



Hydrological Analysis of Sediment Transport in River Ofiki, South-Western Nigeria

Olaniyan, O.S*, Adetoro, J*, Adegbola, A.A* and Ayanlola, J.A**

*Department of Civil Engineering, Ladole Akintola University of Technology, Ogbomoso

**Department of Civil Engineering, Oyo State College of Agriculture and Technology, Igboora

Corresponding e-mail: ayanlolaayandayo@gmail.com

Abstract

Sediment transport is the movement of solid particles due to gravity acting on the sediment. River Ofiki has records of flooding and insufficient hydrological records to model its sediment transportation. In this study, hydrological data were measured to compute sediment discharge. Eighteen years (1980-2010) of gauged records obtained from Ogun-Osun River Basin Authority were used to determine annual mean and maximum gauge on River Ofiki. Landsat images of the area obtained from African Regional Centre for Space Science and Technology (ARCSSTE), Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria was used to produce study map using ArcGIS 10.4 software. Six sampling points that covers upper, middle and down course of the river were chosen. The elevation, slope, stage and flow velocity at the sampling points were measured from November 2017 to December 2018 using surveying equipment and current meter. The hydraulic radius (r_h) and flow discharge (Q) were computed from the measured data. Water samples were collected at the sampling points to determine Suspended Sediment Concentration (SSC) and temperature using laboratory analysis and thermometer, respectively. The annual mean and maximum gauge level of historical data on River Ofiki varied from 0.67-2.39 and 1.17 - 6.60 m, respectively. The measured elevation, slope, stage and flow velocity were 0.100-1.124 m, 0.0028 - 0.0030, 0.18 - 3.10 m and 0.15 - 2.08 m/s. The estimated hydraulic radius and discharge varied from 0.02-1.02 m and 0.1-6.76 m³/s. The SSC and Temperature ranges of values were 2 - 64 mg/l and 24 - 32 °C. Hydrological parameters on River Ofiki was adequately estimated for sediment discharge estimation. This will serve as base line information to compute sediment load that will be useful for effective river management.

Keywords: Sediment, Gauge, Flow velocity, Hydrological, Elevation

Introduction

River is a natural flowing watercourse, usually freshwater, flowing towards an ocean, sea, lake or another river. In some cases, river flows into the ground and becomes dry at the end of its course without reaching another water body. Rivers are part of the hydrological cycle. Water is generally collected in a river from precipitation through a drainage basin from surface run-off and other sources such as groundwater recharge, spring, and release of stored water in natural ice and snow packs. The importance of river cannot be overlooked in life's ecosystem; among its importance are; generation of hydroelectric power, transportation, irrigation system, recreation, habitation of aquatic lives, amongst others (Olaniyan, 2014).

River Ofiki, which is the case study of the research work rises in Oyo state near Saki, and flows through Ogun State into Lagos State. Ikere George Dam in Iseyin Local Government Area of

Oyo State crosses the river. The river has been a source of water for both domestic and industrial purpose for people around the area. It has a dam reservoir on it which has been abandoned for over 30 years. River Ofiki has records of flooding and insufficient hydrological records to model its sediment transportation.

Methodology

Brief Description of the Study Area

The research is on river Ofiki in Atisbo Local Government Area of Oke-Ogun, Oyo State. It is located within the coordinates 7°25'N and 3°7'10" E. The river is about 12.5 km long with frequent flooding in Ofiki or Opara. It rises near Saki. River Ofiki is the main tributary of River Ogun. And it is very useful to the neighborhoods for domestic, agricultural and even industrial purposes. Some of the hydraulics structure along the river includes bridges and culvert that were destroyed due to flood occurrence of the river. It is located

at an estimated elevation of about 78 meters above sea level and its population amounts to 174,152. Municipal waste and eroded soil sediments impart to the lower course stagnation

of the river, resulting in poor drainage and a propensity for flooding (Ogun Osun River Basin, 2017) River Ofiki is a stream (Class H – Hydrographic type feature) in Oyo state Nigeria.

