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Assessment of the Hydropower Capacity of Reservoir from Catchment Area of Joseph Sarwuan Tarka University, Makurdi, Nigeria

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Abstract

A proposed dam is to be built at the North Core watershed of Joseph Sarwuan Tarka University Makurdi. The catchment inflow characteristics and reservoir capacity based on the mean inflow into the site of the proposed dam was assessed and determined. Runoff curve number method was used to determine the inflow into the reservoir. A period of 31 years was used to determine the mean annual runoff. The reservoir capacity was estimated based on the inflow into the reservoir using analytical, mass curve and residual mass curve methods. Catchment area, mean runoff and mean annual catchment yield were found to be, 8.82 km^2, 1222.59 mm and 10,783,243.8 m^3, respectively. The cumulative inflow for the 31 years was used to prepare a mass curve of inflow into the reservoir at drafts 60% and 80%, and draft line superimposed on the cumulative mass curve. At draft 60% a reservoir capacity of 9,513,000 m^3 was obtained, at draft 80%, 10,549, 000 m^3 resulted. A residual mass curve of the inflow was prepared, at draft 60%, a reservoir capacity of 3,632,000 m^3 resulted, while at draft 80%, 4,426,000 m^3 was obtained. Annual sediment discharge from the catchment area of 1302.02 tons was expected. A reservoir capacity of at least 11,000,000 m^3 was recommended for the proposed dam. The reservoir capacity of Analytical method, with storage of 10.549 x106 m^3, gave active storage capacity of

Keywords: Catchment area, Dam, Runoff, Inflow Annual yield, Reservoir capacity, Hydropower, Makurdi.

1.0 Introduction

Water makes life possible and has traditionally been regarded as an inexhaustible gift of nature, which is continuously being renewed through nature's hydrological cycle (Dawei,2010). In reality, the traditional sources of water supply, surface runoff and groundwater stores, are inequitably distributed among people and countries. While some communities live where regular precipitation gives them an ample surplus (having more water than they need but not necessarily at the right place or time) others have barely enough water for current needs and drought is perennial. The extent to which water supply is used depends upon the inter- relationship between the rate of flow at a particular time, area distribution and the technology that can be applied by the people concerned. The planning, design and management of water resources requires knowledge of the time characteristic of flow, hence it is important to have a continuous hydrological record of stream flow data (Mfwango *et al.,*2018) for many years at points of withdrawal and use.

Exploitation of surface water sources involves construction of hydraulic structures (such as weirs, dams.) across a river/stream to impound water,(Werth *et al.,* 2014). These structures, especially dams, vary in sizes, construction materials and methods of construction (Hesham *et al*, 2017; Sadanandam, 2018). An earth-fill dam is constructed primarily of selected engineering soils, compacted uniformly and intensively in relatively thin layers, and at controlled moisture content. Its adaptability to a wide range of site conditions, flexibility in accommodating different fill materials, ability to accommodate an appreciable degree of settlement without risk of serious cracking, and its low cost of construction and maintenance made it more appropriate for developing countries like Nigeria.

A catchment area is a region where water is diverted by the means of structures to redirect water flowing from a river or stream into a dam (HCA, 2015). Most dams are built on rivers or streams to store the water, while other dams, depending on the purpose of construction have inbuilt canal through which water is supplied to dam over a long or short distance from the source of water supply. The most important consideration to make in choosing a site for construction of a dam therefore is the availability of water sources, catchment characteristics such as inflow, dimension, elevation differential from proposed dam site, confluence (if two or more streams are involved) and distance.

This study was done to identify and determine the required design capacity of the proposed dam (reservoir) based on volume of inflow into the catchment area of Joseph Sarwuan Tarka University, Makurdi, that will equally generate hydropower.

1.1 Reservoir (Dam) Storage Capacity

The storage capacity of a dam or reservoir is the volume of water that the dam can accommodate at full supply level (FSL) based on design without overtopping. The storage capacity of a dam is one of the most important considerations made at the point of design, to avoid errors that may arise in the course of the design. The dam capacity is estimated by calculating the volume of water which is expected to flow into the dam from the catchment or a canal built into the dam. The storage capacity of the dam should not exceed the calculated yield from the catchment area. Capacity of dam is calculated using the formula (FAO, 2010, 2019):

$$Q_r = \frac{L \times T \times H'}{6} \qquad (1)$$

Where;

Q_r = Storage capacity of the reservoir in m^3. For design purpose Q_r should not be less than catchment yield.

L = Length of the dam wall at full supply level (FSL) in m

T = Throwback of the reservoir in m and approximately a straight line from the wall.

H' = Maximum height of the dam, in m, at FSL. The 6 is a factor, can be adjusted (to 4 or 5) with experience and local knowledge. (FAO, 2010).

2.0 Materials and Methods

2.1 Study Area

The study area is located at the Joseph Sarwuan Tarka University, Makurdi, North Core area in Makurdi Local Government Area of Benue State. The geographical location of Makurdi is at 7°44' north, 8°32' east. Nigeria is located at latitude 7.7° and longitude 8.5° and the elevation of Makurdi is 104 meters (W S, 2020; FM, 2021)(Figures 1 and 2).

Geologically, the area is located in the Middle Benue trough and falls within a sedimentary basin (FM, 2021). The trough is 80-150m wide and 800 km long, north-west, south-west trending structures. Benue State is underlain by both sedimentary and basement rocks (Jika and Mamma, 2014).

The lithostratigraphy of middle Benue Trough consists of shale, sandstone and limestone as the oldest dated sedimentary rocks, with hard grey to black shales and siltstones. Such deposits are believed to represent typical shallow water deposits (Terkula and Ikechukwu, 2014).

