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Determination of waterflow velocity of River Gongola and its significance to communities in North-Eastern Nigeria

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ABSTRACT

The velocities of waterflow of River Gongola were determined to provide information for sustainable management of its water resources. The study adopted manual Surface Float Method (SFM) in determining flow velocities. The result showed that average monthly velocities for the months of July to October were 1.27, 1.02, 0.87 and 1.12 m/s respectively. August and September had the fastest flows with 1.02 and 0.87 m/s. The highest average surface water levels were attained in July to October with values of 1.74, 2.14, 2.72 and 1.43 m. The lowest stages recorded were in March, April and December 2022 with values of 0.5, 0.56 and 0.6 m and in January and February 2023 with values of 0.57 and 0.5 m. Average annual velocity was 2.14 m/s while average annual stage was 1.11 m. Water levels deeper than 2 meters were recorded in July (19 days), August (23 days) and September (11 days) giving a total of 53 days over an average channel bed of 173.46 m wide. The high velocities and stages of water levels in the four months is significantly high enough to support sustainable supply of water for use in agriculture domestic and industrial purposes for communities living downstream of the gauging station. It is recommended that policies be formulated on transferring the water to North Eastern Nigeria to mitigate the acute water scarcity in the Sahelian region and to recharge Lake Chad to augment the volume of water in the lake which is fast drying up due to climate change.

Keywords: Determination, Waterflow Velocity, Stage, River Gongola and North-Eastern Nigeria.

INTRODUCTION

Stream velocity is the speed of waterflow in streams and values are given in distance per time. Stream velocity is greatest in midstream near the surface and is slowest along the stream bed and banks due to friction (McKerchar, 2016). At low velocity, especially if the stream bed is smooth, streams may exhibit laminar flow in which all of the water molecules flow in parallel paths. At higher velocities turbulence is introduced into the flow. The water molecules don't follow parallel paths. A simple way to estimate the velocity of streams or rivers is to measure the time taken for a floating object to travel a measured distance downstream (United State Geological Survey, 2018 and Wanah, Odihi and Abdullahi 2018). Velocity is not uniform through the mass of flowing water at all places in the stream. It is slower at the sides and bottom of the channel and faster on the surface (McKerchar, 2016). There are various methods of determining waterflow velocity, ranging from manual to remote sensing techniques.

The U. S. Environmental Protection Agency (EPA, 2012) noted that the flow of a stream is directly related to the amount of water moving off the watershed into the stream channel and that it is affected by weather, increasing during rainstorms and decreasing during dry periods. It also changes during different seasons of the year, decreasing during the summer months when evaporation rates are high and shoreline vegetation is actively growing and removing water from the ground.

Alfa, Ajibike, and Adie (2018) conducted an assessment of the change in river discharge-carrying capacity using Remote Sensing and Geographic Information System (GIS) on Ofu River in Kogi State, Nigeria. The study dwelled on the surface expanse of the water thereby ignoring the need for measurement of the velocity of the river which is an important parameter in estimating discharge. With respect to the depth of flowing water in Ofu River, the study found that there was a loss of depth in the river and was attributed to siltation of the river bed due to the high sediment load as a result of soil cultivation within the floodplains. The study recommended that remote sensing and GIS are useful tools to assess the changes in the discharge-carrying capacity of a river. This notwithstanding, the study cast a lot of doubt on the estimate arrived at.

Sichangi, Wang, and Hu (2018) carried out a research on the estimation of river discharge solely from remote-sensing derived data on the Yangtze River. The researchers relied on observations of the river’s velocity from two ocations on the river and estimated the discharge using the time lag and distance between the width measurement at the locations and the estimated velocity of the river was 0.96 m/s. Based on the foregoing, the research concluded that the result was comparable to that computed from an in-situ gauge-observed data. The stage or depth of the river was similarly estimated from temporal depth changes captured by adjusting the estimated depth to the Envisat satellite altimetry-derived water level changes, and river width changes from Landsat ETM+.

Wanah, *et al* (2018) applied manual gauging station and Surface Float Method (SFM) in collecting the velocity of waterflow in River Bagadaza in Gombe State, Nigeria from which the suspended sediment discharged by the river was determined. Daily information on velocity and stage of waterflow in the channel were recorded from which water discharged by the river was estimated and subsequently that of suspended sediment contained therein.

