and ground that typically occur over hours or days, and how the time average of these exchanges combine to define hydrometeorology. This science aims to understand the hydrometeorological phenomena. It is also its realm, to develop tools for water management and for the observation and prediction of hydrometeorological phenomena and to develop models to help in the early detection and warning of floods.

2.1 Hydrology Defined

In its broadest sense, hydrology is the scientific study of water. Because water is an important element of the physical environment, it is studied in one form or the other by practitioners of various disciplines concerned with the physical environment. Water occurs in various forms and locations in the environment and these are connected together by complex processes to form what is known as the hydrological or water cycle. Hydrology is therefore a very broad and interdisciplinary science. Hydrology can be viewed as the scientific study of the water cycle. It is a discipline that studies the properties, occurrence, distribution and movement of water on and beneath the land surface.

Wisler and Brater (1959) defined hydrology as the science that deals with the processes governing the depletion and replenishment of the water resources of the land areas of the world. The *ad hoc* panel on hydrology of the Federal Council for Science and Technology in the United States recommended the following definition of hydrology in 1962:

> "The science that treats of the waters of the earth, their occurrence, circulation and distribution, their chemical and physical properties and their reaction with their environment including their

relation to living things. The domain of hydrology embraces the full life history of water on the earth".

The above definition has practically been adopted world-wide.

Also, the Qur'an told us about the source of springs in the earth; God says: (*See you not that Allah sends down water (rain) from the sky, and causes it to penetrate the earth, [and then makes it to spring up] as water-springs)* (Sûrat Az-Zumar - verse 21). This verse tells us that the source of springs is the water of rain and that is the opposite to the belief of some people who believed that the source of these springs is the sea.

It is quite clear from the above that the scope of hydrology is very wide. What professional hydrologists study is, however, more restricted than the scope of the above and other definitions of the subject. The International Association for Scientific Hydrology recognizes four distinct branches of the subject, of which surface and groundwater have received the greatest attention.

These four branches are:

- surface water
- groundwater
- snow and ice
- limnology – the study of lakes.

Because water, the focus of the study of hydrology, is an ubiquitous element of the natural environment, hydrology traverses the domains of several environmental science subjects such as meteorology, geology, glaciology, oceanography and ecology. Also, scientific hydrology underlies the development, utilization and control of water resources. It therefore has some relationship with social science subjects like economics, political science and sociology. Applications of hydrology are numerous and varied. Hydrology has practical applications in water resources development and management, flood prediction and forecasting, watershed management, design of water control structures and drainage systems, salinity control and pollution abatement among others. These areas make up applied hydrology, although it is often difficult to distinguish between the principles of hydrology and the applications of such principles in the real world (Ayoade, 1988).

2.1.1 Hydrological cycle

As illustrated in Figure 1, the annual average hydrological cycle for the Earth as a whole, together with an alternative set of estimates of water stored made by combining observations with model-calculated data. It is clear that the simple concept of a hydrological cycle that merely involves water evaporating from the ocean, falling as precipitation over land then running back to the ocean is a poor representation of the truth. There are also substantial hydrological cycles over the oceans which cover about 70% of the globe, and over the continents which cover the remainder, as well as water exchanged in atmospheric and river flows between these two.

On average, there is a net transfer from oceanic to continental surfaces because the oceans evaporate about 413×10^3 $km^3 yr^{-1}$ of water, which is equivalent to about 1200 mm of evaporation, but they receive back only about 90% of this as precipitation. Some of the water evaporated from the ocean is therefore transported over land and falls as precipitation, but on average about 65% of this terrestrial precipitation is then re-evaporated and this provides some of the water subsequently falling as precipitation elsewhere over land. On average, about 35% of terrestrial precipitation returns to the ocean as surface runoff, but the proportion of terrestrial precipitation that is re-evaporated and the proportion leaving as surface runoff.

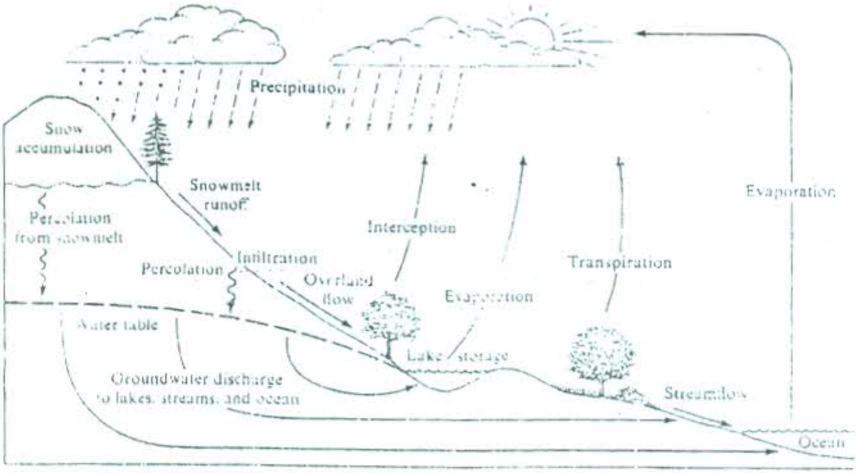

Figure 1: Hydrological Cycle
Source: Adopted from Thomas and Luna (1978)

2.2 Meteorology Defined

Meteorology is the science of the weather. It is a science that deals with the atmosphere and its phenomena and especially with weather and weather forecasting.

Allah said about source of water *"And we sent down from the sky water (rain) in (due) measure, and we gave it lodging in the earth, and verily, we are Able to take it away.)* (Sûrat Al-Mu'minun – verse 18).

A lot of Nigerians have misconception on the subject of meteorology because they believe that it deals with only landing and take-off of aircrafts in our airports (Aviation meteorology). The concept is far from that as the subject covers areas such as agricultural meteorology, aviation meteorology, marine meteorology, dynamic meteorology and synoptic meteorology, etc.

Meteorology in Nigeria is fast gaining ground in the areas of aviation, transportation, agriculture and water resources management. There are many meteorological stations spread around the country owned by both public and private institutions. Some are automated while others are conventional (Abubakar, 2010).

The meteorological elements under constant observation include precipitation (rainfall), evaporation, temperature (ambient, soil temperature, max, min, grass min), visibility, sunshine, radiation, cloud, wind (speed and direction), relative humidity, dew point, temperature, vapour pressure. The meteorological parameters mentioned are very important depending on the area of need.

Also, there is another verse as God be He exalted says: *(And We send the winds fertilizing (to fill heavily the clouds with water), then cause the water (rain) to descend from the sky, and We gave it to you to drink, and it is not you who are the owners of its stores [i.e. to give water to whom you like or to withhold it from whom you like])* (Sûrat A-Hijr – verse 22).

3.0 ELECTRICITY USE IN OUR HOMES AND INDUSTRIES

It is very clear that the use of electricity in our homes and industries has become very important part of our lives. We cannot effectively carry out many activities either in our homes, offices or industries if there is no electricity. The contribution of hydroelectric power generation to our socio-economic well-being has become very imperative.

3.1 Use of Electricity in Our Homes/Offices

Without electricity, our stay at home and office would have been miserable. Electricity is the major source of power to most appliances in the office and at home. Some of those appliances make our work easier in terms of washing, cooking, cutting, slicing, pumping, grinding, mixing, etc. For us to enjoy watching and listening to television and radio, electricity is required. We also need electricity to iron the clothes we wear. The air conditioning systems also need to be powered by electricity.

In our offices, electricity is very important as it powers almost all the office appliances such as air conditioners, refrigerators, computers, television and fans, etc. Without electricity supply our homes and offices will be a miserable and frustrating place to be. One is not expected to give in his/her best once there is power outage.

3.2 Use of Electricity in Industries

Industries require constant supply of electricity to function, as heavy duty machines, and light machines must work during production.

It is very clear that electrification is a prerequisite to modern industrialization; hence we cannot minimize the importance of this notion. It is quite clear that there is no nation which can develop and industrialize without sound electric base. Today we depend on electricity for basic needs such as food, water, shelter, communication, employment and health care. Those needs are served by infrastructures for food preservation, water treatment, heat and light, phone service, internet, offices, factories, hospitals and emergency response, to name a few. Yet all of these essentials cannot function well without electricity. We could easily argue that population growth is fueling the growth in electricity demand. The developing world is rapidly catching up to the electricity hungry lifestyle of the industrialized world, through the electrification of everything which increases the dominance of electricity as the preferred form of energy. Several developments have driven electricity into every aspect of our lives, most notably motors, microprocessors and microwaves. And now another massive change is about to begin; the switch to electric transportation. In an economic sense, energy performances add value to intermediate products as they are progressively transformed into final consumer goods, electric power is of fundamental importance to the economic, social and industrial development of a nation. Electric power is so vital to all aspects of human life; production and service delivery contribute no small measures to the standard of living, such as the right to an adequate standard of living cannot be realized without general electrification. Electric power is properly considered as a key element of the so called Second Industrial Revolution, having considered agriculture to be the first industrial revolution, modern industrial societies are commonly described as energy intensive, which is, perfectly accurate. A central feature of industrial development over the past two decades is that it has been characterized by a growth in the amount of energy utilization per worker, or per person. Electricity's rapid rise to dominance as a source of industrial power was based on a number of compelling advantages. First and foremost, electricity could be packaged in almost any size. In terms of availability, future prospects for electricity appear to be reassuring. "In the industrial world, electricity is widely available to prices that are typically lower in real terms than they were twenty years ago". The demand for energy in this particular form is further reinforced by its energy saving role that has been emphasized thoroughly, as well as its labor saving features that have been neglected.

Moreover, the many possibilities for building "environmentally friendly" new technologies on electrical foundations appear likely to enhance the demand for electricity.

Industrialization, on the other hand, is the transformation of a society or country from a primarily agricultural society into one based on the manufacturing of goods and services. Industrialization includes the use of technological innovation to solve problems as opposed to superstition or dependency upon conditions outside human control such as the weather, as well as more division of labor and economic growth. An area where industrialization had a massive effect was in Eastern Europe. It emerged as a need to modernize and unify Europe. Although Britain led industrialization at first, it quickly exploded from Spain all the way through Russia. Industrialization has brought many changes and even modernized most countries; it also had its negative effects. It is evident that the positive effects outweigh the negative. If not for industrialization, most of Europe would be in the dark. And industrialization also made the world much smaller by most of the inventions such as the steam engine and mass expansion of railroads.

The poor generation of electricity in Nigeria has led to the dearth of many industries in Nigeria. The demand for electricity is estimated to be about 4500MW. However, the present generation level is below 3000MW. There is about 2400MW of self-generation in the form of small diesel and petrol generating sets. The estimated percentage of Nigerians having access to electricity from PHCN is lower than 40% (Mohammed, 2013).

3.3 Electricity Distribution Companies in Nigeria

The government of Nigeria as at April 2014 approved about eleven electric distribution companies to serve different states:

Table 1: Electricity Distribution Companies in Nigeria

Name	Address	States
Abuja Electricity Distribution Company	Wuse Zone 4, Abuja	FCT, Niger, Kogi and Nasarawa
Benin Electricity Distribution Company	No. 5, Akpakpava Street, Benin-City	Edo, Delta, Ondo, and part of Ekiti
Eko Electricity Distribution Company	24/25 Marina, Lagos	Lagos
Enugu Electricity Distribution Company	No. 12, Station Road, Okpara Avenue, Enugu	Enugu, Abia, Imo, Anambra, and Ebonyi
Ibadan Electricity Distribution Company	Capital Building, 115 Ring Road, Ibadan	Oyo, Ogun, Osun, Kwara and part of Ekiti
Ikeja Electricity Distribution Company	Secretariat Road, Alausa, Ikeja	Lagos
Jos Electricity Distribution Company	No. 9, Ahmadu Bello Way, Jos	Plateau, Bauchi, Benue and Gombe
Kaduna Electricity Distribution Company	Nagwamatse Building, Ahmadu Bello Way, Kaduna	Kaduna, Sokoto, Kebbi, and Zamfara
Kano Electricity Distribution Company	No. 1, Niger Street, P.M.B. 3089, Kano	Kano, Jigawa and Katsina
Port Harcourt Electricity Distribution Company	No. 42, Obiwali Road, Rumuigbo, Port Harcourt	Rivers, Cross River, Bayelsa and Akwa Ibom
Yola Electricity Distribution Company	No. 2, Atiku Abubakar Road, Jimeta, Yola	Adamawa, Borno, Taraba and Yobe

Source: Adopted from Wikipedia (2015)

4.0 DAMS

A dam is a barrier that impounds water or underground streams. The reservoirs created by dams not only suppress floods but provide water for various needs to include irrigation, human consumption, industrial use, aquaculture and navigability. Hydropower is often used in conjunction with dams to generate electricity. A dam can also be used to collect water or for storage of water which can be evenly distributed between locations. Dams generally serve the primary purpose of retaining water, while other structures such as floodgates or levees (also known as dikes) are used to manage or prevent water flow into specific land regions (Abubakar, 2000a).

