Available online at www.elixirpublishers.com (Elixir International Journal)

Civil Engineering

Elixir Civil Engg. 95 (2016) 40764-40766

ISSN: 2229-712X

Hydrological Analysis of Sediment Transport on River Oba, South-West Nigeria

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ARTICLE INFO

Article history:

Received: 31 March 2016;

Received in revised form: 28 May 2016;

Accepted: 3 June 2016;

Keywords

Water depth,
Velocity,
Width,
Wetted perimeter of the river,
Depth.

ABSTRACT

River can flood the environment in which it is located and cause loses to lives and properties if not well monitored. River Oba is a natural occurring water course which flows into the ground and becomes dry at the end of it course without reaching another body of water leaving soil material at the bed of the river. In this research, water depth, velocity, width and wetted perimeter of the river were measured on the site. Moreover, depth at different distance interval was measured so as to know the average depth. Soil samples were collected at different location surrounding the river for grain size distribution. Hydraulic Radius, low and cumulative percentage retained were calculated. Reduction in the likely flooding of the area is shown in station Z5 which has the highest hydraulic while Z3 shows high probability of flooding by having the lowest hydraulic radius as compared to other stations. Discharge in downstream has highest value of 414.72m/s compare to upstream and midstream. Grain size analysis shows that soil samples from River Oba contains 3% fine sand, 19% medium sand, 30% coarse sand, 32% fine gravel, and 16% coarse gravel. Conclusively, high value gotten from various parameters indicated deep station of the river.

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1.0 Introduction

River is a natural watercourse, flowing over the surface in extended hollow formations (i.e channels) which drain discrete areas of mainland with a natural gradient. In basic terms the existence of a river depends on three things: the availability of surface water, a channel in the ground and an inclined surface. In this sense, the term "river" includes all kinds of watercourses, from the tiniest of brooks to the largest of rivers. Importance of river to humanity cannot be neglected but as important as rivers are, they are also dangerous to lives and properties if they are not well monitored. Most rivers in Nigeria are not gauged, so their flows are not known. Ogbomosoo is a city in Oyo state, South Western Nigeria in which River Oba is located. It is one of the river with heavy flow in Ogbomoso and also with varying depth which when flowing it picks up debris caused by human activities in that area (John Wiley, 2005).

Ogbomoso has a tropical wet and dry climate, with a lengthy wet season and relatively constant temperatures throughout the course of the year. The wet season runs from March to October, though August seems somewhat of a lull in precipitation. The study area of River Oba is located at an elevation of 184 meters above sea level and its population amount to 626,997. Its coordinate are 7° $28^{1}0^{11}$ N and 4° 7^{1} 60^{11}N. The river is about 45.2 km with frequent flooding. The catchment area of the river is 123.53 km. River Oba is an alluvial river with channels and floodplains that are self-formed in unconsolidated or weakly-consolidated sediments. The morphology of an alluvial river reach is controlled by a combination of sediment supply, substrate composition, discharge, vegetation, and bed aggradations. River Oba is very useful to the inhabitants for domestic, agricultural and waste disposal purposes. Some of the bridges and culverts on the river have been swept away due to frequent flood occurrence. Coordinates of selected area of River Oba are the hallmark of **Table 1.**

Table 1. Coordinates of Selected Area of River Oba.

Sample	Location	Longitude	Lattitude
1	ILUJU	$4^{o}12'12''$E	$8^{o}11'879''$N
2	ONITINRIN	$4^{o}11'307''$E	$8^{o}08'438''$N
3	ODO-OBA	$04^{o}08'645''$E	$8^{o}02'$ $849''$N
4	MOSUNMADE	$^{o}05'439''$E	$7^{o}57'383''$N
5	OWU-ILE	$04^{o}04'430''$E	$7^{o}50'064''$ N

