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Estimation of Reservoir Storage Capacity and Maximum Potential Head for Hydro-Power Generation of Propose Gizab Reservoir, Afghanistan, Using Mass Curve Method

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***Abstract*— *The present study objective is to estimate reservoir storage capacity and maximum potential head for hydro-power generation of the proposed Gizab multipurpose dam site in the Upper-Helmand river basin, Afghanistan. The mass curve is used to estimate the reservoir capacity and maximum potential head for power generation with the utilization of various years mean monthly flow data of the Upper-Helmand River Basin at the proposed Gizab dam site.The reservoir volume is 4709.12 Mm^{3}at 1435m elevation form mean sea level with reservoir capacity of 1114.3 Mm^3 with annual average inflow of 100.9m3/s and annual demand of 100m3/s. The net potential head of the proposed Gizab site is 117m with power generation of 91.822 MW with using of Francis turbine efficiency of 80%.*

Keywords*— *Gizab, Upper-Helmand, Mass Curve, Maximum Potential Head, Francis Turbin.

I. INTRODUCTION

In order to professionally operate reservoirs for hydropower generation, irrigation, and flood control, the management of water quantity within the reservoir is required (Salami et al., 2012). Beside volume of water in the reservoir the water surface elevation within the reservoir can be an indication of available storage. These relationships between elevation and storage volume, similar to area-volume and elevation-area relationships makes it possible that engineers can find fairly accurate value of one parameter from the other (Magome et al.,2003).

From surface water resources the adequacy and reliability of the water supplies for deferent propose are dependent upon the ability of reservoirs to make available sufficient water storage during the critical dry periods (Bharali, 2015). But these surface storage reservoirs also face many problems for their decrease of safe yields such as increases in water demand due to increases in population and gradual loss of reservoir capacity yield because of sedimentation in the reservoirs.

For water resources management the remote sensing and GIS is a supplementary solution, therefore, this techniques provide cost and time-effective estimation of storage capacity, require little human supervision, free of secretarial barriers or political interference, and must be demonstrably reliable over long periods and in all kinds of weather (Salami et al., 2012). Remote sensing data is used to provide elevation contours and water spread area of each contour and volume of reservoir at different water levels of a reservoir.

II. STUDY AREA

The proposed Gizab reservoir (Fig. 1) is a multi-propose project across the Helmnad river basin, Afghanistan. The proposed reservoir is located between 33° 22’ 10”N and 33° 33’ 25” N and 66° 10’ 00” E and 66° 27’ 40” E. The length of the reservoir is measure about 43 km in length and 15.10 km in width at its longest and widest point of reservoir. The reservoir surface area is 74.82 km^2 in 1435m elevation from mean sea level with volume of 4709.12 Mm^3.

Hight of the proposed Gizab reservoir catchment area is varying from 1299m to 5036m w.r.t mean sea level (Fig. 2) with area of 22070 sq km. The catchment area is embodied by large hills, buried pediments, vallies and alluvial plains. The soil textures are silty clay, sandy, loamy and alluvium. The upper-Helmand river basin originated in a westerly extension of the Hindu Kush mountain range near Paghman about 40 kilometers west of Kabul and runs southwesterly to the proposed Gizab reservoir. The river water runoff comes mostly from rainfall at the average elevations of the

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basin in winter and spring season and from snow melting of the glaciers at the high altitude of mountains which escalate to elevations of 5036 meters. Range of Annual precipitations varies between 100mm to 670mm and precipitate mostly at higher altitudes during winter and spring. The Mountains cause many local variations, though the upper-Helmand river basin is categorized by a dry continental climate. The temperature of this region is varying from minus (-)10 °C in winter to plus (+) 34 °C in summer. The fluctuations in temperature are not uniform in character all over the whole basin.