2.1.1 Materials/equipment

The materials that were used for the study are:

- Topographical map of the Federal University of Agriculture Makurdi (FUAM, 2010): For studying the geophysical features of the catchment area.
- Hydrological data of Makurdi (NMA, 2017): For determining annual rainfall, runoff coefficient, annual runoff from catchment and peak flood from catchment.
- Hydrologic soil group chart: For determining the hydrologic soil type of the watershed.
- Table of curve numbers: For determining the curve number of soil type from the hydrologic soil group.
- Google earth satellite and GPS locations software: For surveillance, imaging, marking out catchment areas and measurement of distance on the project area.
- Mathematical set: For reading distances and position on the topographical map.

Figure 1: Map of Nigeria Showing Benue State

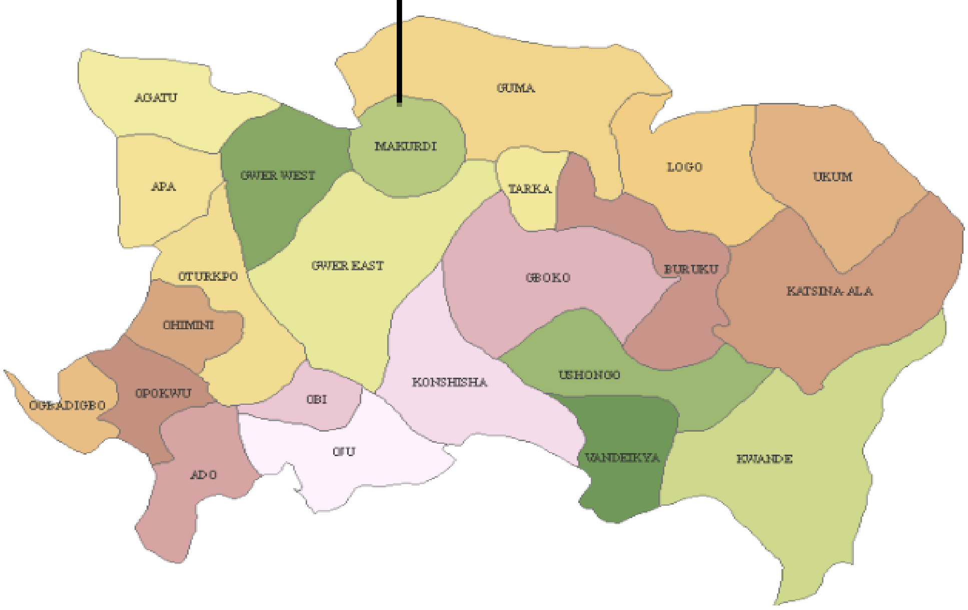


Figure 2: Map of Benue State Showing Makurdi - Project Area (Terkula, 2015)

2.2 Catchment Drainage (Streams)

From survey and site investigations as well as information from topographical map and satellite surveillance there are three major streams that flow within the catchment area of the University identified as: stream A, stream B and stream C (Figure 3 and 4). The three streams flow down from three separate courses to the confluence point A where the dam is to be sited at point D (Figure 5). The topographical map of the project area (Figure 4) clearly shows the catchment streams, the elevation at the source of the streams and the proposed site of the dam which is at the point of their confluence behind the school chaplaincy (Chapel of the Good Shepherd). The map extract in Figure (3) shows clearly the catchment streams and their elevations from their sources. The three catchment streams are identified as:

- **Stream A:** the stream that flows from around the ring road to the west and flows down southwards towards the college of agronomy to the point of confluence behind the school chaplaincy (Figure 4).
- **Stream B:** the stream that flows from North core animal farm to the east of the ring road and flows down towards the college of Agronomy join stream A and flows together to the confluence point.
- **Stream C:** the stream flowing behind the clinic, around it to the north and all the way to the point of confluence.

Distance of stream A to D (X_1cm) was calculated using the formula

$$X_1 cm = \frac{Stream\ A\ dist. \times Map\ scale\ dist. to\ ground}{1000} \quad (2)$$

The X_1 in kilometers(km).

Stream (B) has a measured distance of 17.8cm on the topographical map. Given from the map(1cm = 150 m); 17.8cm = X_2cm

Distance of stream B to D (X_2cm) in figure 3 was calculated using the formula;

$$X_2 cm = \frac{Stream\ B\ Dist. \times Map\ scale\ Dist. to\ ground}{1000}$$

The X_2 in km. Stream (C) has a measured distance of 12.3cm on the topographical map. Therefore: 12.3cm = X_3 cm; Distance of stream C to D (X_3cm) in figure 3 will be calculated using the formula;

$$X_3 cm = \frac{stream\ A\ Dist. \times Map\ scale\ Dist. to\ ground}{1000}$$

2.2.1 Estimation of catchment streams distance from proposed dam site

From the topographical map which has a scale of 1:15000, (1cm on the map represent 150 meters of ground distance) (FUAM,2010), the length of the three catchment streams from their point of flow to the dam site of ground elevation was measured(Plate 1).

Stream (A) (Figure 5) has a measured distance of 15.4cm on the topographical map. Given from the map that 1cm represents 150 meters of ground distance (1cm = 150 m), therefore:

15.4cm = X_1 cm.