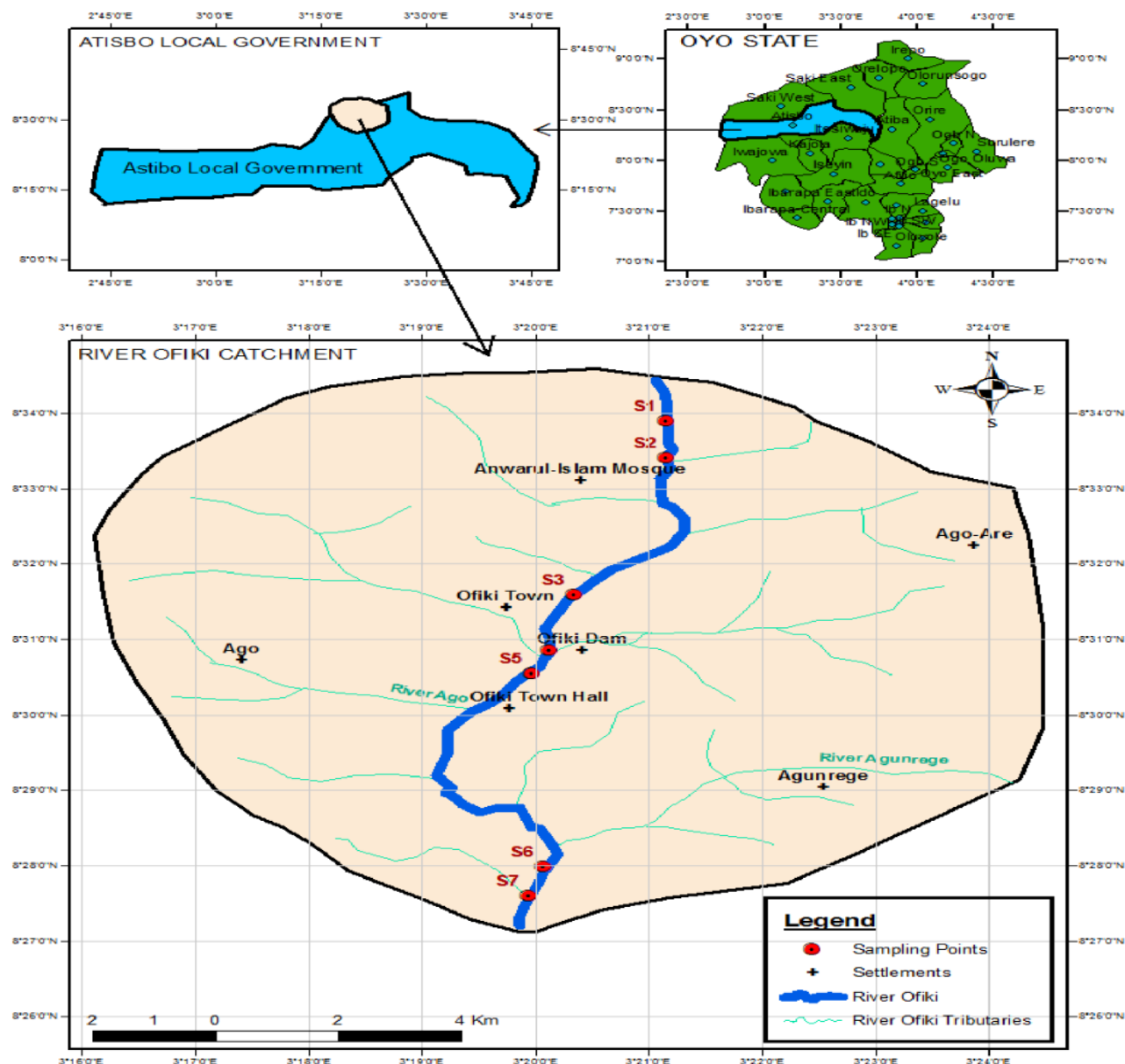


Figure 1: The Location of Sampling Stations and Hydrological Map Across

Data Analysis

Gauge records of River Ofiki from 1980 to 2010 were obtained from Ogun Osun River Basin. The data were processed in Microsoft excel to obtain the median and annual mean value. The temporal variation was plotted in excel and mathematical relationship was developed for the trend and coefficient of regression was determined.