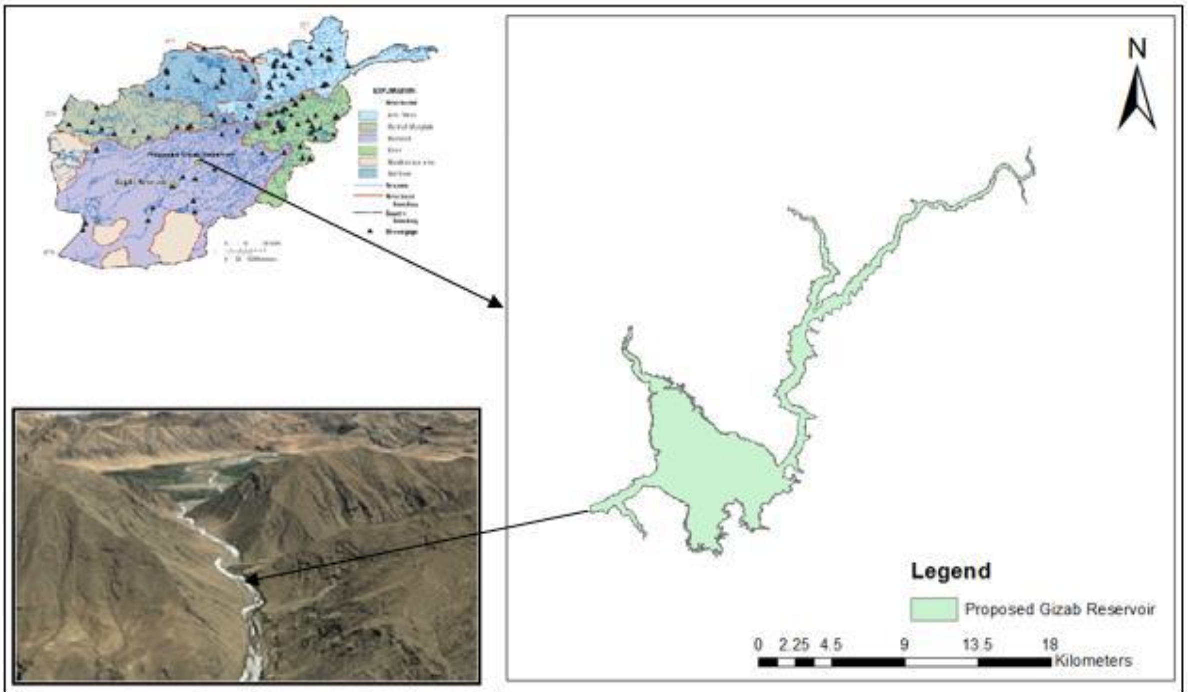

Fig.1: Study Area of proposed Gizab reservoir

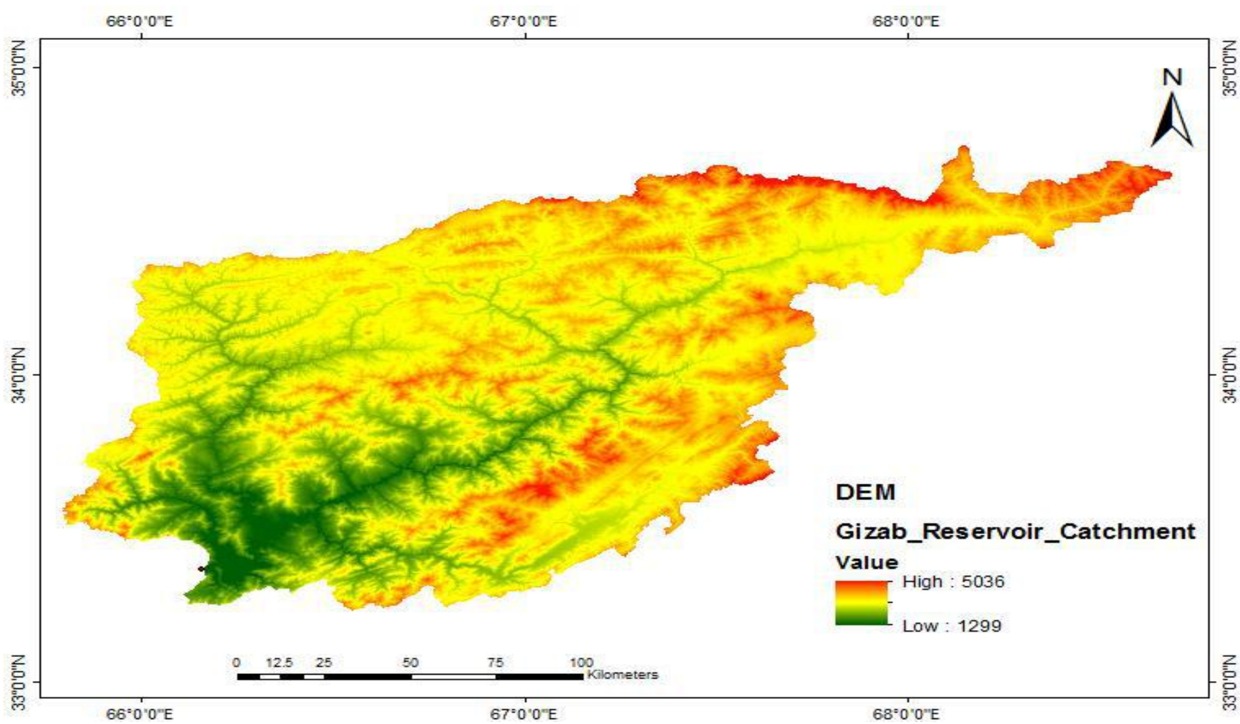

Fig.2: Digital Elevation Model of Gizab Reservoir Catchment Area

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III. METHODOLOGY

3.1 Data Accusation

DEM (Digital Elevation Model) is derived from ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) and downloaded from http://earthexplorer.usgs.gov/. The contour map is generated from ASTER DEM in Global Mapper 18. Stream flow of the Gizab reservoir is downloaded from Water Atlas of Afghanistan.

3.2 Mass Curve

A cumulative plotting of net reservoir inflow versus time duration is a mass curve (or Ripple diagram, 1882) and is expressed as:

$$V(t) = \int_0^t Q(t)\, dt \quad (1)$$

Where $V(t)$ = Volume of runoff and $Q(t)$ = Reservoir inflow, both as function of time.

At any point on the mass curve the slope of the tangent of that point shows the rate of flow at that point on the mass curve and expressed as

$$Q(t) = dV(t)/dt \quad (2)$$

In the design of a reservoir storage capacity, operations procedure and flood routing the mass curve hasvaluable applications.

Mass curve preparation procedure is given below:

Plot mass inflow curve from the flow hydrography of the site for a number of consecutive years

Plot the mass demand curve corresponding to the given rate of demand.

Draw the tangential line parallel to the mass demand curve at peak point of mass inflow curve

Determine the vertical intercepts between the tangential lines and the mass inflow curve.

Determine the largest of the vertical intercept determined in step (4).

The largest vertical intercept represents the storage capacity required.

3.3 Hydro-Power Potential Head

ASTER DEM 30 x 30m is used in Arc-GIS 10.3 platform with Arc-Hydro Tools to delineate catchment area under the study. The delineated watershed and ASTER DEM 30 x 30m of proposed Gizab reservoir is used in Global Mapper 18 to generate contours line map for the reservoir and dam site. The area of each contours are created in Global Mapper 18. Both shape files of contours line map and area of each contour are exported to Arc-GIS 10. Further, from contours line map the Triangular Irregular Network (TIN) is created from Data Management in 3D Analyst Tools. The volume and surface area of each contour is derived from Triangular Surface in 3D Analyst Tools. MS-Excel is used to find the net head of reservoir all the methodology framework is described in Fig.4.