Early dam building took place in Mesopotamia and the Middle East. Dams were used to control the water level, for

Mesopotamia's weather affected the Tigris and Euphrates rivers, and could be quite unpredictable. The earliest known dam is the Jawa Dam in Jordan, 100 kilometres (62 mi) northeast of the capital Amman. This gravity dam featured an originally 9 m (30 ft) high and 1 m (3 ft 3 in) wide stone wall, supported by a 50 m (160 ft) wide earth rampart. The structure is dated to 3000 BC (Wikipedia, 2015).

4.1 List of Dams and Reservoirs in Nigeria

Dams and reservoirs in Nigeria are used for irrigation, water supply, hydro-electric power generation or some combination. They are of particular importance in the north of the country, where rainfall is low (Abubakar, 2000a).

Table 2: List of Some Large Dams in Nigeria

State	Dam	Capacity Millions of m^3	Surface Area Hectares	Primary Usage
Osun State	Ede-Erinle Reservoir		---	Water supply
Oyo State	Asejire Reservoir		2,369	Water supply
Sokoto State	Bakolori Dam	450	8,000	Irrigation
Kano State	Challawa Gorge Dam	930	10,117	Water supply
Gombe State	DadinKowa Dam	2,800	29,000	Water supply
Sokoto State	Goronyo Dam	942	20,000	Irrigation
Oyo State	Ikere Gorge Dam	690	4,700	Hydro-electric, water supply
Niger State	Jebba Dam	3,600	35,000	Hydro-electric power
Katsina State	Jibiya Dam	142	4,000	Water supply, irrigation
Bauchi State	KafinZaki Dam	2,700	22,000	Planned irrigation
Niger State	Kainji Dam	15,000	130,000	Hydro-electric
Adamawa State	Kiri Dam	615	11,500	Irrigation, plans for hydro-electric
Ogun State	Oyan River Dam	270	4,000	Water supply, irrigation, hydro-electric
Niger State	Shiroro Dam		31,200	Hydro-electric power
Kano State	Tiga Dam	1,874	17,800	Irrigation, water supply
Kebbi State	Zauro Polder Project			Irrigation
Katsina State	Zobe Dam	177	5,000	Water supply

Source: Abubakar (2000b)

Table 3: Hydroelectric Dams in Nigeria

Kainji Power Station Reservoir	800 MW	1968	Kainji Lake, Niger River
Jebba Power Station Reservoir	540 MW	1985	Lake Jebba, Niger River
Shiroro Power Station Reservoir	600 MW	1990	Lake Shiroro, Kaduna River
Kano Power Station Reservoir	100 MW	2015	Hadeija River
Zamfara Power Station Reservoir	100 MW	2012	Gotowa Lake, Bunsuru River
Kiri Power Station Reservoir	35 MW	2016	Benue River
Mambilla Power Station Taraba State 6°41'46"N 11°09'16"E Reservoir	3050 MW	2018	Gembu, Sum Sum and Nghu Lake, Donga River

Source: Abubakar (2000a)

4.2 Rivers Kaduna and Niger

4.2.1 River Kaduna

Kaduna River, main tributary to the Niger River in central Nigeria. It rises on the Jos Plateau 18 miles (29 km) southwest of Jos town near Vom and flows in a northwest direction to a bend 22 miles (35 km) northeast of Kaduna town. It then adopts a southwest and southerly course before completing its 340-mile (550-kilometre) flow to the Niger at Nupeko. Most of its course passes through open savanna woodland, but its lower section has cut several gorges (including the 2-mile granite ravine at Shiroro) above its entrance into the extensive Niger floodplains (Abubakar, 2000b).

The Kaduna (meaning 'crocodiles' in the Gbagyi language) is subject to great seasonal fluctuations and is navigable below Zungeru from July to October for light craft; it is used for fishing and for transport of local product. The Gbagyi people have utilized the Kaduna's upper flood plains for swamp rice cultivation, and in the southern plains, in Nupe tribal territory, rice and sugarcane production has become a major economic activity.

4.2.2 River Niger

River Niger is the Principal River of Western Africa. With a length of 2,600 miles (4,200 km), it is the third longest river in Africa, after the Nile and the Congo. The Niger is believed to have been named by the Greeks. Along its course, it is known by several names. These include the Joliba (Malinke: "Great River") in its upper course; the Mayo Balleo and the Isa Eghirren in its central reach; and the Kwarra, Kworra, or Quorra in its lower stretch.

The Niger rises in Guinea at 9°05' N and 10°47' W on the eastern side of the Fouta Djallon (Guinea) highlands, only 150 miles (240 km) inland from the Atlantic Ocean. Issuing as the Tembi from a deep ravine 2,800 feet (850 metres) above sea level, it flows due north over the first 100 miles (160 km). It then follows a northeasterly direction, during the course of which it receives its upper tributaries – the Mafao, the Niandan, the Milo, and the Sankarani on the right and the Tinkisso on the left – and enters Mali. Just below Bamako, Mali's capital, the Sotuba Dam marks the end of the Upper River. From there the Niger once dropped more than 1,000 feet (300 metres) in about 40 miles (60 km) into a valley formed by tectonic subsidence; but the rapids in this stretch have been submerged by the waters backed up by the Markala Dam, located some 150 miles (240 km) downstream of the Sotuba Dam near Sansanding. In this stretch, at Koulikoro, the river takes a more east-northeasterly direction, and its bed becomes fairly free from impediments for about 1,000 miles (1,600 km).

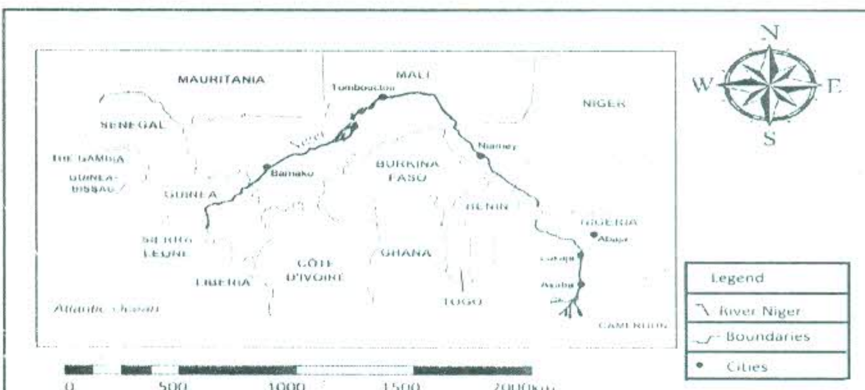

Figure 2: River Niger *Source: Abubakar (2010)*

At Mopti, the Niger is joined by the Bani, its largest tributary on the right, after which it enters a region of lakes, creeks, and backwaters that is often called the "internal delta" of the Niger. These lakes are chiefly on the left bank and are connected to the river by channels that undergo seasonal changes in the direction of flow. At high water, most of the lakes become part of a general inundation. Largest of the lakes in this region is Lake Faguibine, which is nearly 75 miles (120 km) long, 15 miles (25 km) wide, and more than 160 feet (50 metres) deep in places.

The labyrinth of lakes, creeks, and backwaters comes to an end at Kabara, the port of Timbuktu (Tombouctou). There, the river turns almost due east, passing its most northern point at latitude 17°05' N. Some 250 miles (400 km) downstream from Timbuktu, a rocky ridge that obstructs the course of the river is pierced by a defile (narrow gorge) more than a mile long, with an average width of about 800 feet (240 metres) and a depth of more than 100 feet (30 metres) in places. At low water the strong current there endangers navigation. A short way downstream, the river turns to the southeast and widens considerably, flowing to Gao across a floodplain 3 to 6 miles (5 to 10 km) wide. This most northerly bend of the Niger flows through the southern fringe of the Sahara.

The middle course of the Niger River is navigable to small craft during high water as far downstream as Ansongo – some 1,100 miles (1,770 km) in all. Below Ansongo, 430 miles (690 km) downstream from Timbuktu, navigability is interrupted by a series of defiles and rapids. The river becomes navigable to small vessels again at Labbezanga – from which it flows into Niger – and continues to be navigable to the Atlantic Ocean. Navigation is seasonal, however, because of the fluctuations in the water level in the rainy and dry seasons.

Downstream from Jebba, in Nigeria, the Niger enters its lower course, flowing east-southeast through a broad and shallow valley 5 to 10 miles (8 to 16 km) wide. About 70 miles (110 km) from Jebba, it is joined by the Kaduna River - an important tributary that contributes about one-fourth of the annual discharge of the river below the Niger-Kaduna confluence - and about 25 miles (40 km) above Lokoja, the river turns to the south. At Lokoja, the river receives the water of its greatest tributary, the Benue.

Although the Niger has a well defined regime, it also has a double and complementary annual flood regime with corresponding two main periods of peak flows. These are the 'White Flood' and the 'Black flood'. Ordinarily, these floods carry rainfall induced flood water as well as sustain inflow into Kainji and Jebba reservoirs.

4.2.2.1 The white flood

The White Flood is as a result of rainfall which originates from the immediate catchment area of Kainji reservoir especially from the Sokoto-Rima River Basin in Nigeria and Niamey in the neighbouring Niger Republic. The flood occurs only during the rainy season between July and October to peak usually in September (Abubakar, 2009).

4.2.2.2 The black flood

The Black Flood derives its water from the rainfall near the Niger's headwaters in the Fouta D'jallon Mountains in Guinea and Mali; both of which are at the Upper Niger. Due to the consideration length of the river, it takes a very long time for rain water falling near its source to reach Nigeria. By the time the water travels a distance of nearly 3000 km, it will not only deposit most of its silt contents in the Inland Delta or interior lakes but is delayed and, as the river journeys to Nigeria, further loss of silt takes place. By the time the flood reaches Nigeria in November, about six months later, the water looks comparatively clean. The name 'Black flood' is thus applied. The Black flood operates between November and March of the following year (Abubakar, 2009).

5.0 HYDROELECTRIC POWER GENERATION

Hydro electric energy is a form of energy... a renewable resource. Hydropower provides about 96 percent of the renewable energy in the United States. Other renewable resources include geothermal, wave power, tidal power, wind power, and solar power. Hydroelectric power plants do not use up resources to create electricity nor do they pollute the air, land, or water, as other power plants may. Hydroelectric power has played an important part in the development of this Nation's electric power industry. Both small and large hydroelectric power developments were instrumental in the early expansion of the electric power industry.

By taking advantage of gravity and the water cycle, we have tapped into one of nature's engines to create a useful form of energy. In fact, humans have been capturing the energy of moving water for thousands of years. Today, harnessing the power of moving water to generate electricity, known as hydroelectric power, is the largest source of emissions-free, renewable electricity in the United States and worldwide.

Hydropower is an essential contributor in the national power grid because of its ability to respond quickly to rapidly varying loads or system disturbances, which base load plants with steam systems powered by combustion or nuclear processes cannot accommodate.

Hydroelectric power plants are the most efficient means of producing electric energy. The efficiency of today's hydroelectric plant is about 90 percent. Hydroelectric plants do not create air pollution, the fuel – falling water – is not consumed, projects have long lives relative to other forms of energy generation, and hydroelectric generators respond quickly to changing system conditions. These favorable characteristics continue to make hydroelectric projects attractive sources of electric power.

5.1 Generating Power

In nature, energy cannot be created or destroyed, but its form can change. In generating electricity, no new energy is created. Actually one form of energy is converted to another form.

To generate electricity, water must be in motion. This is kinetic (moving) energy. When flowing water turns blades in a turbine, the form is changed to mechanical (machine) energy.

The turbine turns the generator rotor which then converts this mechanical energy into another energy form – electricity. Since water is the initial source of energy, we call this hydroelectric power or hydropower for short.

At facilities called hydroelectric power plants, hydropower is generated. Some power plants are located on rivers, streams, and canals, but for a reliable water supply, dams are needed. Dams store water for later release for such purposes as irrigation, domestic and industrial use, and power generation. The reservoir acts much like a battery, storing water to be released as needed to generate power.