Data Collection and Measurement

One of the basic data required for a study is the surveyed channel cross section. The cross section was established perpendicular to the main body of the flow, the points across the section are surveyed relative to a known or arbitrarily established benchmark elevation. The distance-elevation paired data associated with each point



on the section was obtained by rod-and level survey. The river was divided into 12 different horizontal sections and the corresponding (water surface/bed) elevation against the different horizontal distances were measured using measuring tape and calibrated rope with weight on its end to obtain data for position-elevation (Adegbola and Olaniyan, 2012)

The data measured on the river includes; discharge, water quality, water width, flow depth, hydraulic radius, water-surface slope, Total load and water temperature. The cross-section location was selected in a stable reach to avoid unstable bed conditions during the measurements. The cross sectional depth at regular intervals was measured. The readings were taken throughout the cross section of the river to compute the highest and the lowest stages using leveling instrument (dumpy level). High and low stages readings were taken at a stable and accessible reach across the sampling positions (Adeleke, 2018). The slope was estimated from hydrographical surveying of River Ofiki using leveling instrument. The depth of the rivers were taken at regular distance interval along the path of flow. The difference in height of the river as taken from the surveying staffs divided by the difference in horizontal distance give the slope of flow of the river (Olaniyan, 2014).

The water temperature was obtained from water temperature test using thermometer.

Thermometer was inserted into the river both morning and afternoon to obtain the water temperature across the river. Bed materials were collected using bed material sampler. The materials were taken to the laboratory for grain size analysis (Adejumo, 2018).

According to the U.S. Standard Sieve grain size distribution, grain size analysis was performed to determine the percentage grain sizes contained in sediment. Each of the sieve and bottom pan was weighed. The measured weight and dry sample soil were recorded. The clean sieves were stacked in ascending order of sieve number and dry sample was poured on top sieve and shaken electronically for 15 minutes. The weight of each sieve with its retained soil were measured and the percentage retained on each sieve was estimated.

The sediment size (d_{50}) was obtained from sieve analysis of sediment sample across River Ofiki using the graph of percentage passing on sieve

size against sieve size. The mid of the graph of weight percentage on sieve against sieve diameter (in phi scale) represents mean sediment d_{50} . According to the U.S. Standard Sieve grain size distribution, the following sediment particle sizes were used: gravel (5.0 to 50), coarse sand (2.0 to 5.0), medium sand (0.4 to 2.0), and fine sand (0.07 to 0.4). The study employed the following grain size distributions:

- (i) grain size diameters (D) of particles greater than medium sand that is, grain sizes that are wholly coarse sand and gravel (fine and coarse) (that is, $D > 2.000$)
- (ii) D of particles that are wholly medium sand (that is, $2.000 > D > 0.600$); D of particles that are mixture of medium sand and fine sand (that is, $0.600 > D > 0.200$) and lastly
- (iii) D of particles that are wholly fine sand and silt/clay (that is, $0.200 > D$) (Otun and Adeogun, 2011).

The mean sediment size was obtained from sieve analysis of sediment sample across River Ofiki. The percentage passing on sieve was plotted against sieve size. The mean size sediment was then traced from the graph plotted (Olaniyan and Adegbola, 2012).

The SSC was estimated as ratio of the mass of dry sediment in a water-sediment mixture to the mass of the water-sediment mixture using analytical method. This was done in accordance with ASTM 1999. The initial weight of 0.4 μ m filter paper was measured by analytical weighing balance and used to filter a 100ml water sample taken at the varying depth from the river. The wet filter paper was oven dried and the final dried weight of filter paper was measured and recorded. The suspended sediment concentration is the ratio of difference between final and initial weight of filter paper and the volume of water in mg/l.

