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73rd INAUGURAL LECTURE

HYDROLOGICAL FORECASTING AND PREDICTION: AN IMPORTANT TOOL IN WATER RESOURCES DEVELOPMENT AND MANAGEMENT

by

Engineer Professor Olufiropo Samson Awokola

Professor of Water Resources and Environmental Engineering

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of

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Professor Babatunde Kehinde
B.Sc (Agric Biology); M.Sc (Crop Improvement), Ph.D (Ibadan), FGSN, FAIMP, FIHSC

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FUNAAB INAUGURAL LECTURE SERIES

Engineer Professor Olufiropo Samson Awokola
(Professor of Water Resources and Environmental Engineering)
Civil Engineering Department, College of Engineering (COLENG)
Federal University of Agriculture, Abeokuta.

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PROTOCOLS:

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Members of my Immediate and Extended families,
Friends and Well Wishers,
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Distinguished Ladies and Gentlemen,
Great *FUNAABITES!!!*.

1.0 INTRODUCTION

Praise the Lord! Praise the Lord!! Praise the Lord!!!

Mr. Vice-Chancellor Sir, the most distinguished audience, you may not know or understand why today is very important to me. This is the 73rd Inaugural in the Federal University of Agriculture Abeokuta, the 7th Inaugural Lecture in the College of Engineering and the first from Civil Engineering Department. I give all glory and honour to the Almighty God for giving me this rare and special opportunity to deliver this maiden inaugural lecture in the Department of Civil Engineering. This lecture is to be delivered by my humble self, the pioneer Acting Head of the Department of Civil Engineering, the first PhD candidate to graduate from the Department of Civil Engineering and the first PhD to be awarded by the College of Engineering. Today's lecture is Hydrological Forecasting and Prediction: An Important Tool in Water Resources Development and Management.

1.1 Past Inaugural Lecturers and current one from College of Engineering

S/No	FUNAAB Series	Lecturer	Department
1st	27th	Engr. Prof. Babatunde Babatope Adejuyigbe	Mechanical Engineering
2nd	36th	Engr. Prof. Babatunde Adewale Adewumi	Agriculrural Engineering
3rd	42nd	Engr. Prof. Peter Olaitan Aiyedun	Mechanical Engineering
4th	51st	Engr. Prof. Tajudeen Muraina Adeniyi Olayanju	Agriculrural Engineering
5th	60th	Engr. Prof. Mufutau Adekojo Waheed	Mechanical Engineering
6th	64th	Engr. Prof. Isaiah Adedeji Adejumobi	Electrical and Electronic Engineering
7th	***73rd***	***Engr. Prof. Olufiropo Samson Awokola***	***Civil Engineering***

1.2 Brief History of College of Engineering

The College of Engineering was one of the two Colleges that were established in Phase II of the educational development of the University of Agriculture, Abeokuta.

For this, the Vice - Chancellor then Prof. Okojie in July 1999 constituted a panel of eminent professionals and practitioners with the relevant wealth of experience to develop the programmes and curriculum for the proposed college.

The Members of the Panel are:

1.	Professor F.O. Aboaba	Agric Engineering	Lagos
2.	Professor E.B. Lucas	Agric. Engineering	U.I
3.	Professor I.A. Adeyemi	Food Science & Tech.	LAUTEC
4.	Late Professor S.O. Awonorin	Food Science & Tech.	UNAAB
5.	Late Professor Segun Adebisi	Civil Engineering	A. B. U.
6.	Engr. O.O. Osho	Works & Services	UNAAB
7.	Engr. O.S. Awokola	Water Resources and Agromet	UNAAB
8.	Engr. M.G. Adebayo	Chairman NSE	Abeokuta
9.	Professor O.A. Bamiro	Mechanical Engineering	U.I
10.	Late Engr. A.C. Ukatu	Mechanical Engineering	UNAAB
11.	Engr. (Prof.) E.I.E. Ofodile	Registrar	COREN

The Deputy Vice-Chancellor then, Late Emeritus Professor. I.F. Adu, convened the meeting of the panel from September 6 to 9, 1999. Unfortunately, Professor Ofodile and Bamiro could not join the panel as they had sudden changes in their programmes.

The Vice-Chancellor opened the meeting of the panel and took time to share the vision of the University with the members. The high patronage enjoyed by the Engineering disciplines from the Joint Admission and Matriculation Board (JAMB) students particularly from the southwestern zone support the establishment of the college as being timely and relevant. The panel submitted a comprehensive report and recommended .

College of Engineering and Technology (COLETEC) but later changed to College of Engineering (COLENG).

A six-departmental structure was recommended for the College namely: Agricultural Engineering, Forestry and Wood Products Engineering, Food Engineering, Civil Engineering, Mechanical Engineering, Electrical and Electronic Engineering.
The College was supposed to run 6 programmes of study that will lead to a Bachelor of Engineering (B. Eng) degree to be denoted as:
i) B. Eng. Agricultural Engineering
ii) B. Eng. Civil Engineering

iii) B. Eng. Electrical and Electronic Engineering.
iv) B. Eng. Food Engineering
v) B. Eng. Forestry and Wood Engineering
vi) B. Eng. Mechanical Engineering

The Phase II took off in the 2001/2002 academic year. That year, the first sets of 100 level students was taken under the coordination of the Head of the Department of Food Science and Technology (FST) late Prof. S.O. Awonorin.

1.3 What is Hydrology?

Hydrology deals with the occurrence, movement, and storage of water in the earth system. Water occurs in liquid, solid, and vapor phases, and it is transported through the system in various pathways: through the atmosphere, land surface and the subsurface. Water is stored temporarily in storages such as vegetation cover, soil, wetlands, lakes, flood plains, aquifers, oceans, and the atmosphere. Thus, hydrology deals with understanding the underlying physical and stochastic processes involved and estimating the quantity and quality of water in the various phases and stores. For this purpose, a number of physical and statistical laws are applied, mathematical models are developed, and various state and input and output variables are measured at various points in time and space.

In addition, natural systems are increasingly being affected by human intervention such as building of dams, river diversions, groundwater pumping, deforestation, irrigation systems, hydropower development, mining operations, and urbanization. Thus, the study of hydrology also includes quantifying the effects of such human interventions on the natural system at watershed, river basin, regional, national, continental, and global scales. Water covers about 70 % of the earth surface, but only about 2.5 % of the total water on the earth is freshwater and the rest is saltwater (NASA Earth Observatory website). Of the total amount of the earth's freshwater, about 70 % is contained in rivers, lakes, and glaciers and the rest in aquifers as groundwater.

Hydrology can be studied under several subjects, namely, hydro-climatology, surface water hydrology, soil hydrology, engineering hydrology, glacier hydrology, watershed and river basin modeling, risk and uncertainty analysis, data acquisition and information systems. This lecture discusses some basic concepts and methods for quantifying the amount of water in the various components of the hydrologic cycle as outlined by Gleick (1996).

1.3.1 Hydrologic Cycle

The hydrologic cycle is simply the distribution and movement of water on our planet and it has a cyclic movement as suggested by the name Hydrological Water Cycle (Figure 1). Precipitation falls to the earth and may be temporarily held in freshwater surface storage, infiltrates into the ground where some of it is stored as soil water and groundwater, and some of it is immediately evaporated. That which cannot be stored or immediately returned to the atmosphere then finds its way into streams and rivers and eventually reaches lakes or the oceans. Waters retained temporarily in the soils or in depressions on the land are then transpired by plants (evapotranspiration) or eventually evaporated from soils and open water bodies back into the atmosphere, where they are blown around the globe to begin the cycle once again. Evaporation also occurs across the oceans. Obviously there is a lot more to it than this and we have skipped over many of the finer details (a more detailed description can be found in the introductory chapter of any hydrologic book) but the continuous and cyclic nature of this movement of water is quite apparent. The hydrologic cycle is the planet's cleansing system, removing dust from the atmosphere and flushing streams and rivers clean. It is also critical to all aspects of life as it is responsible for the breakdown and movement of nutrients and therefore the most important geologic process. A regular and consistent supply of clean water has been required by all civilizations and water has for most of civilized history been the major form of transport, particularly of goods and produce. The Figure 1 below depicts the general hydrologic cycle.

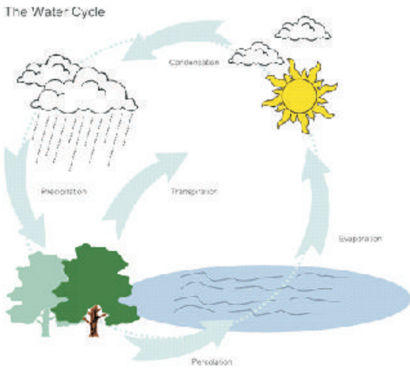

Figure 1: Hydrologic Water Cycle

The Bible provides a statement of important concepts underpinning the hydrologic cycle as we know it today.
Ecclesiastes 1:6-7 “The wind blows to the south and turns to the north; round and round it goes, ever returning on its course. All streams flow into the sea, yet the sea is never full. To the place the streams come from, there they return again”
Embedded in these verses are the concepts of a cycle and of a water balance (conservation of matter). Job 36:27 “He draws up the drops of water, which distil as rain to the streams; [Or distil from the mist as rain] Job 36:28 the clouds pour down their moisture and abundant showers fall on mankind. In these verses you can see several phases of the hydrologic cycle.

