STREAMFLOW CHARACTERISTICS OF RIVER GBAKO AND THEIR IMPACT ON THE CHANNEL MORPHOLOGY.

BY

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SCHOOL OF SCIENCE AND SCIENCE EDUCATION,
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MINNA-NIGER STATE

FEBRUARY, 2001.

CERTIFICATION

This is to certify that this project was carried out and presented by Salisu Mohammed Aminu M. Tech/512/2000/2001 of the Department of Geography in the School of Science and Science Education, Federal University of Technology, Minna.

Dr. Abubakar, A. S. — Date
(Project Supervisor)

Dr. Usman, M. T. — Date
(Head of Department)

[EXTERNAL EXAMINER] — Date

Date

DECLARATION

I declared that this project work titled: **"Streamflow Characteristics of River Gbako"** and their impacts on channel morphology, has been carried out and presented by me to the Department Of Geography, School Of Science And Science Education, Federal University Of Technology Minna, Niger State for the award of Masters Of Technology In Meteorology.

______________________________ ______________________________

SALISU MOHAMMED AMINU **DATE**

DEDICATION

This thesis is dedicated to Almighty Allah (God) for His protection and guidance over me and to my beloved parents, my families, brothers, sisters, friends and all well wishers, and to my Late brother Ado (Fadama).

ACKNOWLEDGEMENT

I would like to express my thanks and appreciation to Almighty Allah (God), who has guided and sustained me throughout the academic exercise.

My sincere appreciation goes to my project supervisor, Dr. Abubakar, A. S. for his guidance and criticism during the course of this thesis. I cannot but also express my profound gratitude to the entire members of staff of Geography Department for their academic training and advice.

I also want to acknowledge with indebtedness the moral and financial support accorded me through my academic pursuit by my parent, particularly Honourable Justice Alhaji Mohammad Aminu Muye (Rtd), Hon. Justice Jibrin Ndajiwo, Niger State Chief Judge, my mothers Hajiya Habiba Ramatu, Saadatu, and my families, brothers sisters and friends.

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Finally, I thank Almighty Allah (God) for His guidance, mercy, support and sustenance.

ABSTRACT

The various interaction of hydrogeomorphic elements within the river Gbako catchment basin, with relevance to stream flow characteristics and its impact on the channel morphology have been observed and analysed. The essence is to facilitate the use of streamflow and channel geometry information for beneficial water resource projects and for checking the destructive role of streamflow consequence in term of floods.

Statistical techniques were used to determine the discharge by monitoring the functions of values on the rating curve so developed for the river, which is a reliable method. since the stream is perennial expressing continuous flow throughout the year. It was discovered through the research that high discharges and stream stage were more obvious during the rainy season months of April to October with a corresponding decrease during the dry months in which at this period, only the reserve water from the aquifer contribute to the discharge and maintain flows.

The rating curve illustrate smooth curve and not parabolic; meaning that the rating does not change when all other factors remain constant.

Geometric data obtained from the field also indicates that the river channel is a stable one with adequate depth-width dimension capable of containing a higher volume of discharge when the need to redirect the river Kaduna flows. Recommendations include the improvement of station staffs efficiency in the process of observation and recording of streamflow events at the gauging station, this is to ensure accuracy and reliability of streamflow records for future simulation.

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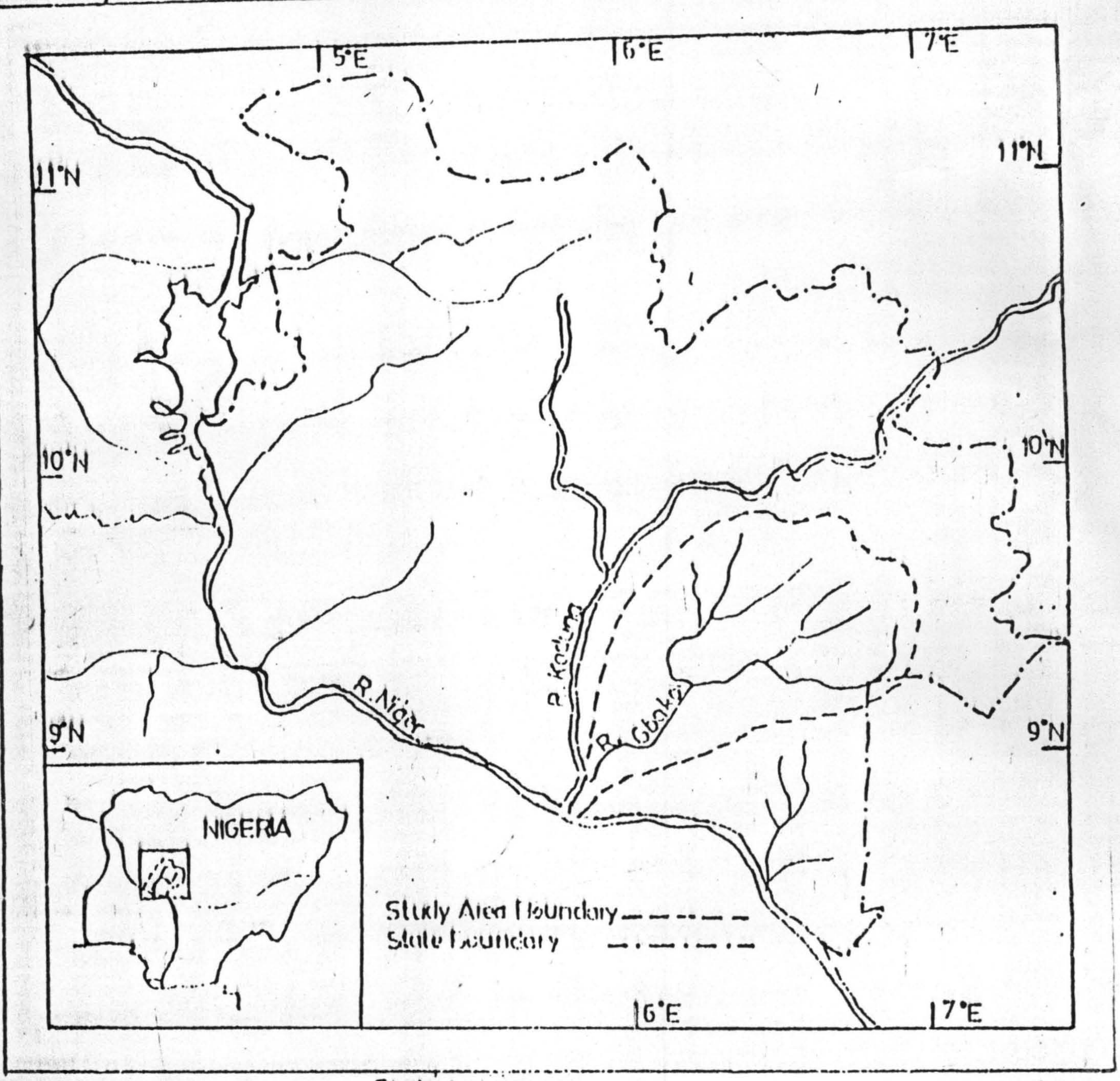
Figure 1: Research Domain (Gbako Basin)



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CHAPTER ONE

1.0.0 INTRODUCTION

1.1 BACKGROUND:

Streamflow characteristics and its incumbent consequences on the basin area and especially its impact on the channel morphology should be continually assessed and understood, because of its relevance in water resource management and land utilization planning and development. Floods, Drought, Land Degradation and Reclamation must be catered for in planning for and management of land and water resources, any alteration to the intensity, frequency and location of flood, drought that may result from the change in one or more of Streamflow characteristics and channel morphology can be expected to have serious consequences for many sectors of the economy. as such, the evaluation of water resource programmes and policies and the development of both hydrological and morphological networks and services including, data collection and processing, hydrological forecasting and warming and the supply data for design purposes becomes invaluable as these help government to prepare National Development plans in response to changing situations.

Water and land especially are the basic needs for human utility, as such rivers have been good origin of town locations as well as source of water. Rivers are also used for trade, communication, and agriculture. Today, many of the great cities of the world have grown from near or even on the banks of major rivers.

The world's greatest burden has always been the problem of land and water for human utilization. Worldwide it is estimated that there are 80% countries with 40% total world population which are experiencing water shortages, in some region or at certain times of the year, nearly one billion people in the world are without clean drinking water and have to rely on whatever kind of water they can get from rivers, streams, lakes, ditches and shallow wells. Many of these sources are frequently contaminated and depend to a large extent on the characteristics of such sources. Furthermore, domestic demand for drinking water and agricultural land are increasing as population rises, likewise the demand for industry and food production sectors.

It is common knowledge that availability of water and agricultural land has been man's means of survival and at times his enemy. Water and land also comes in two quantities, too much, too little; at various places and at different times people migrate from place to place in search of water or to run away from flood and erosion, in his effort to provide a safe and comfortable environment for sustainable development, man has since then continued to intensify research in areas of flood mitigation, erosion control and general science of landscape. It is regrettable to observe that much has not been achieved in this direction, because the real issue has not been addressed (Umoh, 1995).

Furthermore, the acquisition of relevant information for effective management of land and other related resources has been of the major problems of planning in Nigeria (Areola, 1982 and Adeniyi, 1979). Essentially, the complex nature of Nigerian environments and the uncontrolled form of land utilization have necessitated the search for rapid accurate and exquisite and cost effective techniques for the mapping and monitoring of land resources. Experiences of the last two decades have shown that the application and adoption of drainage basin approach is suitable for rapid inventory and monitory.

In addition, the work of Horton (1932), Chorley (1969) and Stranler (1964) identified the advantages of the drainage basin approach to geo-morphological and hydrological unit for regional studies and analyses. However, in Nigeria, the idea of river basin as a planning unit is recent. There is the need to know the nature, magnitude and period of Streamflow characteristics and to extrapolate such knowledge towards forecasting the effects of different actions on the landscape, Thomas (1943).

Human activities such as dam construction is known to affect the environmental variables within the drainage basin. Mrowka (1974) documented three areas of interest in down stream locations. These are the effects of streamflow, the changes in the chemistry of discharged water and the degradation of river channel itself. Olofin (1980) pointed out that the effects on valley side erosion decreases the level of channel flow downstream, thereby lowering the local base level for valley side fluvial processes.

The problem area of research is the functional relationship between environmental impact assessment based on the streamflow characteristic impact on channel morphology data as obtained from the field to analyze and evaluate so as to aid an effective plan for the development of land and water resources as they are central to many planning problems concerned with natural and altered environment.

1.2 JUSTIFICATION OF THE STUDY

Water is central to many planning problems concerned with natural altered environment. It is often a focus for inter-disciplinary analysis and planning that brings together an engineering hydrologist and a plant ecologist, or a geo-morphologist and a specialist in urban design.

Not only for water, the acquisition of knowledge for effective management of land and related resources has been one of the major problem of planning in Nigeria (Areola, 1982 and Adeniyi, 1979).

Essentially, the complex nature of Nigeria's environment and the uncontrolled form of land utilization have necessitated the search for a more rapid, accurate and more diverse approaches to the discovery of certain associating factors that were left unobserved and which indeed participated directly, indirectly and actively in the process of environmental changes.

For the undisputable fact that water is central and important to the human race, the rivers of the world have been receiving undue attention in recent time, the reason is to discover the processes and characteristics as well as to find out the nature of relation it shares with other associate components.

Globally and particularly various researches have been carried out in relation to the Gbako Basin. Among them are Maxlock Group Nigeria Limited (1979), Jones (1953), Short Report on Water Supply for Bida Town, Shekwolo (1983) On The Hydrology of the Gbako Basin, Shekwolo (1990), On Regional Hydrology in the Bida Basin, Umoh (1995) On Rain-Fall-Runoff Relationship on Part of the Niger Basin, Nigeria, Suleiman (1998), Impact of Climate Variability on Flow Regime of

River Gbako and also an Unpublished (B.Tech) Thesis on Streamflow Characteristics of River Gbako (2000). Thus there was no study on channel morphology of that river.

It is the view of the researcher that the result obtainable from this study shall provide collateral information needed for calibration and effective analysis of streamflow data and also serve as a measurable parameter for the assessment of the cause and effect of certain changes that have taken place on the channel morphology of the Gbako stream.

1.3 STATEMENT OF THE PROBLEM

The Gbako river traverse a land of about 240km^2 and caters for and estimated population of over 150,000 dwelling in about 70 towns and villages scattered all over the drainage area which constituted the subject of this research study. Most of the inhabitants are farmers who rely on the waters from the Gbako stream for their domestic agricultural and other uses. Therefore, any plan for development that concerns the inhabitants must take cognizance of the unavoidable importance of the Gbako river. Information about the flow regime characteristics and river channel morphology, has becomes expedient in the planning for and the management of the surface and underground hydrology of the basin catchment area which constitutes the basis for this research work.