Power generation is always depending on two important parameters discharge and head of water from upstream to downstream. Penstock is conveying water from storage reservoir to powerhouse with turbines. The power potential of flowing water is function of discharge, specific weight of water and head between turbine and reservoir active storage capacity level. Hydro-Power potential of water is express mathematically as below:

$$P = \eta\, \gamma\, Q\, H \quad (3)$$

Where P = Power (W)

$\gamma = \rho\, g$ = Specific weight of water (N/m3)

ρ = Mass density (kg/m3) = 1000 kg/m3 for water

g = Acceleration due to gravity (m/s2)

Q = Discharge (m3/s)

H = Head (m)

η = hydraulic turbine efficiency and its typically value is taken from Table. 1

Table.1: Typical efficiency value of different type of turbine

Turbine Type	Efficiency value range
Impulse Turbine	
Pelton	80-90%
Turgo	80-95%
Cross flow	65-85%
Reaction Turbine	
Francis	80-90%
Pump as turbine	60-90%
Propeller	80-90%
Kalpan	80%

Based on the below chart Fig. 3 the turbine was selected for the propose Gizab reservoir

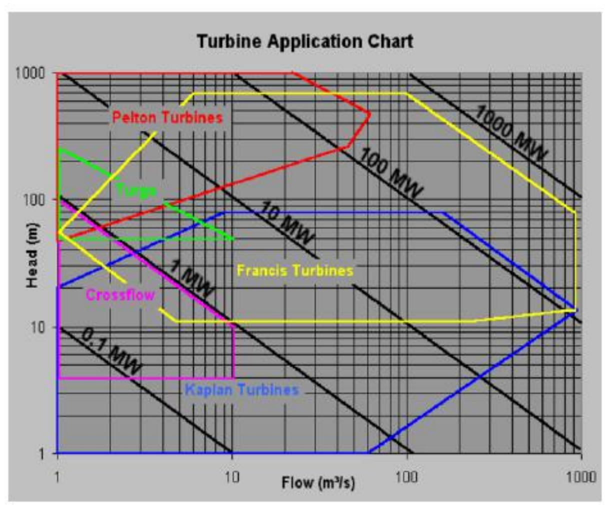

Fig.3: Turbine selection chart
http://rivers.bee.oregonstate.edu/book/export/html/35