The Bible contains many observations of the natural world; the most common reference in the Bible to nature is the aspects of the hydrologic cycle, or the distribution and movement of water. Water is essential to life, a cleansing substance, and a necessary basis for any civilization. Water is also referred to in the Bible as a component of purification, festivals, and ceremonies. Not only are there many statements on the hydrologic cycle in the Bible, but when combined from the various books of the Bible they provide an accurate insight into most aspects of the movement of water and the processes associated with these movements.

1.3.2 Changes in Hydrologic Cycle

The role of changes in hydrologic cycle in urban hydrology processes and effects of urbanization will be briefly discussed for several components of the hydrologic cycle. Some of the components are interception, evapo-transpiration, infiltration and depression storage, overland flow, interflow and groundwater flow.

1.3.2.1 Interception

It is the amount of precipitation that wets and adheres to vegetation until it is evaporated back into the atmosphere, is much higher in rural areas e.g. forest areas. It is not likely, however, to be important in urban stormwater studies.

1.3.2.2 Evapo-transpiration

It is very important for the preparation of hydrologic budgets but has also little practical significance during storm events used in urban runoff studies. Most urban hydrology rainfall-runoff models simulate rainfall losses only by infiltration and depression storage and that is why urban areas produce greater rainfall. To our knowledge such changes were not considered in practical drainage studies.

*1.3.2.3 Depression storag*e

This is the amount of water retained in ground depressions, while *infiltration* is the passage of water through the air-soil interface and is decreased by urbanization.

Despite its limitations, many hydrology models characterize infiltration of urban pervious areas by means of the Horton relation: $f = f_c + (f_o - f_c)e^{-kt}$

Where f is the infiltration capacity at some time t, *mm/hr* , f_o, f_c are initial and equilibrium capacities, k is a coefficient. The infiltration rates have units of depth/time. The value of f_o varies significantly with soil type and antecedent moisture conditions. The natures of the development do have some influence on the value of fc.

1.3.2.4 The overland flow

It is a process whereby water moves on the surface of soil to a channel or other receiving waters is significantly affected by urbanization. This will be further discussed during this lecture with velocity of overland flow for urban areas and slope.

1.3.2.5 The interflow

This is process whereby water moves beneath the land surface but above the groundwater table is rarely analyzed explicitly in urban hydrology where it is usually considered part of the runoff process.

1.3.2.6 The groundwater flow

Unlike many other processes in the hydrologic cycle, is essentially a continuous process which maintains a flow in natural and man-made drainage ways. It may be significantly affected by urbanization which usually decreases base flow and lowers water tables. Reduction of base flow and groundwater level are in general not as well-documented as increases in peak flow and total runoff. The total annual surface runoff will increase with the imperviousness ratios. This will be discussed further in the contribution to knowledge.

Understanding the hydrologic cycle is essential for:

- Sustainable agriculture (foods for the growing population)
- Environmental protection and management
- Water resources development and management
- Prevention and control of natural disasters
- Mitigation of the negative impacts of climatic change

1.4 Engineering Hydrology

The study of those aspects of hydrology which are relevant to the solution of engineering problems in the control or utilization of water. It implies a method of study or analysis which is designed to answer in a quantitative manner, questions arising in an engineering context but without necessarily implying an extension of our understanding of the process involved. Such problems usually arise either in: Forecasting or Frequency prediction.

1.4.1 Forecasting

The estimation of when some hydrological event will occur. Forecasting arise most directly in the operation of hydrological controls e.g., opening of sluice gates in anticipation of flood wave, or the evacuation of the population of a town threatened by a rising river e.g., Ogunpa and Ogun.

1.4.2 Frequency prediction

The estimation of how often an event will occur. Frequency predictions are associated with the design rather than the operation of such controls. Estimation of some aspect of the quantity of water available is of prime importance in water resource engineering. The analysis is basic to the planning, design and operation of water resources systems i.e., culverts in a rural road, reservoirs, levees, and canals.

A multipurpose project may include:

(i) Water supply for municipalities and industries
(ii) Flood plain management and flood damage reduction.
(iii) Hydropower for electricity generation.
(iv) Navigation
(v) Irrigation, drainage and erosion control.

Flood control primarily involves peak rates of discharge, whereas supply for most other uses involves analysis of the periods of lowest flow.

Hydrology is aimed at determining design parameter, which are analogous to design loads in structural analysis.

1.5 Urban Hydrology

Until recently the planning of urban drainage systems was conducted by means of less sophisticated methods than planning at the watershed level. Flow measurements on small, urbanized watersheds were usually neglected. Rain gauges in municipalities did not always give data on very short duration, high intensity storm bursts which may be critical for sewer design. Data on pollutant constituents of urban runoff were not collected and attention was given mainly to pollution caused by raw and treated sewage. Hydrologic problems associated with urban growth cannot be solved without a scientific approach to urban water resources. Hydrologic research traditionally concerned with rural and large watersheds, has therefore increasingly been concerned with smaller urbanized catchments.

Urban hydrology is now a distinct branch of traditional hydrology. Some of its characteristics are:

- Application of advanced hydrologic modeling principles for flow simulation in urban drainage systems.
- Interface of water quality and water quantity analysis.
- A multidisciplinary approach to urban water resources problems with consideration of environmental and urban planning components.
- Development of new techniques for mitigation of storm water effects and eventual beneficial uses.

1.5.1 Consequences of Flooding

An important consequence of peak flow increases may be the dramatic increase in flood damages. The effects of flooding are more devastating because of floodplain occupancy. Human settlements have been historically attracted by water courses and the remedial for flooding caused by large rivers has traditionally consisted of structural measures. Experience with such measure indicates however that structural controls result in increased population of the floodplain.

Development in the floodplain leads to filling and loss of valley

storage which also increases the peak flows. If the stream or river is channelized, the time of concentration is decreased, and the flooding problem moved downstream.
The story of Noah and the flood in the bible started from the book of Genesis Chapter 6. This was another great hydrological event in the Bible. The Bible Patriarchs before the flood from Adam to Noah were 10 and the Patriarchs after the flood from Shem to Abraham were 10, as well. Noah was the tenth and last of the Pre-Flood Patriarchs and was 600 years old at the time of the flood. Prior to the flood, the average age of the Bible Patriarchs was about 857 years. The next 10 generations (Noah to Abraham) after the flood had an average age of 317 years. Did the pre-flood world enable a longer life, or did God enact shorter lives because He was sorry, he had created man (Gen 6:7)? Consider this quote from the King James Version: "Genesis 6:3 And the LORD said, my spirit shall not always strive with man, for that he also [is] flesh: yet his days shall be an hundred and twenty years."
The shorter life span can be attributed to the effect of environmental pollution because of the flood occurrence.

1.6 Water as a Resource
Water plays a crucial role in the survival of living organisms (animals and plants) on Earth. Where there's water, there's life. Even in the driest regions of our countries, even under the deserts, there is always water, even if sometimes it is too deep to be possibly used. Springs, running waters, glaciers and lakes provide animals and plants with that amount of water that is indispensable for their life cycle. Man is interested in drinking water, which is becoming less and less unavailable as the population of the world increases and because of pollution. Water is important in all its forms also because it is an integral part of the earth's landscape. It largely contributes to its shaping and also determines its climate. Fresh as well as salty waters are inhabited by micro-organisms that decompose much of the waste produced by man. This biological cycle is also of crucial importance.

1.6.1 Chemical Properties of Water

The chemical formula of a molecule of water is H_2O: two atoms hydrogen (H_2) linked to one atom oxygen (O). The atom electrons (particles with a negative charge) establish links between themselves. Oxygen is more able to keep them close to it than hydrogen. The water molecule results to be charged negatively near the atom of oxygen and positively near the atom of hydrogen. Since opposites attract, the water molecules tend to join like magnets.

Water is called the universal solvent since it can dissolve more substances than any other liquid. And we are very lucky it can: if it could not, we could not drink a cup of hot sugared tea, because the sugar would remain at the bottom of the cup. Therefore the waters of rivers, streams, lakes, seas and oceans that may look pure at first sight contain in fact a huge number of dissolved elements and minerals released by rocks or by the atmosphere. Wherever it flows, above ground, underground or inside our body, water dissolves and carries an extremely high amount of substances. Water thus performs a precious task: that of carrying, sometimes to long distances, the substances it encounters along its way. Pure water, like distilled water, has a pH of 7 (neutral). Seawater is essentially alkaline, having a pH of around 8. Most fresh water has a pH between 6 and 8, apart from acid rains which of course has pH below 7.

1.6.2 The Physical Properties of Water

Water has a high specific heat, i.e. it needs a lot of heat to heat up and takes long to lose the stored heat and get cold. This is why it is used in cooling systems for instance in car radiators or to cool industrial equipment. This is also why in coastal (or lake) regions the temperature of the air is milder. In these areas, as seasons change, the temperature of the water 'mitigates' the temperature of the air, since it decreases or increases more slowly than that of the air.

Water has a high surface tension: that means that, once poured on a smooth surface, it tends to form spherical drops instead of expanding into a thin film. Without gravity, a drop of water would be perfectly spherical. Surface tension allows plants to absorb the water contained in the soil through their roots. It is surface tension, again, that makes blood, which is largely composed of water molecules, flow through the blood system of the human body.

In addition, water can normally be found in a liquid state, but can easily become solid or gaseous. Pure water goes from liquid to solid, i.e. freezes, at 0 degrees centigrade, while at sea level it boils at 100°C (the higher the level, the lower the temperature at which water starts boiling). The water boiling and freezing values are taken as a reference point to calibrate thermometers: in centigrade scales, 0° on the centigrade scale is the freezing point and 100° is the boiling point.