1.4.0 AIMS AND OBJECTIVE OF THE STUDY

This study is intended to simulate the streamflow characteristics and its impact on the channel morphology of river Gbako catchment basin, using inferential statistics and channel geometry approach. In which streamflow will be converted to discharge and compared with observed data on channel geometry, with a view to explain and provide basic information necessary for effective water and land resource management of Gbako River catchment.

1.4.1 OBJECTIVES

The objectives of this research work includes the followings:-

(i) to analyze the discharge frequency of the river for a period of fifteen years (1980 - 1994).

(ii) to analyze the gauge height frequency for the same record period.

(iii) Based on items i and ii above, the rating curve (discharge and stage height relation) for river Gbako will be produced.

(iv) To develop cross-section of a point along the Gbako stream for channel geometry simulation and also provide date on its channel morphology.

1.5.0 STUDY AREA.

The study area as the topic reflects is the Gbako river basin a major tributary of River Kaduna. The area is located on latitude 09° – 05' longitude 06°- 07' and altitude is under 300ft, the river Gbako gauging site or station is located at Badeggi bridge.

The main project area covers anout 7,540.25km^2 and the area extent is to be found between Gbako, Katcha, Agaie and Bida local government areas of Niger State. As contained in the Nigerian hydrological yearbook, vol.ii of 1991, the River Gbako catchment basin constitute the hydrological area II out of XII identified for the entire nation.

1.5.1 RELIEF

The location is a drainage basin, as such the landscape is entirely that of a low relief formation between 142-150 metres above sea level (Morgan, 1983). The area landscape constitute river channels flood plain and other inundated areas liable to flood. Flat lying in gentle rolling planes covers a major part of the area, on the extreme west and eastern part, the monotony of the landscape is broken by ancient eroded surfaces thought to have formed at the Miocene age (Adeleye, 1971, 1973). The hills occur mainly as conical hills or flat topped laterite or pisolitic iron stone capped hills rising up to about 40-50 metres above surrouinding country (Shekwolo, 1983). An example is the Kochitako hill about 10km North-West of Bida.

1.5.2 DRAINAGE

The drainage pattern here is generally "dendritic" with the major river been the river Gbako. The main water sheds runs parallel to it, tributaries of some minor streams like Musa'a, tsanchita, lanzu,and dakudi have their water shed to the west while lanko, Ekpan, Eghatti and Eriko have their sources from the east. All the streams obtain their supply during the rainy season from the same catchment area and together they drain the whole and entire basin. The Gbako river flows for about 50kms through a narrow channel full of meanders noticeable throughout its routs to the point where it downs Its content in the Niger river, its direction of flow like other major rivers in Niger State is North-south, the river transverse many political boundaries.

1.5.3 CLIMATE

The general climatic characteristics fall within what is obtained in the middle belt region of Nigeria that is tropical hinterland climatic belt.

In the climatic region, temperature and rainfall pattern are the same but with lower humidity (Udoh, 1970). It has lower rainfall when compared with the coastal south region. Ranging between 6 – 8months is recorded. Average monthly precipitation total for 22years (1979 - 1992) indicated "September" as the month of heaviest rainfall in the basin.

In this climatic belt as is the case with the lowlands of Sokoto plains, the Chad Basin and the Niger-Benue lowlands, the mean annual temperature registers over 27^{o}c and altitude and proximity to the sea determine to a large extent the distribution of temperature (Iloeje, 1980). Temperature is highest in the month of March and April just before the onset of the rains with daily values at times reaching 34^{o}c.

1.5.4 VEGETATION

The study area falls within the Guinea Savanna vegetation of Nigeria. The region is a continuous belt which covers the entire middle belt region of Nigeria, also, a transition zone between the true forest and the true Savanna types of vegetation. This type of vegetation is sometimes called the "Parkland Savanna".

or "Woodland Savannah", because of its tall grasses and also contain trees; oil bean, shear butter and locust bean.

The vegetation changes with season, in the wet season, the leaves and grasses are fresh and green, but in the dry season, they wither and die brownish and dark. Often bush fires continue most of them leaving the charred skeleton of trees standing like ghost in the ash-covered earth. The vegetation is not uniformly thick. Along the watercourses where soil is moist, denser, and dark, vegetation called fringe forest is found.

1.5.5 THE RECORDING STATION

Gauge height and discharge records were obtained from Badeggi Town where the recording station is situated. The catchment area is 221sq. miles. The installation consists of 4 stall-gauges fixed on OPS left of the bridge. The zero R.F is 206.6 since 1954 with reference to temporary Bench Mark of value 238.05, the location still remain the same up to the time of the study.

1.6 SCOPE AND LIMITATION

Streamflow records on river Gbako acquired from the hydrological station at Badeggi was for a period of fifteen years and maintained on a daily basis will be statistically corrected before using it for mannual analysis. Topographical map of Bida South-West and Baro North-East of 1967 with a scale 1:50,000 respectively have been collected from the Niger State survey department. The reliability of the result that will be obtained from the study will depend upon the researchers available resources.

Some of the data on streamflow were not available or somehow incomplete, however, the researcher had made effort in comparing his records with that of the station in order to minimize inaccuracies that may occur as a result of the above reason.

Field study was especially adopted to enable the researcher obtain first hand information on the Gbako channel morphology. This giant task required a lot of resources in terms of geometry survey equipment and knowledge of application ., for the later, the researcher was able to produce and carry along a rating curve and channel cross-section which he produced himself and later applied after verification of its applicative status. Various libraries were visited by the researcher in order to acquaint himself with methods and techniques required for this kind of study.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The review of literature will delve on the study of forms on the surface of the earth with particular focus on the processes and history of development of land forms, the relation of geologic material to surface features and by logical extension, the extrapolation of such knowledge towards forecasting the effect of different actions on the landscape, according to Gregory (1973), planning should include in its domain the forecasting of effects but this has not always been the case.

In the light of the above , various parameters that relates to the topic of this project shall be reviewed; i.e. drainage basin in planning, drainage basin form, River channel in planning; discharge velocity and flow resistance; water stage and rating curve, channel shape, average channel dimension, channel pattern; channel response; bedforms, channel cross-section, channel plan form and channel long profile.

2.2 DRAINAGE BASIN IN PLANNING

A drainage basin in define as the area of land that drains water, sediment and dissolved materials to a common outlet at some point along a stream channel. The term can be said to be synonymous with watershed in American usage and with catchment in most other countries. The boundary of a drainage basin in known as the drainage divide (USA) and water shed in other countries. Thus, the term water shed mean an area of a line, the drainage basin can vary in size from that of the Amazon River to one of a few square meters draining into the head of a gully. Any number of a drainage basin can be defined in a landscape as shown in (Fig. 2) depending on the location of the drainage outlet on some water course, Because of the hydrologic and geomorphic effects of natural and human processes within a catchment interests are focussed at its outlet, the drainage basin of interest to planners is often defined as the area draining to some critical point at which they intend to install something. Planners should equally be aware,however, that the drainage basin they define in other to make some design calculation is a portion of some larger drainage basin whose downstream portion may suffer from the effects of design unless, (they are careful).

Often carefully laid plan/schemes are disrupted by something that occurs many miles away from the site. A brush fire or careless logging in nearby hills may release large amounts of sediments which alters stream channels and flooding condition for many miles downstream. The sprawl of urbanization or the location of a power plant may ruin vistas. Conflict can arise between upstream and downstream users of a water supply who wish to take advantage of the stream for irrigation, drinking , waste disposal or for cooling, or merely for looking at , the degree to which these effects are felt over large areas often surprises and perplexes the users, but that is because it is easy to forget that hill slope gullies, rivers, ground water bodies, urban storm drains, industrial cooling systems and irrigation fields are linked as components of drainage basin.

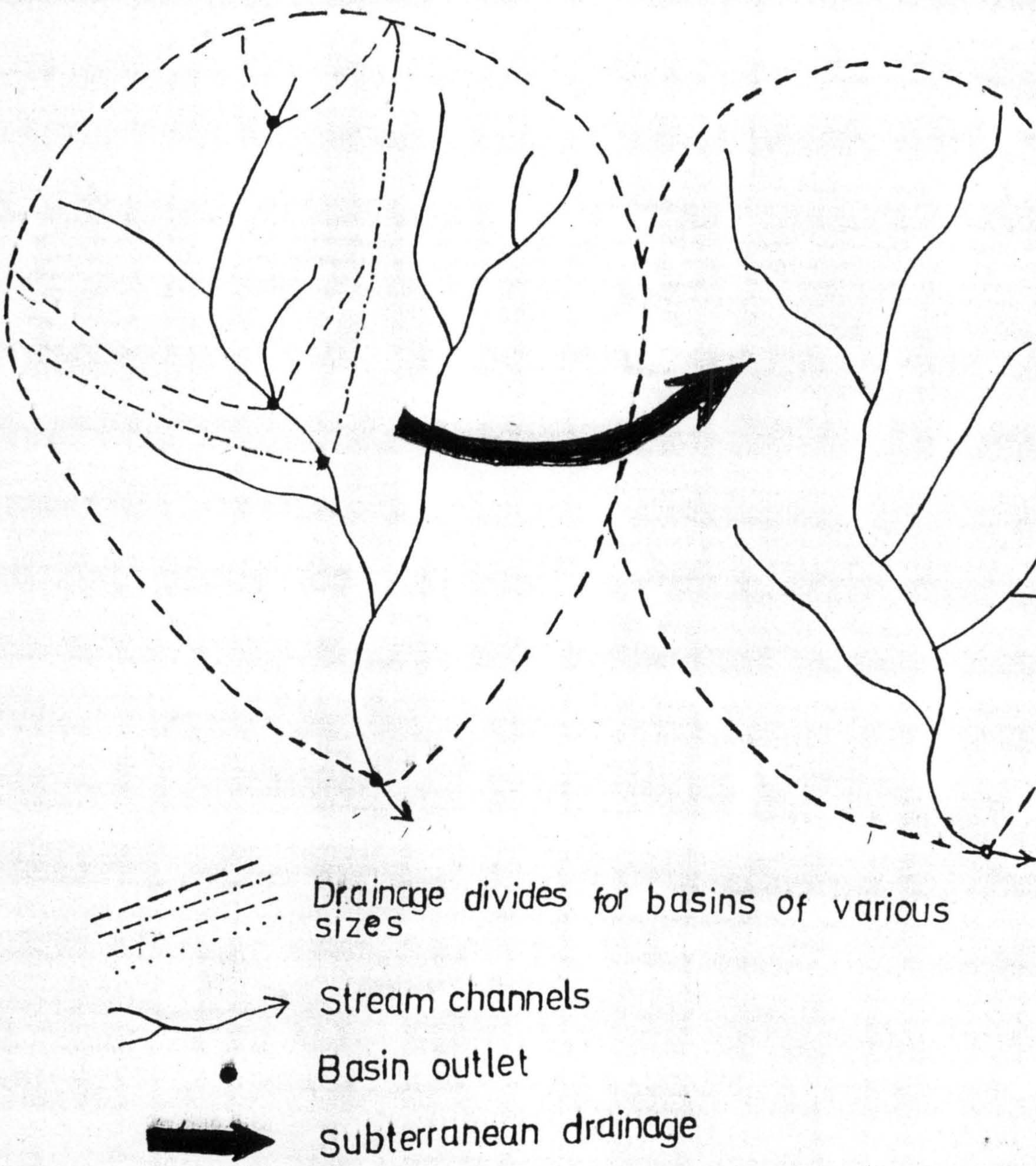


Fig.2 Drainage basins and their boundaries

(AFTER THOMAS DUNE et al 1943)

In some landscapes, the topographic limit of the drainage basin may not coincides with the boundary between sub-surface drainage systems, because pollution and disruption of groundwater supply by the action of some geologic condition affecting groundwater movement which in turn causes extensive damage and suffering elsewhere and could involve them in litigation.

Not all the problems and constraints of physical planning can be examined solely within the context of the drainage basin, however many of them can be removed by solution such as inter-basin transfers of water or waste. There is much to be gained from examining the drainage basin as a convenient unit for understanding the action of hydrologic and geomorphic processes and for appreciating the spatial linkages between different areas that can affect both regional and site planning. As more and more planning is based on an understanding of natural processes, this is increasingly been done. There are now many planners who see the drainage basin not only as a constraint but as an opportunity to exploit the imaginative and beautiful designs (McHarg, 1969).