Velocities and stages of flowing water in streams have been determined by manual and remote sensing techniques. The need for determining these parameters of the River Gongola arose with a view of providing information for decision making for managing discharges of the river for communities living downstream of the gauging station. Information/data on these two parameters for River Gongola at Gombe-Abba Bridge have not been documented. It is with this in mind that the research set to find out the flow velocity and stage of River Gongola at the station. Following the paucity of knowledge, formed the basis for which this research was designed and conducted in order to achieve the primary goal of the study. Streamflow velocity was determined using SFM. The study also looked at the significance and implications of the flow velocities to communities downstream of the station. The study, therefore, aimed at determining the velocities of River Gongola at Gombe-Abba Bridge in 2022 with the following objectives:

i. determine the stage of flowing water in River Gongola at Gombe-Abba Bridge in 2022.

ii. establish the velocities of flowing water in the river at Gombe-Abba Bridge in 2022.

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iii. find the benefits communities downstream of the gauging station will have from the river’s flow velocities.

MATERIALS AND METHODS

Reconnaissance survey was conducted in December 2021 for acquainting researchers with the physical settings of the river at Gombe-Abba Bridge particularly its breadth, bed and banks as well as identifying the site for constructing the gauging station for the research.

Data Collection and Analysis

Data collection

Two sets of data were collected during this research: river velocity and the stage of waterflow which were taken daily from March 2022 to February 2023. The method employed for collection was manual SFM and the data obtained were in units of meters per second (m/s) for velocities and meters (m) for stage.

Data analysis

Descriptive statistical techniques were employed to analyze the data generated from the field. These techniques considered range, average and standard deviation of both the stage of flow and the velocities. The results are presented in tabula form as shown below. Also, the results are shown graphically. Totals and averages were used in summarizing and discussing the findings of the study.

Study Area

River Gongola is located in North-Eastern Nigeria and lies on the Basement Complex Rocks of Northern Nigeria having its source waters 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 drainage basin upstream of Gombe-Abba Bridge lies between Latitudes 9^{0} 0’ 0” N and 10^{0} 45’ 0” N and Longitudes 9^{0} 0’ 0” E and 10 ^{0} 35’ 0” E (Figure 1). 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.

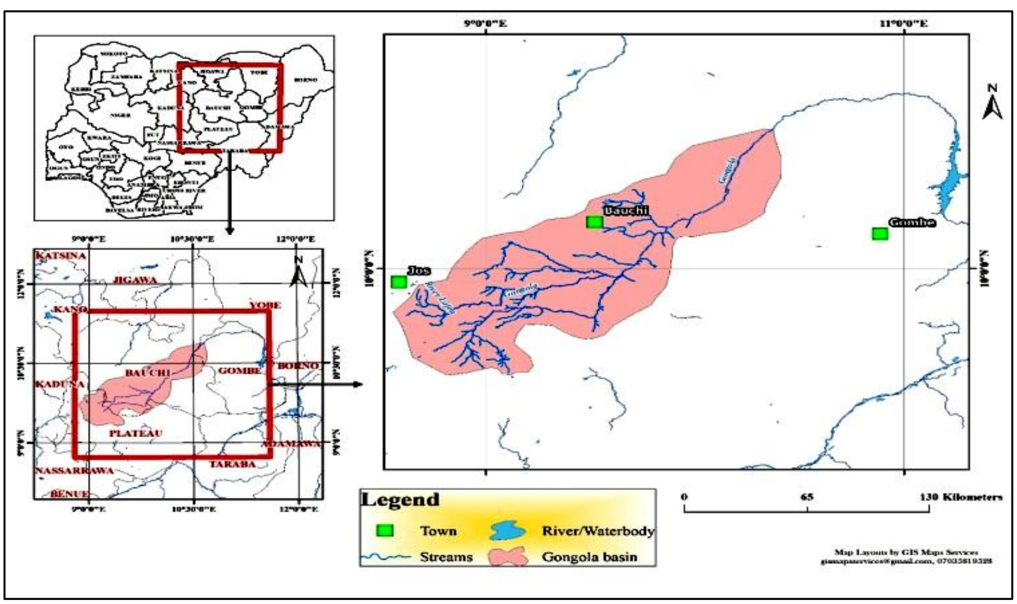

Figure 1: Nigeria showing Gongola Basin Upstream of Gombe-Abba Bridge
Source; Researchers’ fieldwork, 2022

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 from the scarce sources of the region.

RESULTS AND DISCUSSION

This sub-section presents the findings of the research and is organized according to the stipulated objectives of the study along with explanations on each of the objectives. The gauging station was constructed at the bridge and it included four (4) graduated pillars of the bridge as shown in Plate 1. A runway was constructed on the left bank by the bridge for determining flow velocities of the river in that two 6 m galvanized pipes were pecked at exactly 20 m apart.

To determine flow velocity of River Gongola at Gombe-Abba Bridge in 2022, stages of flowing water were taken for 365 days. Stage is an important information required in computing the discharge of a river. Average monthly stages of water at the station are presented in Table 1.