2.0 Literature Review

Essentially, a river represents the excess of precipitation over evaporation for a certain land area (Cleveland, 2008). Discharge volume of water flowing through a cross section in a unit time such as cubic meters per seconds or cubic feet per seconds. Discharge measurement is imperative in any water system for the development of irrigation and power potentials, water supply, flood control and navigation etc. Discharge and gauge measurement are two hydrological parameters that must be measured at any gauging station. Stage or gauge is the elevation of water surface of a river measured relatively to a datum. The datum can be mean sea level or any arbitrary datum (Sharma and Sharma, 2002). Gauging site should be permanent irrespective of scouring or silting of sediment and must give same elevation of water surface corresponding to a given discharge (Sharma and Sharma, 2002). Gauge can be a direct or indirect type. Staff gauge are direct type while self-recorder type and crest stage type are indirect gauges. Gauges can be vertical staff gauge, inclined gauge, hook gauge, temporary gauge and crest stage gauge (Subramanya, 2007; Adegbola and Olaniyan, 2012). Sometimes, discharge and gauge sites may be differ due to site condition. It's very preferable if stage- discharge observations are complementary

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operations. If discharge measurement site is then differ from gauge site, additional qualities should be possessed by discharge sites. These additional qualities include: it should not be too far from the gauging station, located within straight reach; site should be free from aggradation and degradation among others (Sharma and Sharma, 2002).

3.0 Materials and Methods

Water depth was measured at a gauge site and velocity measured with a current meter. A rigid meter rule and a longer pole such as a surveying pole were used for the actual depth readings. A tape measure was stretched from one bank to the other at 90° to the course of the river to find the width. The point of the, starting and finishing point are the points at which dry bank meets the water. The depths which are the distance from the water surface to the bed of the stream bed were computed at each interval across the section during the wet and dry season with a rigid tape. In order to find the wetted perimeter, we must first find the wetted area between each interval at which the stream's depth was measured. The wetted perimeter of a river refers to that part of the channel that is in contact with water. It represent the friction that slows down the water velocity, so the longer the wetted perimeter, the more friction between channel and water. Wetted perimeter will be measured using a heavy chain, rope or measure tape, which should be stretched across the river from one bank to the other. This can be hard to do, especially in larger channel of where the bed is rough. Fast flowing water conditions can also be problematic. Wetted perimeter is often better calculated from the graphed result. The soil samples are collected from different location of Iluju, Onitinrin, Odo- Oba, Mosunmaje, and Owu-Ile for analysis of grain size distribution.

4.0 Results and Discussion

The hydraulic radius is a measure of channel flow efficiency. Flow speed along the channel depends on its cross-sectional shape (among other factors), and the hydraulic radius is a characterization of the channel that intends to capture such efficiency. Based on the constant shear stress at the boundary assumption, hydraulic radius is defined as the ratio of the channel's cross-sectional area of the flow to its wetted perimeter. Thus, the hydraulic radius for each cross-section (points) of the river is shown in Table 2.

$$R_h = \frac{A}{P}$$

Table 2. Hydraulic Radius of each Cross-Section of the River.

Station	Z_1	Z_2	Z_3	Z_4	Z_5
A(m^2)	65.2	59.9	42	197.2	691.2
P(m)	7.3	9.54	13.34	36.22	53.45
R_h(m)	8.93	6.28	3.45	5.44	12.93

R_h represents hydraulic radius (m)

A represents cross-sectional area (m^2)

P represents wetted perimeter (m)

Table 3. Velocity and Discharge Computation at Measuring Stations in Wet Season.