2.3 DRAINAGE-BASIN FORM

The form of a drainage basin provides the planners with various constraints and opportunities-steep slopes with intricate patterns may limit access, confining roads to drainage divides, they may provide secluded building sites with attractive vistas, but required careful planning of waste disposal because the thin soils and steep slopes are unsuitable for septic tanks. Steep slopes also needs to be examined carefully for land slide hazards. In very gentle topography, the sub-

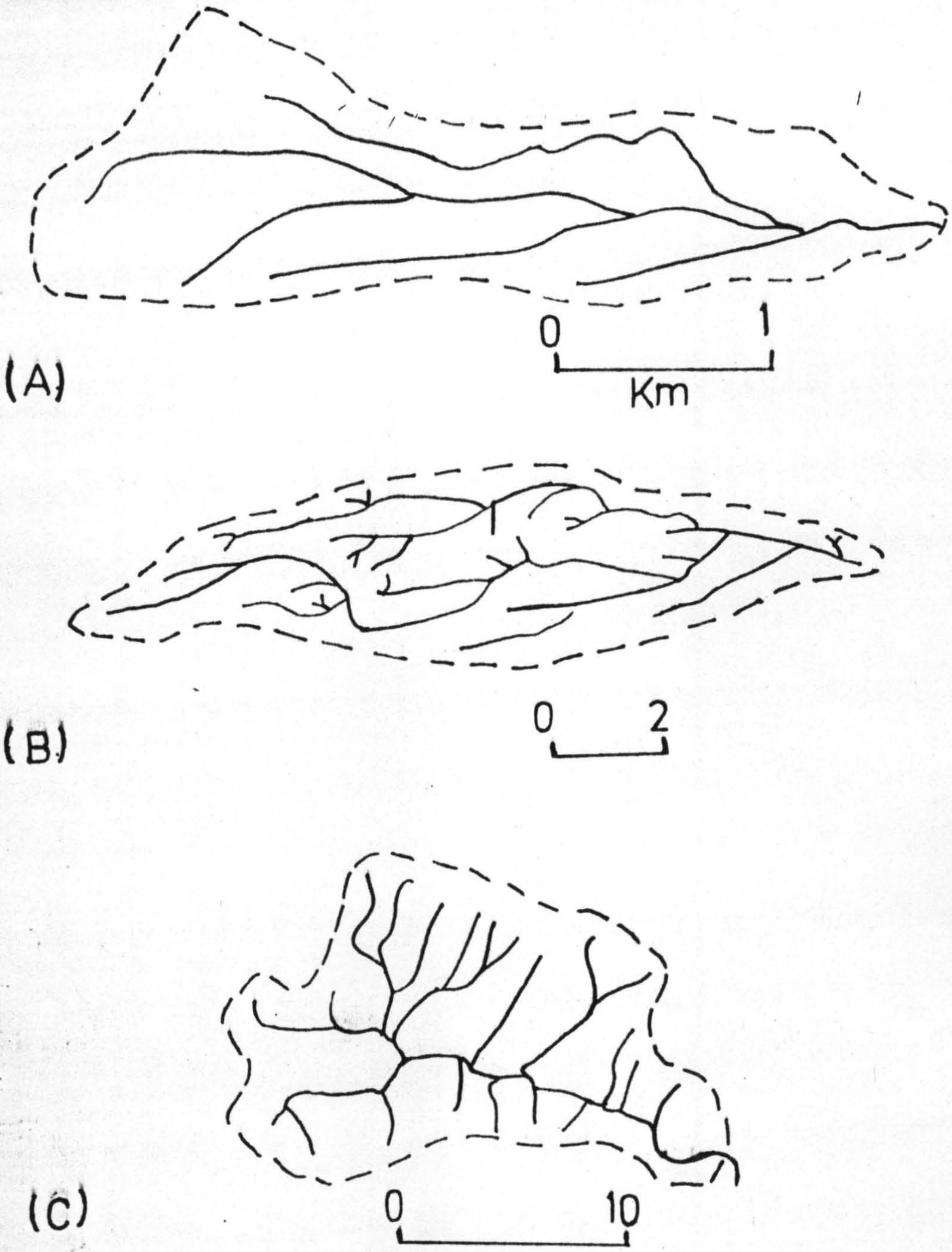


Fig. 3 Example of drainage networks
A & B - are dendritic,
C - Palmate

(AFTER THOMAS DUNE et al 1943)

division of land, construction, and the provision of facilities may be easy and cheap as these are just few examples of the effect of drainage-basin forms on the planning process. Other indirect effects include the manner in which hill-slope gradient, channel densities, channel gradient and valley-floor widths control the generation of floods. Here we will review a few of the more useful measures of drainage-basin form, mostly developed by Robert E. Horton (1941) and Arthur Strahler (1969) who laid the foundation for the qualitative description of drainage basins.

A catchment is drained by a hierarchical network of channels (Fig. 3). Whose size increases downstream from small rills through gullies to small and large river channels as the amount of water and sediments they must carry increases. The stream in these channels have cut the valleys in which they lie and are therefore responsible for the overall orientation of valleys and hill slope in the area.

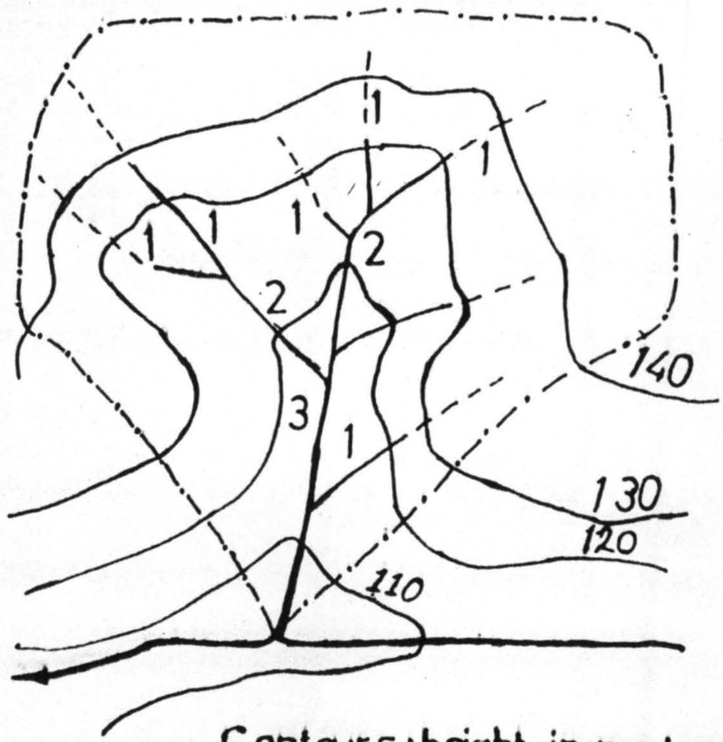
In fairly uniform rocks, the plain view of the network of river channels is usually located dendritic, as shown in Fig.3 (a) and (b). in mountain valleys, many small tributaries may feed a larger stream like the pinnae of pinnate leaf as shown in Fig.3, while at valley heads or valley junctions the network may be strongly palmate. This last situation is very dangerous or merely hazardous one for town sites because simultaneous flooding in the tributary valleys often concentrates heavy runoff at the junction.

Rock structures such as major bedding planes joints or faults are exploited by streams in some areas to form oriented dendritic networks where the drainage network becomes trellised as the weaker formations are carved into valleys between ridges of the resistant members as shown in Fig.3 (c). if the uplands are high and steep enough, transportation routes are confined to the river saps which are therefore choosen for settlement sites, commercial centres and other purpose.

As a means of comparing rivers of different sizes or importance within or between networks, Robert Horton proposed a system of stream ordering which is illustrated in Fig. 4 as modified by Strahler. The smallest stream of the networks which have no tributaries are called first-order streams. When two of these first order streams coalesce they form a second order stream and further along its course this stream may join another second-order channel to form one of the third-order and so on. A low-order stream, such as one of first-order joining another of higher order, does not alter the rank of the latter.

A description of stream orders is usually made by tracing the network from a topographic map or aerial photograph. The stream segments of each order can then be coded by colour. One limitation is the size of the smallest stream that can be recognized from the map or photograph. Leopold and Miller (1956) showed by example that the size or drainage area of the smallest first-order depends on the map-scale. When a basin was mapped at large scale, what appeared to be a first-order stream on a smaller- scale map were increased by four on a large-scale map.

The density of channels in the landscape is an easily obtained measure of the dissection of the terrain. The drainage density is defined as the length of all channels in the drainage basin divided by the basin area when the channel are extended on the map into swales, the values of drainage density is advised to be given with the map scale and details of other channels because of the limitation on the recognition of smaller channels.



——— Contours: height in metres
—·—·— Perimeter of catchment
——— Channels containg flowing water
- - - - - Channels without flowing water
. . . . . . Parts of channel into which channels may extend following high-intensity infrequent rainfall.

1, 2 3 Orders of network according to the Strahler system. Unbranched elements are 1st order; two first orders produce a second order; order only then increases by one if two. streams or channels of the same order join. Thus, when two second-stream order streams joins they produce a third-order stream. However, a 1st or 2nd-order stream joining a third-order stream does not affects its order.

Fig. 4. Stream orders

(AFTER STRAHLER 1969)

This measure of the texture of dissection is associated with geomorphic and hydrologic condition of interest to the planner. Areas with high drainage density are associated with high flood peaks, high sediment production, steep hillslopes and general difficulty of access.

The relief and slope characteristics of a drainage basin can be expressed in a variety of ways, but probably the simplest is the relief ratio, defined as the difference in elevation between the highest and the lowest points of the basin divided by the length of the basin measure is the gradient of the stream channel within a region of roughly uniform climate and geology, these parameters are useful indices of sediment production and flood peaks (Schumm and Hadley, 1961) because they are usually correlated with average hill slope gradient in the basin, the relief ratio or channel gradient can be used to indicate areas possessing advantages and disadvantages of various types of terrain describe earlier.

As river channels join downstream, the resultant stream drains larger and larger catchment, one surprising result of this random confluence is that in most river basins, the drainage area increase with distance downstream at a predictable rate. Example of such application was that of John (1957) of the U.S. Geological survey, whose many quantitative studies of landscape forms have generated much of our understanding of the way drainage basin function.

The rate at which drainage area increases with distance downstream is the dominant control of the rate at which runoff increases downstream, not forgetting the relationship between drainage area, annual yield, low flows and flood discharges. Indeed all the related streamflow characteristic of drainage area also affect sediment yields, channel characteristics and water quality. The downstream increase of catchment size is also related to many morphometric variables described above. There is usually an inverse relationship between drainage basin and relief ratio, average hillslope gradient, channel slope and sometimes drainage density.

The problems identifies here is that of change in emphasis downstream. The lower the location in the drainage basin, the more likely are the problems posed by upstream water use, flood sizes, land drainage and flat uninteresting terrain. Adequate water supply, traficability, and construction difficulties are less likely upstream there is the problem of limited water supply from a single stream or from groundwater by steep terrain, and by many of the problems and possibilities referred to above.

The above review of literature was based on the importance of understanding the drainage basin characteristics as the knowledge of it leads to the understanding of the effect of various geomorphic processes on hydrologic variables as operative in a drainage basin.

2.4 RIVER CHANNELS

Whenever humans make changes in the land surface or its vegetation, they alter some hydrologic cycle with some concomitant effects on the water collecting in the channel system. These effects may include the amount , timing and location of water reaching the channels. The drainage network being an inter-connected system which can pass on a variety of effects far distant from the location where the change was made, it is the continuity within the system that leads to off-site consequences and the essence of researches include the anticipation of such consequences and provision of possible solution of such to planners.

The ability to recognize the possibilities of such effects depends on knowledge of the normal characteristics of channels, their internal processes and thus their probable reaction to imposed changes, beyond mere recognition of possibilities, quantitative estimation requires still greater sophistication in such a knowledge of changes made on the landscape alter the timing and amount of water flowing especially peak or flood flows and low-flows conditions. Overtime, these also affect channel shape and stability especially changes of the later type are delayed and off-site, they may have unwanted and often costly results. Increase in magnitude and frequency of flooding is a typical result of urbanization. It should be known for example, that this effects is greatest immediately downstream of the urbanised area but decreases or fades away with distance downstream.

Because human use of the land usually alters channel factors, planners, land managers, environmentalist and engineers have or should have special interest on how channels 'react to changes on the basin upstream. The difficulty is that even when the principles are well understood, forecasting the specific nature of the rivers reaction to basin alteration is tenuous at best. Therefore, the more widespread the understanding of those facts that are firmly established, the more likely that handling the channel system will be given some thoughtful consideration.

2.5 DISCHARGE, VELOCITY AND FLOW RESISTANCE

Water flowing in a channel is being pulled downhill by gravity, the gravitational force of the weight of the water having a downhill or forward component, just as an automobile parked on a hill might move forward because of the components of its weight in a downhill direction, thus the stream gradient is an essential hydrological factor. counteracting the downhill force is the drag or resistance of the bank and bed tending to retard the flow. Because, in general, the water does not accelerates or decelerates but rather maintains an approximately constant velocity, the component of gravitational force is equal to and opposite the resisting force.