2.2.2 Catchment Area

A catchment area is a river(s) or stream(s) whose flow is diverted by means of hydraulic structures into a dam. Most dams are built on a river, along a river or at the confluence point of streams flowing. The inflow from the catchment which is otherwise known as the catchment yield determines the size of the dam and gives an estimate of the design capacity of the dam that is to be built. The catchment yield Y is given in m^3, by (FAO, 2010);

$$Y = Q \times A \times 1000 \quad (3)$$

Where;

Y = Catchment yield per unit time in a year i.e. catchment yield in an average year (m^3),

Q = Direct uniform runoff (mm);

A = Area of the catchment (km^2).

2.2.3 Catchment area peak flood

The peak flood is the probable maximum flood to be expected as runoff from a catchment following a rainfall of estimated intensity and duration for a selected return period taking into account the hydrological characteristics of the catchment. The peak flood gives the designer insight into the maximum runoff rate from the catchment into the dam; it is calculated using the rationally method of fuller's empirical formula which is used to rationally estimate the peak flood (FAO, 2010) as;

$$Q_{max} = C\ A^{0.8}(1 + 0.8\log T_r)(+2.67A^{-0.2}) \quad (4)$$

where;

Q_{max}= Maximum flow (m^3/s);

C = Runoff coefficient;

A = Area of the catchment in km^2

T_r = Recurrence interval.

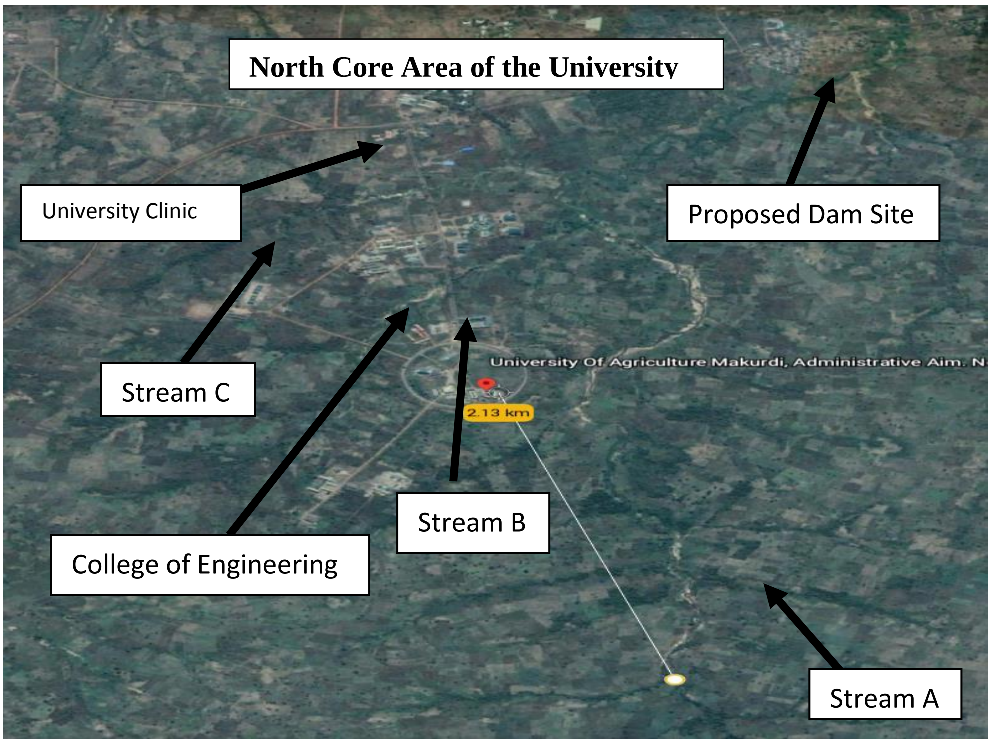


Figure 3: Google Earth Image of Project Area Showing Notable Structures on the Catchment Area (Source: GES 2018)

