Estimation of the Discharge of River Gongola at Gombe-Abba Bridge for Water Resources Management in North-Eastern Nigeria

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ABSTRACT

This research was conducted on estimating the discharge of River Gongola at Gombe-Abba with a view of providing information for sustainable management of water resources. The study adopted manual method where pillars were graduated for daily measurement of the fluctuation in surface water levels were determined while surface float method (SFM) was employed in determining flow velocities. Data collected on was applied on the formula discharge = hydraulic radius x stage x velocity to compute the daily discharges. The computed discharges show that the discharge values for the months of July to October gave x 10^8, 1.7 x 10^9, 1.8 x 10^9, and 9 x 10^8 m^3. The study concluded that River Gongola discharges an average of 8.2 x 10^9 m^3 for the four months which is significantly high enough to support sustainable supply for use in agriculture and domestic purposes. It is recommended that this huge discharge be transferred to north eastern Nigeria to mitigate the acute water scarcity in the Sahelian region of the country and to ultimately discharge the water into Lake Chad to augment the volume of water in the lake which is fast drying due to climate change.

Keywords: Estimation, Discharge, River Gongola, Water Resources and Management.

INTRODUCTION

Rivers' discharge are of immense importance to communities living close to them as well as those located far away as they could be major sources of water supporting their socio-economic development (Zakarova, Nieilsen, Kamenev and Kouraev, 2020). In addition, as source of freshwater suppliers, rivers contribute to support dynamic and assorted life-sustaining systems (Depetris, 2021). Information on water is necessary and important for implementing structural and non-structural measures for flood mitigation and management (Dupe, *et al* 2022). Structural measures namely, the construction of embankments, reservoirs and dams, are used for controlling flood flow. River discharge refers to the volumetric measure of water flowing through the channel of the river past a point in unit time. Generally, it is expressed in unit of cubic centimeter per second (cm^3/sec) or cubic meters per second (m^3/sec) that is transported (Mbaya, 2020; Mahmud and Wood, 2022). The volume of water that a river discharges can be estimated using appropriate methods for the objective of the study. Selection of a method for measuring streamflow may be based on the size of the stream, accessibility of the terrain, accuracy of the results to be obtained, and financial and physical resources available (Slate, 2014). Zakarova, *et al*, 2020 observed that quantification and monitoring of river flow is important not only for sustainable management of water resources, but also for prediction of future conditions of the valuable resource.

Water, as a natural resource, is in abundance in Nigeria especially during the rainy seasons. As much as it is, the resource becomes extremely scarce during dry seasons in the northern parts of the country, a phenomenon that is being aggravated with the impact of climate change (Parsons, Cooper and Wainwright, 2015). In the light of the foregoing, evaluation and monitoring of sources of water, particularly river system, are crucial procedures for water resources assessment and management as information of their output are important in determining the functions into which such sources can be put. Similarly, it is expedient that the volume of water and the various functions it can be put must be established to warrant the kind of investments to be put in place in the light of the controlling climatic factors along the impact of anthropogenic activities. Understanding stream flow and hydrological processes are critical for the efficient and optimum allocation of water resources to meet water requirement for domestic water supply, irrigation, fishing, transport as well as for electricity generation.

There are various methods employed in determining the discharge of rivers. Alfa, Ajibike and Adie (2018) conducted an assessment of the change in river discharge carrying capacity using remote sensing geographic information system of Ofu river in Nigeria. The study relied on the digital elevation model (DEM) of Ofu floodplain and on determined depth of Ofu channel at Oforachi and concluded that the river had lost 12.88 meters amounting to about 42.58 % between 2000 and 2011. The method adopted for the study did not take into cognisance flow velocity per unit time and the significant role of hydraulic radius of flowing water in determining discharge of streams.

One of the applications of remote sensing in estimating river discharge is that carried out by Sichangi, Wang and Hu (2018) over the Yangtze River. The river velocity estimate was computed using the time lag and distance between the width measurement locations producing a resultant velocity of 0.96 m/s. The estimated velocity was comparable to that computed from in-situ gauge station observed data. The channel slope is derived from the digital elevation model averaged over a river section approximately 516 km long. The temporal depth changes were captured by adjusting the estimated depth to the Envisat satellite altimetry. The river discharges were estimated with reasonable accuracy. Since the performance of evaluation of discharge estimation using global satellite datasets was accurate, Sichangi, *et al* (2018) recommended that the methodology be adopted for estimating rivers' discharges worldwide since it represents a promising technique.