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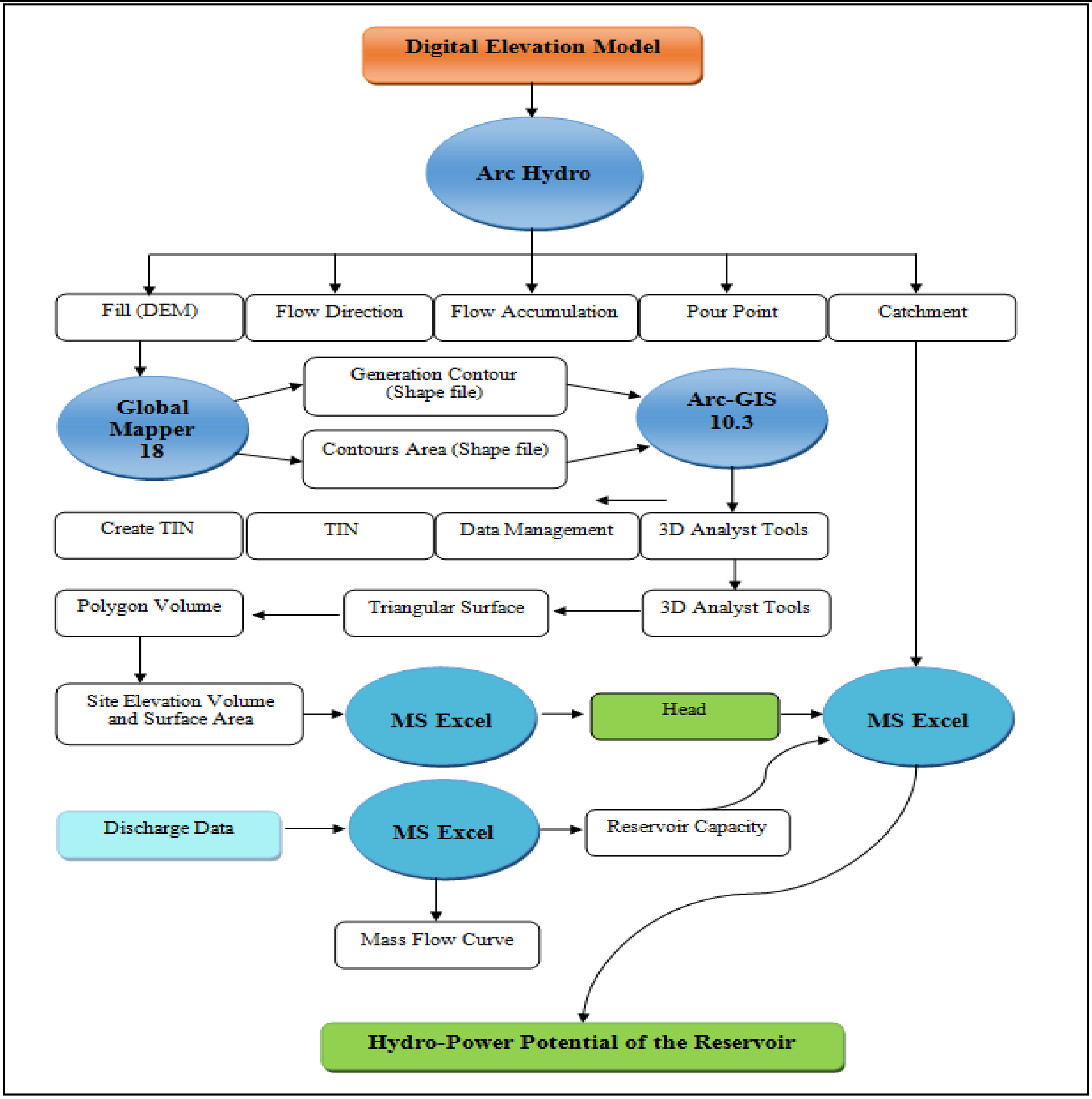

Fig.4: Methodology Framework of Reservoir Capacity and Hydro-Power Potential Head

IV. RESULTS AND DISCUSSION

The relief of the proposed Gizab reservoir catchment area is 3737m. The contours elevation of the proposed reservoirin proposed site is started from 1310m to 1530mfrom mean sea level and carried out by Global Mapper 18. Therefore, reservoir area and volume of each contour is carried out form ASTER DEM using Global Mapper 18and Arc-GIS 10.3 which is given in Table 2.The relationship between elevation -volume and relationship between elevation-area is shown in Fig. 5. Finally the gross potential head of the reservoir full supply level to powerhouse is 130m and the net potential head is 117m with 10% head loss in the conveying. Ten percent of total reservoir storage capacity is used for dead storage capacity of sediment trapping for the design period. The volume of dead storage capacity is 470.912 Mm^3 which is coming under the contour of 1349m height from mean sea level.

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Table.2: Contours Elevation, perimeter, volume and surface area of proposed Gizab reservoir

Contour Name	**Contour Elevation (m)**	**Perimeter (sq km)**	**Volume (Mm^3)**	**Surface Area (sq km)**
1310	1310	0	0	0
1315	1315	13.67	3.633	0.866
1320	1320	42.914	20.354	4.608
1325	1325	32.796	67.914	10.849
1330	1330	37.824	129.316	13.043
1335	1335	41.243	200.831	15.099
1340	1340	45.301	284.119	17.477
1345	1345	50.918	379.391	20.308
1350	1350	52.088	490.504	22.861
1355	1355	68.907	640.255	27.266
1360	1360	82.246	790.932	30.948
1365	1365	92.505	956.390	34.211
1370	1370	103.76	1141.456	37.831
1375	1375	103.58	1335.163	40.461
1380	1380	108.42	1543.405	43.199
1385	1385	111.87	1758.255	45.502
1390	1390	129.6	2000.683	49.065
1395	1395	133.49	2248.741	51.769
1400	1400	137.12	2508.345	54.407
1405	1405	143.84	2781.632	57.305
1410	1410	153.51	3071.348	60.459
1415	1415	153.2	3372.173	63.308
1420	1420	159.39	3686.185	66.030
1425	1425	162.8	4013.118	68.960
1430	1430	166.98	4353.152	71.769
1435	1435	175.06	4709.118	74.822