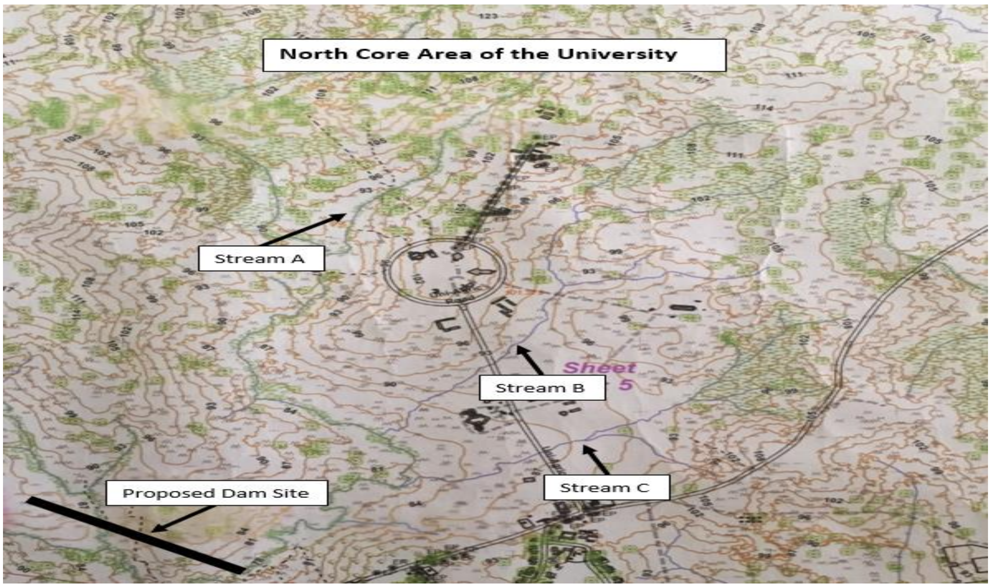
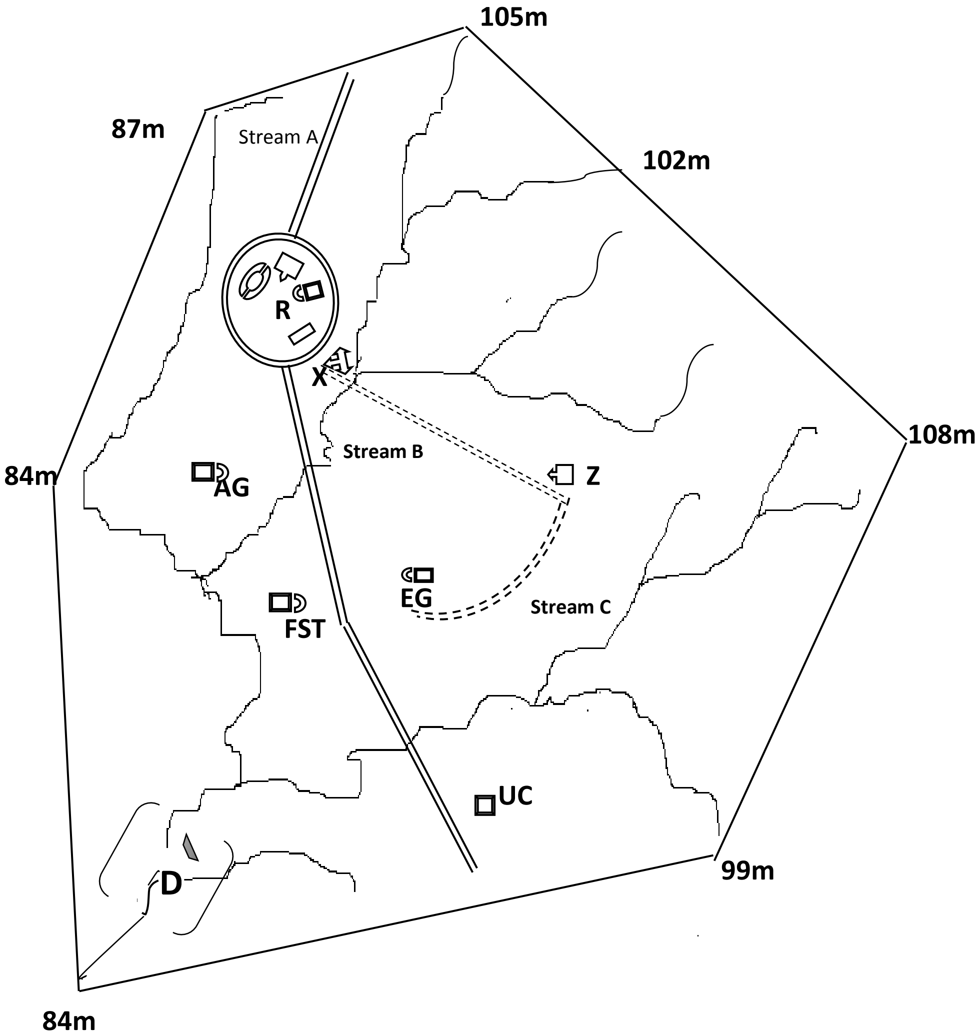


Figure 4: Topographical Map of the Project Area Showing Catchment Streams. (Source: FUAM, 2010).

Plate 1: Catchment streams during Rainy Season into Proposed Dam Site Area
Source: Site Investigation at Catchment Area.



Untarred road

Catchment streams

Untarred road

Ring road

North core road

84m – 108m   Site elevations

KEYS

D	=	Proposed dam site (confluence of the catchment streams)
AG	=	College of Agronomy
UC	=	School Clinic
FST	=	FST Complex
EG	=	Engineering Complex
Z	=	Zamfara Hostel
X	=	College of Agricultural Economics & Extension
R	=	University Ring Road (North core)

Figure 5. Map Outline Showing the Proposed Project Area and the Catchment Streams

2.3 Determination of Reservoir Capacity

The reservoir storage capacity will be determined on the basis of the inflow to the reservoir from the catchment (catchment yield) (Sonowal, 2014). The rate at which the capacity of the reservoir is reduced by sedimentation depends on: The quantity and velocity of sediment inflow; the percentage of sediment inflow trapped in the reservoir and the density of the deposited sediment(Mama and Okafor,2011;Timothy *et al,* 2017; Obialor *et al.,*2019). The rational or analytical, mass curve and residual mass curve methods were used to determine the inflow to the reservoir from the catchment.

2.3.1 The Rational or analytical method

The rational method involves the use of formula, tables, chart and graphs of catchment characteristics to determine the storage of reservoir.The catchment yield is the expected annual runoff from catchment areas and is an important factor in the feasibility of a dam, height of embankment and the capacity of the dam (FAO, 2010). Inflow is determined by the catchment yield which is based on the annual runoff from the catchment. The mean annual rainfall data for Makurdi for 31 years (NMA, 2017), was used to estimate the runoff from the catchment areas. The runoff from the catchment area was determined using the US Soil Conservation Service (SCS), which is a method of determining the runoff from a catchment area rationally.

The US Soil Conservation Service (SCS) runoff curve method number was used to estimate the runoff volume of the catchment. The curve number method considers losses in natural catchment

such as; rain interception by vegetation, infiltration, trapping in soil due to depression and loss due to evaporation. The SCS runoff equation given by (HydroCAD, 2019) as:

$$Q = \frac{(P - I_a)^2}{P - I_a} + S \qquad (5)$$

Where;

Q = Direct uniform runoff (mm);

P = Accumulated rainfall (potential maximum runoff) (mm)

S = Potential maximum retention after runoff begins (mm);

I_a = Initial abstraction

Initial abstraction is (I_a) is the maximum amount of rainfall absorbed without producing runoff.

