Development of Flow Duration Curves for Malaprabha and Ghataprabha sub basins of Krishna River

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Abstract—**The linking of hydrologic processes with ecological outcomes is a starting point for effective, holistic stream restoration design. The basic parameters which are essentially part of the stream flow hydrograph that regulate ecological processes in riverine ecosystem includes magnitude, frequency, duration, timing, and rate of change. Quantification of magnitude, frequency, and duration may be at least in part may be understood through flow duration curve (FDC). FDCs illustrate the percent of time a flow occurred during a given period of record and provide a wealth of information regarding the flow character of a river which is highly essential for river hydrology and ecological studies. In the present study the flow duration curves were derived for two sub basins of Krishna River catchment namely Malaprabha and Ghataprabha basins. The estimated discharge of Malaprabha river corresponding to probability of exceedance of 30%, 50% and 90% are found to be 53.77 m^3/sec, 19.68 m^3/sec and 0.94m^3/sec respectively. In the case of Ghataprabha, the flow varies between 12.73 m^3/sec,78.01m^3/sec and 12.73 m^3/sec with probability of exceedance of 30, 50and 90 per cent respectively. The steep slope found in both the basins throughout indicates a highly variable stream whose flow is largely due to quick runoff of rainfall to the stream. The estimated flow is quite significant in determining the minimum flow required to keep the ecological balance in the stream channel.**

Index Terms— **Probability of exceedence, Flow Duration Curve (FDC), Catchment, Frequency curve**

I. INTRODUCTION

Water is the basic need for human activities and for animals in addition to agricultural and industrial purpose along with many other purposes. For proper management of water it is necessary to plan and design water retaining structures which are essential for efficient distribution of water through harvesting and conservation of water resources. Water resource structures are necessary to ensure the supply of required water demand from various sectors in particular agricultural, drinking and industrial water demand. Flow Duration Curve (FDC) is the complement of the cumulative distribution function of daily stream flow, charactering the relation between the daily, weekly, monthly and yearly (or another time) flow amount and its frequency. They provide a graphical and statistical view of historic stream flow variability in a single catchment or a comparison of inter catchment flow regimes. The Flow Duration Curve is a graph which show percentage of time that flow in a stream or watercourse is likely to equal or exceed some specified value of interest. It is sometime also called Discharge-Frequency Curve or Cumulative-Frequency Curve.

In general, FDCs sort out stream flow data by shifting high flows with high precipitation signals to one end of the curve, medium flows to the middle, and low flows (presumably with low precipitation signals) to the other end of the curve. According to Fennessey & Vogel (1990), FDC applications should be limited to problems in which the sequential nature of stream flow is not important, thereby acknowledging FDC limitations for many reservoir operations issues. Castellarin et al. (2004) reviewed regionalization approaches to predict FDCs and classified these estimation procedures into statistical (Claps et al., 2005), parametric (Mimikou & Kaemaki, 1985) and graphical approaches (Smakhtin et al., 1997).Stream restoration does not exist as an isolated field of study but instead at the intersection of hydrologic and hydraulic engineering, terrestrial and aquatic ecology, geomorphology, geology, and biogeochemistry. Palmer and Bernhardt (2006) identify the linking of hydrologic processes with ecological outcomes as a starting point for effective, holistic stream restoration design. Accordingly, traditional engineering approaches of quantifying hydrologic processes may be adapted and applied to quantify ecological outcomes (Fischenich and McKay 2011). Poff et al. (1997) identified five critical components of a stream flow hydrograph that regulate ecological process in river ecosystems: magnitude, frequency, duration, timing, and rate of change. Importantly, many of these variables are correlated and care should be taken to avoid redundancy in analyses (Olden and Poff 2003). Quantification of magnitude, frequency, and duration may be — at least in part — accomplished by a traditional tool of the river engineer, the flow duration curve (FDC).Development of Regional Flow Duration Curves which will ultimately help in estimating the flow in an ungauged catchments. In the present study, two catchments with similar kind of geology, soil and land use types were identified in parts of North western part of Karnataka with available flow data.