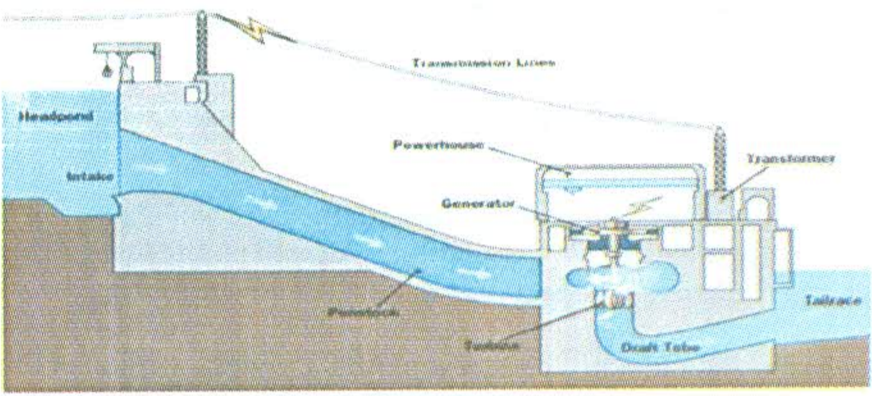

Figure 3: Electric Power Generation
Source: Wikipedia, the free encyclopedia (2015)

When the water has completed its task, it flows on unchanged to serve other needs.

5.2 The Hydro Electric Power Stations

The hydroelectric power dams considered are the large dams that produce above 500 MW of electricity. These dams include Kainji, Jebba and Shiroro.

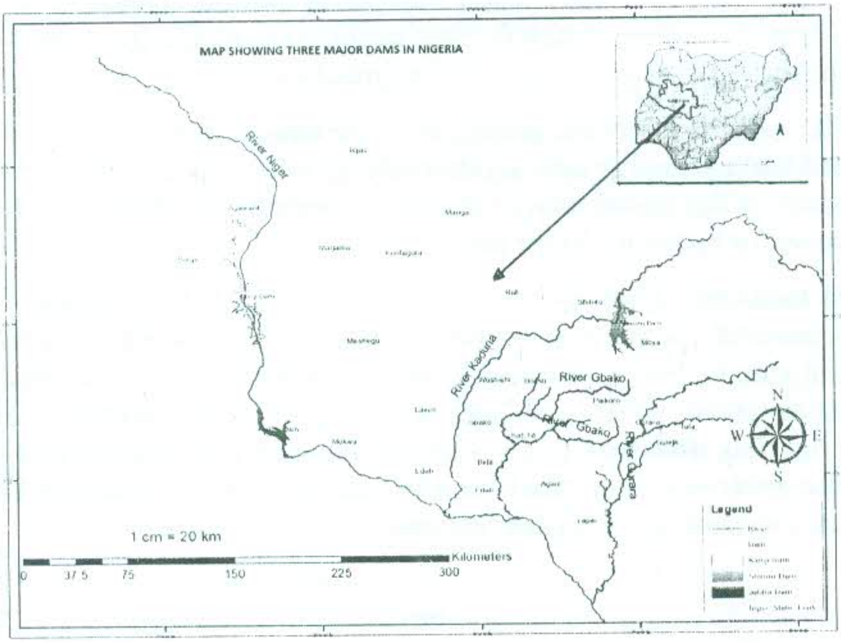

Figure 4: The Three Hydroelectric Dams
Source: Abubakar (2010)

5.2.1 Kainji hydroelectric power dam

Kainji Hydroelectric Power Station is located on the River Niger at the downstream tip of Kainji Island in Borgu Local Government Area of Niger State, some 402 kilometres North East of Lagos and 605 km Northwest of Abuja, Federal Capital of the Federal Republic of Nigeria. It is a Federal Government project which was initiated in 1964 and completed in 1968, initially managed and operated by Niger Dams Authority (NDA) and later National Electric Power Authority (NEPA) which was established by Decree No. 24 of 1st April, 1972 with the merger of NDA and ECN to form NEPA now Power Holding Company of Nigeria (PHCN) was empowered to maintain an efficient, coordinated and economic system of electricity supply to all the nooks and crannies of the nation. Kainji Power Station is thus the fore-runner of PHCN's present three hydro-electric power development schemes in Nigeria. The other two being Jebba and Shiroro hydropower stations (Abubakar, 2009).

Plate 1: Downstream of Kainji Dam

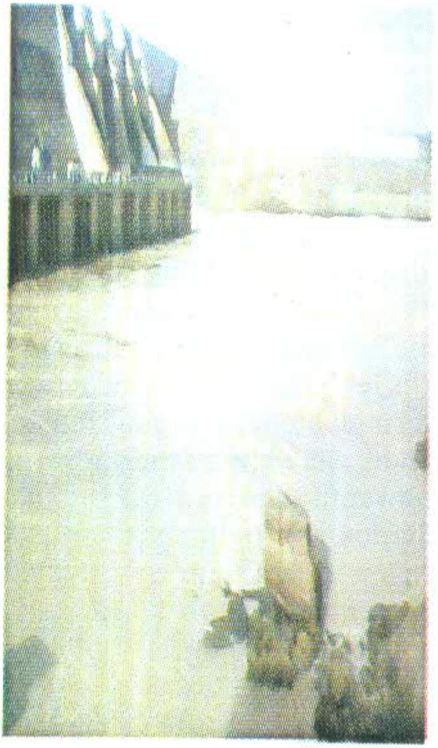

Plate 2: Spill-way at the Kainji Dam

Source: Abubakar (2009)

Table 4: Some Technical Details of the Major Hydropower Dams in Nigeria

Technical Details	Kainji	Jebba	Shiroro
Crest elevation of dam	145 m	108 m	385.0 m
Perimeter length of dam	7.75 km	1287 m	382.5 m
Maximum water surface elevation	142 m	103 m	382.0 m
Minimum water surface operating level	132.60 m	382 m	360.0 m
Draw-down	9.40 m	103 – 99 m	22 m
Normal maximum tail water elevation	109 m	73 m	271.50 m
Operating head	39.6 m	29 m	112 m
Length of Power House	350 m	206 m	-
Number of generating machines	8	6	4
Total installed capacity	760 MW	540 MW	600 MW
Location	9°50'N, 10°55'E	4°30'N, 5°00'E	9°58'N, 6°50' E
Surface area	1250 km^2	303 km^2	320 km^2
Total storage volume	15 billion m^3	1 billion m^3	7 billion m^3
Maximum length	136 km	100 km	32 km
Maximum depth	60 m	105 m	115 m
Dead storage	$3.0 \times 10^9 m^3$	$3.31 \times 10^9 m^3$	$6.0 \times 10^9 m^3$

Source: Adopted from NEDECO and Balfour Beatty (1972)

5.2.2 Jebba hydroelectric power dam

The Jebba hydro-electric power dam is owned and managed by the Power Holding Company of Nigeria. It was built to supplement and boost the current activities of PHCN to be self sufficient in the generation of electricity. The establishment of the Jebba Hydro-Electric Power Station was embarked upon as a formidable way of guaranteeing alternative sources of electric energy as well as exportation of regular and reliable bulk electric power to all parts of the country. The Jebba Hydro Electric Power Station was built strategically on the downstream of the River Niger. It is located on Gungu, Jebba-North in Niger State. From its present location, it is about 350 kilometres North of Lagos and about 200 kilometres southwest of the Federal Capital Territory, Abuja. The central location of the Jebba Power Station between the North and South of the country does not only make it one of the most strategically located but also enhances its proper utilization to the advantage of most parts of the country.

The commencement of studies and the building of the Jebba

Power Station started in the late 1950s as a follow up to Kainji Power Station. Indeed, by 1960, the green light had been given for the construction of Jebba Power Station by the Federal Government. However, serious site development and construction started in 1979 and by 1984, it was ready for commissioning.

The Power House of the Jebba Power Station is a gigantic building of 206 metres long and a width of 36 metres. It is equipped with six intake gates and each gate has a height of 12.4 metres while the width of each intake gate is 10 metres. It also houses an overhead crane of a maximum capacity of 450 tonnes. The Jebba Power Station is equipped with six generators. Each generator is capable of producing 94.6 MW of electricity while the total installed capacity of the Power Station is 540 MW. The level of water intake into the generators varies from season to season. However, the highest and lowest levels of water that can be accommodated for electricity to be generated are 103.15 metres and 99 metres respectively.

Plate 3: Upstream of Jebba Dam at Gbajibo

Plate 4: Spill-Way at the Jebba Dam

5.2.3 Shiroro hydroelectric power dam

The case of Shiroro hydropower dam is however, different. Built on River Kaduna about 40 km Northeast of Minna, the Capital of Niger State, the competing uses of the river upstream and the level of effluents released from industrial activities account for the turbid flow (Abubakar, 1995b). In recent years, due to persistent droughts, the surrounding wooded savanna has deteriorated into shrubs with scanty baobab type trees. However, because Kaduna River and its tributaries take their origin from the Jos Plateau, there is ample 'inflow' into the Shiroro Dam which unfortunately could become too much when rainfall is unusually too heavy.

Plate 5: The Dam Crane at Shiroro Dam

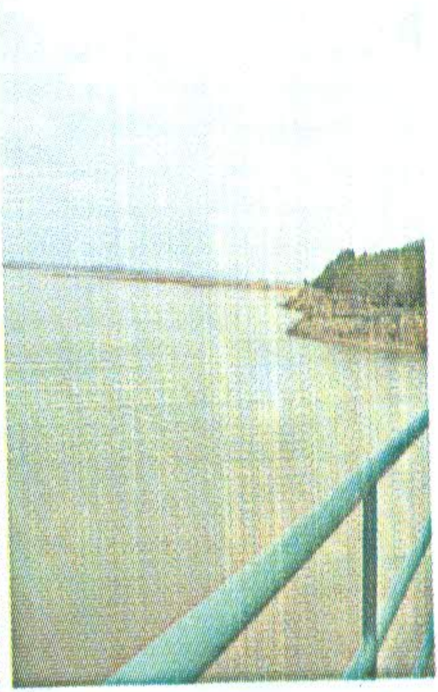

Plate 6: Upstream of Shiroro Dam

Plate 7: Downstream of Shiroro Dam

6.0 OUR RESEARCH EFFORTS

Mr. Vice-Chancellor Sir, distinguished invited guests, I wish to draw our attention to the fact that Allah (SWT) has provided mankind with the knowledge to tap from the abundant natural resources on earth as enshrined in the Holy Qur'an. Whatever is created in the world is considered part of signs of Allah which we have been encouraged to think, learn and study. Allah said *"Behold! In the creation of the heavens and the earth, and the alternation of night and day – there are indeed signs for men of understanding".* [Sûrat 'Ali Imran 3:190]. One of these signs is on sources and uses of water.

The knowledge of hydrology and meteorology can never be downplayed in the operations of hydroelectric power dams.

Some of our past research efforts in hydrology and meteorology include:

(a) **Rainfall – runoff regression in the prediction of discharge**

Abubakar (2000a), utilized rainfall runoff regression model in the prediction of discharge along River Sarkin Pawa which is a tributary to the River Kaduna. Runoff was computed using the expression:

Where:	R	=	runoff
	Q	=	discharge
	t	=	time (hours)
	A	=	catchment area
	c	=	runoff coefficient.

A simple linear regression model expressed as:

Where:	y	=	independent variable
	a_0 and $a_1 n$	=	regression coefficient.

The explanatory power of the regression line was taken as $0.5 > r^2 > 1.0$. The regression models for the months of April, June and August were adopted for the prediction of discharge.

Table 5: Prediction of Discharge

Month	Discharge m³/sec		
	Observed	Predicted	Forecast Accuracy
April	1.33	1.63	81.59%
June	5.42	5.20	95.94%
August	19.97	20.54	97.22%

Source: Abubakar (2000a)

One major setback with this model however is that the prediction is not reliable for the months of May, July, September and October.

A possible high variability of rainfall from one year to another could be the inhibiting factor.

(b) Hydrometeorological aspects of flood forecasting

Abubakar (1994) used both meteorological and hydrological variables to forecast flood along the River Kaduna South at Sumchi. The meteorological parameters used were rainfall and evaporation while the hydrological parameters were gauge height and discharge. Time series analysis was adopted and monthly trendline equation used to make the forecast for all the hydrometeorological variables in question. The value of seasonality index for each month was then multiplied by the trend line equation to obtain the forecast.