Discharge is given as the product of cross-sectional area of flowing water and its velocity or

$$Q = Au = wdu \qquad \text{(Eq. 1).}$$

Where,

Q = Discharge in cfs.

A = Area in sqMetre

U = Velocity inm/sec.

W = width in metre

D = Depth in metre

The same nomenclature can be applied to a natural stream channel where the depth (d) and width (w) are determined but the water flowing in this respect does not fill the channel which has a bankfull depth of d_{bkf} and a bankfull-width of

w_{bkf}. The velocity will be somewhat greater at bankfull, so the discharge at bankfull or when the channel is at capacity would be.

$$Q_{bkf} = W_{bkf} \times U_{bkf} \times D_{bkf} \qquad \text{(Eq. 2)}$$

Velocity as well as depth increases as discharge increases.

If the velocity increases with rising discharge what factors are responsible? The velocity depends on the depth, the slope or the water surface gradient and inversely on the boundary resistance, the relation can be expressed by the well known Chezy formula

$$U = C\sqrt{Rs} \qquad \text{(Eq.3)}$$

where

U = water velocity

C = A resistant factor – large for smooth boundaries and small for rough boundaries offering much resistance.

R = Hydraulic radius, the ratio of cross-sectional area of flowing water to wetted perimeters, A/wp; R is equal to a mean depth for wide channel.

S = The energy gradient which is closely approximated by the slope of the water surface.

2.5.1 CHANNEL RESPONSE

The title of this section is in a sense misleading since it suggests that channel change simply in response to the various processes described in the previous sections. In fact, as has already been indicated in several places, the channel characteristics themselves affect the way in which these processes operate in the river channel system, we have an extra-ordinary complex set of feedback mechanism operating through many different time-scales. The various interactions are so complex that the behaviour of river channels has been considered as indeterminate by some research workers (e.g. Maddock, 1969). In this study, four types of alluvial channel response will be considered, namely, the formation of different bedforms, channel cross-section, channel planform and the river long profile.

2.5.2 BEDFORMS

Within river channels especially those with sand beds, a variety of bedforms are found as the intensity of flow increases. The idealized scheme (fig. 5) is based on flume studies, natural channels and variation in stream velocity in different parts of the channel mean that the same form can co-exists at the same time. Initially, virtually no movement takes place although when the critical threshold for erosion is exceeded, small ripple develop (Fig. 5a) at greater flows dunes develop with their steep face facing downstream, since material is carried up the gentle "stoss slope" over the crest (Fig. 5b) and then falls down the "lee slope" giving rise to cross-bedding and forward movement of dunes. Both ripples and dunes contribute significantly to the channel's resistance flow.

However, at higher stream energies, the dunes are washed out and a "planar channel bed" is formed with even lamination (Fig. 5c). this planar surface is replaced by "anti-dunes" at higher flow intensity which commonly move progressively upstream. As they grow they may be periodically washed out by the breaking of standing waves (Fig. 5d). The resistance to flow by anti-dunes and especially in the planar form is much less than for ripples or dunes (Allen, 1970) for coarser sands, the first stage after sediment movement commences tends to result in plane bed forming first before the ripple stage.

2.5.3 CHANNEL CROSS-SECTION

Explanation of the form of channel cross-section is related to two basic factors; firstly, the overall dimensions are adjusted to transfer, the water and sediment discharges through the channel cross-section. Secondly, the shape of the channel cross-section. Secondly, the shape of the channel is controlled by the resistance of bed and bank materials to the distribution of erosive forces of the river and its sediment load. Although, larger discharges are always associated with larger channels, it is not easy to determine which particular type of discharge controls the channel dimensions. One way to study this problem is to measure the discharge that results when the channel is at bank full stage and to attempt to determine the frequency of this discharge. Although other types of discharges matter, the bankfull discharges have more implications.

Evidence from many rivers around the world suggests that bankfull discharge occurs with a return period between one and two years and for many streams, it is close to one and half years. The return period of a flood is the average interval of time within which the flow can be equalled or exceed once (Gregory and Wallings, 1973). Although the recurrence interval of bankfull discharge varies somewhat even for different cross-sections of a single river, the evidence does suggests that the overall channel dimensions are generally adjusted not to particularly rare events or to very common ones but to event of moderate magnitude which occurs once every one or two years (Wolman and Miller, 1960).

2.5.4 CHANNEL PLAN FORM

Three basic types of river channel planform exists, namely straight, meandering and braided (Fig. 6a). Infact, the first type is unusual since nearly all channels are found to have sinuous courses. In braided channels, meanders are also found but their distinctive characteristics is that a single river course is replaced by two or more channels. Analysis of braided and meandering channels by Leopold and Wolman (1957) suggested that for a given bankfull discharge, braided channel tends to have steeper gradient than meandering channels (Fig 6b). Work by Schumm and Kahn (1972) in flume experiments indicted that braided channels were characterized both by steeper slopes and by greater sediment load compared to meandering channels.

The presence of less resistance banks has also been suggested as being important for the generation of braids, since rapid erosion of the opposite banks in the same reach will naturally encourage a splitting of a single stream into two parts. From numerous field and laboratory observations braided channels are characterized by high channel gradient for a given bankfull discharge and erodible bank associated with low width-depth ratios. Although, several of these properties of braided channels are in accord with intuition, the relatively higher gradients of braided channels are not.

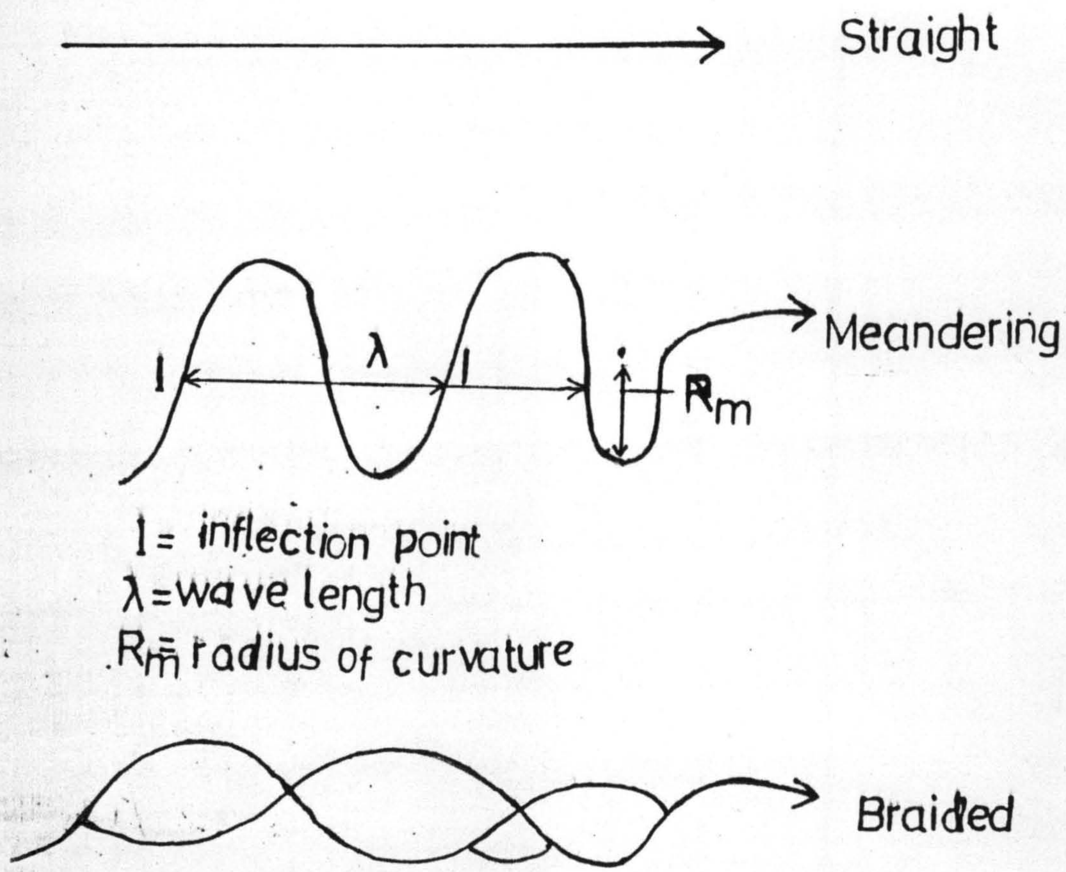


Fig.6. Types of channel planform

(FROM LEOPOLD AND WOLMAN)

Numerous explanations on the cause of river meandering have been proposed, although none offer a complete answer as yet, any explanation of river meandering most take account of the fact that meanders are found elsewhere in nature varying in scale from the giant meanders of the Gulf Stream to the path of rain drop on window pane Langbein and Leopold (1966) found that meanders correspond closely to sine-generated curves defined by the following equation

$$\theta_s = W_{\sin}\left(360\frac{D_s}{D_R}\right) \qquad \text{Eq.4}$$

Where θ_s is the orientation of a particular segment D_s, is the distance downstream D_R is the total reach length and W is a variable describing the maximum deviation at the meander inflection points. As it increases so also the sinuosity (or bendiness) of channel increases.

The particular characteristic of note of the curve is that it involves the maximum variance of change of channel direction. One of the outstanding characteristics of river meanders is that they show little change in form with increasing size or expressed precisely, as channel width increases, the wavelenght increases linearly (i.e. $\lambda \alpha w$). This proportionality is probably related to the fact that when the ratio of the radius of curvature (R_m) to channel width has a value near 2, the minimum resistance due to flow is found (Leopold et al, 1964). Not surprisingly, in view of previous statement (section 2.5.3 cross section) that discharges control channel width, it appears that discharges with return periods around one to two years are not important in the shaping of river channel meanders.

Explanations of the initiation of meanders are associated with the heterogeneity in the resistance of materials to erosion and to variation in stream erosion associated with secondary factor across-channel circulation, super imposed on the main streamflow. Once a deviation from a straight channel exists, then continued erosion and deposition of material will lead to an amplification of the deviation in a positive feedback loop at the apex of meander bands, a rotational flow is found with the surface water moving to the outer bank and at the bed's water moving towards the inside of the bend minimum bed shear stress and erosive power are found in the apex of the band and consequently, a sequence of pools and ripples is found with the later being formed near the inflection point Fig. 6). The wavelenght of the ripple-pool sequence was found by Harvey (1975) to be most closely related to channel width and sub-bankfull discharges on the inside of the river bends, active deposition takes place to produce the so-called point-bar deposits. These within the shallow water near the channel and are associated with progressive lateral channel movement (Allen, 1970).

2.5.5 CHANNEL LONG PROFILE

Examination of field relationships between stream gradient and various possible causative factor has generally shows that the gradient of streams can be expressed as a function of discharge of bed material size. Using data from Appalachian streams in the USA collected by Hack (1957), the resultant equation for stream gradient is as follows

$$S = K\frac{D^{0.78}}{Qm_{0.53}} \qquad \text{Eq.5}$$

Where D is the mean particle size, Qm is the mean discharge and K is constant.

The implication of this relationship is that the stream gradient is adjusted to the discharge and bed material sizes so that the river can transport the sediment entering a reach. Work in South-East England (Penning-Rowsell and Townshend, 1978) has shown that the spatial scale at which stream gradient is measured should be considered in deriving an understanding of the factors affecting channel gradient. Channel reach was found to be most closely related to discharge (measured using drainage area as a surrogate) but for the local gradient over ripples, the strongest relationship is to particle size, in neither case did the shape of the channel significantly relate to slope, although more open channels (with a higher width depth ratio) would be expected to be associated with low gradient because of the lower resistance of flow of such channel, however, for a single channel reached without any variation in discharge. Channel slope was found to be significantly related to width to depth ratio. An important geo-morphological consequence of the relationship between bed material size and the gradient is that when irregularities of the rock types are superimposed on the overall upward concavity of river profiles, they will not be eliminated with time. As long as material of different sizes are supplied to the channel by slope processes and channel bed erosion, the characteristic slopes on different rock type would be maintained.

CHAPTER THREE

3.0 DATA AND COMPUTATIONAL TECHNIQUES

In this chapter various types of data used in this project work are described and the method of computation adopted are also presented.

3.1 DESCRIPTION OF DATA

Two major types of data are used in this project namely; streamflow data (drainage and gauge - height) and channel geometry data.

S/No.	TYPES OF DATA	DURATION
1	Streamflow data (drainage and gauge-height) **Source:** Badeggi gauging station of the Niger State Water and Sanitation Board, hydrology department	1980 - 1994
2	Channel geometry data from topographic map sheets 184 and 204 Bida S/W and Baro N/W scale 1:50.000 **Source:** Niger State Ministry of Land and Survey	1month (1967)

The first set of data i.e (Streamflow data) were obtained from Niger State Water and Sanitation Board office, at the Badeggi gauging station.

The channel geometry data were obtained as a result of simultaneous field survey of the stream at Ewogi.