The United States Geological Survey (USGS, 2018) reported that it started its first stream gauge in 1889 on the Rio Grande River in New Mexico to help determine if there was adequate water for irrigation purposes to encourage new development and western expansion. The USGS operates over 8,200 continuous record stream gauges that provide streamflow information for a wide variety of uses including flood prediction, water management and allocation, engineering design, research, operation of locks and dams, and recreational safety. Gregory and Walling (1973) and USGS (2018) assert that stream gauging generally involves 3 steps: measurements of stage or stream level, water velocity and discharge. Results are generally reported in volume per time (volume/time) and values are generally reported in liters per second (l/sec) or in cubic meters per second (m^3/sec).

Edward, Monjardin Aldrine, & Tan (2017) applied GIS Map Correlation Method in predicting ungauged basins and subsequently applied the technique and estimated the discharge of Sta. Lucia River in Mauban, Quezon in Philippines. The method used was intended to reduce the time and costs of data gathering procedure as it relied on reference of calibrated watershed that has almost the same physical characteristics. Furthermore, the method utilized a set of modeling software which used digital elevation models (DEM), rainfall and discharge data. Reliability of the GIS Map Correlation Method in estimating river basin discharge could be subjective as there are no two drainage basins with same physical characteristics and rainfall.

Obateru, Ogunkoya and Ajayi (2021) carried out a research on water availability in a Nigerian sub-catchment of River Niger and its implications for food security. The research assessed runoff characteristics and water availability between 1955 and 2019 upstream of Baro and found out that the discharge regime of the sub-catchment was characterized by single peak which occurs in September. The sub-catchment's runoff coefficient ranged between 23% and 55% over a period of 64 years, that is from 1955 to 2019. The study observed a decline in river flow and water availability due to climate variability and concluded that the scenario presents impending problems of water crises and food insecurity. Although the conclusion of the study agrees with the effect of climate change, it did not quantify the discharges of the sub-catchment which could have given a more reliable and acceptable conclusion.

In determining the discharge of suspended sediments of River Bagadaza, a relatively small catchment with perimeter length of 18.72 km in Gombe State, Nigeria, Wanah, *et al* (2018) employed manual gauging station as suggested by Gregory and Walling (1973) in determining stage, velocity and breadth of the channel and estimated discharge of the catchment as 7.5×10^4 m^3 in one year which enabled determination of the sediments discharged in 2014.

Most of the recent researches conducted on estimating stream discharges employed remote sensing

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techniques which raised questions as to the actual quantities of water discharged by the rivers. Knowledge on the actual volume of water discharged by the Gongola River at Gombe-Abba Bridge is minimal and it is information that is required for policy making on water resource evaluation, monitoring and management in North-Eastern Nigeria as the river is one of the major sources of water in the zone. Doing so would solve the quest for knowledge on the volume of water the river discharges into River Benue. This study, therefore, sets out to estimate the volume of water the river discharges at Gombe-Abba. The objectives of the research are as follows:

1. determine the width of river channel at Gombe-Abba Bridge.
2. estimate the annual discharge of the river at the bridge.