Evaporation does not affect discharge because the value of the correlation coefficient was weak but showed a negative relationship. As evaporation increases, discharge decreases. Evaporation affects gauge height negatively. A correlation coefficient of -0.75 was obtained which showed a strong negative correlation.

Monthly rainfall forecast

The year 1980 was used as a test for the forecast (Figure 4). The forecast accuracy value and the observed value is not much except for March, April and September. The total difference between the observed and forecast values was 582.30mm. The forecasts for all the months in the year were overforecast. There is no month with an under-forecast. The total yearly accuracy for the forecast was 67.45% and the observed value was higher than the forecast value. For the forecast value the peak is September while for the observed, the peak is August.

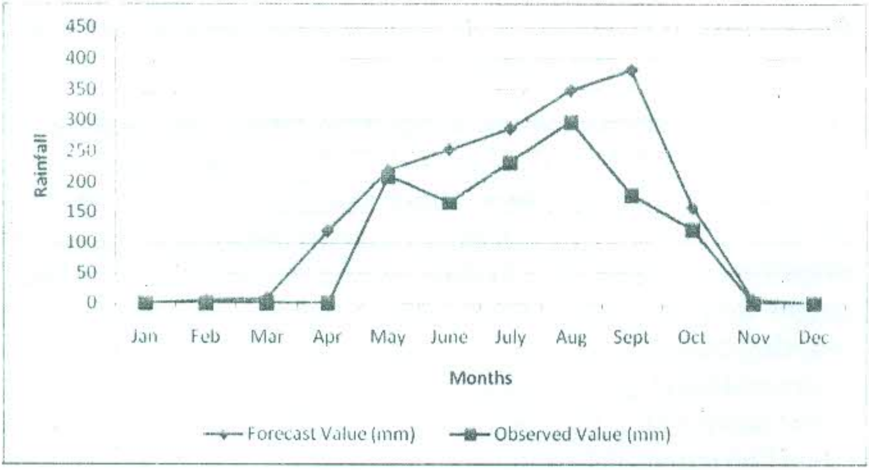

Figure 5: Monthly Rainfall Forecast

Monthly evaporation forecast

The difference between the observed and the forecast value is small (Figure 6). All the forecasts were over forecast except for the months of February, March, May and December that were underforecast. The total deviation between the observed and forecast values is 52.71mm and the percentage forecast accuracy was 97%.

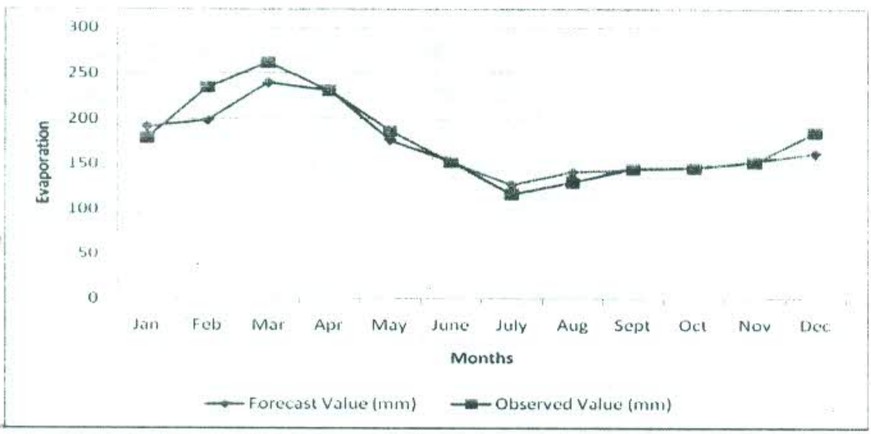

Figure 6: Monthly Evaporation Forecast

Monthly gauge height forecast

There is a slight difference between the observed and forecast values (Figure 7). All the forecasts in the year were overforecast and the total difference between the observed and forecast values was 10.66m. The observed value was less than the forecast value and the percentage forecast accuracy was 74.73%.

The highest peaks for both the observed and forecast value was in September. The lowest value for both the observed and forecast was in April and March respectively. If a forecast is made and the value of the gauge height reaches 7.5 metres which is the flood stage, then flood is to be expected (Abubakar, 1994).

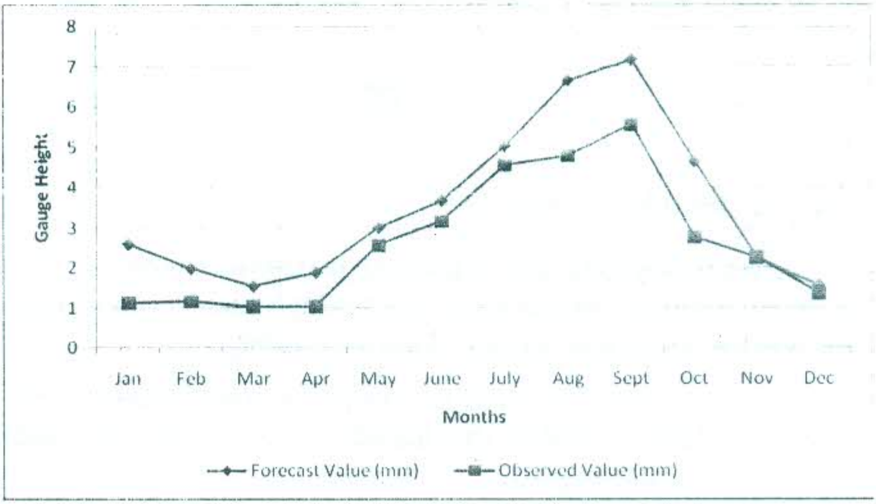

Figure 7: Monthly Gauge Height Forecast

Monthly discharge forecast

For the months of March, May, June, July, August September, under-forecast was made (Figure 8). For the rest of the months, it was over-forecast. The observed value was less than the forecast value and the percentage forecast accuracy was 87.35%.

The forecast value showed a peak in September while the observed showed a peak in August. If a forecast is made and the value of the discharge is 24,000 m^3/sec which is the threshold value, then flood is to be expected.

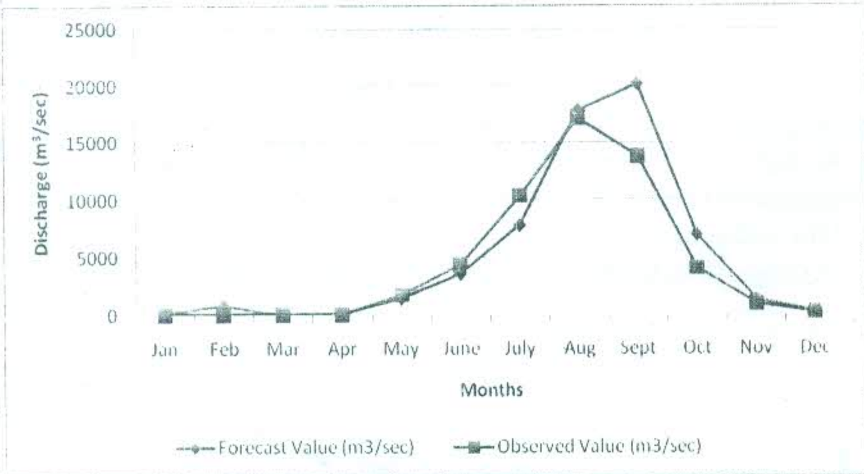

Figure 8: Monthly Discharge Forecast

(c) Streamflow characteristics of the Gbako River

The Gbako River is a major tributary to the Niger River in Niger State. With a catchment area of 221square miles.

Abubakar and Suleiman (2011), employed two measures of variability which included the Standard Deviation (SD) and Coefficient of Variation (CV).

Table 6: The Equations used in the Computations

Values	Terms	Equations
Standard Deviation	SD	Σ(xX)/(n-1)
Coefficient of Variation	CV	SD/ x*100
X = mean value	x = observed value	n = number of observations

The record was collected for fifteen years to enable understanding of flow regimes of the Gbako River.

Table 7: Annual Discharge and Gauge Height Statistics

Year	Total Values		Mean Values		Standard Deviation Values		Coefficient of Variation Values	
	Discharge (m^3/s)	River Gauge Stage (m^3/s)	Discharge (m^3/s)	River Gauge Stage (m^3/s)	Discharge (m^3/s)	River Gauge Stage (m^3/s)	Discharge (m^3/s)	River Gauge Stage (m^3/s)
1980	522.00	73.92	43.5	6.16	6.38	2.41	20.40	39.12
1981	499.2	54.6	41.6	4.55	6.22	2.05	19.95	45.13
1982	614.4	51.6	51.2	4.30	6.95	1.99	22.28	46.32
1983	390	39.84	32.5	3.32	5.45	1.72	17.46	52.05
1984	204.24	27.24	17.0	2.27	3.77	1.39	11.73	61.31
1985	150	33.72	12.5	2.81	3.10	1.57	9.96	56.01
1986	277.2	41.28	23.1	3.44	4.50	1.36	14.42	51.24
1987	268.8	27.12	22.4	2.26	4.42	1.38	14.17	61.42
1988	451.2	53.16	37.6	4.43	5.89	2.02	18.89	45.69
1989	312.24	39.24	26.0	3.27	4.81	1.71	15.43	52.41
1990	402.00	55.32	33.5	4.61	5.54	2.06	17.74	44.86
1991	481.20	30.36	40.1	2.53	6.10	1.48	19.56	58.58
1992	424.8	36.24	35.4	3.02	5.71	1.63	18.28	54.28
1993	331.2	41.52	27.6	3.46	4.97	1.76	15.94	51.10
1994	303.6	54.84	25.3	4.57	4.74	2.05	15.19	45.04

Source: Abubakar and Suleiman, 2011

The highest gauge stage value (73.92 m) was observed in 1980 with corresponding coefficient of variation of 39.12 m while the lowest value (27.12 m) was observed in 1987 with coefficient of variation of 61.42 m. The highest discharge value (614.4 m^3/s) was observed in 1982 with coefficient of variation of 22.28 m^3/sec, while the lowest value (150 m^3/sec) was observed in 1985 with corresponding coefficient of variation of 9.96 m^3/sec.

Table 8: Mean Monthly Discharge and Gauge Height

Months	Total Values		Mean Values		Standard Deviation Values		Coefficient of Variation Values	
	Discharge (m^3/s)	River Gauge Stage (m^3/s)	Discharge (m^3/s)	River Gauge Stage (m^3/s)	Discharge (m^3/s)	River Gauge Stage (m^3/s)	Discharge (m^3/s)	River Gauge Stage (m^3/s)
Jan.	7.05	2.19	2.03	4.96	2.10	1.36	7.27	37.12
Feb.	6.20	2.37	1.79	5.37	1.89	1.42	6.55	38.88
Mar.	6.06	2.16	1.75	4.90	1.85	1.35	6.42	36.82
Apr.	0.02	3.82	1.73	8.66	1.84	1.86	6.38	50.68
May	35.72	4.14	10.3	9.39	5.75	1.95	19.94	53.16
June	50.16	5.09	14.48	11.54	6.89	2.18	23.89	59.42
July	56.40	4.08	16.20	9.25	7.33	1.93	25.40	52.73
Aug.	51.40	4.06	14.84	10.43	6.98	2.06	24.20	56.28
Sep.	59.50	5.17	17.18	13.06	7.54	1.32	26.14	63.47
Oct.	49.63	4.75	14.33	10.77	6.85	2.10	23.76	57.26
Nov.	10.57	2.70	3.05	6.12	2.81	1.53	9.77	41.68
Dec.	7.55	2.42	2.18	4.49	2.21	1.44	7.69	39.35

Source: Abubakar and Suleiman, 2011

The highest values of discharge (59.50 m^3/sec) and river gauge stage (5.17 m) were observed in September while the highest value of coefficient of variation for discharge (26.14 m^3/sec) and river gauge stage (63.47 m) were also observed in September.

The study has shown that the River Gbako is a perennial river with discharge peak in the month of September which suggests that the river could be harnessed for various uses in a sustainable manner.

(d) Flood Frequency Analysis of the Lower Niger at Jebba Dam

We utilized data obtained from Jebba Hydro power station (Hydrology section) and the data include mean monthly reservoir inflow (m^3/sec), discharge (m^3/sec) and monthly reservoir elevation (metres) (Abubakar and Yisa, 2007).

The data were subjected to cumulative frequency distribution analysis, probability analysis (using Gumbell's extreme probability analysis) and time series analysis of Thirkettle (1982).