When freezing, water expands, i.e. its density decreases while its volume remains the same: this is why ice floats on the water or a bottle filled with water and placed in a freezer breaks up.
Water is a special natural resource since it is the only one on earth to be found in all of the three physical states depending on the surrounding temperature: liquid, solid (ice) and gaseous (water vapor). The whole of the processes that make water leave the oceans, get into the atmosphere, reach the emerged lands and flow back to the oceans later on is called hydrological cycle and is fuelled by the energy of the Sun.

The development of water resources requires the conception, planning, design, construction, and operation of facilities to control and utilize water. It is basically a function of Civil Engineers, but the services of specialists from other fields are required.

Each water-development project encounters a unique set of physical conditions to which it must conform; hence standard designs which lead to simple, handbook solutions can rarely be used. The special conditions of each project must be met through an integrated application of the fundamental knowledge of many disciplines. A number of them are economic, social sciences, engineering, and other aspects must be considered in the design of water-management projects. Hydrology, hydraulics and other civil engineering courses are indeed necessary in the field of water resources and environmental engineering.

1.7 Groundwater Considerations

Urbanization seals the natural recharge areas which results in depletion of aquifers. Building of line channels for flood protection or large sewers has also resulted in lowering of groundwater table. Another human activity which may have detrimental effects on aquifers is dredging of sand and gravel which creates trenches that become filled with fine sand and silt, and reduces the permeability. This aspect will be discussed briefly in one of my research contribution to knowledge. Decrease of the quantity of water available for well fields as a result of urbanization may become a major problem and require a water budget analysis. Lowering of the water table may also be the cause of damages to buildings. In coastal areas, groundwater withdrawal and reduction of supply leads to seawater intrusion, which requires control by reduction of extraction, pumping trough and artificial recharge.

Another threat to groundwater losses consists in various forms of pollution, for example deposits of solid wastes in sanitary landfills adjacent to aquifers pose a large potential hazard to groundwater quality. The deposited solid wastes may leach by percolating rainwater due to lack of protective barriers which allows the leachate to percolate into the aquifer. This will be drawn sooner or later to operating wells or emerge in streams, hydrologic and hydrogeologic condition should be properly evaluated before selecting sanitary landfill sites. Wherever possible, they should be confined to impervious formations such as clay.

There are two major lessons from the experience in this area:

(i) The need for comprehensive planning.
(ii) The need for local data collection programmes.

The job of the water-resources engineer may be reduced to a number of basic questions. Since the water-resources project is for the control or use of water, the first question naturally deals with the quantities of water. Where utilization is proposed the first question is usually *how much water is needed?*
This is probably the most difficult of all design problems to answer accurately because it involves social and economic aspects as well as engineering.

Almost all project designs depend on the answer to the question *how much water can be expected?*
Peak rates of flow are the basis of design of projects to control excess water, while volume of low flow or flow during dry periods of time is of interest in designing projects for use of water.

1.7.1 Water Quality Management
In addition to being adequate in quantity, water must often withstand certain tests of quality. Problems of water quality are encountered in:

- Planning water-supply
- Irrigation projects and
- Disposal of wastewater

Polluted streams create problems for fish and wildlife, are unsuited for recreation, and are often unsightly and sometimes odorous. The engineer must then provide the necessary facilities for removing impurities from the water by physical, chemical or biological methods.

1.7.2 Economics in Water-Resources Engineering

The special ability of the engineer is reflected in the planning of projects which serve their intended purpose at a cost commensurate with the benefits. An economic analysis to determine the best of several alternatives is required in planning most projects. It must be demonstrated that the project cost is sufficiently less than the expected benefits to warrant the required investment. It is usually uneconomic to design a project to provide protection against the worst possible flood or to assure an adequate water supply during the most severe drought which could occur. Instead the project design is gauged against a scale of probability so that the probability of the project failing to serve its purpose is small but still positive. Economic analysis is dependent on hydrologic analysis of the probability of occurrence of extreme floods or droughts.

1.7.3 Planning for Water-Resources Development

Planning can be defined as the "orderly consideration of a project from the original statement of purpose through the evaluation of alternatives to the final decision on a course of action".

It includes all the work associated with the design of a project except the detailed engineering design of the structures. It is the basis for the decision to proceed with (or to abandon) a proposed project. Because each water-development project is unique in its physical and economic setting, it is impossible to describe a simple process which will lead to the best decision.

1.7.4 Purposes to be served by a Water-Management Project

In the usual scheme of development for a river basin, all flow that can be suitably regulated is ultimately utilized. The available water is divided among requirements in accordance with a system of priorities. Requirements with highest priority are satisfied at all times if possible, while others are served only when sufficient water is available. Purposes to be served by a project usually include a number of the following: Navigation; Irrigation; Power generation; Flood control; Municipal water supply; Pollution abatement; Industrial use; Recreation, Aesthetics and tradition; Fish and wildlife conservation and other environmental considerations; Salinity and sediment control; and recharge of groundwater. Criteria used in the design and operation of water-resources projects are usually based on obtaining the maximum net benefits from the resources invested in the project. A design to meet the full demand need not always be the most desirable alternative. Conflicts can also occur among the various intangible aspects arising, on one hand, by making supplies available and, on the other, by curtailing demands.

It is the objective of water-resources management to seek an optimal balance between water supplies and demands by quantifying, to the extent possible, the consequences of tradeoffs between the conflicting tendencies on the basis of cost-benefit studies and other considerations.

1.7.5 Multi-purpose projects

With the increasing level of development of water resources throughout the world, it is becoming more important to plan projects that can serve a number of purposes simultaneously. For example, a planned storage reservoir may provide both water supply and flood control downstream. Hydrological data required for the design of a multi-purpose project are basically an aggregate of the data required for the various single purposes involved. The methods of analysis, although similar to those applied in design of single-purpose projects, are more complex. A series of plans involving combinations of project sizes and methods of operation must be made to determine the optimum plan.

There is a basic conflict between the management of water resources for flood control and conservation needs (water supply and low-flow regulation) in multipurpose projects. During the flood season, it is usually essential to maintain empty space in reservoirs in anticipation of possible flood flows, whereas it is usually desired to keep the reservoir as full as possible for low-flow regulation. Toward the end of each flood season, this conflict is particularly critical, because subsequent conservation benefits will depend partly on storage at that time, and it is therefore of particular importance to examine the project operation-plans in relation to flood and low-flow expectations.

1.7.6 Water-resources systems

If more than one water-resources project exists within a river basin, or if water is diverted between basins where water-resources projects exist, their overall effectiveness can be increased by coordinating the operations of the projects. Such coordination requires all the various projects to be treated as one interrelated system by considering the availability of water and the specific purposes of each project as well as the possible interactions and tradeoffs among them. A review of system operation should be undertaken as soon as a new project or a new demand is initiated that could have significant impact on existing operations.

Before appreciable expenditure of time and money can be justified for the planning of a water-management project, a preliminary investigation must be made of its feasibility, desirability, possible scope, and its possible effect on those hydrological factors that influence the environment and the efficiency of other projects.
Although this investigation has to be based on whatever material may be available, e.g. fragmentary hydrological records, old maps and reports, it must be carried out with great care because it is at this stage that conceptual planning decisions are often made and that important aspects and consequences of the project may become apparent. If preliminary investigation indicates that the project potential is favourable, then more detailed studies would normally be initiated. The types of hydrological data required for water management are given in the Table *in chapter 47 WMO168 pages 615-617.*

1.8 Environmental Engineering as a Profession

Designing a water treatment facility to provide clean drinking water to a community can serve society and become a personally satisfying undertaking to the environmental engineer. Environmental engineers now are employed in virtually all heavy industries and utility companies, in any aspect of public works construction and management, and by consulting firms. In addition, every state and most local governments have agencies dealing with *air quality, water quality and water resource management, soil quality, forest and natural resource management, and agricultural management* that employ environmental engineers. Pollution control engineering has also become an exceedingly profitable venture. Environmental engineering has a proud history and a bright future. It is a career that may be challenging, enjoyable, personally satisfying, and monetarily rewarding. Environmental engineers are committed to high standards of interpersonal and environmental ethics. They try to be part of the solution while recognizing that all people including themselves are part of the problem. The sanitary engineer job became essential with the rapid increase of cities and other rural population concentrations. Sanitary Engineering Fields:

(i) Water supply: *(water collection, groundwater, surface water, water treatment and water distribution)*
(ii) Wastewater Management: *(collection systems, treatment, reuse and/or disposal)*.
(iii) Storm water Management: *(Storm water collection, storm water reuse and/or disposal)*
(iv) Solid waste Management: *(collection systems, treatment methods, reuse and or disposal)*

1.9 Data Limitation

In the design of any hydraulic engineering structure, a design flow must always be chosen. In major projects, the design flow must be chosen on the basis of combined hydrologic, hydraulic, and economic factors and safety criteria. Larger rivers within the basin are equipped with flow gauging equipment (that are not maintained, not functioning no data for so many years), while smaller streams are rarely gauged. Where adequate basic information is not available or when it is scarce or unreliable, special hydrologic methods are often applied, coupled with engineering insight and keen understanding in order to obtain the appropriate flood discharges. This is part of the focus of today's inaugural lecture. In Nigeria and other developing countries of the world there are problems of data inadequacy, frequent gaps in the data and non-existence of data at development sites. The problem had created serious design and project management problems (Sonuga, 1990). The likely solution would be proffered in this lecture.