I_a is highly variable but generally correlated with soil cover parameters. Through studies of many small water sheds, I_a was found to be approximated by the empirical equation (Hussein *et al.,* 2020);

$$I_a = 0.2S \qquad (6)$$

By substituting for I_a the equation by (HydroCAD, 2019) becomes;

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (7)$$

S, which is the soil potential maximum retention after runoff begins, is related to the soil and cover conditions of the catchment area through the curve number (CN). CN has a range of 0 to 100, and S is related to CN (HydroCAD, 2019) as;

$$S = \frac{1000}{CN} - 10 \qquad (8)$$

The catchment area is an agricultural watershed of soil group C, the curve number was determined using a table of runoff curve numbers for agricultural watersheds. The catchment yield Y in m^3 is given by (FAO, 2010) as;

$$Y = Q \times A \times 1000 \qquad (9)$$

Where:

Y = Catchment yield per unit time in a year i.e. catchment yield in an average year (m^3)

Q = Direct uniform runoff (mm); A = Area of the catchment (km^2).

The peak flood is the probable maximum flood (PMF) to be expected from a catchment following a rainfall of estimated intensity and duration for a selected return period taking into account the hydrological characteristics of the catchment FAO (2010). The peak flood was calculated usingFuller's formula (Saha, 2002);

$Q_{max}= C \times A^{0.8}(1+0.8 \log T_r)(1+2.67 A^{-0.2})$

(10)

where;

Q = Maximum flow (m^3/s); C = Runoff coefficient; A = Area of the catchment in km^2

T_r = Recurrence interval (taken as 100 years).

2.3.2 Mass curve method

A mass curve of inflow (or mass curve) is a plot of accumulated flow in a stream against time. Sonowal (2014) determined the capacity of a reservoir by the mass curve method. This method is based solely on the historical inflow record. The reservoir mass curve has many useful applications in the design of a storage capacity, such as determination of reservoir capacity, operations procedure and flood routing (Bharali, 2015).

A mass curve of the historical stream flows (annual data) was constructed; the slope of the cumulative draft line was determined and the cumulative draft line for the reservoir was superimposed on the mass curve. Measuring the largest intercept between the mass inflow curve and the cumulative draft line gives the reservoir capacity (McMahon and Mein, 1986). To obtain the reservoir capacity estimation using mass curve method therefore; a stream flow interval of 31 years (1987 to 2017, 372 months) was used to get the maximum available capacity of the reservoir. It is calculated using the relation:

$$\frac{Cf_{yr2}-Cf_{yr1}}{yr2-yr1} \quad (11)$$

Where:

Cf_{yr2} = Cumulative inflow at yr 2; Cfy_{yr1}= Cumulative inflow at yr1

yr1 = First year; yr2 = Last year.

2.3.3 Residual mass curve

McMahon and Mein (1986), defined Residual mass curve as a slightly more complicated version of the mass curve, but with a much more appropriate graphical scale for the determination of the storage size. Residual values are obtained by by subtracting the mean flow from individual flow values of the record. The cumulative residual values are plotted and the cumulative draft line is superimposed such that the draft line is tangential to each hump of the residual curve. The largest intercept between the mass inflow curve and the draft line is the reservoir capacity.

2.4 Sediment Yield

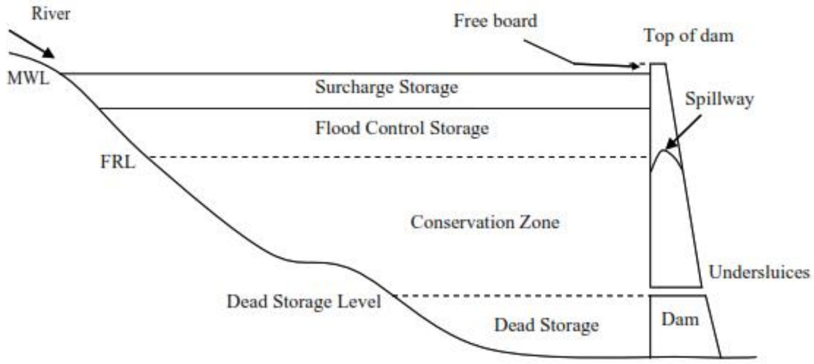
The mean annual suspended load, Q_s in tons as function of mean annual discharge Q in cubic metres per second for various vegetal covers is given by the Fleming equation (Demetris and Lykoudi 2002; Gebiaw *et al*, 2021):

$$Q_s = aQ^n \quad (12)$$

Q_s = Sediment discharge in tonnes per annum; Q = is the mean annual runoff (m^3/s) "a"and "n" are constants for various vegetal cover given by Fleming in 1969.

2.5 Hydropower Capacity of the Reservoir

Reservoir capacity of a dam is made up of active storage and dead storage. The hydropower potential of a reservoir is a function of discharge, specific weight of water and head between turbine and reservoir active storage capacity level (Jain 2020). For efficient working of turbines, it is necessary that head variation must be within a specified range and a discharged head must always be available. This minimum head corresponds to the top of the dead storage zone (Figure 9).In reservoirs, ten percent of total storage capacity is considered as dead storage capacity for sediment trappings (Khan *et al*, 2017).



FRL: Full reservoir level; MWL: Maximum water level

Figure 9. Schematic Diagram of a Reservoir showing the Various Storage Zones (Jain, 2020).

