Surface Water Potential of the River Osun at Apoje Sub-basin Nigeria

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Abstract: In order to archive the millennium goals of which water for all by the year 2015 is a major component; all efforts must be made to efficiently utilise the available water resources in various parts of the world and more importantly in Africa which has been described as the worst hit. In Nigeria, water scarcity in terms of quality and quantity is a major problem. In order to assess the potential of the River Osun at Apoje sub-basin located in the southwestern part of Nigeria, the streamflow and gauge height data of 18 years (1982–1999) were collected from Ogun-Osun River Basin and Rural Development Authourity, Abeokuta, Nigeria. A rating curve was drawn for the station by plotting the gauge heights against their annual maximum discharges. The annual cumulative inflows for each year were determined and plotted against water years to evaluate their spatial distributions. Mass curve was drawn for each year and their potential reservoir capacities were determined. The results show that, at the return periods of 10, 25, and 50 years, the upper flood limits of 430, 451, and 458 m^3/s, respectively, were obtained at 95% confidence intervals and the level of significance of 0.025. The coefficient of determination r^2 of 0.9984 shows a good fit of the rating curve. The annual cumulative inflow in the sub-basin varies from 60 to 306 billion m^3 of water in 18 years. The average annual cumulative inflow was 125 billion m^3 of water while the interannual variability was 42%. The intraanual variability was between 56 and 83%. The maximum potential reservoir capacity of 22 billion m^3 of water can be built in the area to cater adequately for diverse uses in the sub-basin.

Keywords: streamflow; gauge heights; Apoje sub-basin

Water is the most abundant substance on earth. It is very vital to the survival of all living things and is instrumental to the proper functioning and maintenance of the ecosystem throughout the whole world. Globally, there is wide awareness of the contribution of water in maintaining the environmental services and ecosystem. The importance of water in rural and urban settlements cannot be overemphasized. Human beings cannot live for more than a few days without water, shorter than without any other source of sustenance except fresh air. The quality, quantity, and accessibility determine the level of public health, food production, energy, and other aspects of life (Niel 1995). It is essential for all social economic developments in all parts of the world and it is difficult to think of a resource more essential to the health of human communities or their economies than water. The eradication of poverty and hunger in rural areas is closely related to a fair and equitable access for the most vulnerable people to basic livelihood assets (including land and water) for most domestic and productive uses (UN 2006). Water consumption has doubled since 1950 (UNESCO 2003). The direct consumption by the man and animals constitute about 50% of the fresh water use while agriculture (crop production, aquaculture, land and water conservation), which is the predominant user, accounts for about 70% globally, and up to 95% in several developing counties. In order to cope with the ever expanding demand for food, it has been estimated that in the next 30 years, about 14% more freshwater will be withdrawn for agricultural purposes (Zedebiah 1999; Verosmarty *et al.* 2000; UN 2006). The demand for water resources of sufficient quantity and quality for human consumption, sanitation, agriculture, and industrial uses will continue to intensify as the population increases and global urbanisation, industrialisation, and commercial development accelerate (Flint 2004). Therefore, water resource management is one of the most important challenges the world is facing today. In order to meet the demands of different users, efforts should be intensified on the efficient use of all water resources (surface water, ground water, and rainfall) and also on water allocation plans that maximise the resultant economic returns to limited water resources and, at the same time, protect the fragile ecosystem.

Apoje sub-basin is situated in the southwestern part of Nigeria. Human activities in this area such as deforestation, intensive agriculture, urbanisation, and refuse dumping on water ways interfere with the hydrologic cycle and ecosystem (Eberhard 1983). These activities can be beneficial to the communities, but their impacts on the hydrology of the sub-basin cannot be underrated (Linsley *et al.* 1988; Morgan 1996). Deforestation with little or no replacement makes the area very vulnerable to desertification, soil erosion, and flooding which in recent times had damaged farmland and infrastructural facilities in the area (Adeboye 2005). Water resources in the area have not been utilised efficiently for the agricultural productions (Alatise & Adeboye 2005). Therefore, the focus of this study is to use statistical tools to evaluate the quantity of the surface water in the area and determine their interannual and intraannual spatial distributions in the study period (1982–1999). Also, attention of different stakeholders in the water resources sector will be drawn to this invaluable resource for efficient exploitation.