The derivation of relationships between hydrological variables is of great importance for the transfer of information from the few-gauged rivers to the many other rivers from hydrological similar catchments for which no measured stream flow data exist. The water cycle regulates and reflects the natural variability of the physical processes which impact on ecosystems. There is a need for an approach to ascertain the actual changes in hydrological response of a particular watershed within a drainage basin, which can reveal land transformations and interactions that occurred in the past. The results will be useful for engineers, conservationists and planners at gauged and ungauged sites. My research focus had always been how to produce results or product that will be useful for engineers, conservationists and planners at gauged and ungauged sites. It will also reveal the threshold of flood discharges required for the economic design of hydraulic structures and economic feasibility analysis of water resources management and environmental impact assessment of projects.

The urgent need for developing nations to construct hydraulic structures cannot allow an indefinite wait for adequate data. The hydrologist, therefore, has to use his skills to appropriately choose those methods, which will, as accurately as possible, predict the design-oriented parameters. The basic problem is to find the relation between flood magnitude and return period at a site for which no record of flows is available. The nature of stream flow in a region is a function of the hydrologic input and the physical, vegetative and climatic characteristics of the region. The physical characteristics of a catchment may be grouped under a number of general headings e.g. size and shape, density and distribution of streams, overland and channel slope, catchment storage, soils, geology, rainfall and other climatic features. The geometric characteristics i.e. *area, shape, length of streams and average mainstream slope affect the form of the hydrograph and peak discharge from a given watershed area.* In this lecture, the relationship and effect of the geometric characteristics of Ogun and Osun drainage basin and the flood frequency will be presented. There is still much to be done in refining the tools of water resource systems analysis, particularly those that can operate with limited data. There is in fact ample evidence of a world-wide downward trend in such work, involving both developed and developing countries (WMO). Past hydrological, data are essential in assessing not only the magnitude of a body of fresh water and its extent in space, but also its variability with time. The frequency of past floods and droughts can be assessed with a fair degree of accuracy, but an estimate of the future frequency of such events is clouded with considerable uncertainty. Yet it is for the future that water-resource systems are to be designed. Between the known past and the uncertain future, lies the present when existing systems must be operated as efficiently as possible. It is here that hydrological forecasting has a vital role to play.

1.10 A Brief Review of Flood Forecasting Techniques and their Applications

Flood forecasting is one the most challenging and difficult problems in hydrology. However, it is also one of the most important problems in hydrology due to its critical contribution in reducing economic and life losses. In many regions of the world, flood forecasting is one among the few feasible options to manage floods.

Among all observed natural hazards, water-related disasters are the most frequent and pose major threats to people and socio-economic development (Noji and Lee 2005, ICHARM 2009).
Over the period of 1900-2006, floods accounted for about 30% of the total number of natural disasters, claiming more than 19% of the total fatalities and more than 48% of the total number of people affected (ICHARM 2009). ICHARM (2009) also reports that water-related disasters account for about 72% of the total economic damages caused by natural disasters, out of which 26% of all the damages are attributed to floods. These losses are expected to escalate in the future due to climate change, land use change, deforestation, rising sea levels, and population growth in flood-prone areas, causing the number of people vulnerable to flood disasters globally to increase to two billion by 2050 (Bogardi 2004, ICHARM 2009, Vogel et al. 2011).
Traditional flood management, primarily composed of structural protection measures (i.e. dams and levees), emphasizes modifying a flood's characteristics to reduce the peak elevations and spatial extents.

Floods can be of many different types and scales and this drives differences in the architecture and implementation of flood forecasting systems. Hydraulic structures are usually operated in accordance with a set of rules which take account of the current state of the system, the demands being made upon it, and some estimates of future rainfall, streamflow, evaporation and the like. At the least, all important water resource systems should incorporate the real-time collection of hydrological data and their use in developing forecasts of future conditions relevant to the operation of the systems. The costs of collecting the data and preparing the forecasts are a fraction of the cost of constructing and operating the system itself and will usually be far outweighed by their potential benefit in improved safety and operational efficiency.

There is therefore a strong case to be made for the use of hydrological forecasts in the operation of water-resource systems. The importance of hydrological forecasting, for both water-resource management and disaster mitigation, has long been recognized by the World Meteorological Organization (WMO). Central to any hydrological forecasting system is a model which takes as input the relevant data on the past and present state of the natural system and produces an estimate of its future state.

2.0 MY RESEARCH CONTRIBUTION: COMBINING TOWN WITH GOWN

I wish to report here that the accumulation of the experience to be discussed today started since 1977 when I was employed as a Technical Officer after the completion of my Ordinary National Diploma by Inaolaji Builders on road construction (Ikirun-Inisha-Ekosin-Okua-Igbaye road). Keeping of detail records of activities on site is a must. I later worked with Profen Consultants on Eleiyele-Ijokodo-Sango Road I was in charge of the Earthwork, Soil and Concrete testing. A thorough knowledge of the subject matter was important otherwise the contractors will play a fast one to cut cost. During my National Youth Service, I was involved in the design of the drainage system for New Gbagi Market.

I was a member of the consultant in the following studies, as part of my mandate as an academic that determine to combine town with gown, I played a dual role as a professional and a researcher.

(I) Detail Study, Design and supervision of Construction of an earth Fill Dam for Federal Polytechnic, Ilaro.
(ii) Full scale studies and design of suitable measures to control flooding potential of Oora Stream, Ilesa.

(iii) Reconnaissance Survey of Fadama Development Potential of Ondo State - A World Bank/FACU/ADP Project.

(iv) World Bank Multistate Water Project Ogun State Feasibility Studies and Preliminary Design of Water Supply Schemes to 17 centres covering all Local Government areas. Surface water quality appraisal of major streams in the state.

(v) Asejire Dam Monitoring and Hydrological Analysis of Osun Basin.

(vi) Baseline Survey for National Rural Water Supply Programme (PTF-NRWSP) in Ogun State. This includes both the technical and socio-economic survey. The Baseline Survey Report defines scope of work through identification of 400 project locations, which form basis for subsequent award of drilling and rehabilitation of some existing wells fitted with hand-dug-wells, boreholes and rehabilitation of some existing wells fitted with hand pump, with emphasis on community participation.

(vii) Feasibility Report on Improvement of Water Supply in Urban and Rural Areas of Ekiti State.

(viii) Feasibility Report on Improvement of Water Supply in Urban and Rural Areas of Edo State.

My involvement in the above studies and understanding of the knowledge-gap to be filled or augmented and the need of my professional colleague in the industry contributed to my focus in research activities.

Acting Vice-Chancellor, Sir, my contributions had been to appropriately choose methods, which will, as accurately as possible, predict the design-oriented parameters. My research focus has been based on the understanding that the flow regime of rivers is an essential component of parameters to be considered in the design of hydraulic structures and the realization that in many developing nations essential data is not available for most water resources engineering problems.

The need for adequate planning and development of water resources in the country put pressure on the engineers, hydrologist and planners to analyze critically available data. Projects are being designed on the basis of fragments of information, memories of long-time inhabitants and engineering judgment. Of major significance is the estimation of flood discharges hydraulic structures could withstand. Solutions to such problems are necessary in any engineering activity connected with streams in which flow rates are stochastic in nature.

A flood protection scheme is certainly one of the challenges of hydraulic engineering in which the inter-relationship between stream flow mechanics, dynamics and hydrology must be carefully studied and interpreted. Accurate assessment cannot be made with scanty or no data at all, projects are designed with a large element of risk. In fact, in most projects a high safety factor is used, which in effect increase the cost of a single structure considerably, and reduces the number of developmental projects. My major areas of research focus can therefore be the application of the following subjects:

(i) Open Channel Hydraulics
(ii) Analytical Hydrology
(iii) Hydrologic Frequency
(iv) Hydrometry
(v) Hydrologic Computation
(vi) Water Resources Management and Environmental Engineering.

My contributions can now be discussed under six main headings:

(i) Environmental Studies
(ii) Hydrology and Flood Frequency Analysis
(iii) Hydrology and Rainfall-Intensity-Duration-Frequency Analysis
(iv) Ecological and Natural Disaster Studies
(v) Ground Water Pollution and Shallow Aquifer Studies
(vi) Erosion Rate Investigation and Estimation

2.1 Environmental Studies

Acting Vice-Chancellor Sir, Martins and Awokola (1996) realized that research efforts on hydrochemistry of rivers in Nigeria centre mostly on major rivers. Despite the existence of numerous drainage basins and their suitability for model studies very limited information is available on the river water quality and quantity. We decided to study the total dissolved solids of selected rivers in Southwestern Nigeria. The discharge values of the sampled rivers ranged from 0.1 m^3/s to 1.7.m^3/s . Although rivers of the sub-humid zone tend to have larger drainage basins, their discharges are often disproportionately lower than those of the main forest belt.

Martins et.al. (2001) noted that series of estuaries and lagoons characterize the Nigerian coastal areas, in the south-west, the Lagos and Lekki lagoons form a transition between four major rivers (Yewa, Ogun, Osun and Ona-Ibu) draining the hinterland, and the Atlantic Ocean. As a way of presenting insight into the nature of solutes, sediments and dissolved solids delivery to the coastal lagoons of southwestern Nigeria, the dominant water types of the rivers as well as the total suspended sediments, the mean annual total discharges, the total dissolved solids, the chemical denudation and the mechanical erosion rates were estimated. The average chemical denudation and mechanical erosion rates are $1.86x10^6$ tons/year and $5.11x10^6$ tons/year respectively, while the average total dissolved solids and the average total suspended sediments are 113.23 mg/l and 155.65 mg/l respectively. Three types of ionic series are recognized representing the low salinity, the medium salinity and high salinity environments of the fresh water influx zone, the mixture of marine and fresh water zone and marine water zone respectively.