Results and discussion

The temporal variation in the gauge from 1980 to 2010 is presented in Figure 2. The mathematical equation that describe the trend is $y = 0.0099x^2 + 39.9617x - 39476$ with coefficient of determination of 25.96%. This also showed the probabilistic nature of climatic data as its very difficult to fix a curve with higher coefficient of determination.

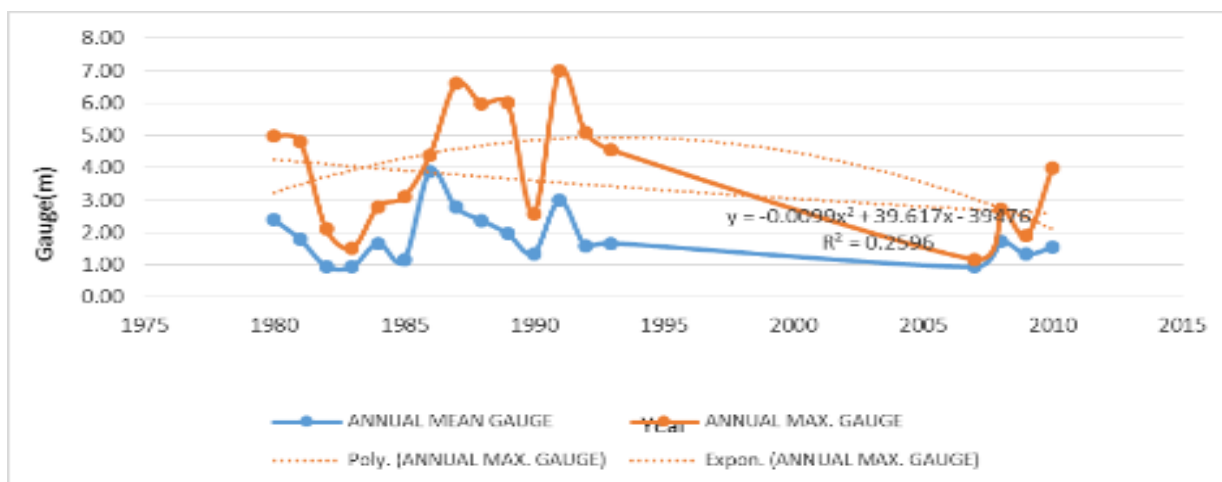


Figure 2: Temporal Variation in Gauge Reading across River Ofiki

The River Ofiki cross section was established perpendicular to the main body of the flow with 10.8 m width on the upstream sampling point of at Labaowo market. The points across the section were surveyed relative to a known or arbitrarily established benchmark elevation as shown in Table 1. The distance elevation paired data associated with each point on the section was obtained by rod-and level survey. The river was divided into 12 equal sections to compute depth/bed- water surface. The result of position and

elevation showed the shape of the cross sectional bed and the elevation of each points as measured from the calibrated rope and measuring tape error were avoided during the marking of points along the cross section.

The cross sectional depth at regular intervals were used to compute the highest and the lowest stages. The low and high stages were taken across the width of the Ofiki river at the upstream, midstream and downstream which ranged from 0.3-0.56, 0.7-3.1, and 0.18-0.28 m, respectively as shown in Table 1.

Table 1: Position-Elevation across River Ofiki

Position	Elevation (Stage)
0	0.38
1	0.42
2	0.47
3	0.51
4	0.56
5	0.60
6	0.64
7	0.60
8	0.56
9	0.52
10	0.48
11	0.44
12	0.41

The cross sectional depth at regular intervals were used to compute the highest and the lowest stages. The low and high stages were taken across the width of the Ofiki river at the upstream, midstream and downstream which ranged from 0.3-0.56, 0.7-3.1, and 0.18-0.28 m.