Cumulative Frequency Distribution

Frequency distribution was fitted to a sample of floods observed at Jebba Dam for the period 1984 – 2000 and the estimated parameters of the distribution were then used to predict the average recurrence intervals of floods of chosen magnitudes.

Cumulative frequency distribution (inflow, discharge and gauge height)

Table 10 shows the cumulative frequency values obtained by ranking the inflow values according to their size and by giving the smallest inflow the rank m=1. The highest value has a rank m = 17.

The highest discharge value which ranked m = 17 with a value of 1357(94.44%) also coincided with the 1999 flood year while the lowest ranked m = 1 with a value of 553m^3/sec (5.56%). Comparing the inflow of 1581.1m^3/sec and discharge of 1357m^3/sec, it is clear that water must be retained in the dam and is not all utilized for generation of electricity.

Cumulative frequency distribution values (gauge-height)

Table 11: Cumulative Frequency Distribution (Gauge-Height (m)

Values (Ranked)	Frequency (%)
101.2	5.56
101.4	11.11
101.6	16.67
101.7	22.22
101.8	27.78
101.9	33.33
101.9	38.89
101.9	44.44
101.9	50
102	55.56
102.2	61.11
102.2	66.67
102.2	72.22
102.4	77.78
102.5	83.33
102.5	88.89
102.6	94.44

Source: Abubakar (2010)

The frequency of 94.44% corresponds with flood magnitude of 1995. It can therefore be deduced that reservoir elevation may not necessarily correspond with years of maximum flood event, because as the dam receives the excess inflow, it is spilled to avoid overtopping of the dam which may cause system collapse. The lowest frequency of 5.56% has a value of 101.2m which is a good way of utilizing and managing the water for hydroelectricity generation (Abubakar, 1995a).

ii) Probability Analysis (inflow, discharge and gauge height)

Probabilities of obtaining less than certain inflow value in any year

Table 12: Probabilities of Obtaining Less than Certain Inflow Value in any Year

Values (m^3/sec)	Probabilities (%)
1600	93
1500	87
1400	84
1300	78
1200	72
1100	65
1000	52
900	45
800	32
700	25
600	5.6

Source: Abubakar (2010)

The probability of obtaining less than 600 m^3/sec is 5.6%, while it is 93% for 1,600 m^3/sec. The result from Table 13 also indicates good water management strategy by the dam authorities at Jebba H.E.P Station.

Probabilities of obtaining less than certain discharge values in any year

Table 13: Probabilities of Obtaining Less than Certain Discharge Values in any Year

Values (m^3/sec)	Probabilities (%)
1500	93
1400	84
1300	82
1200	73
1100	63
1000	55
900	42
800	33
700	15
600	7.2

Source: Abubakar (2010)

The probability of obtaining less than 600m^3/sec is 7.2% while it is 93% for the value of 1500m^3/sec. This again has shown that water is retained as much as possible in the dam.

Probabilities of obtaining less than certain gauge height values in any year

Table 14: Probabilities of Obtaining Less than Certain Gauge Height Values in any Year

Values (m)	Probabilities (%)
102.8	92
102.6	83
102.4	75
102.2	61
102	55
101.8	28
101.6	23
101.4	15
101.2	6.6
101	0

Source: Abubakar (2010)

The probability of obtaining less than 101m is 0, while it is 92% for 102.8m. Operating the dam between 101m and 102.8m is a very good strategy for maintaining water level in the dam.

Time Series Analysis (Inflow, discharge and gauge height)

Three months moving average – mean monthly inflow

The time series graph (Figure 8) for stream inflow was plotted and smoothened using 3 months moving average. The graph reveals that maximum flood event peaks are obtained within the second half of the year (Aug – Oct) which corresponds with the arrival of white flood with its peak between September and October at Jebba. It also shows an upward rise in flood event from 1988 with its maximum peak in 1999. Generally, for the period under study, years of maximum flood events are interwoven with years of minimum flood events.

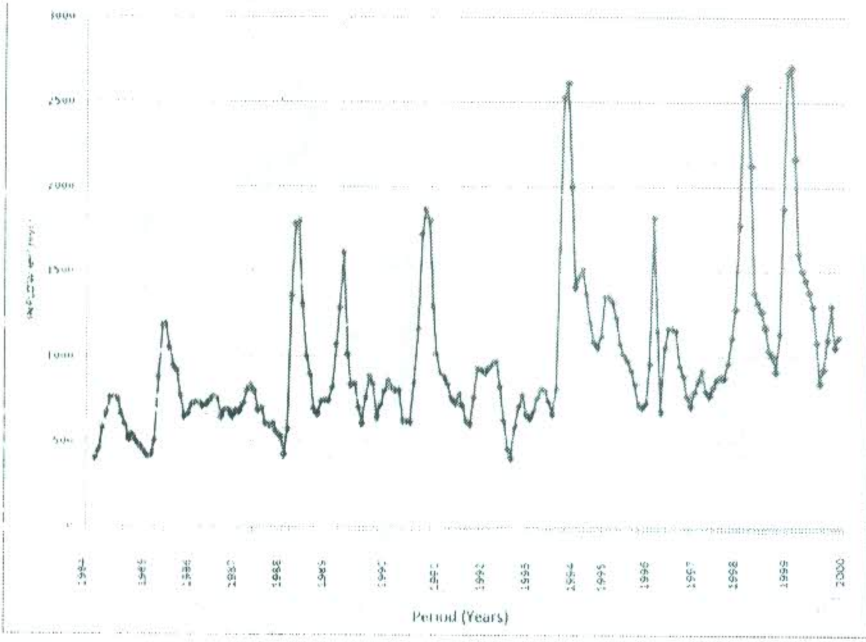

Figure 9: 3-Month Moving Average of Inflow for River Niger at Jebba (1984 – 2000)

Three months moving average – mean monthly discharge

It is noted from Figure 10 that highest discharge coincides with the period of white flood arrival at Jebba (Aug - Oct) and black flood which peaks at January every year. Discharge peaks also correspond with stream inflow peaks for the same period. Generally, the two graphs have the same trend.

Three months moving average – mean monthly gauge height

It is evident from Figure 11 that there is no significant difference in stream elevation except for 1985, 1996 and 1998. It is an indication that gauge height does not correspond with peaks of maximum flood events; because for the water level to be controlled at the dam, spilling of excess water is necessary to avoid overtopping of water on the dam.

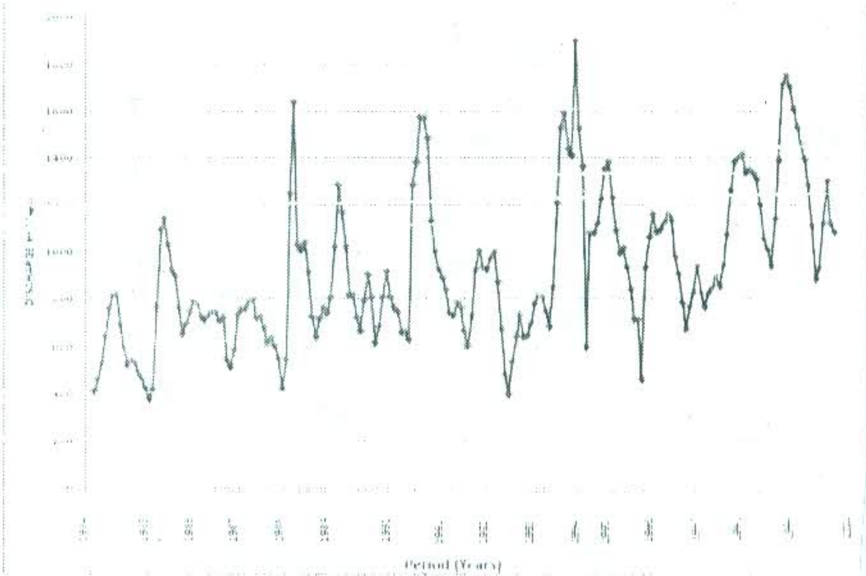

Figure 10: 3-Month Moving Average of Discharge for River Niger at Jebba (1984 – 2000)

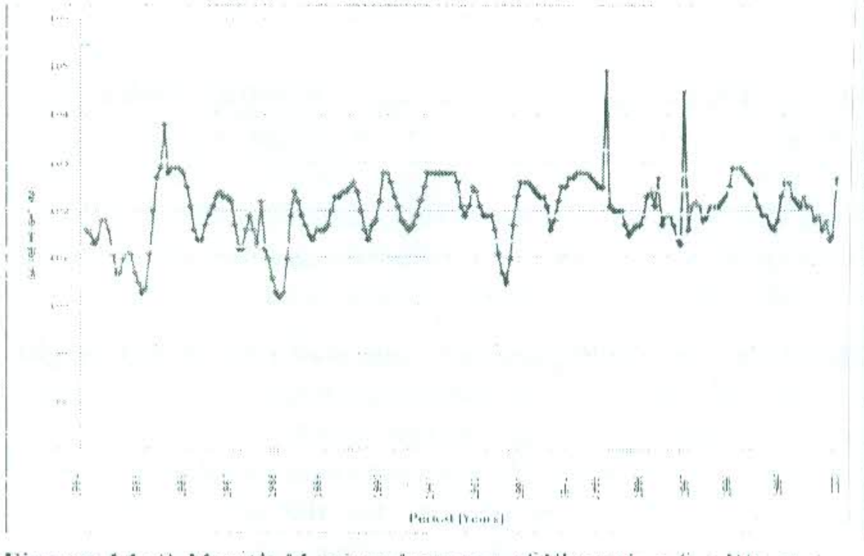

Figure 11: 3-Month Moving Average of Elevation for River Niger at Jebba (1984 – 2000)

e) Hydrometeorological variables and hydroelectricity generation

We investigated the relationship between hydrometeorological variables and power generated in the three hydroelectric dams. The goal is to see if a change in the independent variables (which in this case are: rainfall, temperature, relative humidity, evaporation, gauge height, inflow and outflow) will result in a change in the dependent variable (power generated). This information will help to understand the power generated predictive ability. The analysis was done both for rainy and dry seasons.

i. Shiroro Hydroelectric Power Dam

Rainfall and Power Generated in Shiroro

The relationship between rainfall and power generated in Shiroro Dam of Niger state was illustrated in Figure 12. The correlation value (rainy season: 0.51 and dry season: -0.87) shows that, there is a strong relationship between rainfall and power generated (that is, during the rainy season, increase in rainfall result in increase in power generated while in the dry season, decrease in rainfall is decrease in power generated). The results agree with the work of Abubakar, 1993(a) for both the rainy and dry seasons.

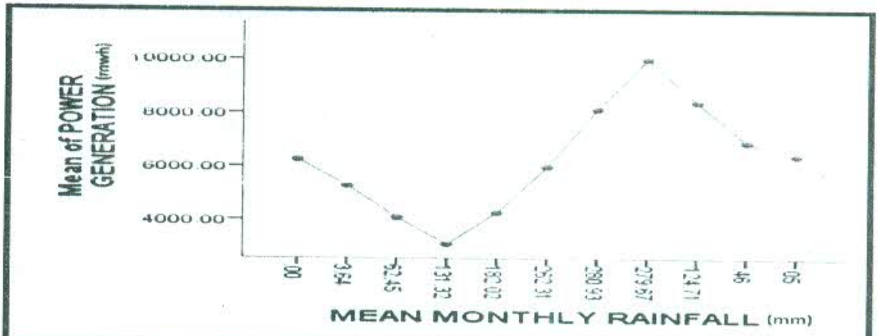

Figure 12: Relationship between rainfall and power generated in Shiroro Dam

Relative humidity and Power Generated in Shiroro

The relationship between relative humidity and power generated in Shiroro Dam of Niger state is shown in Figure 13. The correlation value (rainy season: 0.62 and dry season: -0.71) shows that, there is a strong relationship between relative humidity and power generated (that is, when relative humidity increases, the power generated also increases during the rainy season). But the power generated decreases as relative humidity decreases in the dry season).