MATERIALS AND METHODS

The study area lies in the latitude of 8°20’ and 6°30’N and longitude of 5°10’E and 3°25’E as shown in Figure 1. The basin covers an area of about

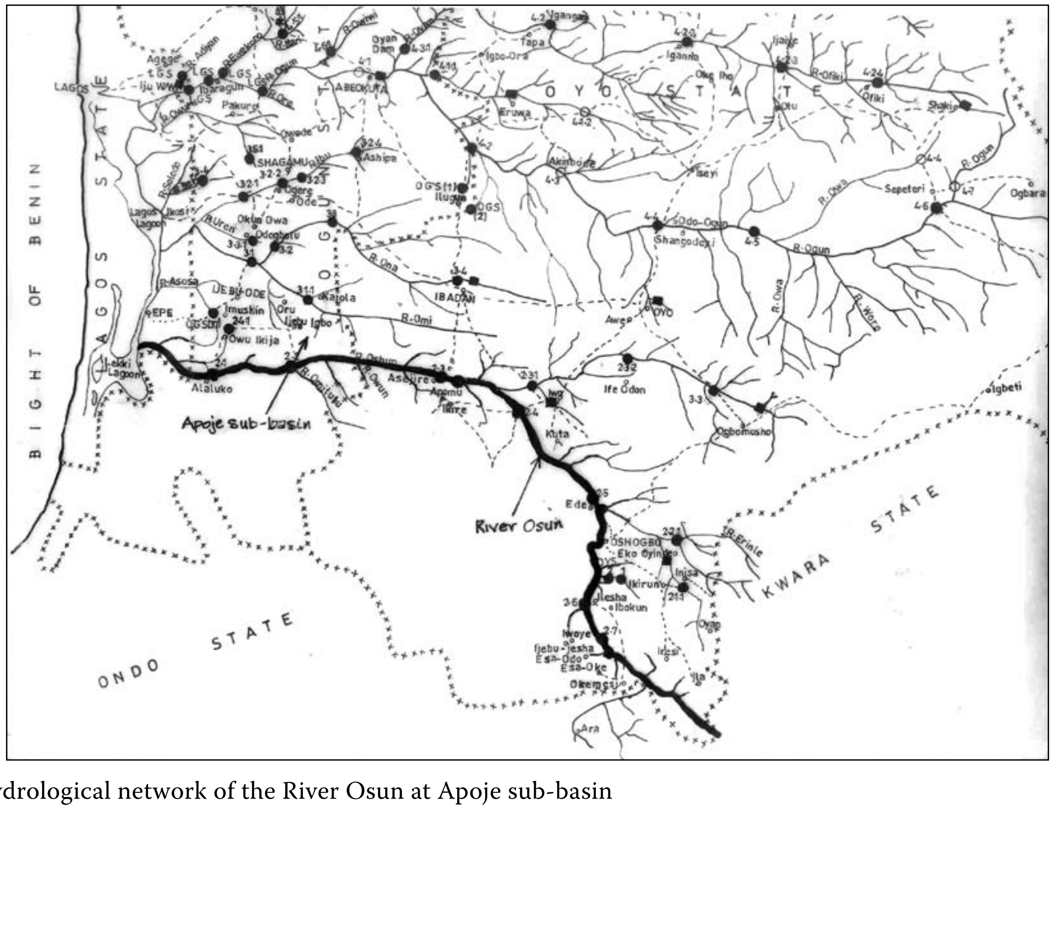

Figure 1. Hydrological network of the River Osun at Apoje sub-basin

16 700 km^2. As reported by ADEBOYE (2005), the main tributary to the River Osun is the Oba River which rises about 15 km North of Ogbomoso. Seasonal variation is the major characteristics of the rainfall distribution in the area.

Methods of data analysis

The annual peak discharges were plotted against their corresponding gauge heights. The daily streamflows of each month were added up to obtain the monthly total discharge. The estimated monthly discharges were converted into the volume of flow using the equation

$$V_m = Q_a \times D \times 24 \times 3600 \quad (1)$$

where:
V_m – monthly total volume (m^3)
Q_a – monthly total discharges (m^3/s)
D – number of the days in which the observed discharges were recorded

For each year (January to December), the cumulative inflow was determined using the expression

$$V_c = \sum_{i=1}^{n} V_m \quad (2)$$

where:
V_c – annual cumulative volume (m^3)
n – number of months in a year that is, (12);
V_m – as previously defined

The statistical variate mean, standard deviation and the coefficient of variation of the annual inflow were determined using the equations

$$\overline{V_a} = \frac{1}{n}\sum_{i=1}^{n} V_c \quad (3)$$

$$S_v = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(V_c - \overline{V_a}\right)^2} \quad (4)$$

and

$$CV = \frac{S_v}{\bar{V}_a} \quad (5)$$

where:
$\bar{V}_a$ – mean of the cumulative inflow (m^3)
S_v – standard deviation of the annual cumulative inflow (m^3)
CV – coefficient of variation of the cumulative inflow (–)
n, V_c – as previously defined

The annual cumulative inflows were plotted against the respective years to determine the spatial distribution over the years under investigation. The mass curve was drawn for each year by plotting the annual cumulative inflow against their corresponding months. For each year, a uniform rate of withdrawal of the annual cumulative inflow was assumed and this was obtained by dividing the annual cumulative inflow by 12. The potential reservoir and spillway capacities were determined by finding the maximum departure of the mass curves from the uniform rate of withdrawal during the periods of low and excess inflows, respectively. The maximum potential reservoir capacity for each year was determined by adding up the highest reservoir and spillway capacities.