REGION	STATION	R_h(m)	V(m/s)	A(m^2)	Q(m^3/s)
UPSTREAM	Z_1	8.93	0.15	65.2	9.78
	Z_2	6.28	0.6	59.9	35.52
MID-STREAM	Z_3	3.45	0.5	42	21
	Z_4	5.44	0.4	197.2	78.88
DOWNSTREAM	Z_5	12.93	0.6	691.2	414.72

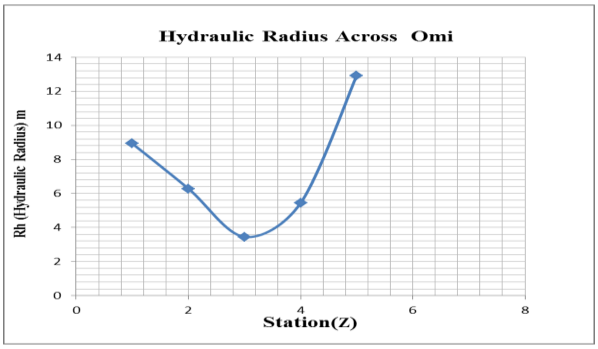

Figure 1. Hydraulic Radius across River Oba in Wet Season.

A river with a high gradient loses height quickly and is typically fast flowing and youthful. The gradient of a river is a measure of how steeply it loses height while that with very gentle gradient loses very little height and it is typically a slow flowing matured river. Station (Z_5, Z_1, Z_2, Z_4, Z_3) have hydraulic radius value in ascending which indicate that the greater the hydraulic radius, the more the efficiency of the channel which result to the reduction in the likely flooding of the river as shown in Figure 1. The hydraulic radius is a function of the shape of the pipe channel or river in which the water is flowing. The hydraulic radius along River Oba increases downstream with value of 12.93m.

The computed velocity was higher at upstream than other section, this follow the normal trend on a river with highest velocity at upstream compared to mid-stream and downstream respectively as shown in Table 3.

4.1 Effective Mean Size of the Sediment

Soil sample was taken from point Z_3 and was taken to the laboratory to know the particle size distribution of the sediment in point Z_3, which the result of the gradation is the hallmark of Table 4.

Table 4. Gradation of Soil Sample in Odo Oba.

Sieve Diameter(mm)	Mass Retained (g)	Percentage Retained (%)	Cumulative Percentage Retained (%)	Percentage Passing (%)
20.00	0	0	0	100
8.00	35.40	7.08	7.08	92.92
4.00	97.80	19.56	26.64	73.36
2.00	105.10	21.02	47.66	52.34
1.00	75.10	15.02	62.68	37.32
0.710	45.70	9.14	71.82	28.18
0.425	72.20	14.44	86.26	13.74
0.355	20.20	4.04	90.30	9.70
0.250	25.00	5.00	95.30	4.70
0.125	18.40	3.68	98.98	1.02
0.075	2.40	0.48	99.46	0.54
<0.075	2.70	0.54	100.0	0.00

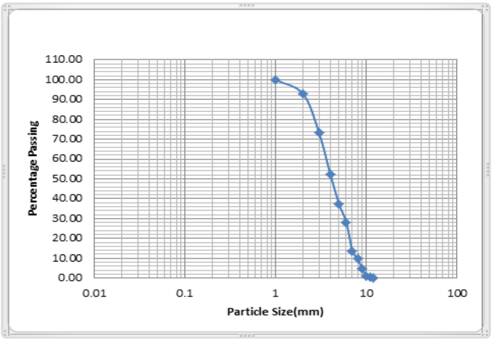

Figure 2. Percentage Passing Graph against Particle Size (mm).

The soil sample contained 3% fine sand, 19% medium sand, 30% coarse sand, 32% fine gravel and 16% coarse gravel as shown in Table 4. D_{50} is the mean sediment particle diameter which is the 50% passing in the sieve from the sieve analysis result. Tracing 50% on Figure 2 it strikes at 1.85mm and the grain size distribution of bed material from River Oba is shown in the Table 4. The percentage distribution of grain size greater than 1.89mm was 50% as shown in Figure 2.

4.2 Conclusion

Based on the findings from the study, the conclusions are drawn:

(i) The hydrological parameters of the river were obtained by the determination of the Width, Depths and the Wetted perimeter of the river.

(ii) The hydraulic radius, flow rate of the river constitute the hydraulic parameters of the river.

(iii) The obtained result shows that, the highest values occurs when the channels are deep, narrow, and semi-circular in shape

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