II. Study Area

The study area Malaprabha and Ghataprabha are the tributaries of river Krishna catchment (Figure 1a) and originates from Western Ghats region of Karnataka and Maharashtra respectively. The Malaprabha River originates from Chorla Ghats, at an elevation of about 792 m about 35m south-west of Karnataka in the district Belgaum. Before meeting the river Krishna it traverses a length of 306 km. The principle tributaries of Malaprabha catchment are Bennihall and Hirehalla. Ghataprabha River originates in Chaukul, a village in Sawantwadi taluka of Maharashtra at the eastern part of the Hiranyakeshi River, one of its important tributaries. The river joins the Krishnaat Kudalisangam at an elevation of 500 m, about 16 km from Almatti. It enters Karnataka and flows for about 283 km covering parts of Belgaum and Bijapur districts. The tributaries called Tamraparni and Markandeya are few of the major tributaries which contributes flow into Ghataprabha River at different locations.

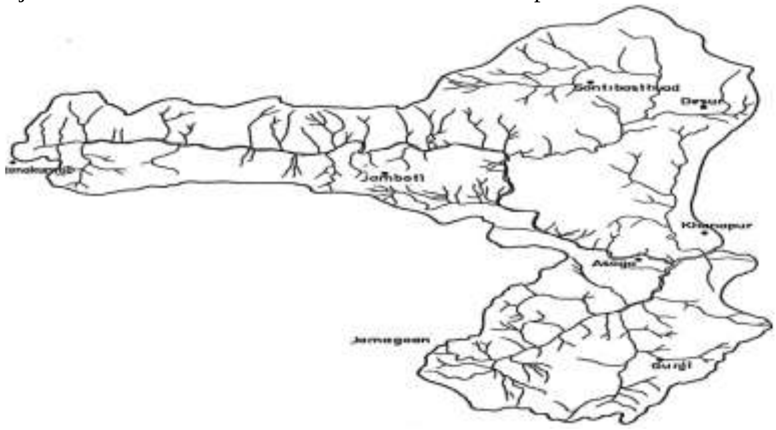

Figure 1a: Malaprabha sub-basin up to gauging site (Khanapur)

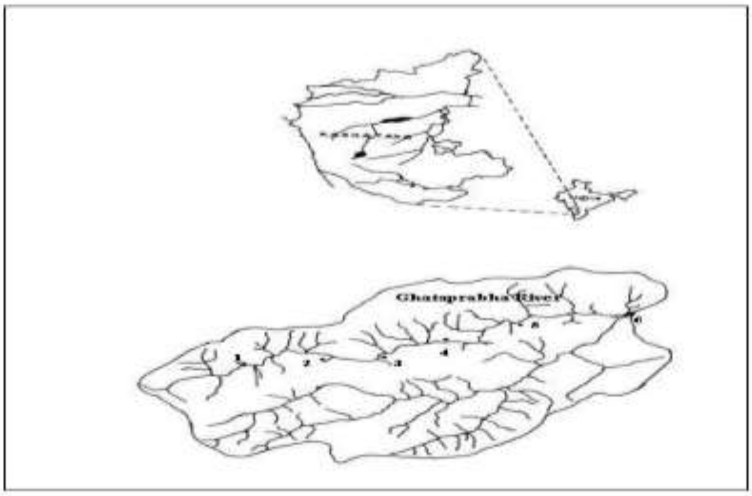

Figure 1b: Ghataprabha sub-basin up to gauging site (Daddi)

III. Methodology

Data pertaining to flow was collected from WRDO, Bangalore. Catchment details and hydrological information have been collected from NIH, Belgaum. The procedure adopted for the study is shown below.