Plate 1: Graduating one of the four Pillars adopted for determining Stage

Source: Researchers' fieldwork, 2022

Table 1: Averages of Monthly Stages and Velocities of River Gongola

S/No	Month	Stage (m)	Velocity m/s
1	Mar 22	0.5	2.87
2	Apr	0.56	2.41
3	May	0.9	1.55
4	Jun	0.99	1.47
5	Jul	1.74	1.27
6	Aug	2.14	1.02
7	Sept	2.72	0.87
8	Oct	1.43	1.12
9	Nov	0.72	2.14
10	Dec	0.6	3.69
11	Jan 23	0.57	3.86
12	Feb	0.5	3.36
	Average	**1.11**	**2.14**

Source: Researchers fieldwork, 2022

Stages of Flowing Water in the River in 2022

The lowest surface water levels recorded were in March, April and December 2022 with values of 0.5, 0.56 and 0.6 m respectively and in January and February 2023 with values of 0.57 and 0.5 m in that order. The highest average surface water levels of the river were attained in July, August, September and October with values of 1.74, 2.14, 2.72 and 1.43 m respectively (Table 1). The high daily stages recorded in August were in 23 days with an average depth of 2.14 m depth of water under the surface while September had 11 days with deeper than 2.72 meters. In determining waterflow depth of River Bagadaza in Gombe, Wanah *et al* (2018) found that the depths ranged from 0,05 to 0,5 m. The shallow water levels were due to the rapid infiltration of soil on which the flows. The daily recordings at Gombe Abba show that July had deeper than 2 meters for 19 days. Adding the days together gives a total of 53 days during which the river had water flowing deeper than 2 meters over an average channel bed of 173.46 m wide. There were days when peak water levels in the river reached 4 m. For instance, on the 21st of September, 2022, water level reached 4.3 meters. This, along with other days in August and September when the levels reached 3 meters explains the volume of water (8.4×10^9 m^3) the river discharged at Gombe-Abba Bridge in one year, 2022.

Velocities of Flowing Water in the River

Velocity of flowing water in River Gongola was measured daily using the SFM in 2022 (365 days) and the values were recorded as meters per second (m/s). Averages for each of the months are presented in Table 1. Calculating the average for the twelve months of the year gave 2.14 m/s (Table 1). The highest velocities of the waterflow in the river were in July, August, September and October with 1.27, 1.02, 0.87 and 1.12 m/s respectively with August and September having the fastest flows of 1.02 and 0.87 m/s.The average velocity for the four months, July-October was 1.07 m/s. In assessing water carrying capacity of Ofu River, Alfa, *et al* (2018) between 2000 and 2011 estimating water discharge of the river at Oforachi between 2000 and 2011 in percentages with a rate of 1.171 m per year. The method used did not enable them to have had accurete quantification of the discharge of the river as against the SFM used in this research. Generally, the fastest velocity recorded at Gombe-Abba was on the 22nd of September with the value of 0.87 m/s. The daily velocities recorded were used along with stage and breadth of the river channel in computing the discharge of the river. According to Newell (2018) stream velocity increases as the volume of water in the stream increases which also means as the volume of water increases, stage of the flowing water rises. Stage is an ingredient for estimating discharge. Velocity determines the kind of organisms that can live in a river as some need calm and quiet pools while others need fast-flowing water. Velocity also affects the amount of silt and sediment carried by the stream. Fast moving streams keep sediment suspended longer in the water column than in quiet, slow-flowing ones in which sediment settle quickly to the bottom. Fast-moving streams have higher levels of dissolved oxygen than slow streams.

Relationship between Stage and Velocity

Edward, *et al,* (2017); Newell, (2018); and Olayinka-Dosunmu, *et al* (2022) reported the relationship between stream velocity and stage which indicated that as stage or the surface of waterflow in a river rises, the velocity increases and thus the discharge of the river. The relationship is graphically presented in Figure 2. The figure shows that as stage of water rises, velocity increases.