RESULTS AND DISCUSSION

Rating curve

The observed water levels were plotted against their corresponding annual maximum discharges. Figure 2 shows the variation of the gauge heights with annual peak discharges. The coefficient of determination r^2 of 0.9984 shows a perfect fit and this is in compliance with (CHOW *et al.* 1988). At 95% confidence level, the annual peak discharges at the return periods of 10, 25, and 50 years were 430, 451, and 458 m^3/s, respectively. River flooding which occurs frequently in the sub-basin can be prevented by using these flood estimates in the design and construction of water retaining and hydraulic structures.

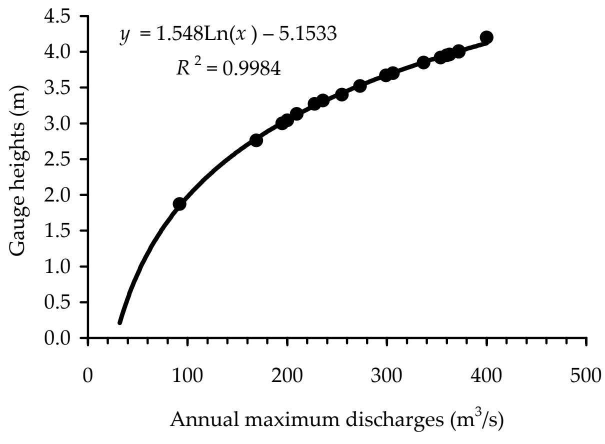

Figure 2. Rating curve of the River Osun at Apoje sub-basin, Nigeria from 1982 to 1999

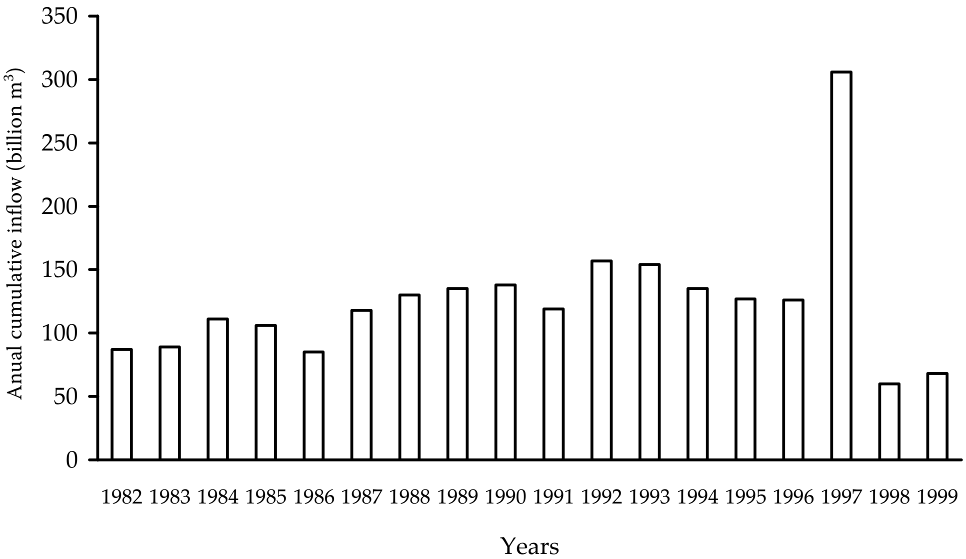

Figure 3. Distribution of the annual cumulative inflow at Apoje sub-basin, Nigeria from 1982 to 1999

Spatial distribution of the cumulative inflow

The annual maximum discharges were used in determining the cumulative inflow using Eq. (1) while the mean, standard deviation and the coefficients of variation were determined using Eqs (3), (4), and (5), respectively. Figure 3 shows the distribution of the cumulative inflow over the years. The cumulative

Table 1. The mean, standard deviation and coefficients of variation of the annual cumulative inflow at Apoje sub-basin from 1982 to 1999 (in billion m^3)

Water years	Mean flow	Standard deviation	*CV* (%)
1982	47	29	62
1983	45	29	64
1984	53	38	72
1985	46	37	80
1986	48	29	60
1987	53	40	76
1988	61	44	72
1989	62	47	76
1990	65	45	69
1991	65	36	56
1992	75	52	69
1993	75	50	67
1994	69	44	64
1995	53	44	83
1996	59	42	71
1997	161	91	57
1998	25	18	72
1999	29	21	72