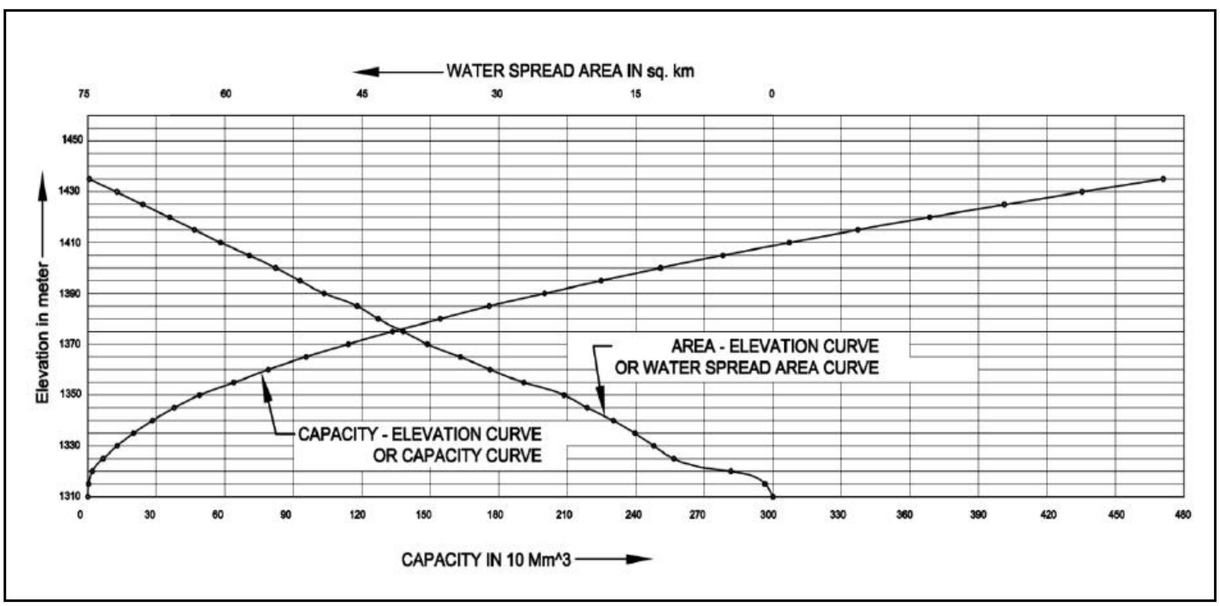

Fig.5: Capacity-Elevation and Area-Elevation curve of proposed Gizab Reservoir

The mean monthly discharges are given in Table.3 the maximum discharge is 310.347 m^3/s in the month of June and the minimum discharge is 30.119 m^3/s in the month of December. The average discharge of 12 month is 100.899 m^3/s. The reservoir storage capacity form the mean monthly inflow is driven from mass curve is 1114.356 Mm3 Fig.6. Also the reservoir storage capacity is driven analytically from monthly mean inflow Table.3.