Proof of inputs of untreated domestic sewage, municipal garbage and industrial wastewater from the shores of the lagoons is provided by the high concentration of trace metals (Cu, Cr, Zn, Fe,

Mn, Ni, Pb and Cd) in the sediments of Lagos lagoon.
Acting Vice Chancellor Sir, other collaborative researches are in the area of environmental impact assessment, Adeofun et.al (2011) studied the environmental impact assessment of sand dredging and land reclamation in Lagos coastal areas. Results showed that the project will displace about 1,500 people living in 159 make shift structures. About 2 million cubic meter of sand will be needed to completely sand fill the proposed island which will likely affect fishing and fish ecology. The proposed estate will generate 2,400kg/day of solid waste and 360,000litres of sewage per day which is quite sufficient for polluting the lagoon if not treated. Considering the need for building space in the city, the paper suggests ways of ameliorating the likely impacts at the end of the project.

Akinyemi et.al. (2012) determined the thermal properties of rock samples using modified thermal block method. Thermal properties are usually the key parameters governing the heat transfer through any material. Hence in modeling the thermal behavior of materials, accurate determination of thermal properties is quite imperative. The study was conducted with the determination of thermal conductivity, thermal diffusivity and volumetric heat capacity of rocks by block method with thermal contact resistance consideration and the validation of the results with that of KD2 device. Thermal conductivities with or without Thermal Interface Material (TIM) were tested statistically and it was found that using TIM to contact resistance was significant at ($P>0.05$).

Akinyemi et.al (2012) studied the thermal properties that are usually the key parameters governing the heat transfer through any material; hence in modeling the thermal behavior of materials, accurate determination of thermal properties is quite imperative. The paper deals with the determination of thermal conductivity, thermal diffusivity and volumetric heat capacity of rocks by block method with thermal contact resistance consideration and the validation of the results with that of KD2 device. Thermal properties of granite, limestone and gneiss rocks were determined in the laboratory with the use of thermal interface material (TIM) Arctic Silver to find out the effect of contact resistance. KD2 probe was also used with and without TIM to compare thermal conductivities results.

Thermal conductivity of granite, limestone and gneiss increased from 2.96 to 3.96 W/mK, 2.02 to 2.68 W/mK, and 1.64 to 2.20 W/mK respectively while Thermal diffusivity increased from 0.41 x 10-4 to 0.67 x 10-4 m2/s, 1.09 x 10-4 to 7.38 x 10-4 m2/s, and 0.65 x 10-4 to 1.44 x 10-4 m2/s respectively. Thermal conductivities with and without TIM were tested statistically using (FPLSD) and it was found that using TIM to correct contact resistance was significant at ($P > 0.05$).

Awopetu et.al. (2014) studied the role of waste-pickers in the management of solid waste management in Nigeria. They are involved in recovering recyclable and reusable materials from the waste stream. Waste-pickers retrieve nearly 35% of recyclable and reusable materials from the solid waste stream in Nigeria. Their work results in waste separation, waste reuse, aiding recycling, and reducing pressure on the environment. Solid waste composition influences the roles and activities of waste-pickers, the study highlights the activities of waste-pickers and the composition of solid wastes in Nigeria, based on a literature review. It was recommended that: waste-pickers and their organizations should be formally integrated into the solid waste management system; landfills should be designed to enable safe rummage by waste-pickers through garbage before it is deposited and buried and basic education should be made accessible and affordable to the children of waste-pickers.

2.2 Hydrology and Flood Frequency Analysis

Awokola and Martins (2001) studied the Regional Flood Frequency of Osun Drainage Basin, South Western Nigeria. Regional flood frequency curve (RFFC) for Osun Basin, South Western part of Nigeria was developed, usable at gauged and ungauged sites with only a few years of hydrologic record or predicted mean annual flood. Estimation of a flood magnitude corresponding to a selected return period of 5,10,25,50 and 100 years using statistical procedure i.e. Extreme Value Type 1 distribution was developed.

The Regional Flood Frequency curve was established using the Index Flood Method with the confidence limits envelope for 95% upper and lower limits. The results obtained can be adopted for the basin and hydrologically similar areas. This can be made use of in estimating flood magnitudes required for the design and economic appraisal of hydraulic structures and estimation of flood risk particularly in flood plain management and flood-drainage mitigation.

Acting Vice Chancellor sir, realising early enough during my search to combine town with gown, I realised that our problems can only be identified and solved by ourselves.

Awokola (2001) studied the Regional Flood Frequency of Ogun Drainage Basin. Four commonly used distribution methods were adopted in the study viz Normal Distribution, Exponential Distribution, Extreme Value Type 1 Distribution and 2-Parameter Log Normal Distribution.

The Extreme Value Type 1 Distribution was found to best fit Ogun River. Regression analysis was applied to develop regression models to predict Mean Annual Flood (MAF) from gauged catchments and the results show that the MAF can be reasonably predicted from

$$Q_M = 0.038A^{0.96} \quad \cdots\cdots\cdots \quad (r = 0.94) \quad \cdots\cdots\cdots\cdots 2$$

The Q_M (m^3/s) i s the Mean Annual Flood or the Index flood, i.e. the required peak discharge at ungauged sites and A is the total catchment area (m^2) . The Regional Flood Frequency analysis evolved can fairly determine the flood magnitude of the study area and other hydrologically similar areas.
The quantiles at ungauged sites can be estimated by first estimating the magnitude of the index flood and then multiplying it by the ratios read from the regional frequency curve for various return periods.

Awokola (2003) derived rating equations for seven gauging stations in Osun Basin, South Western part Nigeria that had established rating tables. The derivation of relationships between hydrological variables is of great importance for the transfer of information from the few-gauged rivers to the many other rivers from hydrological similar catchments for which no measured stream flow data exist. The model basic parameters used to obtain the equations for each of the rating curves while four others were further investigated and the results are in Table 1. The equations will be useful for engineers at gauged and ungauged sites and it will ease the computation of flood discharges required for the economic design of hydraulic structures and economic feasibility analysis of water projects. Although graphical and rating table may be acceptable for hand calculations, the rating equations will be well suited to computer analyses.

Table 1. The derived Rating Equations for each station.

Location of Station	Stations No	Derived Rating Equations	Type of Equation	Remark
Asejire	5	$Q_5=17.36H^{2.27}$	Power	Perfect Fit
Iwo Railway Station	25	$Q_{25}=8.23H^{3.99}$	Power	Perfect Fit
Ede	27	$Q_{27}=0.24H^{4.73}$	Power	Poor Fit
		$Q_{27}=10.06H^2 +15.67H-62.39$ ($r^2=0.996$, $r=0.998$)	2[nd] Degree Polynomial	Perfect Fit
Awe/Ife-Odan	35	$Q_{35}=7.44H^{1.59}$	Power	Perfect Fit
		$Q_{35}=2.47H^2+8.02-2.78$ ($r^2=0.999$, $r=0.9995$)	2[nd] Degree Polynomial	Perfect Fit
Oyo/Ogbomosho Road	39	$Q_{39}=4.96H^{1.68}$	Power	Good Fit (Range 0.03-3.15 meter)
		$Q_{39}=6.87H2-11.11H+5.71$ ($r^2=0.993$, $r=0.9965$)	2[nd] Degree Polynomial	Good Fit (Range 2.01 meter and above)
Ilase	52	$Q_{52}=2.56H^{2.24}$	Power	Perfect Fit
Esa-Odo	64	$Q_{64}=6.25H^{1.25}$	Power	Good Fit (Range 0.03-2.4 meter)
		$Q_{64}=3.14H^2-0.14H-0.96$ ($r^2=0.9989$, $r=0.999$)	2[nd] Degree Polynomial	Perfect Fit

The logarithmic and linear equations derived for Ogun basin with the geometric characteristic (area) i.e. $Q_M = 0.038A^{0.96}$ and $Q_M = 0.0278A + 0.4206$ can be used to predict the mean annual flood (MAF) for ungauged catchments in Ogun drainage basin. Awokola (2005). The results of the regression analysis showed that the values of the exponent of area (A) for most of the derived regressions in Southern Africa range between 0.4-0.8 while that derived for Ogun basin in Western part of Africa is 0.96. There is a high percentage difference decrease in descending order of 92% to 1% in the area range of 1-100km^2 while a low percentage difference increase in ascending order of 1% to 10% in the area range of 3000 to 30000 km^2.

Morawo and Awokola (2006) modeled the runoff of Bodija Stream in Ibadan, Nigeria, a rainfall/runoff model, for simulation of runoff for the ungauged stream. The model developed was used to simulate 52-year runoff data for the stream. The performance of the developed model was verified by comparing the simulated runoff with the observed flow records. The regression analysis between them resulted in correlation coefficient of 0.987. The statistics was significant at 95% probability. The closeness of the simulated and observed flows was the ability of the model to account for water losses through infiltration, interception, evapotranspiration and basin parameters.