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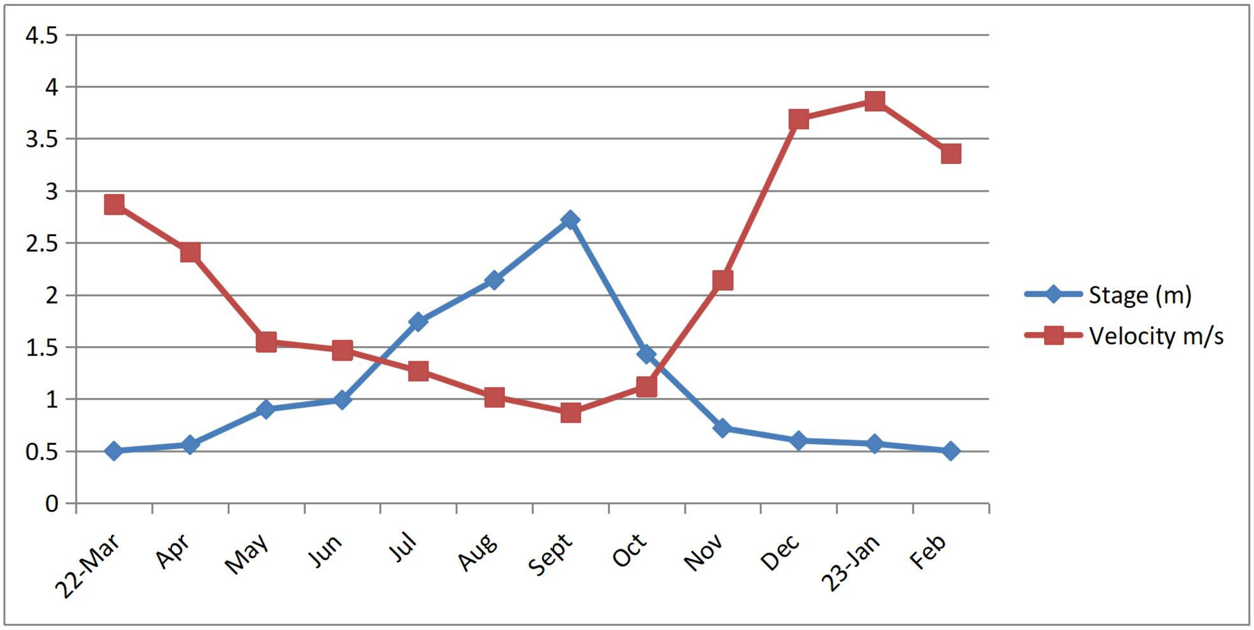

Figure 2: Relationship between Stage and Velocity
Source: Researchers fieldwork, 2022

Significance of Flow Velocities to Communities Downstream of the Gauging Station

The high flow velocities observed in River Gongola from July to October have some economic values to communities living downstream of the gauging station and to North-Eastern Nigeria. The advantages that can be derived from the high flow velocities of the river include:

i. Appraisal of water resource and allocations: Streamflow study provides information on the amount of water that is available and may form the basis for decision-making on allocation of the resource for various uses.

ii. Information on streamflow velocity is required to determine how much water is available to ensure there is adequate water supply especially with the effect of climate change and to carter for water in drought afflicted regions. The information will guarantee whether or not flow velocities will sustain inter-basin transfer of water of, say, between River Gongola Drainage Basin and Lake Chad Basin.

iii. Information on streamflow velocity is used for the kind of engineering designs for infrastructural development to guide against over or under designing as inaccurate information can be costly.

iv. Construction of dams for reservoirs rely on streamflow information on velocity to know how much water can be impounded, how much to release and when to release it, whether for flood control or for hydropower production.

v. Streamflow information is used in making flood forecasts and in delineating flood prone areas to help protect citizens from building or developing in areas that have high probability of being flooded.

vi. Information on streamflow velocity is required to assess the amount and timing of incoming flow to decide when boaters, swimmers, and fishermen if the streamflow is appropriate for them to visit their favorite locations.

CONCLUSION

This study determined the waterflow velocity of River Gongola at Gombe-Abba Bridge in 2022. Surface Float Method was employed in determining the velocity of waterflow and the highest velocities recorded in four months were 1.27, 1.02, 0.87 and 1.12 m/s in July, August, September and October respectively with August and September having the fastest flows (1.02 and 0.87 m/s). Stage of waterflow in the river were determined as 1.74, 2.14, 2.72 and 1.43 m deep which were in July, August, September and October respectively with annual average of 2.14 m. Lack of a weir under the bridge might have undermined the accuracy of the determined velocities and stages of waterflow in the study. Information of waterflow velocities is significant to communities downstream of the bridge for it enables flood forecast for delineating flood prone areas to help protect citizens. Knowledge on flow velocities will help in deciding construction of dams for reservoirs rely on streamflow information on velocity to know how much water can be impounded, It is recommended that a weir be constructed under the bridge to ensure more accurate determination of the two parameters. Communities downstream of the Gombe-Abba Bridge can take advantage of the high velocities and stages of waterflow in the river from July to October and formulate policies for distributing the resource through transferring water to communities within the north-eastern part of the country to revamp agricultural production and other economic activities in the region as well as collaborating with other countries around Lake Chad to consider rechanneling the river's huge water resources for recharging the lake.

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