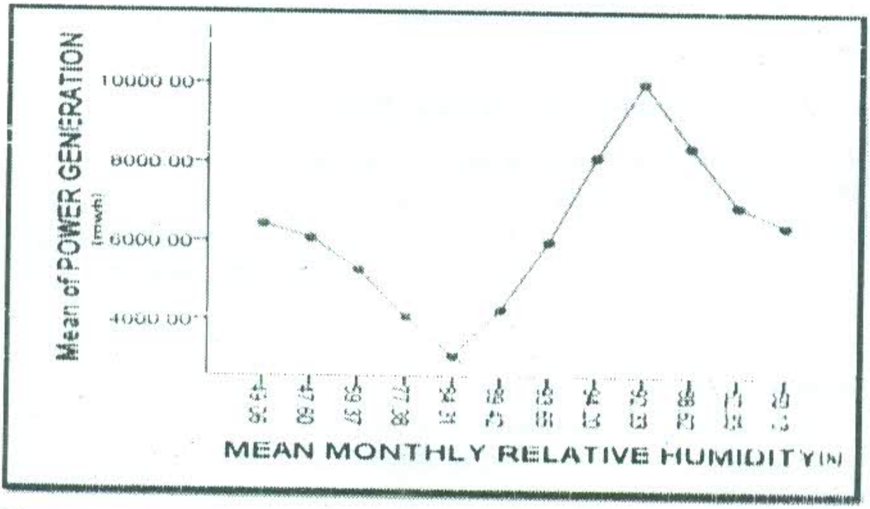

Figure 13: Relationship between relative humidity and power generated in Shiroro Dam

Temperature and Power Generated in Shiroro

Figure 14 shows the relationship between temperature and power generated in Shiroro Dam of Niger state. The correlation value (rainy season: -0.84 and dry season: -0.82) indicated that, there is a strong negative relationship between temperature and power generated (that is, when temperature increases, the power generated decreases and vice visa both in the rainy and dry seasons)

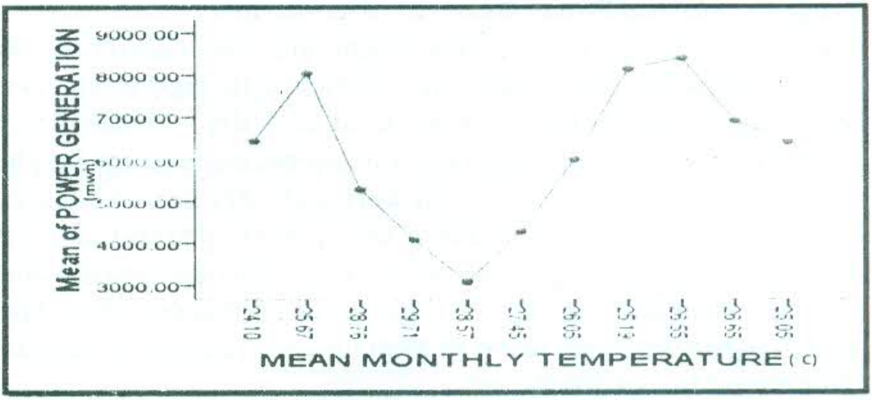

Figure 14: Relationship between temperature and power generated in Shiroro Dam

Evaporation and Power Generated in Shiroro

The relationship between evaporation and power generated in Shiroro Dam of Niger state is shown in Figure 15. The correlation value (rainy season: 0.58 and dry season: 0.78) shows that there is a strong relationship between evaporation and power generated (that is, when evaporation increases, the power generated decreases and agrees with the work of Abubakar, 1993b).

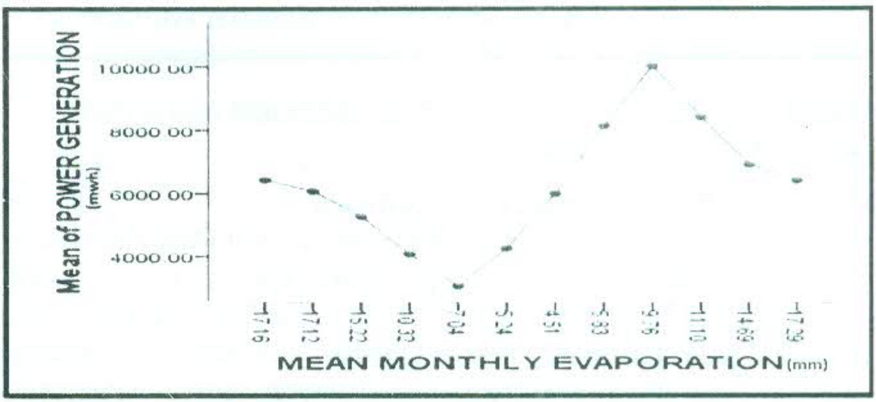

Figure 15: Relationship between evaporation and power generated in Shiroro Dam

Gauge height and Power Generated in Shiroro

The relationship between gauge height and power generated in Shiroro Dam of Niger state was depicted in Figure 16. The correlation value (rainy season: 0.38 and dry season: 0.96) shows that, there is a strong relationship between gauge height and power generated particularly during the dry season (that is, when gauge height increases, the power generated also increases). It is observed to be weak during the rainy season and could be attributed to the constant spill of excess water. The results agree with the work of Mohammed, (2013), Abubakar, (2000c) and Idris, (2015).

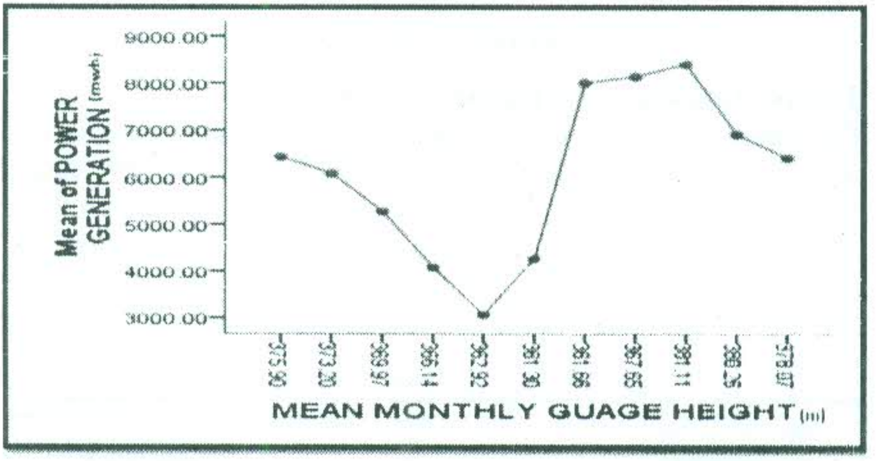

Figure 16: Relationship between gauge height and power generated in Shiroro Dam

Inflow and Power Generated in Shiroro

Figure 17 illustrates the relationship between inflow and power generated in Shiroro Dam of Niger state. The correlation value (rainy season: 0.92 and dry season: 0.71) shows that there is a high positive relationship between inflow and power generated (that is, when there is increase in inflow, the power generated also increases) for both the rainy and dry seasons.

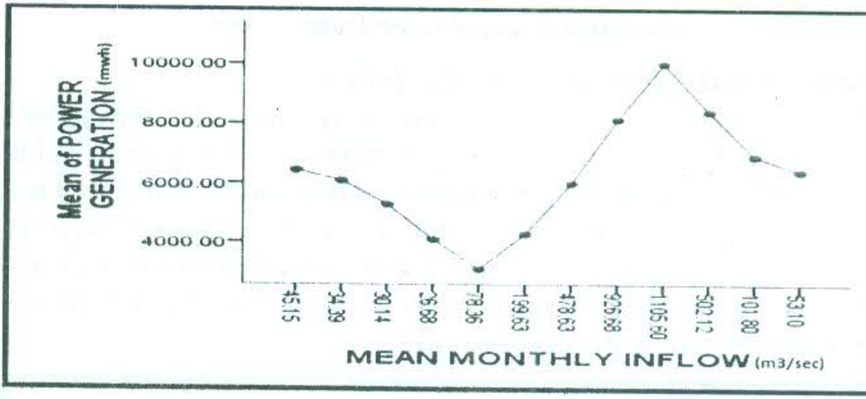

Figure 17: Relationship between inflow and power generated in Shiroro Dam

Outflow and Power Generated in Shiroro

Figure 18 shows the relationship between outflow and power generated in Shiroro Dam of Niger state. The correlation value (rainy season: 0.90 and dry season: 0.76) shows that there is a strong positive relationship between outflow and power generated (that is, as outflow increases so also is the power generated) for both the dry and rainy seasons. This agrees with the work of Mohammed (2013).

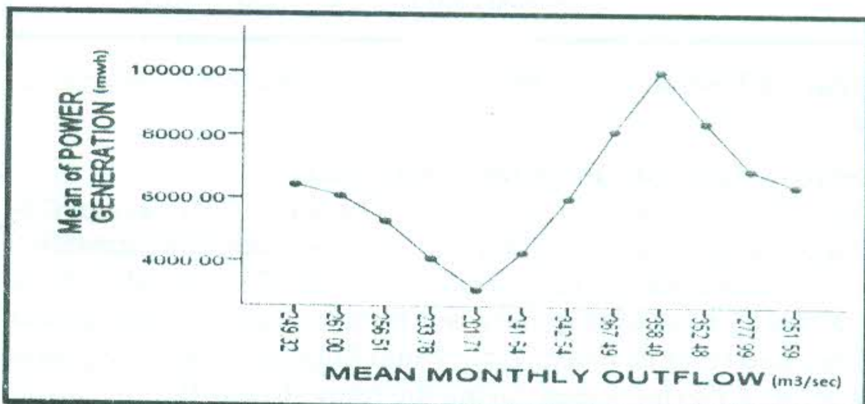

Figure 18: Relationship between outflow and power generated in Shiroro Dam

ii. Jebba Hydroelectric Power Dam

Rainfall and Power Generated in Jebba

Figure 19 depicts' the relationship between rainfall and power generated in Jebba Dam of Niger state. The correlation value (rainy season: 0.70 and dry season: -0.88) shows that, there is a strong relationship between rainfall and power generated (that is, during the rainy season, increase in rainfall results in increase in power generated while decrease in rainfall results in decrease in power output in the dry season).

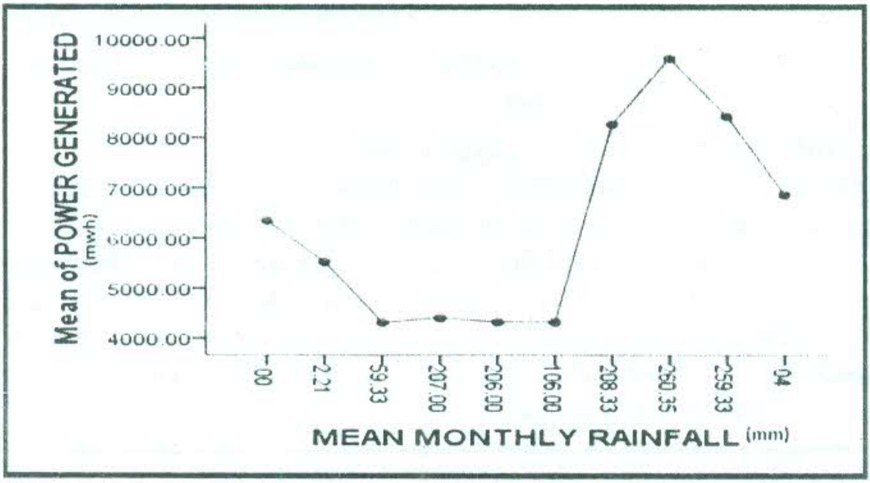

Figure 19: Relationship between rainfall and power generated in Jebba Dam

Relative Humidity and Power Generated

Figure 20 illustrates the relationship between relative humidity and power generated in Jebba Dam of Niger state. The correlation value (rainy season: 0.62 and dry season: -0.57) shows that, there is a strong relationship between relative humidity and power generated (that is, when relative humidity increases, the power generated also increases during the rainy season. But the power generated decreases as relative humidity decreases in the dry season.

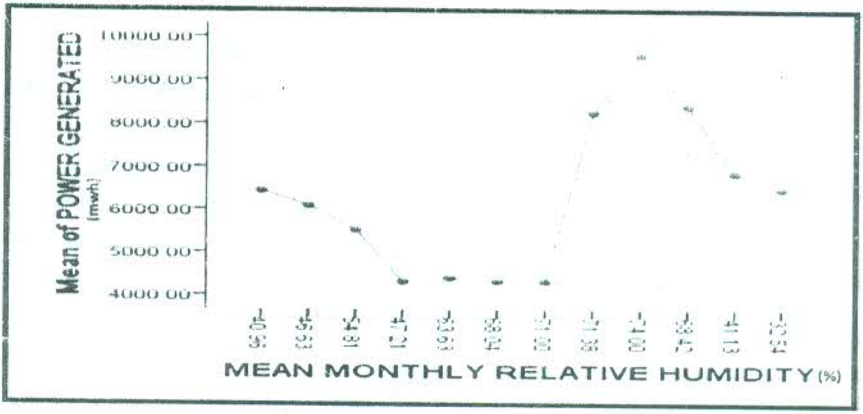

Figure 20: Relationship between relative humidity and power generated in Jebba Dam

Gauge Height and Power Generated

The relationship between gauge height and power generated in Jebba Dam of Niger state is shown in Figure 21. The correlation value (rainy season: 0.74 and dry season: 0.62) indicated that, there is a strong relationship between gauge height and power generated (that is, when gauge height increases, the power generated also increases both for the dry and rainy seasons).