CV – Coefficient of variation

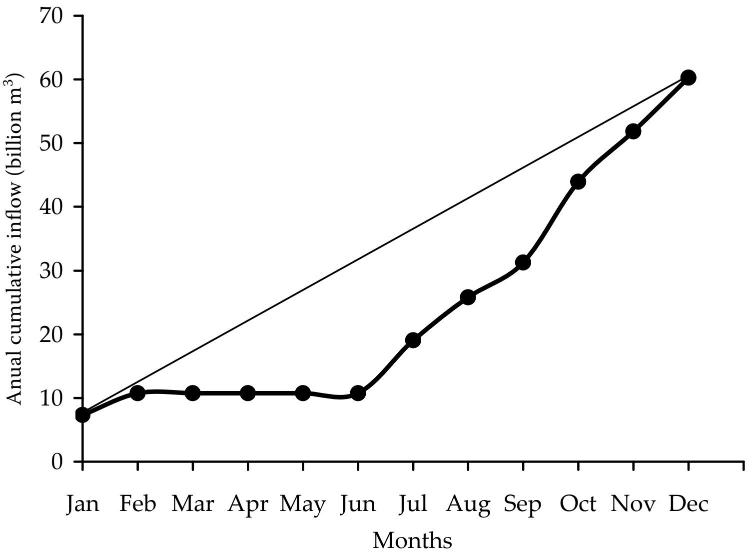

Figure 4. Mass curve of the River Osun at Apoje sub-basin in 1998

inflow of 87 billion m^3 was observed in 1982 but it later increased to 111 billion m^3 in the year 1984. There was also an increase from 118 to 138 billion m^3 of water from 1987 to 1990, respectively. The highest inflow was 306 billion m^3 of water in 1997 while the minimum was 60 billion m^3 in 1998. Table 1 shows the mean, standard deviation and the coefficients of variation of the inflow in each year. The highest mean flow and standard deviation of 161 and 91 billion m^3 of water were observed in the year 1997 which had the highest annual cumulative inflow as shown in Figure 3. The interannual variability of the annual cumulative inflow was 42% while the intraannual variability was between 56 and 83%. This shows that the cumulative inflow in the sub-basin fairly varied in the years under investigation.

Table 2. Potential reservoir capacities (m^3) of the River Osun at Apoje sub-basin from 1982 to 1999

Water years	Reservoir capacity March–June	Spillway capacity July–October	Maximum reservoir capacity (million m^3)	Rate of monthly with-drawals (billion m^3)
1982	1 800	6 200	8 000	7
1983	24 600	2 300	26 900	7
1984	55 800	3 800	59 600	9
1985	83 500	2 400	85 900	9
1986	1 733	6 400	8 133	7
1987	16 575	–	16 575	10
1988	15 550	–	15 550	11
1989	16 575	4 800	21 375	11
1990	14 450	–	14 450	12
1991	2 550	5 000	7 550	10
1992	16 600	–	16 600	13
1993	13 375	–	13 375	13
1994	10 075	–	10 075	11
1995	18 575	5 200	23 775	11
1996	15 950	–	15 950	11
1997	8 725	–	8 725	26
1998	12 850	3 233	16 083	5
1999	13 600	–	13 600	6

Potential reservoir capacity

For each year, the monthly cumulative inflows were plotted against their corresponding months. The potential reservoir and spillway capacities were determined by finding the maximum departure of the uniform rate of water withdrawal from the mass curve. Figure 4 shows the mass curve for 1998. Between January and April, 18% of the cumulative inflow was recorded while about 73% was recorded between May and October. The uniform rate of withdrawal represented by the straight line (Figure 4) and the maximum reservoir capacity were 5 billion m^3/s and 12 850 million m^3 of water, respectively. Table 2 shows the estimated potential capacities at Apoje sub-basin from 1982 to 1999. The maximum reservoir capacities were adequate to meet the monthly demands except in 1991 and 1997 although the maximum inflow was observed in 1997 (Figure 3).

CONCLUSION

A rating curve of the River Osun was drawn. The annual cumulative inflows were determined. Also, the mass curve was drawn for each year by plotting the monthly cumulative inflows against the respective months. Based on the results obtained, the following conclusions were made:

– At the return periods of 10, 25, and 50 years, the upper flood limits of 430, 451, and 458 m^3/s, respectively, were obtained at 95% confidence interval;

– The annual cumulative inflow in the sub-basin varies from 60 to 306 billion m^3 of water in 18 years. The interannual variability of the annual cumulative inflow was 42% while the intraannual variability was between 56 and 83%. The average cumulative inflow was 125 billion m^3 of water;

– A water reservoir of about 22 billion m^3 of water can be built in the area;

– Based on the analysis given above, Apoje sub-basin has abundant water resources which could be well utilised to meet the needs of different water users in the area.

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