2.5.1 Hydropower potential of the reservoir

Hydro-Power potential of water in a dam is estimated mathematically (Khan *et al,* 2017, FMC, 2020) as :

$$P = \eta * \rho * g * Q * H/10^6 \qquad (13)$$

Where:

P is the potential power estimate

η is the overall efficiency of power plant

ρ is the density of water (1000 kg/m³)

g is the acceleration due to gravity (9.81 m/s²)

Q is the volume flow rate passing through the turbine (m³/s)

H is the net head (m)

For small hydropower system rough estimation, 87 percent is used as typical overall

Plant efficiency (for turbine, driven systems and generator)(87% x 9.81= 8.5), then the above equation (NMC, 2020) is simplified to:

$$P\ (kW) = 8.5 * Q * H \qquad (14)$$

Where:

P = potential power (estimate) (kW)

Q = estimate discharge (m³/s)

H = Hg (gross head) (m).

3.0 Results

3.1 Reservoir Capacity

3.1.1 Determination of reservoir capacity by rational/analytical method

Calculating catchment yield per annum

From equation 8, CN was determined to be equal to 74; the value of S was calculated as:

$S = \frac{1000}{74} - 10$; $\qquad S = 3.51\ mm$

Direct uniform runoff Q in mm (from equation 7) is determined from mean annual rainfall for 31 years (1987 – 2017) and found to be 1226.86 mm; P is therefore equal to 1226.86mm.

Direct uniform runoff Q is calculated as thus:

$$Q = \frac{(1226.86 - 0.2 \times 3.51)^2}{1226.86 + 0.8 \times 3.51};$$

$$Q = 1222.59\ mm$$

Mean Annual Catchment Yield, Y was calculated using equation (9) and was found to be approximately 8.82 km².

Mean Catchment Yield Y per annum calculated as:

$Y = 1222.59 \times 8.82 \times 1000$;

$Y = 10{,}783{,}243.8\ m^3$

Calculating peak flood from catchment

Peak from catchment was calculated using equation 10, as:

$Q_{max} = 0.2 \times 8.82^{0.8}(1 + 0.8log100)(1 + 2.67 \times 8.82^{-0.2})$

; $Q_{max} = 8.09 m^3$/s.

The mean total of the annual inflow which was obtained from calculated monthly, annual and mean inflow between the periods of 1987 – 2017 from the catchment to the reservoir was found to be approximately 10.459 × 10^6 m^3 and gives the required design capacity of the reservoir based on the inflow from the catchment. Figure 6 is a curve of the total annual inflow between 1987 and 2017.

3.1.2 Mass Curve Method

This method is based solely on the historical inflow record. The reservoir capacity was determined by preparing a mass curve of the cumulative inflow between the period of 1987 and 2017.

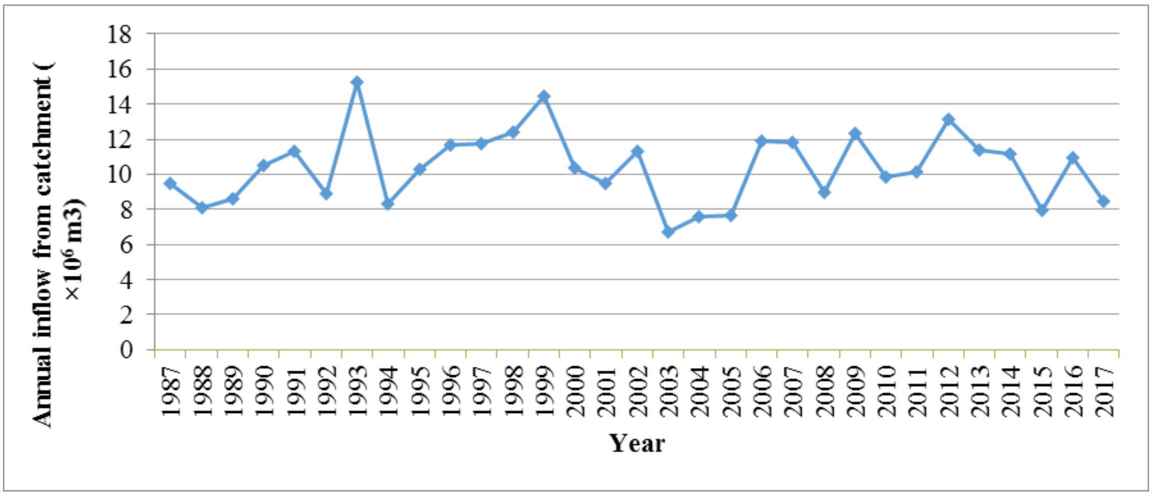


Figure 6. Inflow Hydrograph of Catchment (1987 – 2017)

