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Low Flow Charecterzation of Satluj River

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Abstract
The present study was envisaged to estimate low flow characterization of Satluj River. For the present study, Satluj river basin upto Kasol gauging site has been considered and the low flow charecterzation has been done at three locations viz. Rampur, Suni, and Kasol. The daily discharges of Satluj River at these sites for the years 1964-2011 were used for low flow characterization. These data have been aggregated to construct the average monthly, average 10-daily and average weekly discharge series. Flow duration curves for Satluj River at these three sites have been obtained by using the Weibull's plotting method. For this purpose, average monthly discharge series has been used. Further, the flow characteristics related to low flow domain estimated in the present study were Mean Annual Runoff (MAR), Absolute Minimum Flow (AMF), Q20, Q50, Q90, Q20/Q90, Q50/Q90, and Q90/Q50, these parameters have been obtained by using the mean monthly flow series of Satluj River at these three sites. Mean annual runoff of Satluj river varies from 10,606.43 MCM (Rampur) to 13,192.72 MCM (Kasol); Absolute minimum flow from 44.18 cumecs (Rampur) to 73.05 cumecs (Kasol); Q20 from 625.75 cumecs (Rampur) to 826.55 cumecs (Kasol), Q50 from 167.25 cumecs (Rampur) to 206.14 cumecs (Kasol), Q90 from 84.60 cumecs (Rampur) to 98.34 cumecs (Kasol), Q20/Q90 from 7.39 (Rampur) to 8.41 (Kasol), Q50/Q90 from 1.98 (Rampur) to 2.10 (Kasol), and Q90/Q50 from 0.47 (Kasol) to 0.51 (Rampur) respectively.Further, Low Flow frequency curves have also been developed for average weekly and average 10 daily flows. The flow characteristics related to low frequency analysis estimated in the present study are mean of annual series of minimum 10-day average flow (MAM10), mean of annual series of minimum 7-day average flow (MAM 7), 10 day and 7 day minimum flows corresponding to 10 and 2 year return periods respectively (10Q10, 10Q2,7Q10, 7Q2). These parameters have been obtained by using the average 10 daily and weekly flow series of Satluj River. Minimum 10-day average flow (MAM10) of Satluj River varies from 80.67 cumecs (Rampur) to 92.30 cumecs (Kasol); 10Q2 varies from 78.45 cumecs (Rampur) to 89.91 cumecs (Kasol) and 10Q10 varies from 102 cumecs (Rampur) to 112.46 cumecs (Kasol). Similarly, for average weekly flow, minimum 7-day average flow (MAM 7) varies from 79.02 cumecs (Rampur) to 91.10 cumecs (Kasol); 7Q2 varies from 78.05 cumecs (Rampur) to 89.11 cumecs (Kasol) and 7Q10 varies from100.1 cumecs (Rampur) to 109.63 cumecs (Kasol) respectively. All these values are a very good indicator of aquatic habitat for various species during different growth stages and environmental flows globally are used for recommending.
Keywords: Environmental Flow, Flow Duration Curve, Low flow characterization, Satluj River.

1. Introduction

The river system is considered as one of the most vital components of the natural ecosystem that is closely related to the humans. For a long period, the water flowing from the rivers into the sea has been considered as a waste. During the 1960s, the developed nations primarily concentrated on maximisation of water management through flood protection, water supply and hydropower generation. As a result, there was huge modification made in the flow of the rivers due to the construction of impoundments such as dams and weirs, extraction of water for agriculture, irrigation and urban purposes, maintain the flow for navigation purposes, drainage water inflow, and flood management structures (Dyson et al., 2003; Postel and Richter, 2003). Environmental flows serve to represent water allocation for ecosystems. As ecosystems, in turn, provide services to people, providing for environmental flows is not exclusively a matter of sustaining ecosystems but also a matter of supporting livelihoods of village people who make direct use of river water for a variety of purposes including religious worship.

1.1 Objective

The main objective of this paper to characterize the low flow hydrologic profile of the Satluj River.