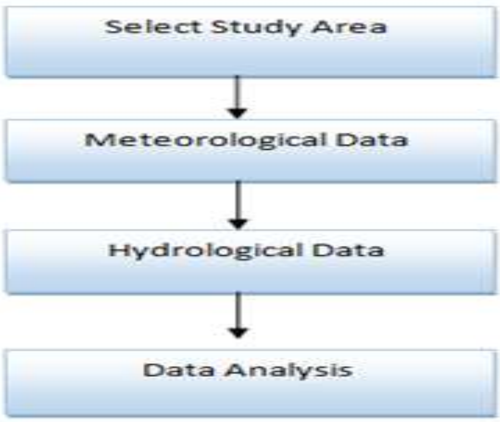

Figure 2. Flow Chart defining the work executed.

In the present work, the flow duration curves were developed using McCarthy Excel with the Method of moments and the Weibull's methods (Castellarin, et al 2004) for the available annual flow data. The data was collected from WRDO (Water Resources Development Organisation), Bangalore, Karnataka.

IV. Result and Discussion

Figure 3 shows the flow hydrograph of the Malaprabha river observed at Khanapur gauging station for the years 1980 to 1990. It is observed that the peak flow varied between 200 cumecs and 800 cumecs during June-July months of every year. In the subsequent months there is a drastic reduction in the flow which ultimately reduced to negligible flow condition from the month of November to May. It can also be noticed that the months of March, April and May experience very low flows. The year 1985 to 1987 receives lesser rainfall may be because of change in the rainfall pattern and the climate. The change may also due to the change in the land use and land cover in that area.

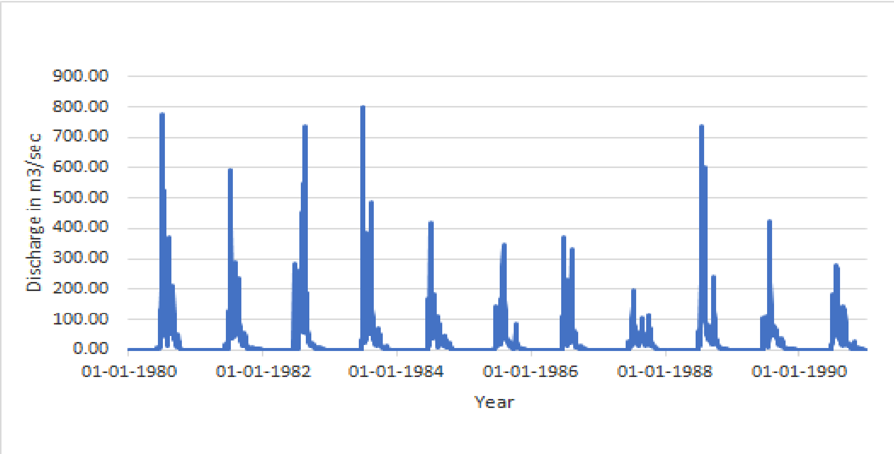

Fig. 3. Daily Flow Hydrograph for the period from 1980 to 1990.

The daily discharge data of Ghataprabha (figure 4) river was analysed for period from 2003 to 2015 and the highest discharge observed was 1395.44 cumec which was recorded in the month of September. The daily discharge, similar to Malaprabha River, it varies between 150 cumecs to 1400 cumecs which was observed in the year 2012. The higher discharge in the Ghataprabha is attributed to the catchment size which is two times greater than Malaprabha.