The slope was estimated from hydrographical surveying of River Ofiki using leveling instrument. The slope of the river is 0.0032 downstream, 0.0030 midstream and 0.00275 upstream. The average slope was estimated as 0.003 from the steepest point. The river channel slope recorded

in the upstream, midstream and downstream shows there is steady flow in the river from the upstream, through the midstream to the downstream. The river temperature varied from (30-32)°C in the morning and (24-29)°C in the afternoon. Different simulation runs were taken to reflect the situation at both periods. Temperature is among the important water quality indicator, which affects the Dissolved Oxygen level. As the temperature of water increases, the Oxygen solubility decreases. A rise in temperature speed up chemical reactions in water.

Turbidity can increase water temperature as suspended particles may absorb heat from solar radiation quickly than water. Heat transfer from particles to water molecules will then take place. Winxpro software generates reliable sediment discharge at ambient sediment. The measured

temperature in this study is within the specified standard by the software to generate reliable sediment discharge. Every increment in water temperature from 30-50°C, the percentage of SSC increase by 20.6, 2.48, 2.99 and 3.59%, respectively (Anna *et al.*, 2018).

Laboratory Analysis Result

Grain size analysis was performed to determine the percentage grain sizes contained in sediment. The percentage passing of the sediment on each sieve are presented in Figure 3. The d_{50} sediment size was obtained to be 1.8mm from sieve analysis of sediment sample across River Ofiki when percentage passing on sieve size was plotted against sieve size (Olaniyan, 2009). The mid of the graph of weight percentage on sieve against sieve diameter (in phi scale) represents mean sediment d_{50} as shown in Figure 3

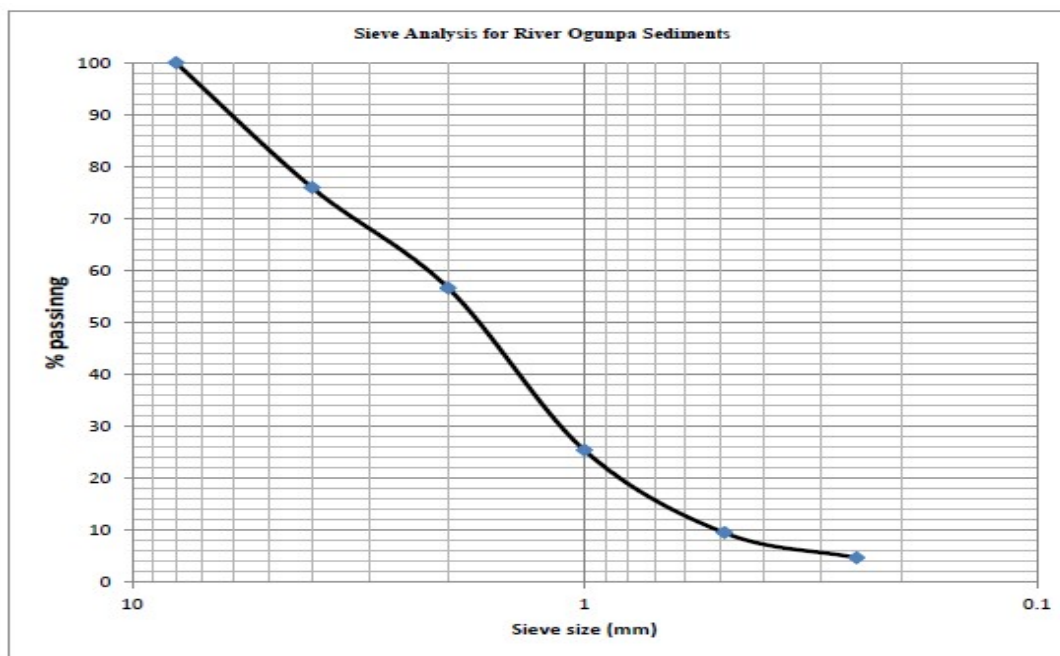


Figure 3: Grain Size Analysis on River Ofiki Sediment

The average values of SSC measured on River Ofiki is shown in Table 2. The SSC increases as the rainfall intensity increases. The value is higher during rainy season than dry season. Channel slope, human activities and river morphology also contribute to the measured values. The SSC values tend to increase from April, 2018 when the rainy season commenced. Also, the SSC value at the upstream is higher than the downstream which suggest that sediment is trapped at the midstream. Farming activities spread across the upstream through the midstream, which could act as a source of the transported sediment. The highest value of SSC on the river was 64 mg/l, which was obtained in May 2018. The lowest value was 2 mg/l, which was measured in December, 2017.