2. STUDY AREA

Himachal Pradesh is drained by a number of rivers and streams. Satluj is an important river that rises in Tibet. The name Satluj is derived from the Sanskrit name “Satadru” or “Satudri” meaning "running in a hundred streams". The Satluj is believed to be an antecedent river because of its existence prior to the phase of Upper Pleistocene uplift of the Himalaya, which is evident from the formation of canyons and gorges along its course. For this present study, the Satluj River basin up to Kasol gauging site has been considered. The basin area of Satluj River at Rampur, Suni, and Kaol sites are 50,800 sq.km, 52,983 sq.km, and 53,768 sq.km respectively. The daily discharge data of Satluj River at Rampur, Suni and Kasol for the years 1964-2011 have been used for the analysis.

3. METHODOLOGY

The methodology followed in the present study has been elaborated in the following sub-sections of low flow charectrization.

LOW FLOW CHARACTERIZATION: The term ‘low flow measure’ is used here, and refers to the various methods that have been developed for analyzing that is in the form of graphical form at which the low flow regime of a regime can be obtained. The term ‘low flow index’ is used dominantly to define particular values obtained from any type of low flow measures.

3.1 Flow Duration Curve: A flow duration curve (FDC) is one of the most descriptive methods of exhibiting the complete range of river discharges from low flow to high flow (flood) events. It is a relationship between magnitude and frequency of stream flows discharges. FDC may be constructed using different time resolutions of stream flow data: annual, monthly, m-day or daily. In the present study of flows, monthly, weekly and ten daily flows are available; hence these are used for the derivation of FDC. An FDC is constructed by challenging the flow time series values in decreasing order of magnitude.

m = order of event, N = total number of events

Probability, P = m/ (N+1)

3.2 Low Flow Domain: The arbitrary ‘upper bound’ to low flow hydrology may be given by the Mean Annual Runoff (MAR), which is mean value of the available flow time series of total annual flow. The lowest recorded ten daily discharges may be referred to as Absolute Minimum Flow (AMF). The information content of this index varies with the length of record of flows and depends upon the measuring limits of stream flow gauges. Where, Q20 is discharge corresponding to 20% exceedance probability,Q50 is discharge corresponding to 50% exceedance probability,Q90 is discharge corresponding to 90% exceedance probability, Q20/Q90 is Measure of streamflow variability, Q50/Q90 is measure of variability of low flow discharge and Q90/Q50 is index representing proportion of flow originating from ground water storage.

3.3 Low Flow Frequency Analysis: A low flow frequency curve (LFFC) shows that return period or recurrence interval that the river falls below a given flow rate. LFFC is constructed on the basis of a series of annual flow minima (daily or monthly minimum discharge or flow volumes), which are extracted from the available original continuous series (one value from every year of record) where, MAM10 is the average of annual series of minimum 10-day average flow is known as Dry Weather Flow or Mean Annual 10-day Minimum Flow (MAM10), MAM 7is the average of annual series of minimum 7-day average flow is known as Dry Weather Flow or Mean Annual 7-day Minimum Flow (MAM7), 10Q10 is 10-day minimum flow corresponding to 10 year return period, 10Q2 is 10-day minimum flow corresponding to 2 year return period, 7Q10 is 7-day minimum flow corresponding to 10 year return period and 7Q2 is 7-day minimum flow corresponding to 2 year return period.

4. RESULTS AND DISCUSSION

LOW FLOW CHARACTERISATION OF SATLUJ RIVER: The daily discharge data for Satluj River at Rampur, Kasol and Suni for the years 1964-2011 have been used for low flow characterization of Satluj River at these three sites. These data have been aggregated to construct the average monthly, average 10-daily and average weekly discharge series of Satluj River at these three locations.

4.1 *Flow Duration Curve*: Flow duration curves for Satluj River at Rampur, Kasol and Suni have been obtained by using the Weibull’s plotting method. For this purpose, average monthly discharge series has been used. It is clear from the figures that all the three FDCs are following very similar pattern except that the discharge values are lowest at Rampur site and highest at Kasol site. This is in agreement with the fact that Kasol site is having larger basin area in comparison to Rampur site. Thus obtained flow duration curves have been presented as Fig.1.