Awokola et.al (2009) made use of limited hydrological data and mathematical parameters for catchment regionalization of Osun drainage basin. Daily-stage and daily-discharge equations for seven stations and their corresponding coefficients of determination were used to classify the basin into three distinct zones. These are Zone I (coefficient of determination within the range of 0 to 6% for the daily-stage and daily-discharge), Zone II (coefficient of determination within the range of 7 to 10.5% for the daily-stage and daily-discharge), and Zone III (coefficient of determination within the range of 11 to 22% for the daily-stage and

daily-discharge). These are detailed in Table 2.
The exponents of the stage-discharge equation were also used for spatial classification. Zone A exponent is in the range of 1.3 to 1.7, Zone B exponent is in the range 2.2 to 2.3 and Zone C exponent is in the range 4.0 to 4.7 (Table 2). The combination of the two zoning methods resulted into three distinct unitary zones: Au for stations 35, 39 and 64; Bu for stations 5 and 52, and Zone Cu is for stations 25 and 27 (Table 3). The derived unitary zoning of hydrometrically-similar catchments within the Osun River Basin is represented in Figure 2. These results can be used for preliminary selection of hydrometrically-similar catchments within the Osun basin. An optimized hydrometric regionalization protocol could provide a useful tool for catchment evaluation and management in Nigeria and beyond.

The derivation of relationships between hydrological variables is of great importance for the transfer of information from the few-gauged rivers to the many other rivers with hydrologically-similar catchments for which no stream flow data exist. We need an approach to ascertain the actual changes in hydrological response of a particular catchment within a drainage basin, which can reveal land transformations and interactions that occurred in the past. The 'region of influence' (ROI) approach adopted by Burn (1990) is limited to measures which do not rely on actual flow data. Regionalization or regional typification has been extensively analysed (Hosking *et al.,* 1985; Lettenmaier *et al.,* 1987; Chowdhury *et al.,* 1991; Hosking and Wallis, 1997).

The results will hopefully be useful for engineers, conservationists and planners at gauged and ungauged sites and it will reveal the threshold of flood discharges required for the economic design of hydraulic structures and economic feasibility analysis of water resources management and environmental impact assessment of projects. In a previous study, Elkaduwa and Sakthivadivel (1998) observed that adverse environmental impacts were directly related to changes in flow regimes and that rapid runoff was responsible for high soil erosion rates, loss of land productivity and more frequent flash floods. The high rate of sediment supply due to accelerated erosion caused degradation of stream channels, increasing the likelihood of flash floods, deposition of coarse material and silting of irrigation canals.

Table 2: Classification of the Basin into Zones

Zone	Station number	Criteria
I	5, 25 & 39	R^2: range 0-6%
II	27	R^2: range 7-10.5%
II	35, 52 & 64	R^2: range 11-22%
A	35, 39 & 64	Exponent: range 1.3-1.7
B	5 & 52	Exponent: range 2.2-2.3
C	25 & 27	Exponent: range 4.0-4.7

Table 3: Combination of the two derived zones

Station No.	Zone	Zone	Joint Zones	Groupings	Unitary Zone
5	I	B	IB	IB, IIIB 5, 52	B_u
25	I	C	IC	IC, IIC 25, 27	C_u
27	II	C	IIC		
35	III	A	IIIA	IIIA, IA, IIIA 35, 39, 64	A_u
39	I	A	IA		
52	III	B	IIIB		
64	III	A	IIIA		

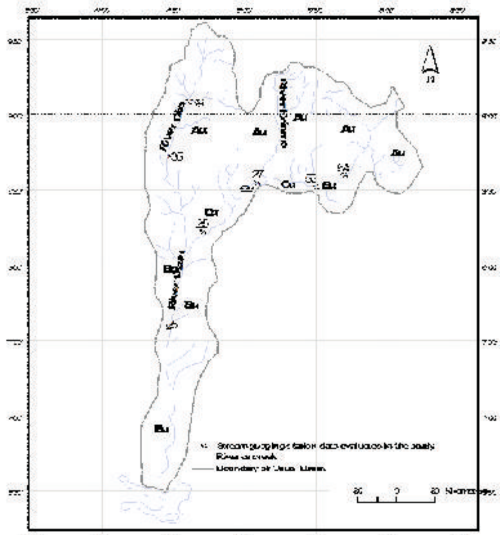

Figure 2: Unitary Zoning of Hydrologically similar Catchments of the Osun River Basin

Figure 2: Unitary Zoning of Hydrologically similar Catchments of the Osun River Basin

In Awokola and Coker (2009), the correlation matrix for maximum stage and maximum discharge revealed that there are 18 regression equations with correlation coefficients of over 50% from maximum stage while only 10 can be obtained from the maximum discharge matrix for the seven stations. Analysis of variance (ANOVA) was used to evaluate whether there are differences between the average value and mean, across several population groups. The appropriate equations were derived for the maximum stage (H) and maximum discharge (Q), with the coefficient of correlation r ranging between 50 and 99% and coefficient of determination r^2 ranging between 25 and 99%. It was observed that four equations out of the eighteen derived for the maximum stage (H) have negative slopes while three out of ten equations derived for maximum discharge (Q) have negative slopes. All the equations with negative slope are from the stations upstream of the basin. It was also observed that station 35 was highly correlated to stations 52 and 64 for both the maximum stage and maximum discharge and the four equations derived with station 35 as dependent variable are all having negative slope. It could be concluded that the derived equations for the maximum stage (H) and maximum discharge (Q) can be adopted for mitigation of natural disasters and could be used for warnings for short-term events like flash floods to seasonal outlooks of the potential water supply for irrigation and even design of small hydraulic structures such as culverts.

Acting Vice-Chancellor Sir, Awokola et.al. (2010) embarked on another study of the derivation of regional flood frequency curve and equation for Ogun drainage basin in South Western, Nigeria. The study was designed to develop regional flood frequency curve and equation for Ogun Basin in South Western part of Nigeria. The relationship and effect of the geometric characteristics of Ogun drainage basin and the flood frequency were investigated. Annual maximum discharge series of Ibaragun, Olokemeji, Oyo/Iseyin and Shepeteri gauging stations were analyzed. Four commonly used flood frequency statistical distributions namely Normal, Exponential, Extreme Value Type 1 and 2 Parameter Log Normal were tested. Regression analyses were applied to predict mean annual flood (MAF) from ungauged catchments using catchment characteristics. The results of the analysis showed that catchment area gives a good correlation with MAF yielding an expression of the form $Q_M = 0.038A^{0.96}$ (correlation coefficient, r=0.94). A generalized equation for the estimation of discharge of particular recurrence interval with the catchment area and return period of interest as independent variable for the study location is of the form $Q_T = 0.038A^{0.96}\left[\left(0.4255Ln\left(X_T\right) + 0.6572\right)\right]$. These equations are usable at gauged and ungauged sites and may ease the computation of discharges required for the economic design of hydraulic structures thus improving the economic feasibility of water

projects.
The estimation of the flooding potential at a site is required for the design of a variety of urban plans and river engineering works. Obtaining an accurate estimation of the relationship between extreme flows and the associated recurrence interval become more complicated if the length of the available stream flow gauging record at the site of concern is shorter than the return period of interest.

Awokola's (2010) study was to determine a discharge-return period (Q-T) relationship at any required site on a river and also to derive appropriate equations for the different gauging stations from the use of an asymptotic formula for estimating confidence intervals for the Extreme Value Type 1 (EV1) distribution. The EV1 distribution was adopted as an example of a typical two-parameter distribution for which standard errors of quantile estimates was derived analytically. The different levels of variability in the observed flood samples may be attributed to varying hydrological phenomena responsible for generating the flood events over the different catchment areas; notably geology, soils, vegetation, physiographic and mean annual rainfall. The standard error of the quantiles estimate was calculated with 95% confidence limits that provide a measure of uncertainty in the design flood. The equations of the 95% confidence limit derived can be used in estimating flood quantiles needed in hydrological design for ungauged catchments within the region.

2.3 Hydrology and Rainfall-Intensity-Duration-Frequency Analysis

One of the most important tools in engineering hydrology is the Intensity - Duration Frequence Relationship. The derived relationship between the intensity-duration and frequency of rainfall for any location determined from the analyses of the rainfall records obtained at that location can be made use of in various civil and hydraulic engineering designs and planning e.g.

design of sewer systems, drainage works, highway and agricultural drainage designs, spillways, canals and dams.

There are several methods available for the preparation of point rainfall data for intensity-duration –frequency analysis. There are also problems of inadequate length of available records and areal coverage. The identified problems of inadequate data and area coverage impose limitations on the type of analysis to which the available data can be subjected.

Oyebande and Longe (1990) stated that attempts to overcome the problem have led a number of research workers to turn to the regional analysis approach. The approach entails pooling together of data for individual stations to yield larger regional samples. One of the benefits of the regional analysis approach is that the statistical values obtained can be applied to the region as a whole and to every point within the region. Sir, I also critically analyzed the available rainfall data and obtain a single equation that will generalize the Intensity-Duration-Frequency relationships for the Southern region of Nigeria.

Mr. Vice Chancellor Sir, Awokola (2004) derived Intensity-Duration Frequency Equations for 6 selected locations in Southern Nigeria, i.e. Ikeja, Ibadan, Ondo, Enugu, Calabar and Oweri. The results are shown in Table 4.

Where I = rainfall intensity (mm/hr).
t = duration (hr).
T = return period or frequency of occurrence in years.

Table 4: Intensity-Duration-Frequency Equations For the Six Stations

Stations	Equations (mm/hr)
Ikeja	$I_{Ikeja} = \frac{61T^{0.24}}{(0.1+t)^{0.94}}$
Ibadan	$I_{Ibadan} = \frac{48T^{0.23}}{(0.1+t)^{0.92}}$
Ondo	$I_{Ondo} = \frac{53T^{0.26}}{(0.1+t)^{0.94}}$
Enugu	$I_{Enugu} = \frac{53T^{0.3}}{(0.1+t)^{0.96}}$
Calabar	$I_{Calabar} = \frac{61T^{0.25}}{(0.1+t)^{0.95}}$
Owerri	$I_{Owerri} = \frac{54T^{0.32}}{(0.1+t)^{0.94}}$

In Awokola (2004), the 10-year 24-hour and 2-year 24-hour daily rainfall study for Kilosa catchment in Tanzania was carried out, with data from three representative stations, using five commonly used distributions i.e. 2-Parameter Log Normal, Normal, Exponential, Extreme Value Type 1 (EV1) or Gumbel Distributions and Probablity Weighted Moments Distribution(PWM). The results showed that EV1 and PWM distributions gave the best estimates and compare favourably with Forsgate and Grigg (1975) mapping method.