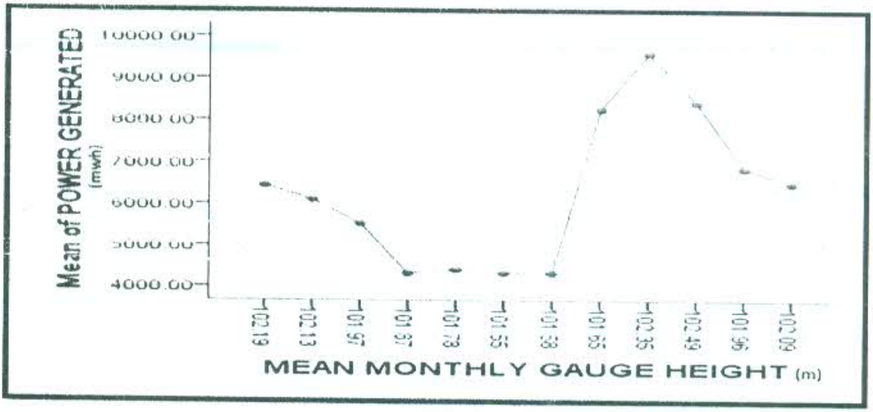

Figure 21: Relationship between gauge height and power generated in Jebba Dam

Inflow and Power Generated

Figure 22 shows the relationship between inflow and power generated in Jebba Dam of Niger state. The correlation value (rainy season: 0.90 and dry season: 0.75) shows that, there is a high positive relationship between inflow and power generated- that is, when there is increased inflow, the power generated also increases for both the rainy and dry seasons and also agrees with the work of Mohammed (2013).

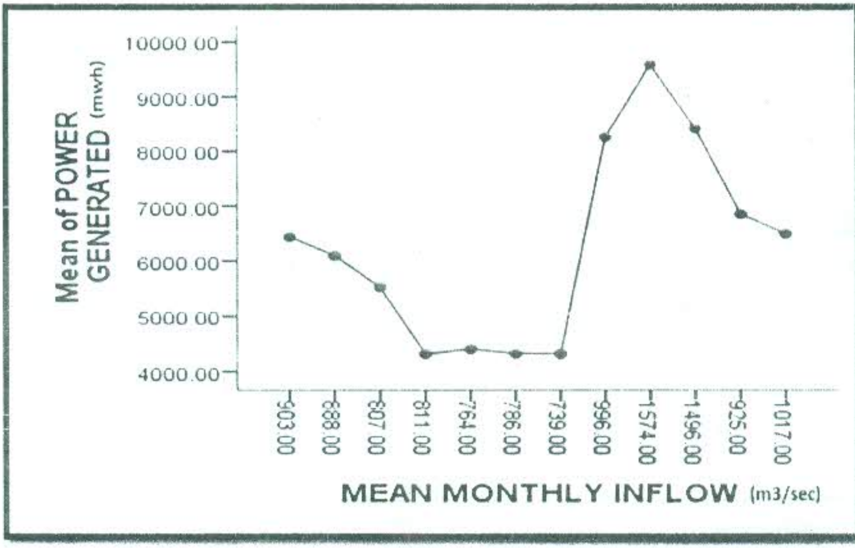

Figure 22: Relationship between inflow and power generated in Jebba Dam

Outflow and Power Generated

Figure 23 shows the relationship between outflow and power generated in Jebba Dam of Niger state. The correlation value (rainy season: 0.91 and dry season: 0.94) shows that there is a high positive relationship between outflow and power generated (that is, when outflow increases, the power generated also increases for both the dry and rainy seasons). This result agrees with the findings of Mohammed (2013).

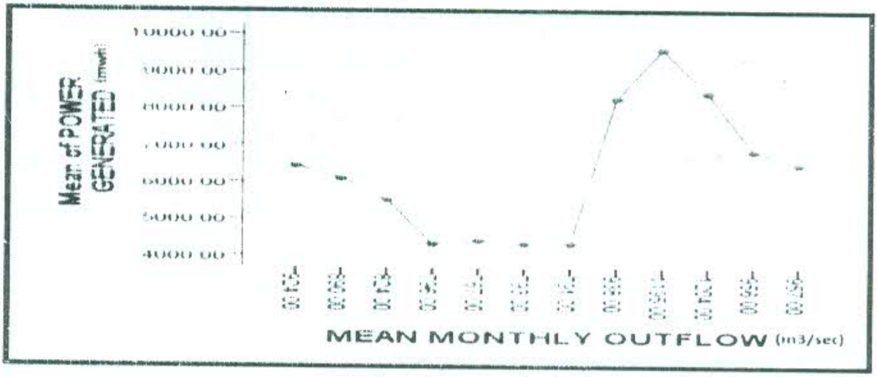

Figure 23: Relationship between outflow and power generated in Jebba Dam

iii Kainji Hydroelectric Power Dam

Rainfall and Power Generated in Kainji

Figure 24 shows the relationship between rainfall and power generated in Kainji Dam of Niger state. The correlation value (rainy season: 0.90 and dry season: -0.69) shows that, there is a strong relationship between rainfall and power generated in the rainy season (that is, during the rainy season, increase in rainfall results in increase in power generated while decrease in rainfall results in decrease in power generated). The result agrees with the findings of Mohammed (2013).

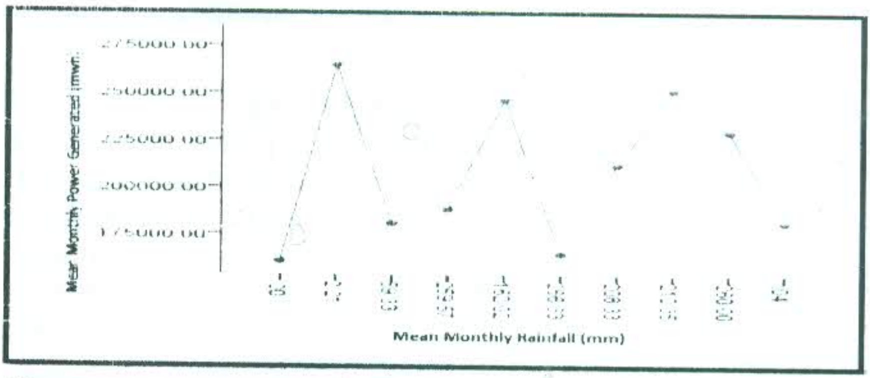

Figure 24: Relationship between rainfall and power generated in Kainji Dam

Relative humidity and Power Generated in Kainji

The relationship between relative humidity and power generated in Kainji Dam of Niger state is illustrated in Figure 25. The correlation value (rainy season: 0.75 and dry season: -0.65) shows that, there is a strong relationship between relative humidity and power generated (that is, when relative humidity increases, the power generated also increases during the rainy season). But the power generated decreases as relative humidity decreases in the dry season.

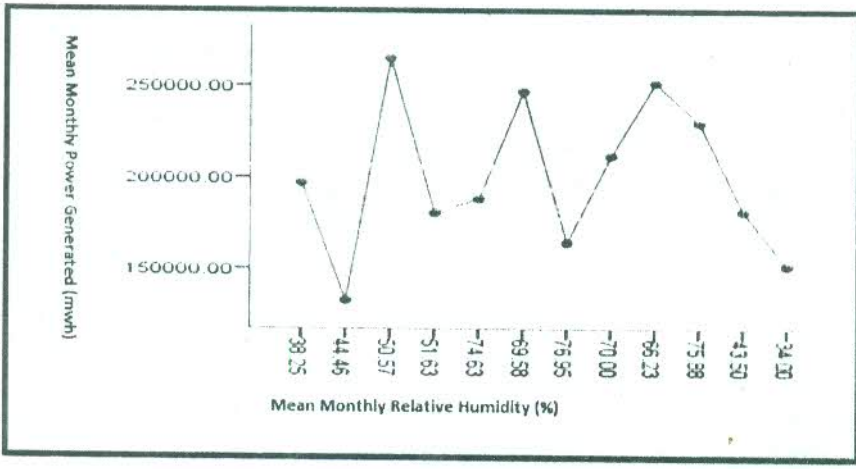

Figure 25: Relationship between relative humidity and power generated in Kainji Dam

Gauge height and Power Generated in Kainji

The relationship between gauge height and power generated in Kainji Dam of Niger state is depict in Figure 26. The correlation value (rainy season: 0.64 and dry season: 0.82) shows that, there is a strong relationship between gauge height and power generated (that is, when gauge height increases, the power generated increases particularly both in the rainy and dry seasons and the results agrees with the findings of Abubakar (1994).

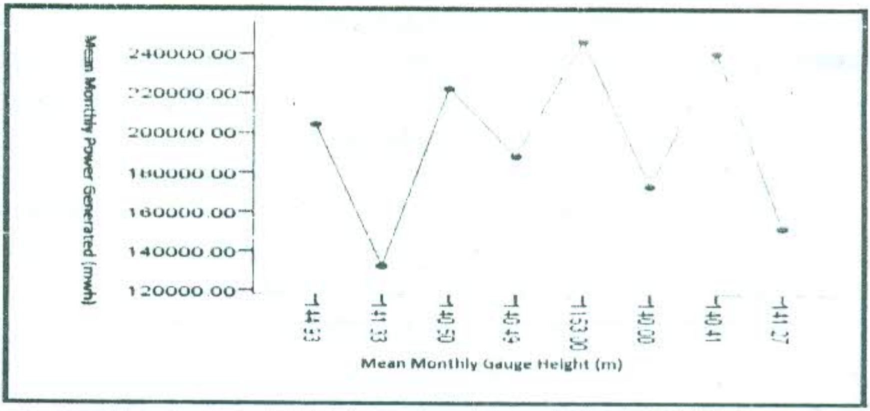

Figure 26: Relationship between gauge height and power generated in Kainji Dam

Inflow and Power Generated in Kainji

Figure 27 shows the relationship between inflow and power generated in Kainji Dam of Niger state. The correlation value (rainy season: 0.85 and dry season: 0.70) shows that there is a strong relationship between inflow and power generated (that is, when there is increased inflow, it results in increased power generated both in the rainy and dry seasons).

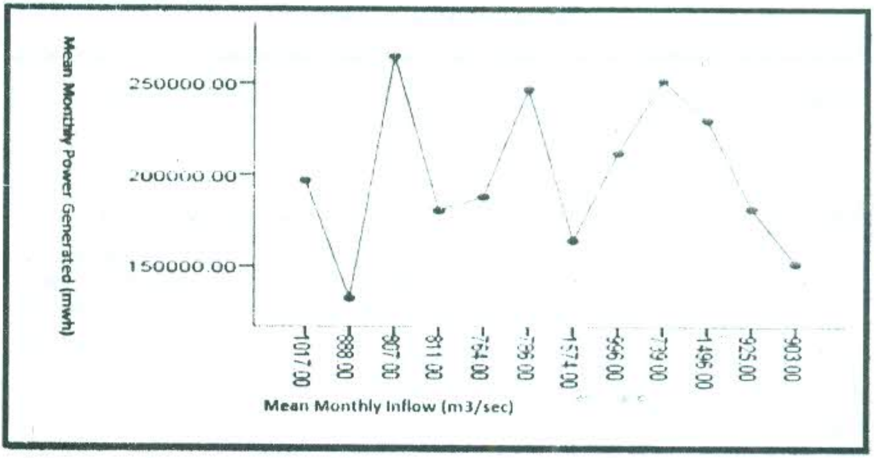

Figure 27: Relationship between inflow and power generated in Kainji Dam

Outflow and Power Generated in Kainji

The relationship between outflow and power generated in Kainji Dam of Niger state is illustrated in Figure 28. The correlation value (rainy season: 0.66 and dry season: 0.90) shows that there is a strong positive relationship between outflow and power generated (that is, when there is increase in outflow, the power generated also increases for both the dry and rainy seasons). The results agrees with the findings of Abubakar (2009).