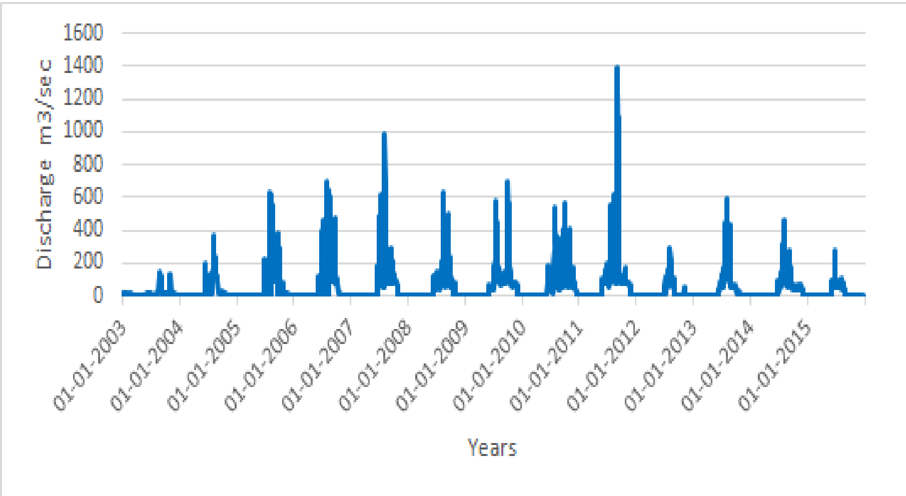

Figure 4. Daily Flow Hydrograph for the period from 2003 to 2015 (Ghataprabha river)

The annual discharge values for the period 1980 to 1990 are shown in figure 5. It is observed that there is a reduction in the flow pattern from 1980 to 1990. Minimum annual flow was observed in the year 1987 and the maximum was in 1980. This wide variability in flow pattern could be attributed to change in rainfall pattern and catchment characteristics such as land use, soil cover and morphological changes.

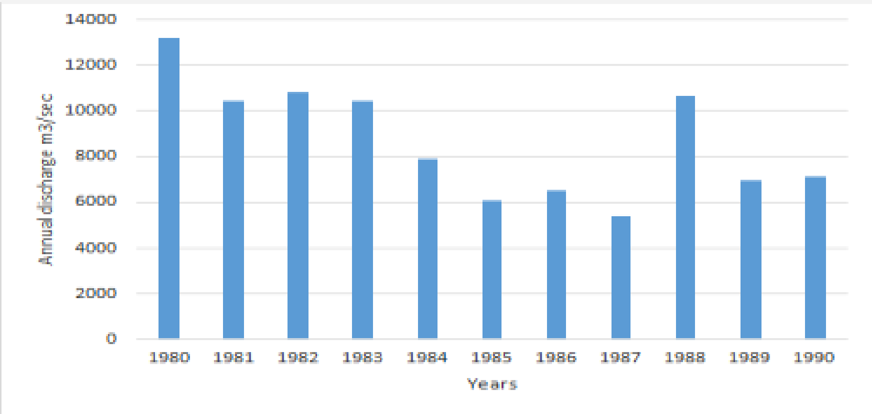

Figure5. Annual Flow Pattern of Malaprabha river from year 2003 to 2015.

The annual discharge of Ghataprabha River shows that the flow varies significantly from 5000 cumecs to 35000 cumecs during the period from 2003 to 2015. Minimum annual flow observed was 5000 cumecs in the year 2003 and the maximum was 34000 cumecs in the year 2011.

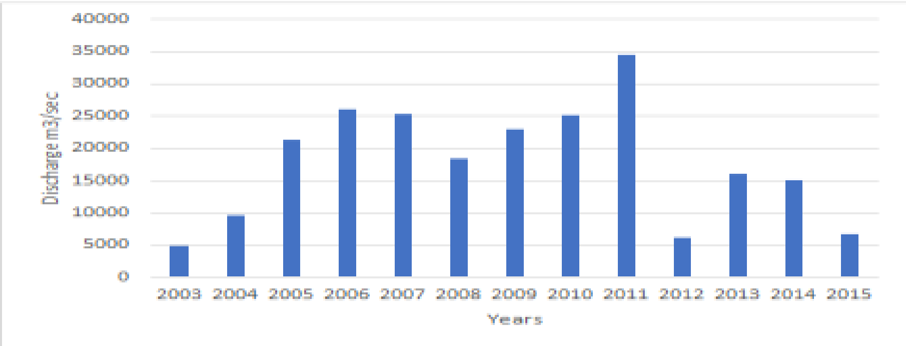

Figure6. Annual Flow Pattern of Ghataprabha river from year 2003 to 2015.

Flow Duration Curve for Malaprabha River Sub-basin

The flow duration curve (figure 7) of Malaprabha river based on daily data indicates that the flow which exceeds 90% probability is only 0.94 cumecs. The flow variation with probability of exceedance at 30% and 50% are 19.68 cumecs and 53.77 cumecs. This clearly confirmed that the river maintains low flows during majority of the observation period.