3.2 COMPUTATIONAL TECHNIQUES

The researcher has adopted the use of inferential statistical measures for the computation and analysis of the streamflow data, from which monthly and seasonal changes in Gbako catchment basin is followed.

Two measures of variability were also employed, namely, standard deviation (STD) and coefficient of variation (CV).

(1) $$SD = \sum_{i-1}^{n} \left[\frac{x - \bar{x}}{n - 1} \right]$$

(2) $$CV = \frac{Sd}{\bar{x}} \times \frac{100}{1}$$

In order to standardise the SD for data series, it is divided by the mean value to produce CV.

Regression analysis (linear regression model) was applied to examine the degree of relationship between discharges and gauge height and also in the process of hydrograph and geometric analysis.

CHAPTER FOUR

4.0 ANALYSIS AND DISCUSSION OF RESULTS

Understanding the mechanism of variability in discharges and water level as reflected in streamflow records taken on time scales of seasons to several years is a pre-requisite for any prediction of flow regimes of rivers and stream. As well as to the understanding of various characteristic elements of the stream. Simulating the streamflow characteristics of River Gbako is the main aim of this research study, therefore, the following is the statistical analysis of records of streamflow (Discharges and gauge height) for the river Gbako with a view to its studied trend.

The streamflow statistics was adopted from Suleiman *et al.* (1990) in his study of the same river in relation to the impact of climate on its flow regime. However, data on gauge height were produced by the researcher using the same method.

The regimes of rivers, that is, their seasonal variation volume due to trends in their discharge relation to gauge datum has received much attention in recent years in connection with problems and scheme of flood control and water supply. The seasonal precipitation, the steepness of slopes in the catchment area, the nature and pattern of streams and their channel form and the character of vegetation are all salient factors in determining the general character of streams. In tropical latitudes, where temperature and evaporation are constantly high flood clearly follow the rainfall regime (Monkhouse, 1980). As such the most single generator of streamflow in the study area is rainfall.

Streamflow in the study area is therefore perennial because it essentially flows the year round with fluctuations during the rainy periods as will be indicated in the following analysis.

4.1 ANNUAL DISCHARGE FREQUENCY ANALYSIS

The strong seasonality in rainfall over the study area is reflected in the flow regime of the river under study (Fig. 7) illustrate the discharge

Table 1: Annual discharge statistics for river Gbako

Year	Total	Mean(m^3/s)	SD(m^3/s)	CV(%)
1980	522	43.5	6.38	20.4
1981	499.2	41.6	6.22	19.95
1982	614.4	51.2	6.95	22.28
1983	390	32.5	5.45	17.46
1984	204.24	17.02	3.77	11.73
1985	150	12.5	3.10	9.96
1986	277.2	23.1	4.50	14.42
1987	268.8	22.4	4.42	14.17
1988	451.2	37.6	5.89	18.89
1989	312.24	26.02	4.81	15.43
1990	402	33.5	5.54	17.74
1991	481.2	40.1	6.10	19.56
1992	424.8	35.4	5.71	18.28
1993	331.2	27.6	4.97	15.94
1994	303.6	25.3	4.74	15.19
	375.472	31.2	5.23	16.76

NIGERIA HYDROLOGICAL YEAR BOOK VOL.II (1991)

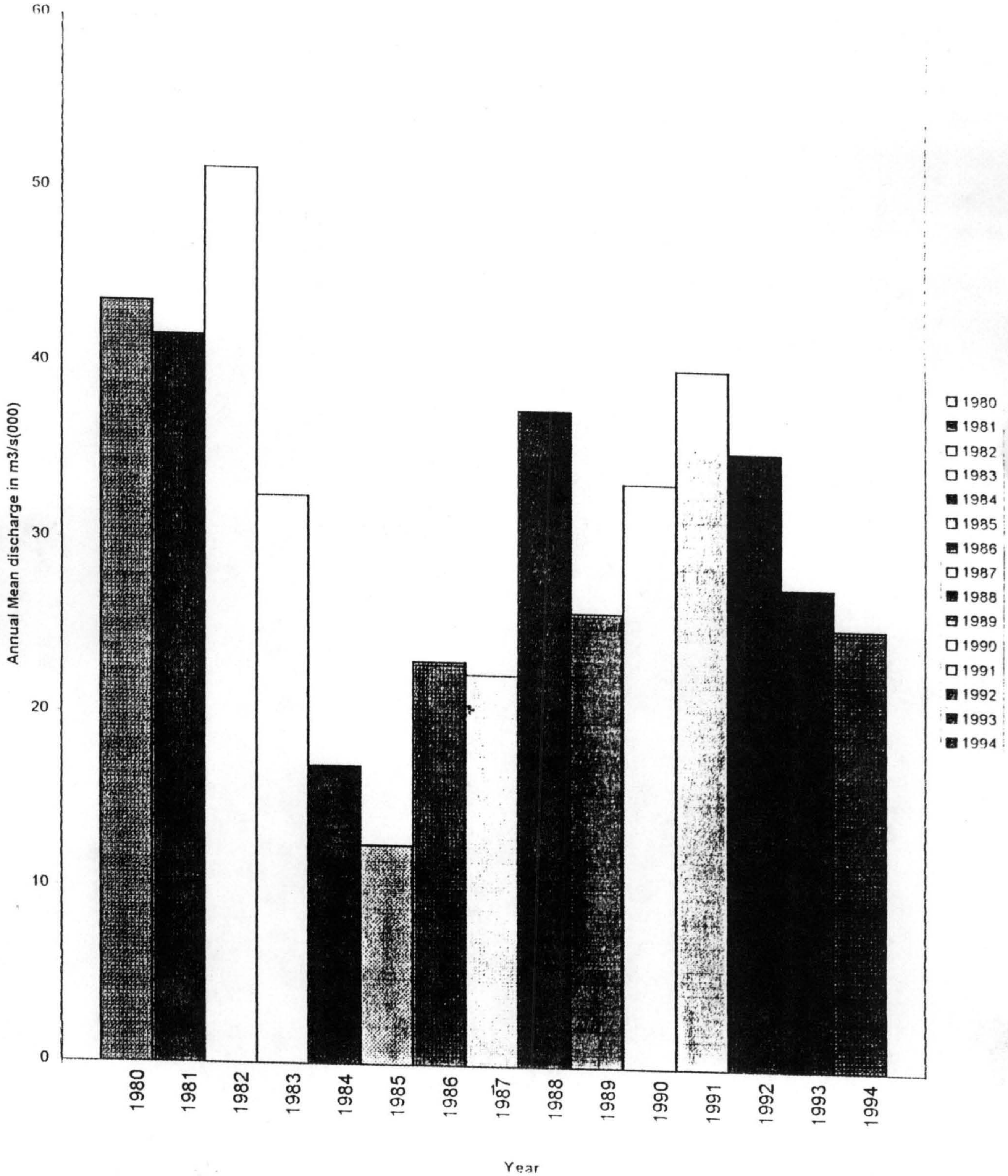


Fig. 1: Annual discharge statistics for river Gbako (1980 – 1994).

NIG. HYDROLOGICAL YEAR BOOK VOL. II (1991) hydrograph for river Gbako. The annual streamflow statistics reflect the temporal distribution character of the flow regime. See Table 1, which shows the annual discharge statistics for a 15 years period.

The total discharge recorded for the study period is 5632.08 cubic metre/sec with a total mean of 375.472m3. the highest discharge was recorded in 1982 which is 614.4 cubic metre/sec with 22.28% variation above the mean total. While the lowest discharge was recorded in 1985 with total annual discharge of 150 cubic metre/sec and 3.10% deviation from the total mean. The decline in annual maximum is particularly obvious from 1980 and the annual maximum equally obvious after 1985 see also Fig. 7. This feature is indicative of the fact that within the basin annual discharge is not normally distributed for all years (Adefolalu, 1986). Thus the decline in the stream discharge could be directly associated with the decline in rainfall over the basin.

4.2 ANNUAL GAUGE HEIGHT FREQUENCY ANALYSIS

The knowledge and appreciation of the existing strong seasonality in the volume of water at various stages or datum in river is a very significant yardstick in the prediction of hydrological events especially the trend of discharges from streams.

The annually treated records of the water stage in the study area within the research period shows both spatial and temporal variations see table 2.

Table 2: Annual gauge height statistics for River Gbako

Year	Total	Mean(m)	SD(m)	CV(%)
1980	73.92	6.16	2.41	39.12
1981	54.6	4.55	2.05	45.13
1982	51.6	4.30	1.99	46.32
1983	39.84	3.32	1.72	52.05
1984	27.24	2.27	1.39	61.31
1985	33.72	2.81	1.57	56.01
1986	41.28	3.44	1.36	51.24
1987	27.12	2.26	1.38	61.42
1988	53.16	4.43	2.02	45.69
1989	39.24	3.27	1.71	52.41
1990	55.32	4.61	2.06	44.86
1991	30.36	2.53	1.48	58.58
1992	36.24	3.02	1.63	54.28
1993	41.52	3.46	1.76	51.10
1994	54.84	4.57	2.05	45.04
		3.66	1.79	50.97

Table 2 shows the annual gauge height statistics for the Gbako River. It can be seen that the highest level of water was recorded in 1980 where the datum is 73.92 metres with a variation limit of 39.12% while the lowest recorded datum was 27.12 metres in 1987 representing 1.33 metre as deviation from the annual mean total. The decline in the annual maximum height of water recorded is particularly obvious from 1982 and equally obvious is the minimum stage recorded after 1984 Fig 8 is a graphical illustration of Table 2.

4.3 MONTHLY DISCHARGE FREQUENCY ANALYSIS

Abstraction from a river although taking place regularly for domestic and other water supply scheme are usually quantified on a monthly basis- J.P Clark (1963). Hence, a very useful statistics of river discharge is the average of the daily mean discharge over a month (the mean monthly discharge). Table 3 shows the monthly discharge statistics for river Gbako at Badeggi, while fig. 9 is a graphical presentation of the same data.

As can be seen from Table (3) low discharge were recorded between the months of November and April, a period of 6-7 months. During these periods, monthly mean discharges ranges between 10.37 and 6.02 cubic metres per seconds representing 1.7% and 3.05% of the annual total discharge. At the same period other section of the river channel witness quite lower flows (discharges) see evidence from geometry survey.

In contrast to the period of low discharges is the period of high discharge which was between the months of May to September a period of 5-6 months. During these period monthly mean discharge recorded were between 35.72 and 59.5m3/sec representing about 10.1 and 17.18% of the animal total discharge. The mean monthly variability ranges between 19.94% in May and 26.14% in September.

One important significance of the monthly data is that it may be used more directly for the evaluation of the amount of storage required in a reservoirs to guarantee a given demand or supply rate. The period of maxima and minima representing seasonal variation the flow regime of the Gbako river. Fig. 9 serve as a useful tool for the estimation of extreme events of flood or droughts in the study area. The significance of this flow variation is also noteworthy where extreme peak flows causes serious problems of flooding. Fig. 9 shows the hydrograph for the Gbako river at Badeggi which illustrate this flow variation (adapted from Shekwolo, 1984).

Table 3: Mean Monthly Discharge Statistics for River Gbako (1980-1994).