Table 2: Summary of Suspended Sediment Concentration (SSC) on River Ofiki

Month	Stream course	Average SCC (mg/l)
Nov., 2017	Upstream	64
	Midstream	58
	Downstream	59
Dec., 2017	Upstream	14
	Midstream	9
	Downstream	2
Jan., 2018	Upstream	7
	Midstream	6
	Downstream	5
Feb., 2018	Upstream	8
	Midstream	6
	Downstream	5
Mar, 2018	Upstream	6
	Midstream	4
	Downstream	1
Apr., 2018	Upstream	26
	Midstream	28
	Downstream	17
May., 2018	Upstream	64
	Midstream	53
	Downstream	32
Jun., 2018	Upstream	55
	Midstream	53
	Downstream	30

Conclusions and recommendations

Conclusions

The following conclusions were made based on the results obtained:

- The stage, channel slope, temperature and velocity of flow along river Ofiki ranged from (0.7 – 3.1), (0.002 – 0.003), and (24°C – 32°C) respectively.
- The suspended sediment concentrate ranged from 2 – 68 mg/

- Measurement of sediment concentration and periodical de-siltation of the sediment should be encouraged for effective river management.

References

- Adegbola, A. A. and Olaniyan, O. S. (2012). Temporal Variation of Sediment transport in River Omi, South-western Nigeria. *International Journal of Applied Engineering Research*. **4**(7), 421 – 431.
- Adeleke, W.S. (2018). Sediment Transport in River Ogunpa, using Winxpro. *M.Tech Thesis*, Department of Civil Engineering, Ladoke Akintola University of Technology, Ogbomosho, Oyo State.

Recommendations

The following recommendations were drawn from the study:

- Channelization of major rivers is strongly recommended to reduce the possibility of incessant flooding.



Adejumo, K.S. (2018). Numerical Modelling of Sediment Transport in River Osun, South-Western Nigeria. *M.Tech. Thesis*, Department of Civil Engineering, Ladoke Akintola University of Technology, Ogbomoso, Oyo State.

Adeogun, B. K., Igboro, S. B. and Ibrahim, F. B. (2011). Estimate of Bed Load Transport in Kubanni Watershed in Northern Nigeria using Grain Size Distribution Data. *International Journal of Water Resources and Environmental Engineering*. **3**(5):102–108.

American Society for Testing and Materials (1999). 'Standard Test Method for Particle Size Distribution (Gradation) of Fine - Grained using the Sedimentation Analysis. www.ASTM.org west Conshohocken, P.A: ASTM International, Retrieved 16th May, 2017.

Anna, C., Peter, M., Laura, S., Maarten, B., Tiago, A., and Silver, F. (2018). Temperature Signal in Suspended export from an Alpine Catchment. *Hydrology and Earth System*; **22** (1): 509-528.

Olaniyan, O. S. (2009). Hydrological Analysis of Sediment Transport in a Turbulent Flow. *Unpublished M. Sc. Thesis*, Vrije Universiteit Brussels, Belgium, pp. 97.

Olaniyan, 2014. Numerical Modelling of Sediment Transport in River Omi, South-Western Nigeria. *PhD Thesis*, Department of Civil Engineering, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.

Olaniyan, O. S. and Adegbola, A. A. (2012). River Geometry Computation on River Omi SouthWestern Nigeria. *LAP Publisher*, Germany.

Ogun – Oshun River Basin Development Authority (2011). Government Administration, Alabata oad, Abeokuta, Ogun State 110121.NG. www.oorbda.com.ng