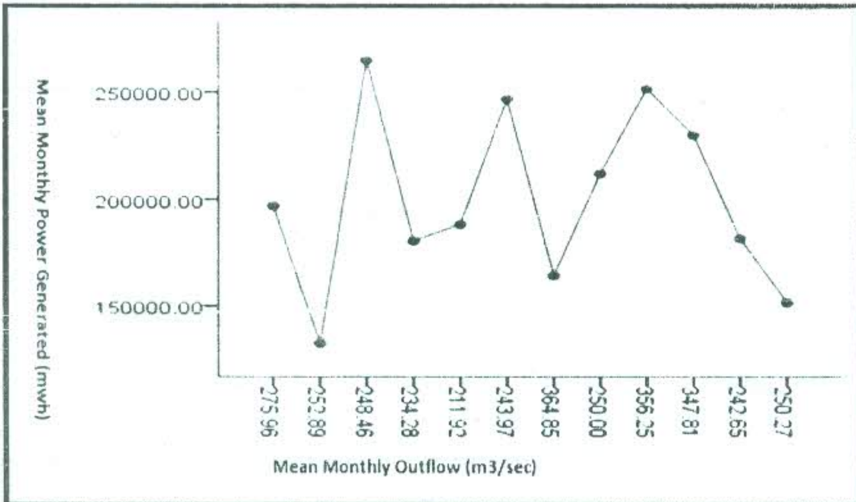

Figure 28: Relationship between outflow and power generated in Kainji Dam

Table 15: Summary for the three hydroelectric dams

	SHIRORO		JEBBA		KAINJI	
	RAINY SEASON	DRY SEASON	RAINY SEASON	DRY SEASON	RAINY SEASON	DRY SEASON
RAINFALL	0.51	-0.87	0.70	-0.88	0.90	-0.69
EVAPORATION	0.58	0.78				
HUMIDITY	0.62	0.71	0.62	0.57	0.75	0.65
TEMPERATURE	-0.84	-0.82				
GAUGE HEIGHT	0.38	0.96	0.74	0.62	0.64	0.82
INFLOW	0.92	0.71	0.90	0.75	0.85	0.70
OUTFLOW	0.90	0.76	0.91	0.94	0.66	0.90

The inflow and outflow exert more influence on the power generated as the lowest and highest values of correlation is 0.70 and 0.91 respectively. The lower value of correlation in gauge height indicates that excess water must be spilled at all times. In terms of meteorological variables however, temperature and rainfall exert stronger influence on power generated as the lowest and highest values of correlation is 0.51 and 0.90 respectively. Evaporation and relative humidity have the lowest correlation values of between 0.57 and 0.78.

CONCLUSION

Mr. Vice-Chancellor Sir, distinguished invited guests, ladies and gentlemen, Allah (SWT) Has provided mankind with abundant natural resources on earth either in the atmosphere, lithosphere, biosphere or hydrosphere.

In this lecture, Man has harnessed the resources from the atmosphere (rainfall, evaporation and temperature) and hydrosphere (streamflow and gauge height) to enhance the generation of hydroelectricity which is a clean energy and environment friendly if used in a sustainable manner.

It is important that Nigeria utilizes her manpower expertise as already in the pipeline to develop more of the hydroelectric power plants at selected perennial rivers at Zungeru, Lokoja, Mambilla, etc. to boost the energy production in Nigeria.

For the remaining large dams in existence, proper dredging should be carried out to increase the efficiency of the dams especially Kainji and Jebba dams that are silting up.

We are all aware of the frustration, and anger if electricity suddenly goes off in our homes/offices and industries. Most of the household appliances are rendered useless including office equipment. It is more of disaster for industries that utilize heavy duty machines for daily production. We can never relegate the subject of hydrometeorology because of its strong influence on hydroelectricity power generation.

Mr. Vice-Chancellor Sir, the more electricity we have from hydroelectric power plants, the better will be for our environment. The more comfortable we shall be in our homes and the more productive hours the Government will realize from her workers. The industries will come alive and the economy will surely receive a big boost. Generation yet unborn will have cause to salute our courage in sustaining the environment in our quest to harness the power of water in motion long after we are gone.

RECOMMENDATIONS

- There is the need to upgrade and refurbish the existing conventional meteorological instruments around the three major hydroelectric power dams with emphasis on ambient temperature, maximum temperature, wind, evaporation and relative humidity.

- Automatic weather stations to be installed in all the major hydroelectric dams to complement the conventional (manual) weather stations. This could be spread along perennial rivers that may offer potential for the construction of hydroelectric dams in the future and also for dense network of weather stations.

- The Nigeria Hydrological Agency (NHA) should step up its drive in the installation of instruments for the measurement of streamflow and gauge height. There should be deliberate effort by the Agency to monitor the major rivers from their headwaters down to the coast.

- The NHA should collaborate with NIMET to come up with early warning systems to mitigate the effect of flooding upstream and downstream locations of the dams.

- The three major hydroelectric power dams should be desilted to allow for better efficiency and avoid the unnecessary weight of the silt (sediment) to affect the toe of the dam which could be catastrophic.

CURRENT RESEARCH EFFORT

- Identifying and Mapping of Critical Watershed in Niger State for Effective Wetland Management.
- Investigation of Waste Dump Effects on Groundwater Resources in Suleja, Niger State, Nigeria.

ACKNOWLEDGEMENT

Almighty Allah: I must thank Allah (SWT), The Creator of the universe who Has made it possible for me to go through the various stages of my academic endeavour. He alone made it possible for me to be alive and healthy and be able to stand before this gathering to deliver the 36th Inaugural Lecture.

My Dad and Mum: Mallam Wakili Abubakar and Mallama Hauwa Abubakar; I don't know how to thank you enough for the love, care and attention. The discipline you imparted in me to make me a better person in future has yielded result even though you are not alive to witness it. May Allah (SWT) grant you Aljannat-Firdaus.

My Wife and Children: Princess Hajara, I want to appreciate and thank you for the attention and solidly standing by me like the Rock of Gibraltar. My cuties (Farida, Sudais, Abdulrahman, Alhassan, Rahima and Gimbiya), I love you all. I want to say that you are all wonderful kids that any father should be proud of.

My Brothers: My late elder brother, Alhassan Abubakar! I wish you were alive to see your little kid brother whom you enrolled in primary school in Sokoto who has risen to the position of a Professor and delivering his inaugural lecture today. May his soul rest in peace. My elder brothers, Col. J. Y. Madaki (rtd) and Alhaji Idris Azozo Abubakar, you have been wonderful and may Allaah (SWT) continue to strengthen you in all that you do.

Vice-Chancellor: Prof. M. A. Akanji Sir, I am short of words in appreciating the *"push"* you gave me which was a challenge to me to prepare for my inaugural lecture. Mr. Vice-Chancellor Sir, I have paid my due. Thank you for the encouragement.

Former Vice-Chancellors: I want to appreciate all the former Vice-Chancellors of this esteemed University starting with Prof. J.

O. Ndagi (Foundation Vice-Chancellor), to Prof. M. S. Audu, who inspired and motivated me to get to the level that I am today.

Principal Officers of the University: Both the present and past Principal Officers of Federal University of Technology Minna, I say a very big thank you for the cordial relationship that exists between you and me.

My Colleagues in SPS: I feel honored to be in the midst of my senior colleagues who taught me during my undergraduate level programme. Prof. Oyedum and Prof. Udensi, I honestly appreciate the fatherly support you have been giving me since I assumed office as the Dean of the School of Physical Sciences. Other colleagues in the School, I say a very big thank you for the support and cooperation, especially the Heads of department.

My Academic Mentors: Professor D.O. Adefolalu (late), Prof. J. M. Baba and Prof. G. N. Nsofor, who mentored and saw me through from undergraduate to post graduate levels. I am most grateful!

My Students: All my students at both undergraduate and post graduate levels, I say a big thank you for putting me on my toes and giving me the challenge at all times either in the class, teaching or supervising your theses.

Research Assistants: For your dedication and hard work, we have secured many research grants which is a manifest of our research efforts.

Staff of SPGS (IBBU Lapai), CPES, SAD, Geography, CCCFR and SPS: You are all recognized and appreciated for the wonderful support you gave me as the one-time Head of these Units and Centres.

Friends: The number is too large! All my friends are well recognized for their loyalty.

Prof. (Mrs.) Z. Osunde: Thank you for the pressure, and reminder which actually kept me on my toes. It is appreciated.

My In-laws: They are too numerous to mention, the list is too long but I must not fail to mention the Emir of Minna, Alh. (Dr.) Umar Farouk Bahago and Hajiya Zainab Bello. You are sweet In-laws.

The Secretariat: Abdulkadir, Grace, Dr. Suleiman, Tola, Emma and Kawu; you guys have been wonderful by staying with me extra hours to ensure the completion of this lecture. My must profound thanks.

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PROFILE OF THE INAUGURAL LECTURER

Professor Ahmed Sadauki Abubakar was born on the 25th April, 1964 at Gawu in Gurara Local Government Area of Niger State. For 25 years, between 1972 and 1997, the young Ahmed attended various educational institutions and bagged outstanding qualifications. He had his primary education at Turaki Primary School, Sokoto and Central Primary School, Minna between 1972 and 1978. Between 1979 and 1983, he was at the Federal Government College, Minna, and between 1985 and 1997, Professor Ahmed Sadauki Abubakar was at the prestigious Federal University of Technology, Minna for his First degree, Master of Technology and Doctorate degrees. He bagged his First School Leaving Certificate in 1978, General Certificate of Education (GCE O' Level) 1983, Bachelor of Technology degree (Second Class Upper Division) in Geography with Meteorology in 1990, Master of Technology degree in Meteorology in 1994 and three years after, he crowned it with a Doctorate degree in Hydrometeorology in 1997.

Professor Ahmed Sadauki Abubakar has a rich academic and administrative experience. As one of the best graduating Students with a Second Class Upper Division in 1990, he was retained as a Graduate Assistant in the Department of Geography, Federal University of Technology, Minna. He has since remained with the University where he steadily rose through the ranks. He was promoted to the rank of Assistant Lecturer in 1994, and rose steadily to the rank of Professor in October, 2012.

Professor Ahmed Sadauki Abubakar served and still serves the Federal University of Technology, Minna in various Academic and Administrative capacities. He was the Assistant Examinations and Time Table Officer of the Department of Geography; two-times Deputy Dean, Students' Affairs Division; Member, University Seminar, Ceremonies, and Minor Works Committees;

Chairman, University Loans Committee; School of Science and Science Education; Seminar and Colloquium Committee; Junior Staff Disciplinary Committee; University Alumni Relations Officer; Deputy Director, Centre for Climate Change and Freshwater Resources (CCCFR); Director, CCCFR; Vice Chancellor's nominee, Junior Staff Appointments and Promotions Committee; Chairman, Bus Service Management Committee; Director, Centre for Preliminary and Extra Mural Studies (CPES); Head, Department of Geography; Member of the Senate; Member, Appointment and Promotion Committee; Chairman, Committee on the Ejection of Illegal Settlers at Gidan Kwano Campus; Dean, Student Affairs Division; and presently, Dean, School of Physical Sciences.

Outside the University, Professor Ahmed Sadauki Abubakar served as Director of School of Preliminary and General Studies, Ibrahim Badamasi Babangida University, Lapai; Member, Governing Council, Niger State College of Education, Minna; Member, A & PC of Niger State College of Education, Minna; Member Niger State Science and Technical Schools Board and Member, Committee to determine the viability of the establishment of Niger University of Education, Minna; Member, National Universities Commission Accreditation Team to fourteen Nigerian Universities between 2012 to date; Member, Nigerian Meteorological Society and Member, Association of Nigerian Geographers. He had served as External Examiner to the St. Clements University, Australia, Nasarawa State University, Keffi; Bayero University, Kano; and University of Abuja. He has also served as External Assessor to the Modibo Adama University of Technology, Yola; Nasarawa State University, Keffi and University of Abuja.

Professor Ahmed Sadauki Abubakar has more than forty published original research articles in peer reviewed journals to his credit at national and international levels; ten technical reports, fifteen conference and workshop papers, and seven research activities, some completed and some on-going. He has mentored and trained many students at all levels and has graduated eight PhD students and over fifty M.Tech students and several PGD and B.Tech. students. He has served as editor and assessor to many national and international journals.

A widely traveled man and a community leader, holding the traditional title of Ciroman Gawu, Professor Ahmed Sadauki Abubakar is happily married to Princess Hajara Ahmed Sadauki and has six Children, three Boys and three Girls. His hobbies include: reading, travelling and jogging.