Months	Mean Discharge (m^3/s)	% of Annual Discharge (m^3/s)	Standard deviation	Co-efficient of variation (%)
Jan	7.05	2.03	2.10	7.27
Feb	6.2	1.79	1.89	6.55
March	6.06	1.75	1.85	6.42
April	6.02	1.73	1.84	6.38
May	35.72	10.3	5.75	19.94
June	50.16	14.48	6.89	23.89
July	56.40	16.20	7.33	25.40
August	51.40	14.84	6.98	24.20
September	59.5	17.18	7.54	26.14
Oct	49.63	14.33	6.85	23.76
November	10.57	3.05	2.81	9.77
Dec	7.55	2.18	2.21	7.69
Ann. Total	346.24	100	314.32	16.76

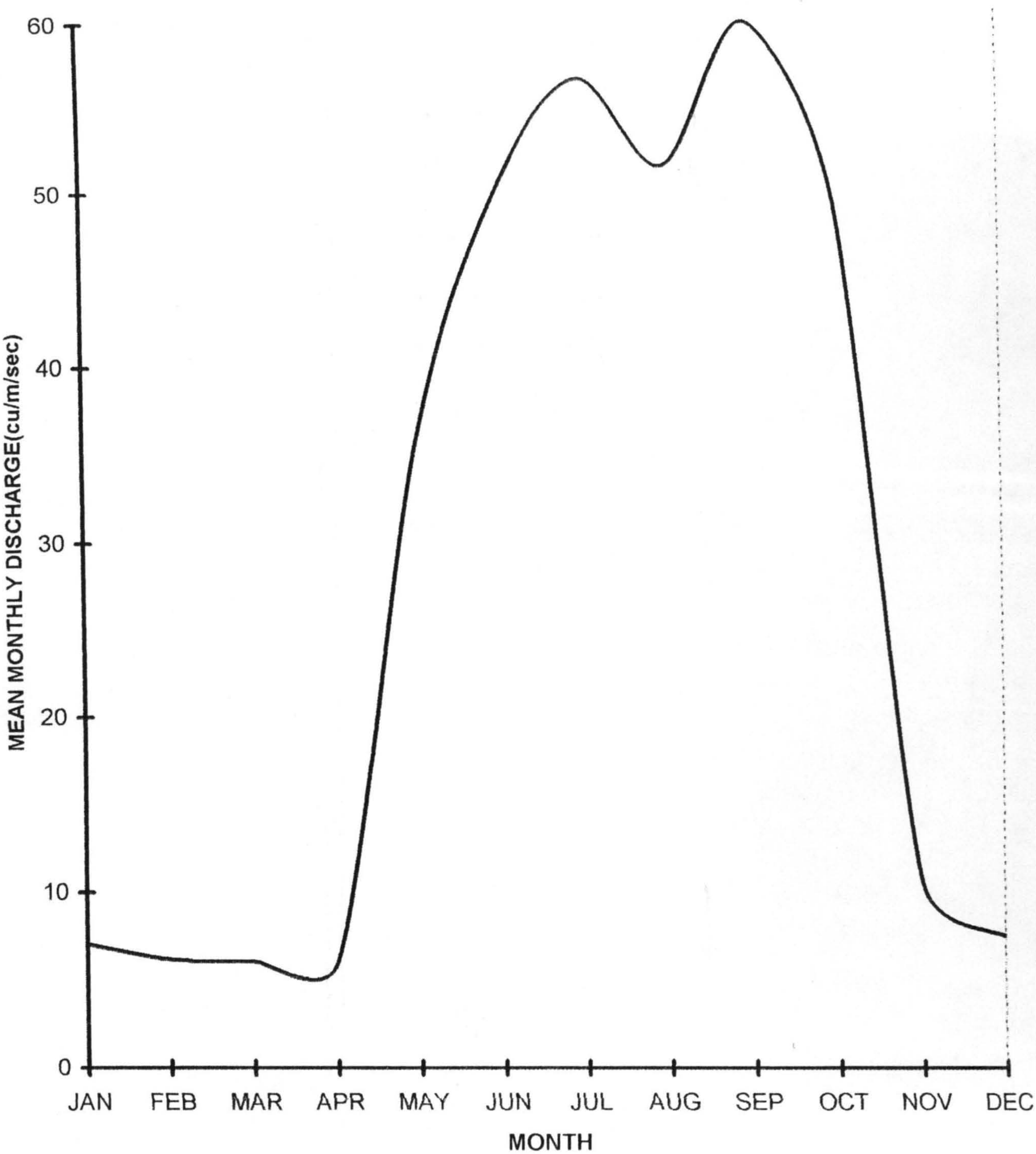


Fig. 9: Mean Monthly Discharge Statistics for River Gbako (1980-1994).

4.4 MEAN MONTHLY GAUGE-HEIGHT ANALYSIS

The mean monthly gauge-heights records is retained from the average of daily gauge readings over a month. (the mean monthly gauge datum). Table 4 and Fig. 10 are statistics and graph of the gauge height data.

As can be observed from Table (4), low water stage were recorded between the months of November to March, a period of five months. During these periods, the mean gauge datum ranges between 2.16 to 2.70metres representing about 4.90% of the annual total.

In contrast to the period of low stage is the period of higher water stages. This is recorded between the months of April to October, a period of 7 months. During this period the mean monthly datum rises to between 3.82 metres to 5.76metres in September, see also Fig. 10 for further observation on the river datum trend.

Table 4: Mean Monthly Gauge Height Statistics for River Gbako (1980-1994).

Months	Mean Gauge Height (m)	% of Annual Gauge Height (m)	Standard deviation (m)	Co-efficient of variation (%)
Jan	2.19	4.96	1.36	37.12
Feb	2.37	5.37	1.42	38.88
March	2.16	4.90	1.35	36.82
April	3.82	8.66	1.86	50.68
May	4.14	9.39	1.95	53.16
June	5.09	11.54	2.18	59.42
July	4.08	9.25	1.93	52.73
August	4.06	10.43	2.06	56.28
September	5.17	13.06	2.32	63.47
Oct	4.75	10.77	2.10	57.26
November	2.70	6.12	1.53	41.68
Dec	2.42	5.49	1.44	39.35
Ann. Total	44.08	100	21.5	48.90

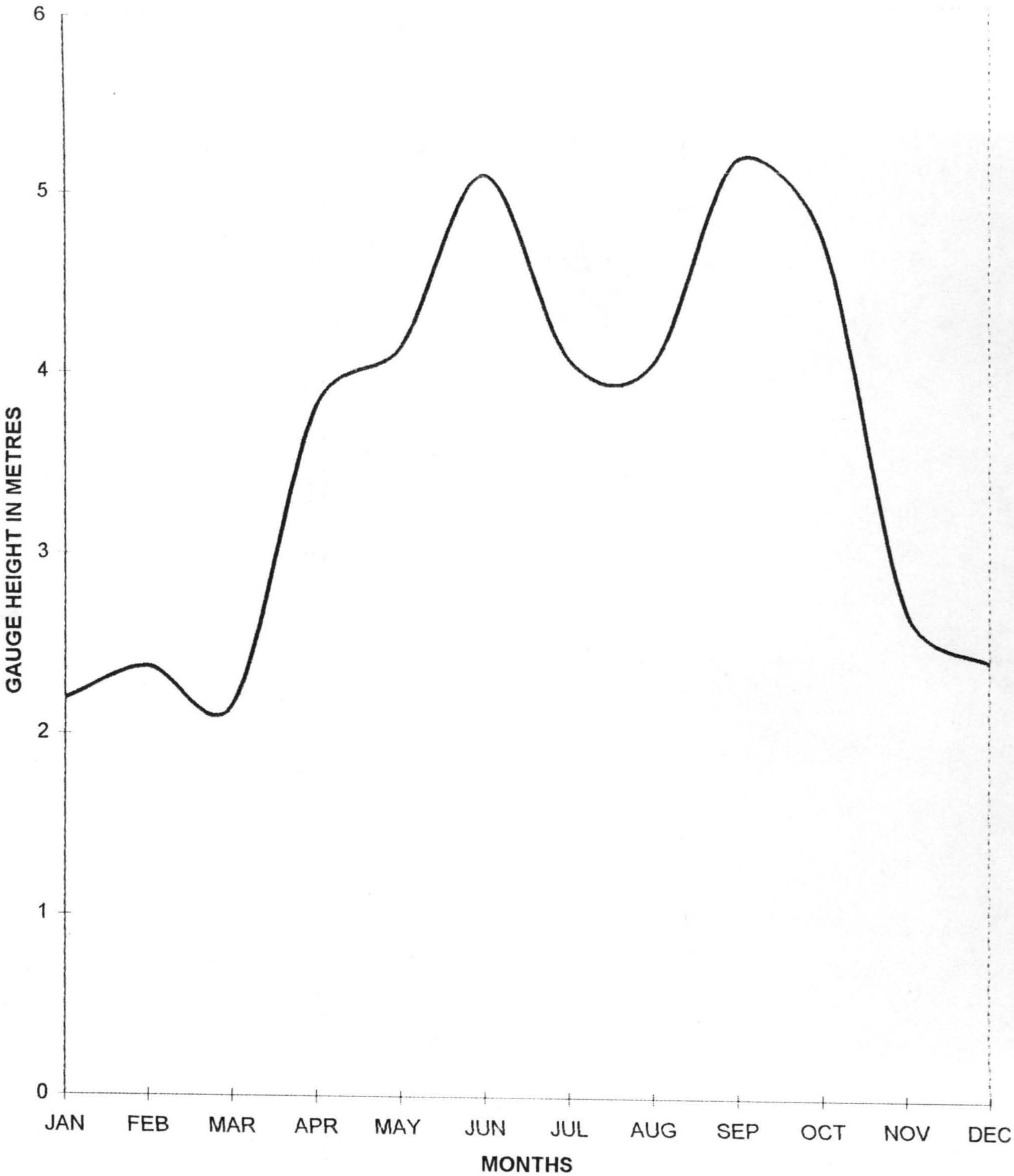


Fig. 10: Mean Monthly Gauge Height Statistics for River Gbako (1980-1994).

4. 5 STAGE HEIGHT-DISCHARGES RELATIONSHIP OR RATING CURVE

If a site is visited regularly and simultaneous discharge and stream depth observations are made over a large range of discharges a stage-discharge relationship can be developed then discharges can be determined simply by monitoring the water level.

The stage-discharge relationship is expressed as a rating curve. In a natural stream, a relationship must be developed by plotting measured stage against discharge (Nancy et at, 1992).

Fig. 11 shows the rating curve developed for river Gbako as a result of statistical analysis of discharge and gauge height records of 15 year period. The values of discharge and gauge height were obtained from the grouping of monthly records into three year classes so as to produce three points values for the rating . see Table attached.The use of only three points for the development of the rating curve was base on the fact that it produces a more reliable result (Milhous and Bovee, 1978).

The discharge a dependent variable is plotted on the x-axis while the independent variable (gauge-height) is plotted on the Y-axis. This method makes the plot follow the direction of the rising and falling limb.

The highest discharge and stream level is obvious during the first 5 years of the study (1980-1984). Discharge was 37.16m^3/s at a stage of 4.12 metres.

Discharge and gauge height reduces in the following years (1985-1989) with a discharge of 24.32 m^3/s at a stage of 3.24 metres.

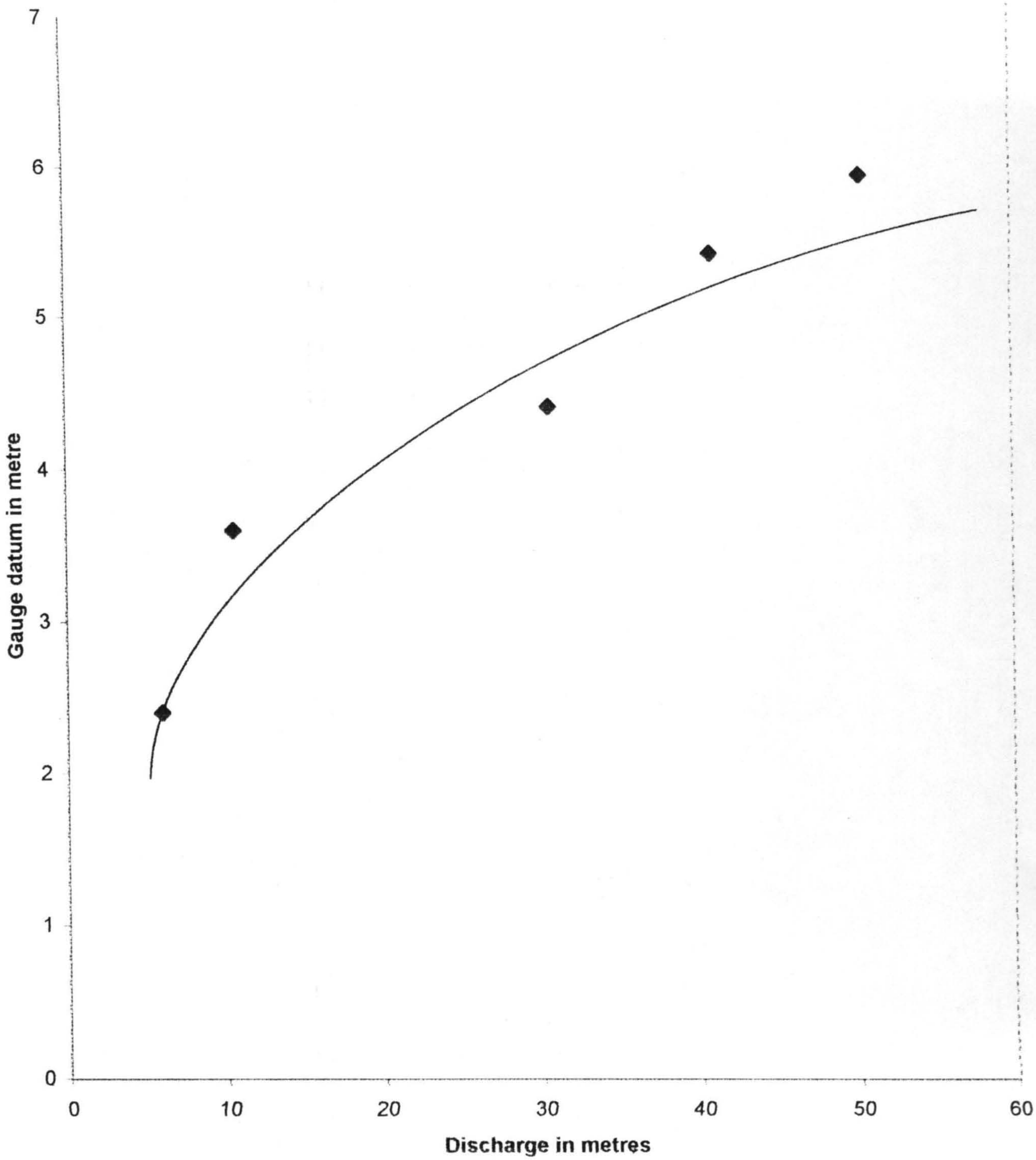


Fig. 11(a): Monthly Fluctuation Rating Curve for River Gbako

In the years (1989 - 1994) discharge and water level both rises above what obtain previously recording 32.38m^3/s and 3.64 meters of stage.