Awokola (2005) derived rainfall Intensity-Duration-Frequency Equations for Southern Nigeria, for the most commonly used return periods (T=2,5,10,25,50 and 100years) in design of hydraulic structures. While graphical rainfall curves may be acceptable for hand calculations, they are not well suited to computer analyses.

It was concluded that the derived equations for all the daily durations (Intensity-Duration-Frequency Equations for (t=5minutes-24hours) i.e. $I_2 = 55.795t^{-0.8651}$, $I_5 = 70.804t^{-0.8651}$, $I_{10} = 84.787t^{-0.8651}$, $I_{25} = 107.6t^{-0.8651}$, $I_{50} = 128.84t^{-0.8651}$, $I_{100} = 154.29t^{-0.8651}$, be adopted for Southern Nigeria. The equations gave perfect fit with coefficients of determination ($R^2 = 0.9966$). The reality of the interpretation of coefficient of determination was also realised from the graphical comparison of the result which showed a perfect fit for all the selected return periods as shown in Figure 3.

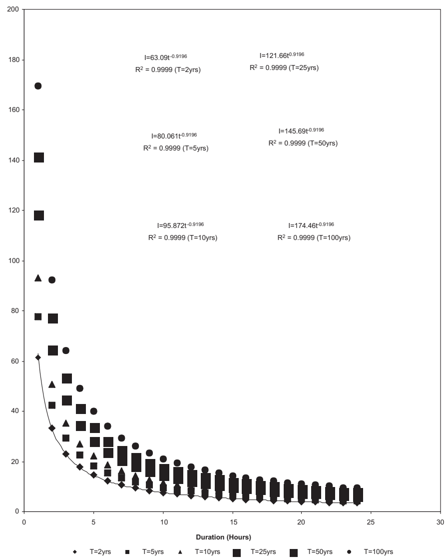

Fig. 3: Intensity-Duration-Frequency Curve (t= 1hour-24hours)

2.4 Ecological and Natural Disaster Studies

Coker et.al (2008) conducted a survey of housing quality and neighborhood environments of Ibadan City, to evaluate the housing infrastructure and to identify those areas where there is a likelihood of future incidences of disease and epidemics. Based on existing demographic and land use characteristics, the city can be divided into high, medium and low-density zones. Penalty scoring, rather than positive scoring, was used to assess the conditions and quality of houses and the neighborhood environment in each of the zones.

Houses in the high-density area have the worst property and environmental characteristics followed by houses in the medium-density area. Based on housing condition alone, approximately half of all the dwellings surveyed in the three zones are categorized as either substandard or unfit for human habitation. Based on neighborhood environment, none of the high and medium-density housing areas and only one of the low-density areas attained the good-scoring grade. This is attributed in part to many residents being polygamists which means the houses are overcrowded with perhaps up to eight persons per room and to tenant abuse by internal conversion to increase the occupancy rate. More than half of the houses surveyed have at least one or more major defect.

Recommendations include government directed infrastructure improvements; a regeneration-drive by private investors with possible displacement of residents from the high-density zone to new towns; a vigorous programme of housing and health education; enhanced collaboration between stakeholders to develop enforceable standards for existing housing stock and future

2.5 Ground Water Pollution and Shallow Aquifer Studies

Ojo and Awokola (2012) studied the physico-chemical parameters of shallow aquifers in Agbowo and Ajibode in Southwestern Nigeria. Abundant as it may seem, in Nigeria, access to clean and potable water is a great challenge. Hence, the reason the physico-chemical properties of the groundwater in Agbowo and Ajibode communities in Oyo State, Southwestern Nigeria was analyzed. Water samples were collected from fifteen shallow wells, with varying depths. The water quality parameters were analyzed in accordance to standard methods. The ground water analysis reviewed includes pH, electrical conductivity (EC), total dissolved solids (TDS), total suspended solids (TSS), turbidity, and hardness. Others include inorganic chemical constituents and the presence of coliform organisms. Results indicated that the parameters measured have some falling within the limits and some above the maximum permissible limit of Standard Organization of Nigeria (SON), European Union (EU) and World Health Organization (WHO) for drinking water.

In general, the data revealed that maxima and minima concentrations of the priority physico-chemical water quality parameters examined in the 15 water sources were mostly within the target water quality range (TWQR) for domestic use with little exceptions at some points, making these 15 water sources available in the area less potentially health hazardous to inhabitants. The overall implication of this observations, call for sustenance and improved water resources management strategy for the area in order to prevent the deterioration of the water sources quality, which may pose associated health risk and environmental hazard.

Awokola et.al. (2013) studied the direction of ground water flow and also establish the parametric relationship of the measured topographical and derived data for the management of exploration and exploitation of groundwater in shallow aquifers of Abeokuta. The methods involve the selection of ten wells around the Federal University Agriculture, Abeokuta. The wells were used to obtain information on ground water topographical information. Data was acquired using a Global Positioning System (GPS) Garmin 76csx which is satellite based equipment for position determination. The data acquired were wells coordinates and the elevation of the well location above mean seal level (amsl), while the water level values of wells as measured with the aid of an Electronic Water Level Indicator was used to measure the water surface depth from the ground surface.

The relative positions of the wells were plotted using AutoCAD 2012 version and it was superimposed on the base map of the area. Suffer for window (version 8, topographical analysis software) was used to produce the contour of the Ground Level, Water surface Level and the Well Level water flow direction. Simple regression analysis was applied to the computed values according to their functional relationships, ground level-water surface level, ground level-well level and depth of well-depth of water surface. The derived equations from the measured and derived parameters were of the linear, power, exponential, logarithmic and 2nd degree polynomial types. The coefficient of determination (R^2) obtained from the various analysis ranges from 0.85 to 0.98. The coefficient of determination (R^2) of 0.98 is close to unity which is the highest theoretically possible thus indicating that whenever the values of the independent variables or assigned variables are known exactly, the corresponding values of the dependent or derived variables can be evaluated with a high degree of accuracy. In all the relationships, the 2nd degree polynomial is consistent with higher values of the coefficient of determination.

The results of the equations derived from this study indicate that there was an explanatory independent variable for ground level in predicting water surface level with a coefficient of determination r^2 of 98% and also the results of well level prediction of r^2 of 94% - 95% and depth of well prediction of 85% - 97% for all the five different equations considered in the study. The equations established can be a useful and essential tool in the development of sound groundwater management plans, formulation of policies for exploration and exploitation of shallow aquifers.

It can be concluded that knowledge of the direction of ground water flow can be a useful tool in the management of exploration and exploitation of shallow aquifers and in the reduction or minimization of groundwater contamination. It can be used as a guide to map out the land use of the study area and thereby take steps to ensure that land use activities in the recharge area will not pose a threat to the quality of the ground water. The flow directions in Fig. 4 is in the West-East and East-West direction, and pollution producing activities must be sited downstream of the wells.

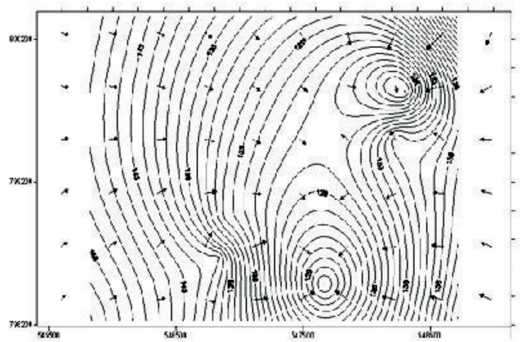

Fig. 4: Contour Map of Water Level Showing Flow Direction

2.6 Erosion Rate Investigation and Estimation

The growth of urbanization has resulted in extremely difficult problems in various areas of the urban water management, such as water supply, wastewater management, urban drainage, flood and erosion control in urban areas and water-related recreational activities.

These activities are interrelated. Some of my studies deal with evaluation of erosion rate for urban development and management practices. The major water quality impact during construction in urban centers is caused by soil erosion. Eroded materials are deposited in reservoirs, which results in loss of storage, rivers and harbors where they require dredging or even additional treatment facility for water supply projects.

Soil erosion is a serious threat to man's existence, particularly in developing countries where scarce financial resources are being committed to combat the menace. Its assessment requires careful use of *predictive techniques* to determine the extent of erosion and its future severity.

In order to avoid economic and environmental losses caused by erosion, it is appropriate to regulate construction methods, limiting the areas with exposed soil using temporary soil stabilizers, reduction of overland flow velocity and building of temporary sedimentation ponds. There is need for strict enforcement of approval of site planning for sediment control.

Evaluation of erosion control measures is generally done by means of the Universal Soil Loss equation, USLE developed by Weischmeir 1965 which gives the soil loss per unit area and year in terms of the erosion force of a specific rainfall, a soil erodibility factor, two factors related to the slope, a cropping management factor and an erosion control practice factor.
Evaluation of erosion rate will be discussed in this section using the hydrologic and hydraulic parameters.