4.2 *Low Flow Domain*: The flow characteristics related to low flow domain estimated in the present study are Mean Annual Runoff (MAR), Absolute Minimum Flow (AMF), Discharges pertaining to 20%, 50% and 90% exceedance probability (Q20,Q50, Q90), Q20/Q90, Q50/Q90, and Q90/Q50. These parameters have been obtained by using the Mean Monthly Flow series of Satluj River at Rampur, Kasol and Suni sites. The values of these parameters are given in Table 1.

4.3 *Low Flow Frequency Analysis*: Low Flow frequency curve have been developed for average weekly and average 10 daily flows as shown in Fig 2 to Fig.3. It is clear from figures that low flow frequency curve pattern is almost similar for given three sites for Average 10 daily and average weekly discharge data. The portion of LFFC representing higher discharges of Suni location are not having the synchronous pattern is that of Rampur and Kasol location. This might be due to some abstraction of water upstream of Suni location due to Rampur Hydropower Project.

The flow characteristics related to low frequency Analysis estimated in our present study, the parameters Have been obtained by using the flow series of minimum average 10 daily Flows and minimum average weekly flows of Satluj River at Rampur, Kasol and Suni sites respectively. The values of these parameters are given in Table 2. All these values are a very good indicator of environmental flow and are used for various hydrological index methods globally.

5. SUMMARY AND CONCLUSIONS

The main objective of this research is to assess the environmental flows by using the suitable methodology based on the data availability for the western Himalayan River. For the present study, Satluj River has been selected for this research as low flow characterization

The daily discharge data for Satluj River at Rampur, Kasol, and Suni for the years 1964-2011 have been used for low flow characterization. These data have been aggregated to construct the average monthly, average 10-daily and average weekly discharge series. Flow duration curves for Satluj River at Rampur, Kasol and Suni have been obtained by using the Weibull's plotting method. For this purpose, average monthly discharge series has been used. Further, the flow characteristics related to low flow domain estimated in the present study were Mean Annual Runoff (MAR), Absolute Minimum Flow (AMF), discharges pertaining to 20%, 50% and 90% exceedance probability (Q20, Q50, Q90), Q20/Q90, Q50/Q90, and Q90/Q50. These parameters have been obtained by using the mean monthly flow series of Satluj River at Rampur, Kasol and Suni sites. Mean annual runoff of Satluj river varies from 10,606.43 MCM (Rampur) to 13,192.72 MCM (Kasol); Absolute minimum flow from 44.18 cumecs (Rampur) to 73.05 cumecs (Kasol); Q20 from 625.75 cumecs (Rampur) to 826.55 cumecs (Kasol), Q50 from 167.25 cumecs (Rampur) to 206.14 cumecs (Kasol), Q90 from 84.60 cumecs (Rampur) to 98.34 cumecs (Kasol), Q20/Q90 from 7.39 (Rampur) to 8.41 (Kasol), Q50/Q90 from 1.98 (Rampur) to 2.10 (Kasol), and Q90/Q50 from 0.47 (Kasol) to 0.51 (Rampur) respectively.