Table.3: Mean monthly inflow and propose Gizab reservoir capacity

Date	**Inflow in m^3/s**	**Inflow in Mm^3**	**Demand in m^3/s**	**Demand in Mm3**	**Deficit In Mm3**	**Surplus in Mm3**
Jan.	32.465	86.955	100	262.660	175.705	
Feb.	36.081	93.523	100	262.660	169.137	
Mar.	38.577	103.326	100	262.660	159.334	
Apr.	55.657	149.073	100	262.660	113.587	
May.	55.227	133.606	100	262.660	129.054	
Jun.	178.966	479.344	100	262.660		216.684
Jul.	310.347	804.419	100	262.660		541.759
Aug.	240.462	644.053	100	262.660		381.393
Sep.	105.050	272.290	100	262.660		9.630
Oct.	97.372	260.801	100	262.660	1.859	
Nov.	30.119	80.670	100	262.660	181.990	
Dec.	30.467	78.971	100	262.660	183.689	
Total					1114.356	1149.465

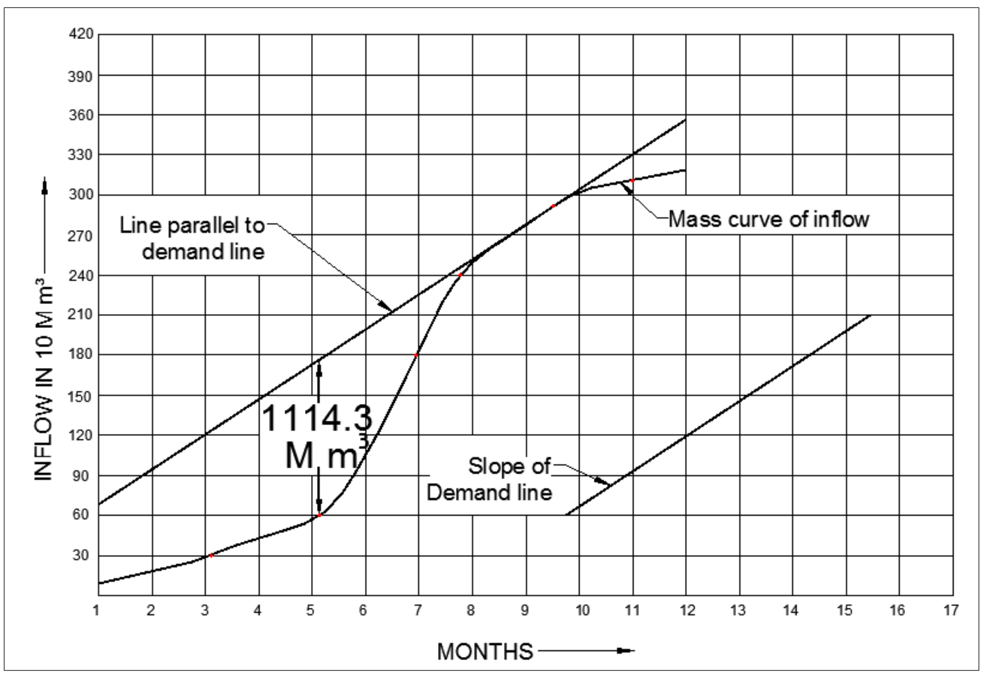

Fig.6: Mass inflow curve diagram of Gizab reservoir

Based on the flow rate and estimated net available water potential head 117 m the assessed hydropower potential is calculated using Eq. (3) as 91.822 MW. Francis turbine has selected for this study from turbine selection chart and the hydraulic efficiency of the turbine is 80%. The analysis shows that the Gizab reservoir has a good storage capacity with a good water potential head for the generation of hydropower establishment.

V. CONCLUSION

- The reservoir capacity is the most important aspect for hydrologic design.
- The reservoir capacity is design for mean monthly inflow data of several years using Mass Curve method and the storage capacity is 1114.3 Mm^3.
- The gross storage volume of the proposed Gizab reservoir is 4709.118 Mm^3 and carried out from ASTER DEM using Global Mapper 18 and Arc-GIS 10.3.
- The gross potential head of the reservoir full supply level to powerhouse is 130m and the net head for the generation power is 117m with 10% head loss of gross potential head at system operation.
- The Francis turbine with 80% efficiency has used for the study.
- At available head with use of Francis turbine and its efficiency of 80%, the hydropower potential is 91.822 MW.

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