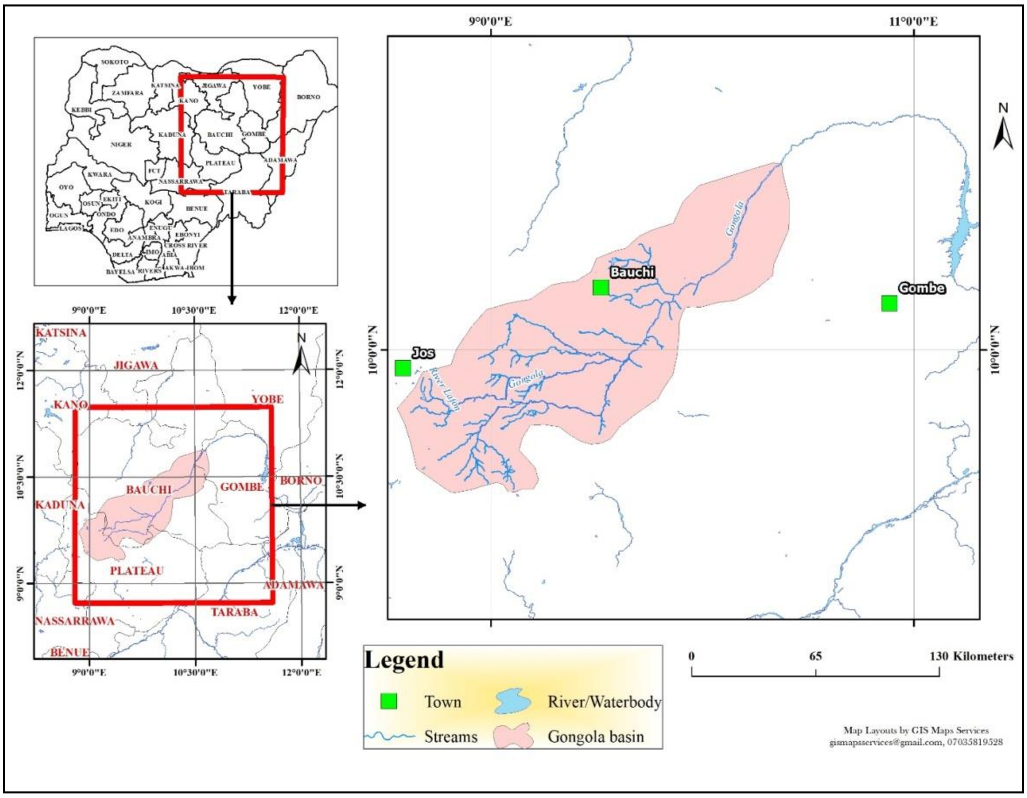
MATERIALS AND METHODS

Reconnaissance survey was conducted in December 2021 to acquaint researchers with the physical setting of the site and the bridge for constructing a gauging station for the research.

The Study Area

River Gongola Drainage Basin upstream of Gombe-Abba Bridge (Figure 1) lies on the Basement Complex Rocks of Northern Nigeria with the river taking off from the surroundings of Ngell and Bukuru on the Jos Plateau and flows towards the north-east of Nigeria (Udo, 1981; Guiraud, Ponsard, and Saugy, 1989). The basin is located in the wet and dry climate of West Africa and spans over the area occupied by Guinea and Sudan types of vegetation with a relatively longer rainy season on the Jos Plateau from where much surface water drains into the river. Udo (1981) observed that River Gongola might have been the source of water into Lake Chad but made a sudden change of direction at the vicinity of Ngalda in Yobe State, Nigeria from a north-east direction to south-west emptying into River Benue. Nyanganji (2002) indicated that the change in direction of flow of River Gongola took place about 6000 years ago and it is presumed that the change in direction of the river is responsible for the continuing drying of the lake. The huge lake that emerged consequent to River Gongola emptying into the Chad Basin is geomorphologically referred to as Mega Chad.

Figure 1: Gongola River Drainage Basin upstream of Gombe-Abba Bridge



Source: Federal Ministry of Land and Survey, 2021

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Evaporation in the drier and hotter eastern part of the basin, alongside with the effect of climate change, might be aggravating further loses of water in the lake. There is need for Nigeria and other countries surrounding the lake to consider re-channeling the river to the basin to commence recharging the lake which will eventually restore it to manageable size.

The width or breadth of the bed of the river channel under the bridge was measured with the aid of 100 meter tape. For measurement of stage, enamel gauge plates were graduated used and marked with divisions of 10 cm with water resistant paints and nailed on the walls of the pillars of the bridge such that one can easily read off the level of water accurately at a convenient distance (Gregory and Walling, 1973). The markings on the enamel were done such that the initial mark of the graduation was made to be below the surface of the river bed. The stage is reported in cm.