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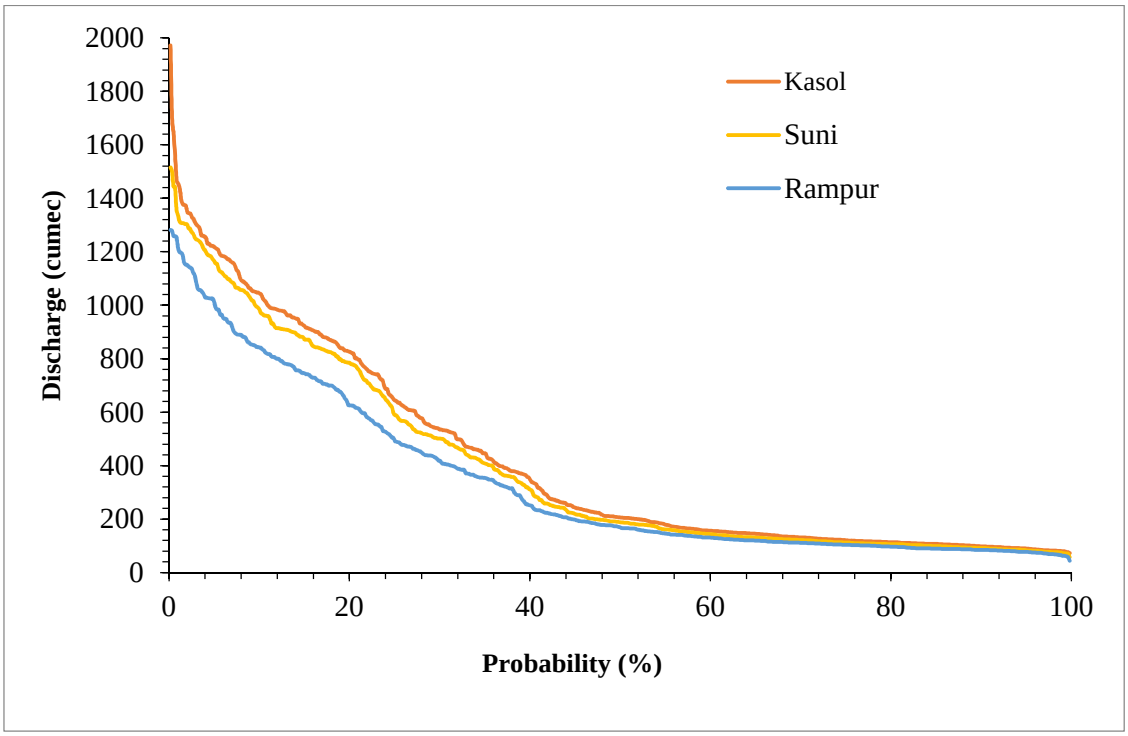

Fig. 1: Flow Duration Curves of Satluj River at Rampur, Suni and Kasol sites

Table 1: Parameters of Low Flow Domain for Satluj River at different location

Parameter	*Rampur*	*Suni*	*Kasol*
MAR, MCM	10,606.43	12324.28	13,192.72
AMF, m3/sec	*44.18*	57.36	73.05
Q20, m3/sec	*625.75*	785.54	826.55
Q50, m3/sec	*167.25*	187.98	206.14
Q90, m3/sec	*84.60*	91.74	98.34
Q20/Q90	*7.39*	8.56	8.41
Q50/Q90	*1.98*	2.05	2.10
Q90/Q50	*0.51*	0.49	0.47