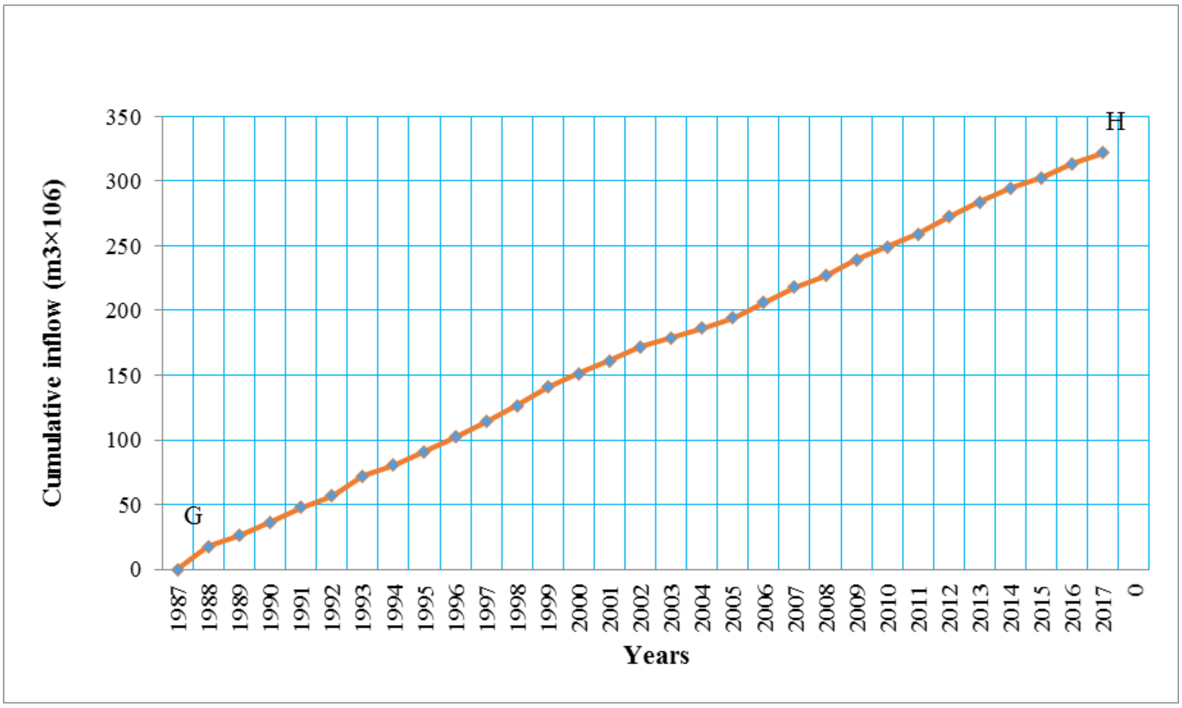


Figure 7: Mass Curve of Cumulative Inflow (1987 – 2017)

The cumulative draft line is superimposed on the mass curve. The largest intercept between the mass inflow curve and the cumulative draft line gives the required design capacity of the reservoir as the mass curve of cumulative inflow (Figure 7). The line GH in Figure 7 is the cumulative draft line of the mass curve. According to Alrayess *et al.*, (2017), a slope of 60% and for draft at 80% yr1 = 1989 and yr2 = 2014, 80% of the draft line is taken to determine required design storage of the reservoir.

Cf_{2014} = 294.906 × 10^6 m^3 (Figure 7); Cf_{1989} = 26.124 × 10^6 m^3 (Figure 7).

$$\text{Slope for draft at } 80\% = \frac{(294.906 - 26.124) \times 10^6\, m^3}{2014 - 1989}$$

$$= 10.751 \times 10^6 m^3$$

$$\text{Slope for draft at } 80\% = 10.751 \times 10^6 m^3$$

Measuring largest intercept between the mass inflow curve and the draft line, required reservoir capacity from cumulative curve = 313.8 ×10^6 m^3.

$$\text{Reservoir capacity per annum} = \frac{313.8 \times 10^6}{31}$$

= 10.123 ×10^6 m^3

Required design capacity of reservoir for draft at 80% per annum = 10.123 ×10^6 m^3.

3.1.3 Residual mass curve method

The largest intercept between the mass inflow curve and the draft line is found to be 10,459,000 m^3. Figure 8 showed the residual mass of curve of the cumulative residual inflow from the catchment. A draft of 60% and 80% is taken to estimate reservoir capacity. Line EF on the residual mass curve corresponds to draft 60% on the mass curve and the estimated reservoir capacity is 3.632 ×10^6 m^3. Line IJ corresponds to draft 80% on the residual mass curve and the estimated reservoir capacity is 4.426 × 10 m.

3.1.4 Calculating sediment discharge from catchment

Sediment discharge from catchment to reservoir will be estimated using Fleming's equation 12 as:

Mean annual runoff of 10.549 ×10^6 m^3 .

Sediment discharge, Q = 1302.02 tonnes per annum.