The method used for measuring water velocities is that of Surface Float Method (SFM) and it involved two indices: data on time and length of travel of the float. SFM was adopted for the study for it is simple qnd has the advantage of determining waterflow velocities more accurately than other float methods as pointed out by the United States Department of Interior (USDI, 2019). Data on time was achieved with the aid of Stop Watch and the time were recorded in seconds over a flow distance of 20 meters marked with pecks perpendicular to the river channel. Both were pecked downstream of the bridge. The first peck served as the starting point while the second, 20 meters downstream of the first, marks the end point of travel of the float at which the stop-watch is stopped. The float is thrown 3-5 meters upstream of the starting point to allow it stabilize on the surface of the water. When the float came under the starting point, the stop-watch was started. The time taken by the float to travel from the first peck to the second one was recorded and converted into centimeters per second (cm/sec) or meters per second (m/sec). Readings of water velocities are taken at 6 am daily for 365 days.

Measurement of river discharge involves both stage and velocity. Stage of flowing water enables the determination of hydraulic radius of flowing water which gives the volume of water passing through a defined point over a unit time (Gregory and Wallis, 1973; USGS, 2018; Wanah, *et al* 2018). The technique was used in determining the discharge of water at Gombe-Abba Bridge in one year, March 2022- February, 2023. Units used for recording the river's discharge was that of volume per unit time (volume/time) and values reported in cubic meters per second (m^3/sec).

Data Analysis

The statistical technique used in analyzing the data collected from the field, namely water velocities and discharges of water, was simple descriptive statistics. Totals and averages were used and the results are presented in tables and graphical charts and were used in discussing the findings of the research..

RESULTS AND DISCUSSION

This sub-section presents the results of the research according to the objectives of the study along with explanations on each of the objectives. The gauging station was constructed at the bridge and it includes four (4) graduated pillars of the bridge as shown in Plate 1 and a runway by the bridge and on the left bank for determing riverflow velocities.

Plate 1: Graduated Pillars of the Bridge

Width/Breath of the Channel of the River at the Bridge

Width or breadth of the channel of River Gongola at Gombe-Abba Bridge was measured using 100 meter tape and was found to be 300 meters. The bridge has 12 pillars each is 25 meters from the adjacent one giving 300 meters as the total length of the gauged potion of the channel. At the time of the construction of the station, 125 meters of the bed of the river was covered with water indicating that the bed was flat and covered by sand. The width of the river at the gauging station varied with the volume of water flowing on it during the rainy season and the graduated pillars marked the width under water. The average breadth of the channel under water throughout the one year of study was 166.63 meters (Table 1). The varied channel widths were incorporated in calculating daily discharges.

Estimation of the Discharge of River Gongola

The discharge of a river refers to the volumetric measure of water flowing through the channel of the river past a point in unit time (Mahmud and Wood, 2022). The discharge of River Gongola was determined manually by taking daily measurements of the depth of water flowing through the channel as well as the velocity of each of the flowing water for 365 days. The data gathered were used in calculating the discharge, which is the product of hydraulic cross-sectional area and mean water velocity using the formula:

Discharge = Area x Velocity.

The width of the channel is incorporated in the hydraulic cross-section of water. Monthly averages of the daily discharges are presented in Table 1.

Summing up the monthly discharges, the volume of water the river yielded at the bridge in one year (365 days) was 8.2×10^9 m^3/yr (8,258,696,927.8 cubic meters) per year as presented in Table 1. This amount of water is released into River Benue which flowed to the Atlantic Ocean through River Niger. Although the river has been dammed at Dadin-Kowa and Kiri for irrigation and other economic purposes, the large quantity of water the river releases shows that the river is an important water resources for the North-East of Nigeria and it needs to be looked at as such by decision makers for formulating policies for the management of the resources. For instance, the river can be considered as a reliable source of water for re-channeling through diversion to the drier parts of the north-east and for recharging Lake Chad. Doing so would mitigate the acute problem of water scarcity in the zone, and it would boost agricultural, fishing, industrial, and transportation, among other benefits communities living close to the diversion channel will have.