From the above it can be inferred that discharge increases with corresponding increase in the height of water stage.

4.6 SUMMARY OF DISCHARGE-GAUGE HEIGHT ANALYSIS

In this chapter, the discharge and gauge height data for 15 years record period have been discussed presented and analyzed with the view of meeting the outlined objectives of this project work as predicated in Chapter One.

The following is a summary of what was treated:-

- By all indication, the Gbako river is perennial, that is , it flows all year round. This is proved by the following equation of the base flow index.

$$\text{Base flow index} = \frac{\text{lowest mean monthly flow}}{\text{mean annual flow}}$$

$$\therefore \text{Base flow index} = \frac{6.02}{375.5} \times 100$$

$$= 1.60$$

Streamflow is fairly constant at value near 1 and above for perennial streams. (Hamilton and Bergerseen, 1984).

- The stream discharges and stage height increases with rainy periods, that is from the month of April till October.

- The months of May to October produces high advantage during which monthly values lies between 535.80 and 892.5 m3/sec. over a stage height of 40.50 metres.
- The month of September was when the highest discharges were recorded through out the period under study. That is highest discharge and stage height are expected every September or of a 1 year reoccurrence interval.
- The floor characteristics of the Gbako river expresses strong seasonability.
- The period of maximum streamflow is between the months of June and October. The discharge values during this period is between 20.6 m3/sec and 29.5m/sec. the dry season witness how discharges of between 1.7m^3/sec and 6.1m3/sec.
- The decline in gauge datum is reflected by the overall decline in stream discharge and hence varialibility in annual rating situation.

4.7 GEOMETRY SURVEY

The researcher has carried out a geometry survey with a view to complimenting the major aim of the study which is to simulate stage-discharge relationship with the channel morphology.

Fig. 12(a) is a cross-section of the river at a point 3.5km from the bridge along the stream and Fig. 12(b) shows the channel in relation to its bankful stage and average discharge stage.

Data obtained from the field survey are absorbed into the cross-sections, and Shown in Table 5.

From Table 5, it can be seen that the cross-sectional area is 1524 sq metres using the Leopold formula; with x depth of channel is the cross-section area in square metre.

The bankful discharge is 59.5m3/sec which correspond with the value Of a yearly return period. Table 5: Channel Geometry Survey Data for River Gbako at Ewogi of a one year return interval. The average discharge at that point was recorded as 25.6cms obtained by dividing the cross-section area with the bankful discharge.

Table 5: Channel Geometry Survey Data for River Gbako at Ewogi

Cross-section area (Sq/m)		1524
Average discharge (cms)		25.6
Discharge of 1 year R.I (cms)		59.5
Discharge of 1 year R.I (cms)		59.5
Depth = D	Qave (cms)	15.25
	Q. 1yr. interval	60.96
Velocity u(m/s)	Qave (cms)	2.5
	Q. 1yr. interval	3.5
Width (m)	Qave (cms)	6.25
	Q. 1yr. interval	25
Bed Material size D50 (mm)		52
Slope		11.43
Gauge Height at BKF (m)		18.9

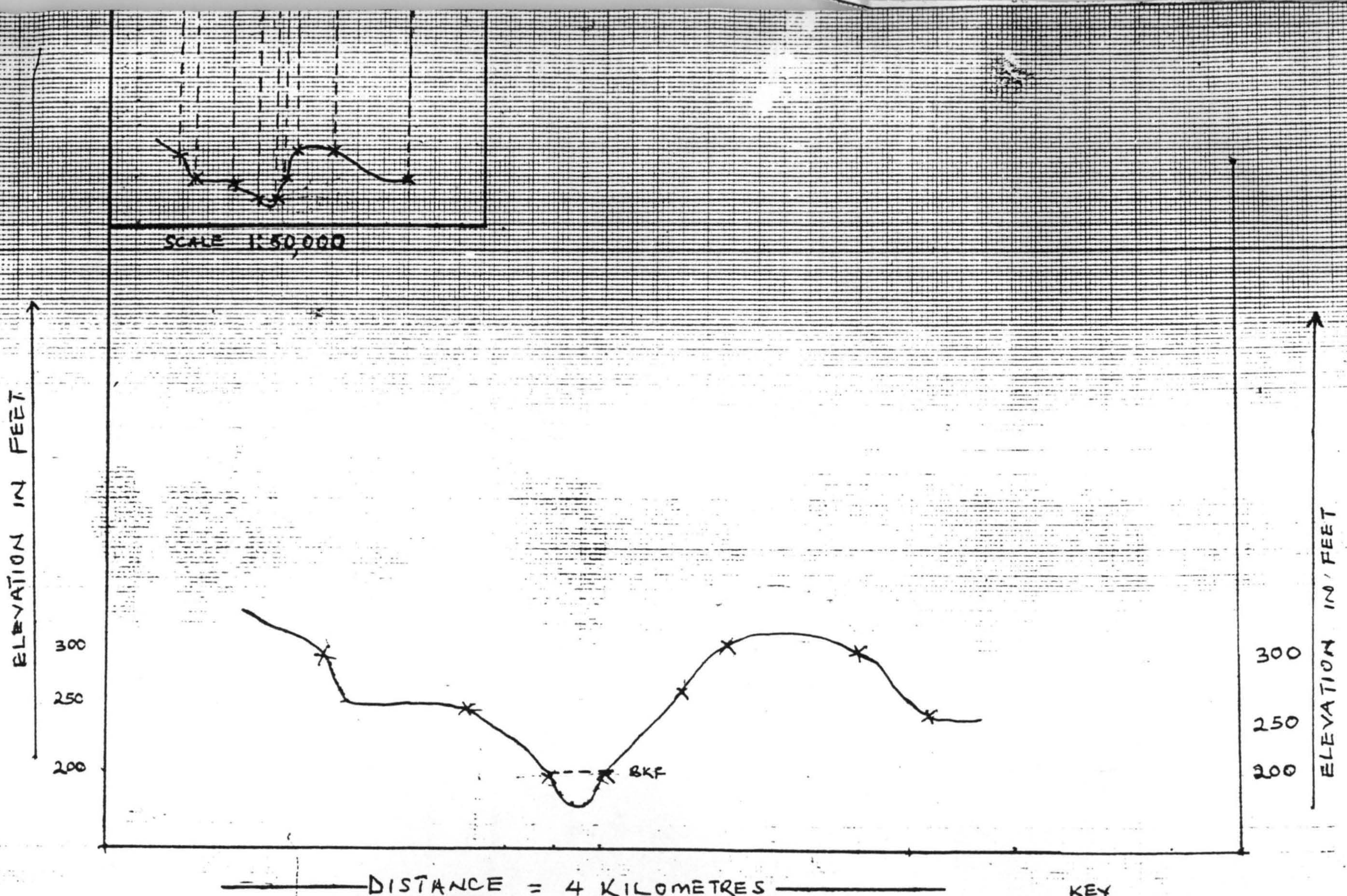
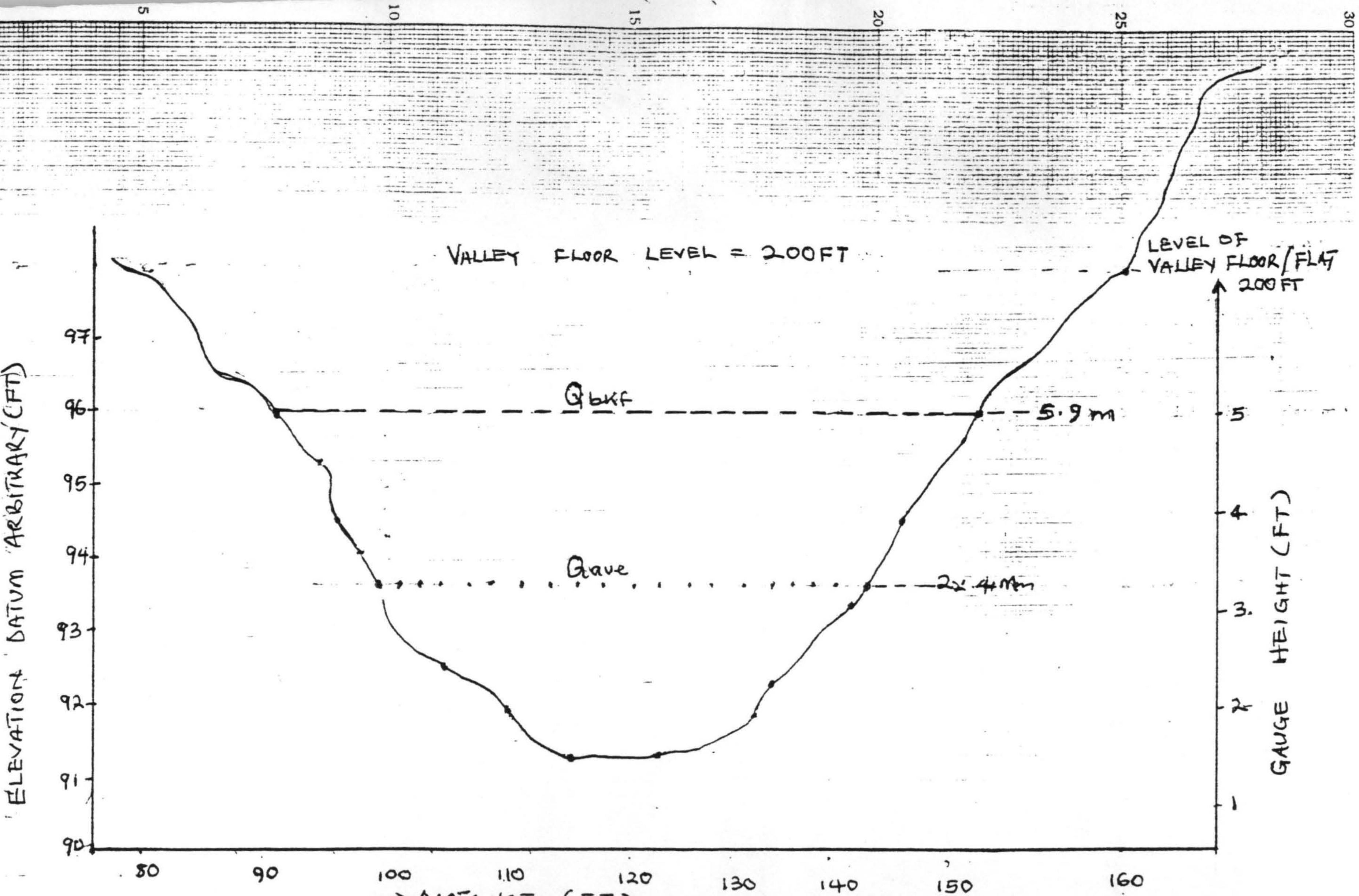


FIG. ~~E7~~.12(a)
SHOWING THE RELATION OF CHANNEL TO VALLEY FLOOR



RIVER GBAKO AT EWOGI.

CROSS-SECTION: AREA 1.524Km²; SLOPE 1/1.42; BED MATERIAL D50 52mm; Q100 585; Qbkf 595m³/Sec; Qave 25.6m³/Sec.

16:13:08 – SHOWING THE LEVEL OF BANKFULL STAGE AND QAVE STAGE.

The velocity at bankful was estimated to be 30m/s also given as the four tenth of depth at bankful.

The bed material size are found to be within average size i.e. D50 of 52mm among samples taken.

The stream gradient is determined by subtracting the highest point of elevation at the upstream and the lowest point of elevation in the down streams. The highest point is 350ft while the lowest is 200 at the stream bank. The range which is 150ft is divided by the numbers of stream profiles to produce

11.43 metres.

The gauge height recorded on the field is 18.9 metres.

The following are the implications of the research study in relation to flood and erosion at the Gbako river.