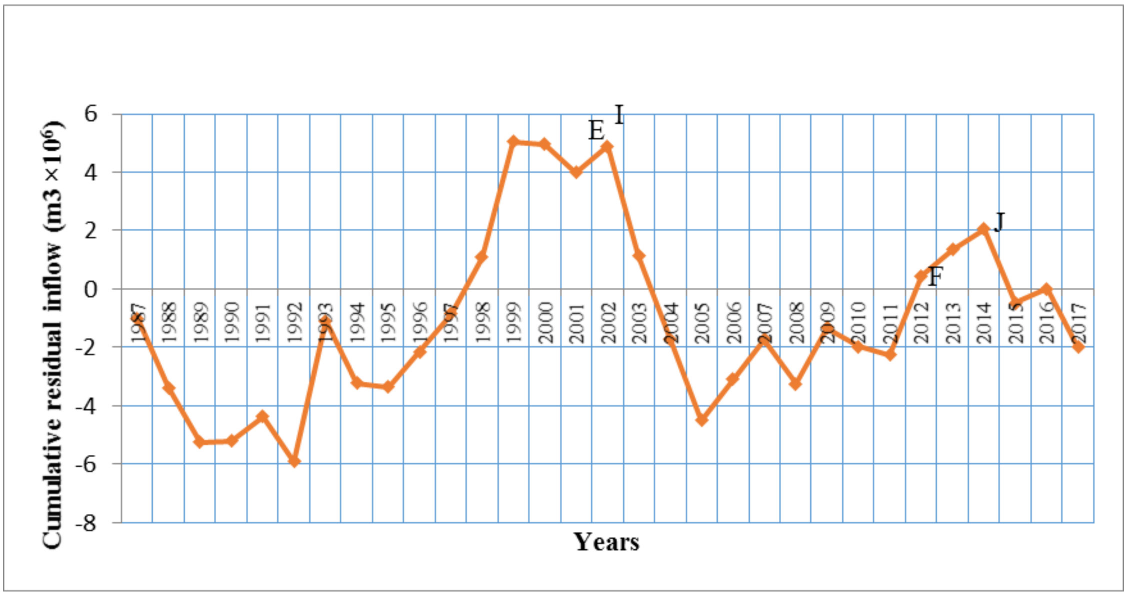


Figure 8: Residual mass curve of cumulative residual inflow (1987 – 2017)

4.0 Discussion

4.1 Rational/analytical method of determining the reservoir capacity

Catchment characteristics were investigated during field-work at the catchment to determine its runoff properties. The catchment area is made up of soil of fine texture, having slow infiltration rate when thoroughly wet hence impeding the downward movement of water (infiltration), the soil has a slow rate of transmission. From the catchment investigation, the catchment soil is of the hydrologic soil group C(Soils having a slow infiltration rate). The catchment area consists of good pasture and grassland, with portions used for mild farming of tuber, legume and grain (rice) crops. From the runoff curve numbers for agricultural lands (Table

1), the catchment soil HSG group C has a runoff curve number of 74. The analytical method gives an approximate value of the required design capacity of the reservoir based on the inflow from catchment. The reservoir capacity was calculated to be approximately 10,783,243.8 m^3. With a time reoccurrence of 100 years and a runoff coefficient of 0.2, the peak flood from catchment was estimated to be 8.02 m^3/s. Mean annual inflow from catchment was calculated to be 10.549 $\times 10^6$ m^3.

Table 1: Comparison of the Reservoir Capacity by Different Methods

Methods	Storage Estimate ($\times 10^6$ m^3)
Analytical method	10.783
Analytical method (Tabulated)	10.549
Mass curve method (draft at 60%)	9.513
Mass curve method (draft at 80%)	10.123
Residual mass curve method (draft at 60%)	3.632
Residual mass curve method (draft at 80%)	4.426

4. 1.1 Mass curve method

The graph of the mass curve is given in figure 7. The cumulative inflow from catchment is given in Table1. A draft at 60% and 80% was taken on the draft line GH (Figure 7) to estimate the reservoir capacity. For draft at 60%, the required reservoir capacity was 294.6 $\times 10^6$ m^3 and 9.513 $\times 10^6$ m^3per annum. For draft at 80%, the capacity was 313.8 $\times 10^6$ $m^3$and 10.123 $\times 10^6$ m^3.

The residual curve of the inflow is given in Figure 8. The residual curve gives the residual reservoir capacity for dry periods, the curve gives the least design capacity of reservoir sufficient to hold the inflow from the catchment. A draft at 60% and 80% was used to estimate reservoir capacity. Line EF (Figure 8) represents draft at 60% and line IJ (Figure 8) represents draft of 80%.

The intercept between the mass inflow curve and the draft line gives the required design capacity of the reservoir. For draft at 60%, reservoir capacity is 3.632 $\times 10^6$ m^3 and for draft at 80%, reservoir capacity was 4.426 $\times 10^6$ m^3. The comparative reservoir capacities by the 3 different methods (Analytical, Mass Curve and Residual Mass Curve) are as shown in Table 1.

4.1.2 Hydropower capacity of the reservoir

From the feasibility study of the site and preliminary design, the hydraulic head is estimated to be 9 m and flow rate is estimated to be 2.500 m^3/s. Using Analytical method of the reservoir capacity with storage estimate of 10.549 $\times 10^6$ m^3 as active storage capacity of the dam (Table 1), while 10% is taken as dead load, the reservoir capacity will be 9.4941 $\times 10^6$ m^3.

Therefore, the hydropower capacity of the reservoir, calculated from equation (14) will be:

$P\ (kW) = 8.5 * 2.50 * 9 = 191.25\ kW$.

The power potential of about 19.125kW will be available for six months during dry season, but will be improved on in the rainy season when inflow and reservoir storage is replenished. Balance for the reservoir storage for all year round hydropower will be accounted for during the detail engineering design and at construction stages.

5. Conclusion

Dam reservoir capacity is the most important aspect for hydro power design. Analytical, Mass Curve and Residual Mass Curve were used in determining the reservoir capacity.

Monthly and annual mean flow data was calculated from monthly rainfall data for a period between 1987 and 2017. Analytically:

- Highest reservoir capacity was obtained from Analytical method and Mass Curve method for draft at 80% (10.783×10^6 m^3) and (10.123×10^6 m^3) respectively.
- The least capacity (3.623×10^6 m^3) was from Residual Mass Curve Method at 60% draft.
- The maximum reservoir storage capacity was observed in year 2002 and the minimum in 1992.
- Sediment yield into the reservoir was estimated to be 1302.02 tons per annum.
- The reservoir capacity from Analytical method of $10.549 \times 10^6 m^3$ gave an estimated active storage capacity of the dam to be 9.4941×10^6 m^3, and can generate hydropower capacity of 191.25 kW from the dam.

It is recommended that; the Analytical method should be used to size the capacity of the reservoir. Improve on the reservoir storage capacity during the detail engineering design and construction stages, to generate all year round hydro power.

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