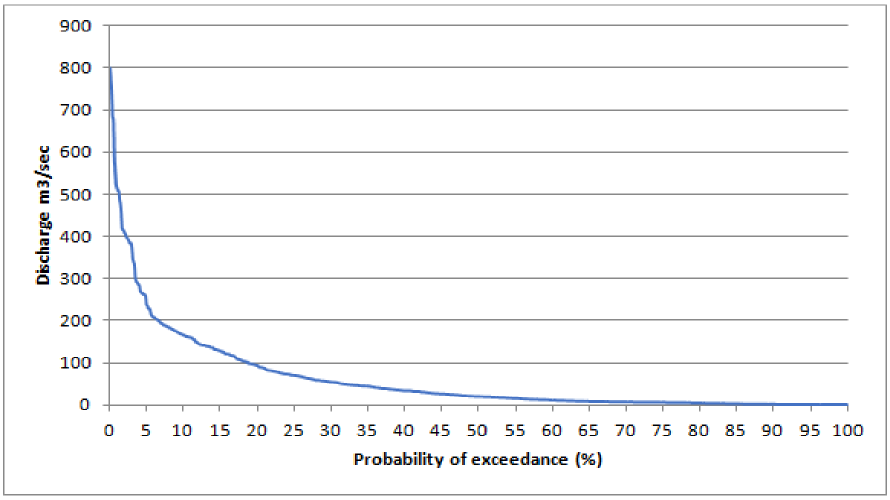

Figure 7. Flow Duration Curve of Malaprabha Sub-basin (1980-1990)

Figure 8 illustrates the flow duration curve of Ghataprabha river basin. The probability of exceedance varies between 12.73 cumecs (90%) and 118.26 (30%). An intermediate flow of 78.01 cumecs was observed with the probability of exceedance of 50%. The flow in the Ghataprabha river shows a considerable flow even during lean flow season.

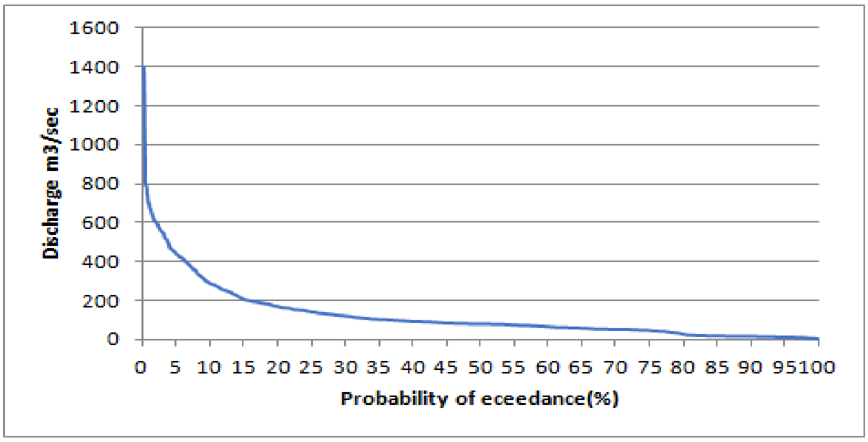

Figure.8 Flow Duration Curve of Ghataprabha Sub-basin (2003-2015)

V. CONCLUSIONS

The hydrographs of both Malaprabha and Ghataprabha sub-basins shows large variations in the flow pattern. In Malaprabha sub basin the probability of exceedence of flow at 90% is 0.94 m^3/sec, followed by 53.77 cumecs at 50% and 19.68 m^3/sec at 30%. Ghataprabha sub-basin exhibited higher flow at all levels of probability of exceedence, i.e.12.73 m^3/sec at 90%, 78.01m^3/sec at 50% and 118.26m^3/sec at 30%. Ghataprabha shows higher flow than Malaprabha which is attributed to variation of rainfall and catchment characteristics.

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