Table 1: Average Monthly Discharges of River Gongola

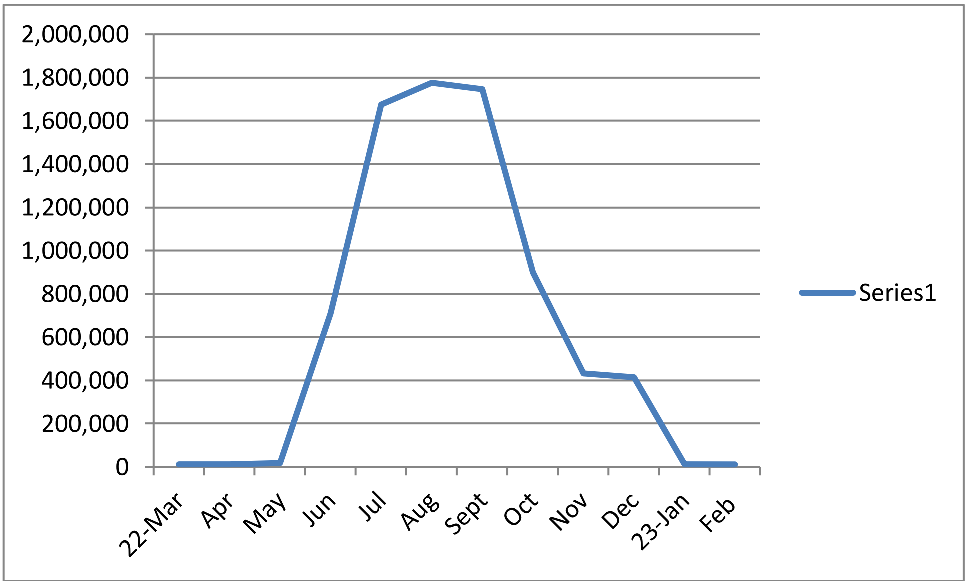
S/No	Month	Velocity (m/s)	Discharge (m^3/s)	Discharge (m^3/year)
1	Mar 22	2.87	143.5	1.2×10^7
2	Apr	2.41	148.46	1.2×10^7
3	May	1.55	213.76	1.8×10^7
4	Jun	1.47	135	7.1×10^8
5	Jul	1.27	137.5	1.6×10^9
6	Aug	1.02	150	1.7×10^9
7	Sept	0.87	155	1.7×10^9
8	Oct	1.12	137.5	9.6×10^8
9	Nov	2.14	135	1.1×10^7
10	Dec	3.69	134.5	1.1×10^7
11	Jan 23	3.86	134	1.1×10^7
12	Feb	3.36	134	1.1×10^7
	Average	**2.14**	**144.58**	
	Total			**8.2×10^9**

Source: Researchers' fieldwork 2022-2023

The mean monthly discharges of the river are presented graphically in Figure 2. The hydrograph shows high discharges from June to October with August as the peak discharge. March and April 2022 and January and February 2023 were months with the least average discharges.

Presenting the average monthly discharges of the river graphically gives a hydrograph which conforms with the finding that the discharge of the river was high from June to September 2022 as reflected in Figure 2.

Figure 2: Hydrograph of Mean Monthly Discharges of River Gongola



Source: Researchers fieldwork, 2022-2023

CONCLUSION

This research estimated the discharge of River Gongola at Gombe-Abba Bridge in Gombe State, Nigeria. The method employed include graduating pillars of the bridge for recording stage of flowing water as well as the use of SFM in determining daily velocities of waterflow. The estimated discharge of the river was 8.2 x 10^9 m^3 of water in one year. Lack of a weir under the bridge might have undermined the accuracy of the estimated volume discharged. For more accurate estimation of the discharge of River Gongola, it is recommended that a weir be constructed under the bridge. It is also recommended that Nigeria should formulate policies for utilizing the huge water resources for revamping agricultural and other economic activities in the north-east of the country as well as to collaborate with other countries around Lake Chad to consider inter-basin transfer of water from the river to recharge the lake. Furthermore, the research is recommended to students interested in basin water resources studies and management, and for international organizations that are focusing on measures for mitigating the fast drying lake in order to support the large human and animal populations within the Lake Chad Basin and for the restoration of aquatic and terrestrial ecosystems in the basin.

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