Flooding and erosion are usually associated with surface run-off in general and heavy or intense rainfall in particular in terms of flooding are recognized of the three types of flooding identified above. Flood plain flooding is the most predominant in the study areas occurring in almost all rainy season when the stream receives greater volume of water. This occur when excessive discharges cannot be contained within the confines of the river channel particularly between the months of July and September, closely associated with the flood-plain, flooding is the general flooding both of which results in localized inundation due to tidal effects on low lying riverine areas. Fig. 13 illustrates the magnitude of flood and erosion in the area.

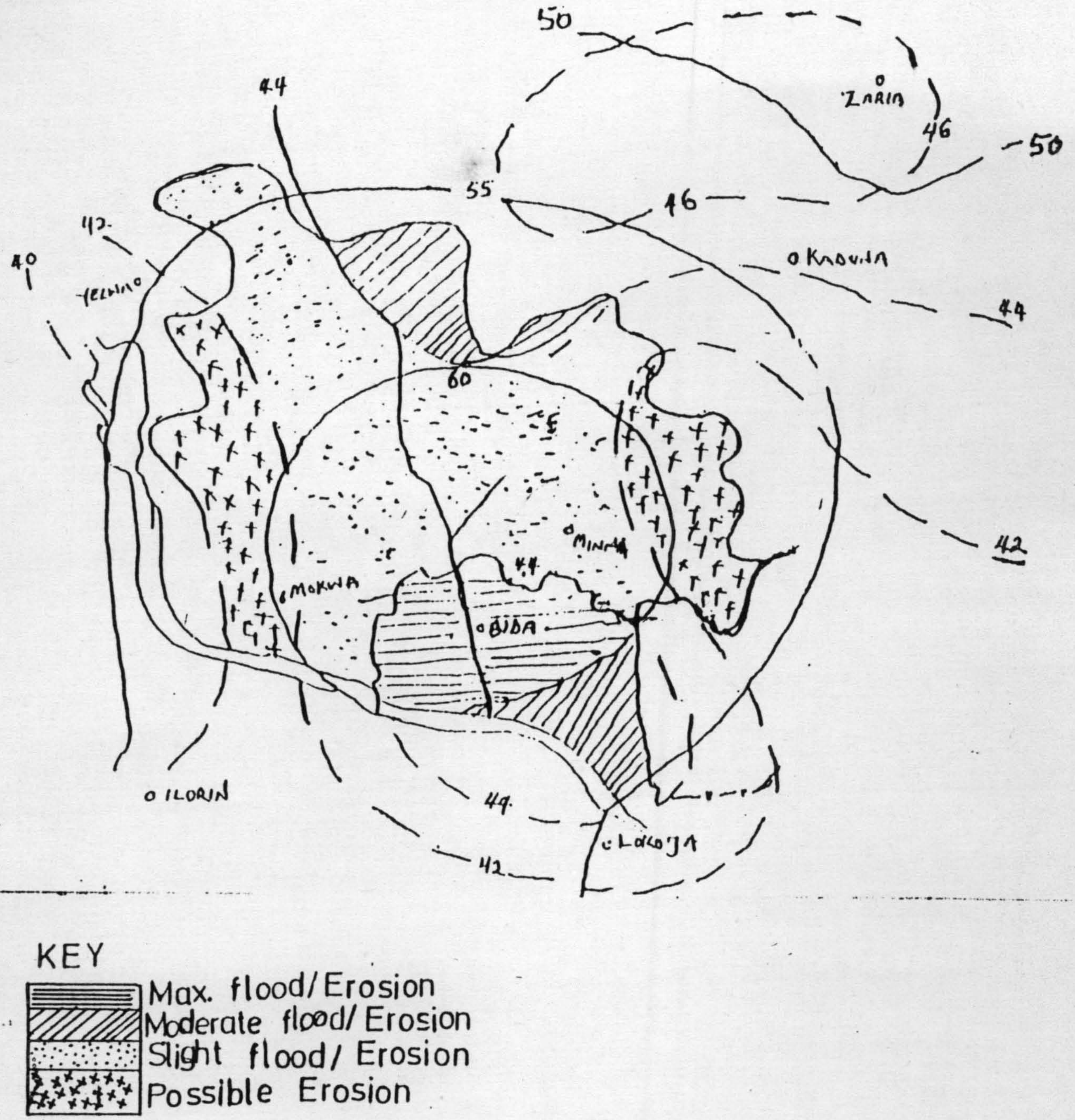


Fig. 13. Rainfull intensity (RI) in mm^{-1}, showing magnitude of Flood and Erosion (AFTER ADEFOLALU, 1991)

In view of the above, regulation of river flow to combat problems of flooding and to create permanent and dependable water supply for various uses is quite important in the study area. This can be achieved through the construction of dams but there are problems.

According to Ayoade and Oyebande (1987') the total domestic water needs in homes and amenities is 115 litres per person per day. Therefore, 17,250.000 litres is required to meet the demand of 150,000 people that rely on the stream for their water needs. However, the demand is hardly met because of cases of water shortage both urban and rural during dry seasons.

CHAPTER FIVE

5.0 CONCLUSION

5.1 INTRODUCTION

Various method and techniques have been used in the course of carrying out this research r· ˙ ´ ·, all geared toward the accommodation of the aim and objectives (see 1.4.0). in this chapter, conclusion are presented by enumerating empirical finding as well as suggestion relative to water and land resources management.

5.2.0 EMPIRICAL FINDINGS

ANALYTICAL TREATMENT OF THE RATING CURVE PRODUCES THE FOLLOWING FINDINGS.

(a) The Gbako river discharges an appreciable amount of water between 535.80m^3/sec in the month of May and October, an average of 74.5metre^3/sec in November and March

(b) though the stream is perennial its flow is characterized by strong seasonality alternating between high and low flow periods. In this context 5 to 7 months of high discharges having a return period of the average 1.0 year was recorded 4-5 months of flow average discharges were also recorded.

(c) The flow regime of the Gbako river is variable both in term of stream discharges and stage height which is consequent upon the strong seasonal relation or the influence of the rainy season upon streamflow.

(d) the period of maximum streamflow is between the month of June and October, the discharge value range between an average of $35.72m^3/sec$ and $59.5m^3/sec$.

(e) The average annual discharge is between $34.01m^3/sec$. The highest annual mean was record between 1980 and 1984 from which it dwindles to about $1\text{-}7m^3$ (sec to $6.06m^2/sec$).

(f) The decline in streamflow (discharge) is reflected in the decline stream stage and hence the variability in the streamflow characteristic in the Gbako Basin.

(g) It could be inferred that the period when flooding may be expected has decreased. The increasing duration of flow (as the analytical treatment of the data indicated) may now pose a more significant environment problem in the study area with particular reference to irrigation and dam design.

5.2.2 FINDING FROM CROSS-SECTIONAL DRAWING AND CHANNEL GEOMETRY SURVEY

(a) The Gbako river drains an area of land about 240 square kilometers together with other tributary rivers in the catchments.

(b) The valley floor is never under 200 feet throughout its transverse of over 50 kilimetre.

(c) That the channel banks are formed of silt and clayed silt material not easily erodabel due to the presence of adequate cement material.

(d) The bed material is composed of gravel and occasional sand particles and silt on the channel bars. Which suggest little scour.

(e) The channel pattern is sinuous to strongly meandering.

5.3 SUGGESTIONS

It is the . view of the researcher that a trend should be established for the acquisition of detailed information on the different components of the Bio-physical and human environment.

Adequate hydrological records of the area should be collected and integrated with frequent geometry survey of the river channel. The application of geographic information system (GIS) is necessary to properly integrate the different data sets.

The area has inadequate record of hydrometeological information. This can be provided by the use of meteorological satellite data that can provide temporal and spatial data on that subject.

A proper and effective method of record maintenance as well as that of equipment should be deviced.

However, there are both technical and management problems that should be taken into consideration, particularly in future resource assessment studies to solve the technical problem station staff should be regularly furnished with knowledge of modern techniques and methodology available for the effective execution of their duties.

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APPENDIX A

Mean Monthly/yearly Discharge Records in Cubic Metre/Sec for 1980 – 1994 of River Gbako

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann Mean
1980	7.64	20.43	18.9	9.6	70.62	50.61	58.49	68.2	97.21	90.47	16.72	13.5	43.53
1981	4.53	5.43	20.62	21.15	62.01	16.67	57.10	103.92	115.15	78.65	5.67	8.26	41.60
1982	3.37	1.52	50.43	56.43	80.58	98.74	52.33	54.79	102.61	103.22	5.71	4.51	51.18
1983	4.75	3.61	3.41	34.55	62.9	51.1	67.73	43.38	43.4	61.49	12.7	1.39	32.53
1984	2.39	4.57	2.4	8.63	5.74	57.11	12.17	9.03	20.45	10.48	10.24	13.11	17.02
1985	5.45	4.50	3.39	1.56	43.82	29.10	15.25	10.06	21.21	10.36	3.24	1.90	12.49
1986	6.88	2.56	1.39	2.54	25.66	23.14	93.0	19.6	40.9	50.6	6.71	4.53	23.09
1987	2.38	3.5	2.39	5.9	10.05	77.5	86.1	25.05	51.40	58.16	21.0	2.4	22.36
1988	3.40	4.5	5.09	184.74	21.0	61.7	13.8	60.55	50.1	20.4	15.0	11.5	37.64
1989	5.03	2.3	1.4	35.0	12.1	45.59	80.5	47.0	50.2	15.01	10.0	8.1	26.02
1990	4.98	3.9	3.0	85.02	20.0	91.4	91.2	33.01	19.01	19.02	16.0	15.10	33.47
1991	1.36	5.3	2.5	90.6	15.8	50.9	80.44	103.0	70.008	38.1	20.2	12.7	40.08
1992	17.9	15.6	12.8	7.7	17.9	17.9	48.6	83.45	5.7	85.2	17.6	14.75	35.42
1993	8.21	6.1	3.5	4.0	20.7	50.4	38.6	60.6	60.1	53.1	20.0	6.1	27.61
1994	4.1	7.3	10.1	6.5	18.9	30.61	50.6	48.5	65.0	50.6	5.9	5.4	25.29
Mean	7.05	6.2	6.06	6.02	35.72	50.16	56.40	51.4	59.5	49.63	10.57	7.55	
Max	1.36	1.52	1.39	1.56	5.74	17.9	12.17	9.03	19.01	10.36	3.24	1.39	
Min	17.9	20.43	50.43	90.6	80.58	98.74	93.0	103.92	115.15	103.22	21.0	15.10	

APPENDIX B

MEAN MONTHLY GAUGE HEIGHT DATA IN METRE FOR 1980 – 1994

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann Mean
1980	5.58	5.03	4.0	6.1	10.45	5.1	10.32	2.12	8.3	8.06	5.21	3.11	6.16
1981	1.40	1.41	9.7	7.6	2.21	10.6	3.24	6.24	3.7	2.54	1.0	5.0	4.55
1982	1.95	1.68	1.66	2.66	5.33	2.8	6.41	7.64	10.82	8.36	1.06	1.25	4.30
1983	1.97	2.53	1.39	2.88	5.41	3.18	1.51	6.51	6.5	4.19	3.2	0.88	3.32
1984	0.88	1.88	1.0	2.51	1.77	2.5	2.81	1.96	3.37	1.30	2.3	5.0	2.27
1985	1.42	2.42	1.96	0.90	1.0	3.0	3.14	2.1	3.0	4.70	1.18	0.80	2.81
1986	4.48	3.35	0.99	1.23	6.4	9.6	1.61	5.13	2.0	4.0	1.06	1.40	2.44
1987	1.08	2.08	1.25	2.5	1.08	0.95	3.3	7.6	2.21	3.24	9.7	0.88	2.26
1988	1.90	1.08	1.9	2.5	3.5	1.33	6.5	5.0	8.9	8.0	3.0	9.3	4.43
1989	1.40	0.9	0.5	8.8	6.0	2.5	5.23	3.51	4.0	1.0	3.5	2.01	3.27
1990	3.58	1.12	1.2	7.02	5.12	8.11	4.0	5.61	8.6	7.0	3.01	0.97	4.6
1991	1.66	0.8	0.99	2.04	1.63	6.14	2.16	2.5	6.19	2.4	0.69	3.2	2.5
1992	1.12	0.96	0.8	0.48	1.12	1.12	3.04	7.2	8.48	7.2	3.6	1.12	3.
1993	2.5	4.3	3.1	3.8	4.0	1.0	6.0	4.01	5.3	2.6	1.0	4.01	3
1994	2.0	6.0	2.1	5.6	7.2	1.8	2.1	3.1	5.0	6.1	1.02	4.0	
Mean	2.19	2.37	2.16	3.82	4.15	5.09	4.08	4.6	5.76	4.75	2.70	3.42	
Max	0.88	0.8	0.5	0.48	1.0	0.95	1.51	2.12	2.0	1.0	0.69	0.88	
Min	5.58	6.0	9.7	8.8	10.05	10.5	10.23	7.64	10.82	8.66	9.7	9.3	