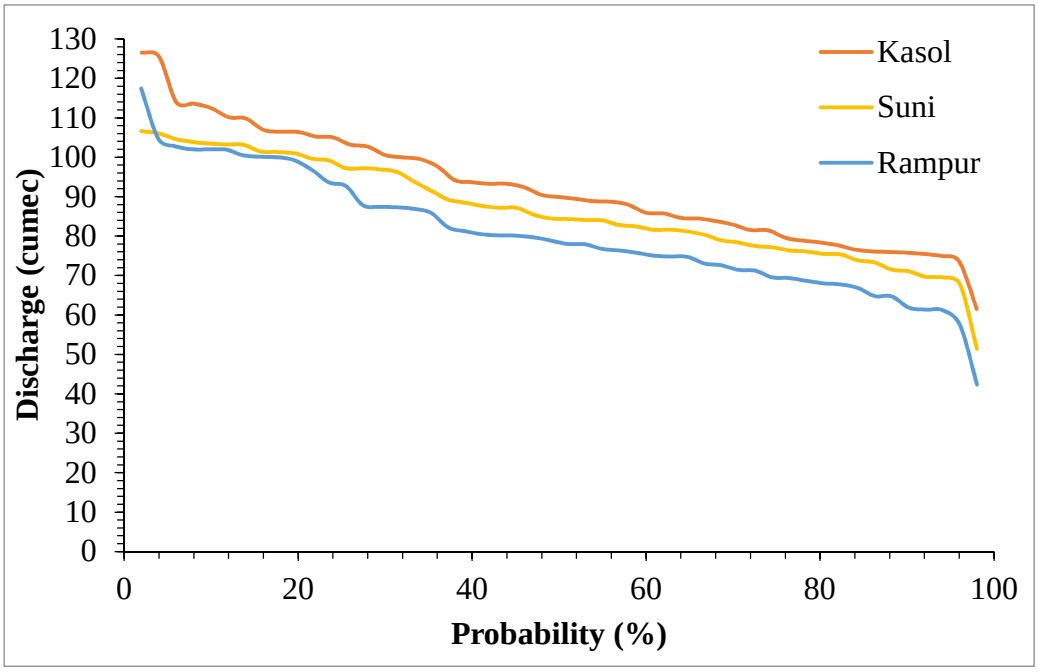

Fig. 2: Low flow frequency curve for average 10 daily discharge data

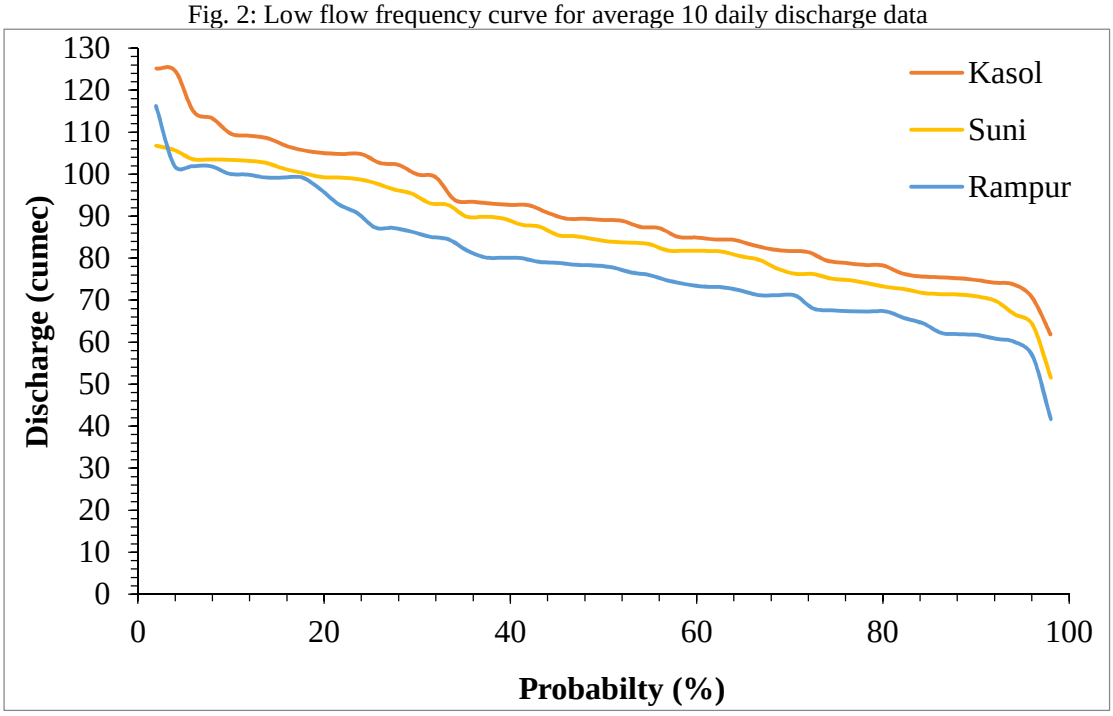

Fig. 3: Low flow frequency curve for average weekly discharge data

Table 2: Parameters of Low Flow Frequency Analysis for Satluj River at different locations

Parameter	*Rampur*	*Suni*	*Kasol*
For average 10 daily flow			
MAM10	*80.67*	86.44	92.30
10Q2	*78.445*	*84.39*	*89.91*
10Q10	*102*	*103.46*	*112.46*
For average weekly flow			
MAM7	*79.02*	85.56	91.10
7Q2	*78.05*	*84.49*	*89.11*
7Q10	*100.1*	*103.4*	*109.63*