Soil erosion is a serious threat to man's well-being and to his very existence, but most parameters used in erosion rate equation are derivable from studies in small flumes and backed by mathematical analysis.
Awokola and Martins (1996) embarked on a procedure that will require estimation of soil erosion only by hydraulic parameters that can be easily measured on site.
The hydraulic discharge and hydrologic discharge equation were employed using
Mannings equation

$$Q = \frac{A}{n} R^{2/3} S^{1/2} \text{...} 3$$

Where Q = discharge (m^3 / s), A = (m^2) , n is the Mannings roughness coefficient, R is the hydraulic radius (m) and S the slope (m/m). All the parameters in the equation except ***n*** were obtained from cross section measurement. Mannings roughness coefficient (***n***) was obtained from the grain size distribution analysis and the mean value was adopted for the study.

The hydrologic equation for estimating peak flows based on rainfall-runoff relationship (Rational Method) was also considered for the study area.

$$Q = 0.278CIA .... 4$$

Where Q = discharge (m^3/s) in, C = coefficient of runoff, I = rainfall intensity (mm/hr) and A = total catchment area (Km^2)
Erosion rate equation of the form $E = 1.5488x10^{-6}Q^{3.133}$ was established for gully erosion. Ogburu gully erosion rate E in kg/m^2hr can be reasonably predicted with a logarithmic $E = 0.025(1.022Q)^{15/8}L^{3/8}S^{1/2}$ equation with Q in m^3/s.

The result shows that the erosion rate increases considerably with increase surface run off. This established relationship will make planning of erosion prediction and control reasonably possible with only the hydraulic parameters and discharge data.

Awokola (2003) studied the prediction of the effect of slope and run-off on erosion rate.. The results of erosion rate against the discharge were plotted for different degrees of slope from 1% to 6%. From all the derived power equations, it is clear that there is a perfect fit and the coefficient of determination (R^2) revealed that 100% of variation in the dependent variable (erosion rate) was due to the independent variable (discharge). The discharge was found to significantly influence erosion rate even for the different degrees of steepness of slope. The higher the discharge and slope the higher the erosion rate. The slope was also found to significantly influence the erosion rate even for different levels of discharge. It was observed that only derived equation for discharge of 8 cumecs is a linear function i.e. (E=6*10^13S-7*10^13), while the rest are power equations.

The combined effects of discharge and slope on erosion rate prediction were highly correlated with r = 0.97 and r^2 = 0.95 and the equation of the form $E = 0.0003Q^{2.57}S^{0.74}$.

Figure 5 is a typical Erosion-Rate-Discharge-Slope Curves

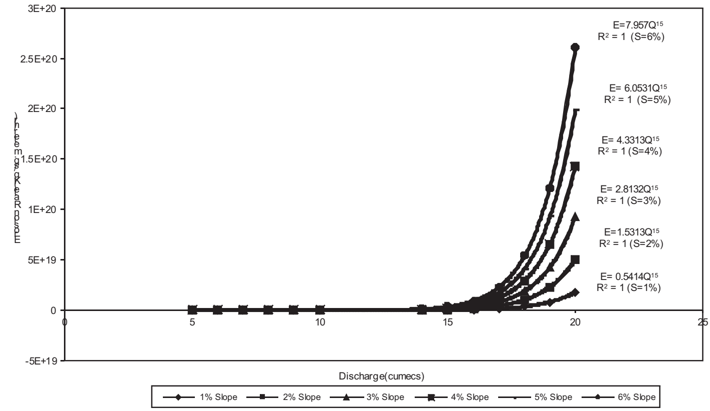

Fig. 5. Erosion-Rate-Discharge-Slope Curves

Acting Vice-Chancellor sir, my research covered some selected erosion sites in Ogun State. An expression for erosion rate was developed which revealed that the calculated discharges with limited hydraulic and hydrologic data can be used to establish erosion rate equation. One of such is

Another equation that takes into consideration the grain size of the eroded material is of the form

$$E = \frac{0.0105}{D_{50}}(0.5I)^{15/8} L^{3/8} S_o^{\ 3/2} \text{ ....6}$$

Summary of various trend line equations of Erosion Rate, Shear-Stress and Discharge are as shown in Table 5.

Table 5: Summary of various trend line equations of Erosion Rate, Shear-Stress and Discharge

Relationship	Equations	Type of Equation	Coefficient of Determination R^2
Shear-Stress vs. Discharge	$\tau = 0.0004Q^3 - 0.0955Q^2 + 9.2514Q - 25.93$	3rd degree polynomial	0.547
	$\tau = 5.5146Q^{0.8658}$	Power	0.855
	$\tau = 30.923e^{0.0179Q}$	Exponential	0.694
Erosion Rate vs. Shear-Stress	$E = 0.0389\tau - 3.9206$	Linear	0.872
	$E = 3x10^{-08}\tau^3 + 1x10^{-05}\tau^2 + 0.0052\tau - 0.1903$	3rd degree polynomial	0.991
	$E = 6x10^{-08}\tau^{3.0451}$	Power	0.971
	$E = 0.0053e^{0.0123\tau}$	Exponential	0.65

3.0 CONCLUSION

In most of my research work, the constraints posed above have been looked into while reliable techniques and uniform methods have been developed to:

(i) Minimize the delays and risks in the implementation of water resources projects,

(ii) Make different users of the methods get answers that are in close agreement when it is applied to the same problem,

(iii) Compute flood peak required for the economic design of highway drainage structure and establish a relationship between mean annual flood and catchment area for the gauged catchments,

(iv) Derive regional frequency curve for Ogun and Osun basins.

(v) Estimate reliably the magnitudes of small and large floods that are often required in the design of diversion works in a stream and for purposes of designing spillways of dams with the short records.

Water is the most important natural resource needed by man in all ramifications; both among the rural and urban dwellers, governments need to make water availability their priority.
Water is life and to ensure adequate provision of quantity and quality water, information about the weather, climate and the rock formation were key factors.

The provision of quality water to the people is one of the major challenges facing the government of the day. Various factors had led to shortage of water, such as population explosion, opening up of new locations and cases of new sites springing up in urban areas. This had led to the shortage of laying and expansion of water pipes, with most of the new communities having to provide for themselves, reliable means of water supply. Power supply had also been another major factor militating against the provision of water as most water stations had to run on generator for power supply and spending more on diesel to power the generator.

There is plenty of evidence of non-functioning boreholes in major communities across the country some of which were constructed by some government agencies. The only way to ensure that such is reduced is if government should choose their priority right, choose appropriate contractors with the right equipment and Consultants that check the borehole design to handle such jobs. After completion the government should charge the community with such borehole the responsibility of monitoring and maintenance since "what belongs to everyone belongs to nobody". It is not appropriate for policy makers to sit in an office and make generalized decisions for the drilling of borehole across the country without considering the geologic differences in various parts of the states and the country.

In conclusion, my research focus can be simply summarized as the aspect of Water Resources and Environmental Engineering that are relevant to the solution of engineering problems in the control and utilization of water.

I am satisfied with my modest contribution in the field of Engineering Hydrology especially in situations of limited data. Government must as a matter of urgency strengthen all the agencies that are connected with gathering related hydrological information. Governmental agencies are the largest employers of hydrologists as such they should have major interest in stimulating hydrologic education.

Mr. Vice-Chancellor sir, I wish to suggest that Hydrology and Climate Change programme be introduced as another area of specialization in Civil Engineering Department both at undergraduate and postgraduate level.

4.0 ACKNOWLEDGEMENTS

To God only be the glory for making it possible for me to stand before you today to present this inaugural lecture, what a AWESOME GOD! A plank seller, a tailor, a printer, an assistant technical officer, technical officer and a Professor, the inaugural lecturer of today. 1Samuel. 2:8 He raises the poor from the dust and lifts the needy from the ash heap; he seats them with princes and has them inherit a throne of honour. “For the foundations of the earth are the Lord's; upon them he has set the world.”

I need to thank so many people that have touched my life. Space and time will not permit me to do so but be rest assured that you are all important to me. My late parents come next since I have given glory and adoration to the Lord, **Pa Joseph Akinola Ajiboye Ashola Awokola** who died on the 16th of January 1965 (Sabere dowo oko Adedewe, bo ti da Olorun lo mo), my mother Madam Racheal Olateju Esuu Awokola (nee Fagbemi) who died on 16th of September 2004, over thirty-nine (>39) years after the death of her husband. Thank you for your love, perseverance and steadfastness in God (Iya 'Ropo). My brother Ezekiel Oladosu Awokola, you are the best brother in the whole world. You made a lot of sacrifice for me to be educated. In 1968 you sent me to Kiriji Memorial

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I appreciate all the former Vice-Chancellors of this great University: The foundation Vice-Chancellor, Prof. Nurudeen Adedipe who employed me as Lecturer II in 1991, Prof. Julius Amioba Okojie upgraded me to Lecturer I in 1994, Prof. Israel Folorunso Adu promoted me Senior Lecturer in 2001, Prof. Ishola Adamson, Prof. Oluwafemi Olaiya Balogun promoted me Reader in 2011, Prof. Olusola Bandele Oyewole promoted me Professor in 2014, Prof. Ololade A. Enikuomehin who acted as Vice-Chancellor and the immediate past Vice- Chancellor Professor Felix Kolawole Salako, the current Acting Vice-Chancellor Professor Olusola Babatunde Kehinde.
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.
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Last but not the least, I appreciate all of you, here present, that have listened to my lecture with rapt attention. Finally, join me as I conclude this lecture with this song:

‘E seun baba, Baba e ma se, E seun, Olorun mi E seun baba.’

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