Instream Flow Requirement of Dudhkumar River in Bangladesh

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Abstract: *Dudhkumar is an international river shared by Bhutan, India and Bangladesh. Bangladesh being the lowermost riparian country, the water of the river is very vital for the sustenance of livelihood of the people, planning of new water resources projects including evaluation of existing projects and her natural resources at desired level. In-stream flow requirement of Dudhkumar river using three methods of hydrological approaches viz., the Mean Annual Flow, Flow Duration Curve and Constant Yield method have been conducted. All available data on water level and discharge for the period from 1965 to 2008 were utilized in this respect. The study showed that for most of the months during low flow season given due consideration to various demands, there were a deficit or shortage of water in the river, while during flood season most of the demands could be met and duration of deficit period was shorter.*

Keywords: *Instream Flow Assessment, environmental flow, Dudhkumar river, hydrological approach, water demand-availability scenario.*

1. INTRODUCTION

Instream Flow Assessment (IFA) for a river may be defined as an assessment of how much of the original flow regime of a river should continue to flow down it in order to maintain specified, valued features of the ecosystem [1]. instream flow assessment produces one or more descriptions of possible modified hydrological regimes for the river, each linked to a predetermined objective in terms of the ecosystem's future condition such as maintenance or enhancement of the entire riverine ecosystem, maximizing the production of commercial fish species, conserving particular endangered species or protecting features of scientific, cultural or recreational value etc. An instream flow can also be defined for navigation requirements or for hydro-power, as these functions are also dependent on the river ecosystem [2]. Dudhkumar river is located in the north-east corner of north-west region of Bangladesh. It is an international river shared by Bhutan, India and Bangladesh. Within Bangladesh, Kurigram Flood Control, Drainage and Irrigation Project, North Unit (KIPNU) is located on the right side of Dudhkumar river. Dudhkumar river is very important for sustaining the livelihood and environment of the people of the region and for this reason the river has been selected for assessing the Instream Flow Requirement.

1.1. Description of Dudhkumar River

The river originates in the Himalayan foothills in Bhutan and flows south south-easterly direction from the foot hills through India to its outfall into the Brahmaputra river in Bangladesh. The river enters in Bangladesh near Shilkhuri of Bhurungamari Upazila in Kurigram district. Total catchment area of the river is about 5,800 km^2 out of which about 240 km^2 is in Bangladesh. Dudhkumar River is about 220 km of which only 52 km lies in Bangladesh. The catchment area of Dudhkumar along with other international river is shown in Fig. 1.

The mean annual rainfall gradually decreases from 3000 mm in the north to 1800 mm in the south, with an average annual rainfall of 2700 mm [3]. Flows in the Dudhkumar river at Pateswari during the dry season (November to May) comes down to an average of 159 m^3/s and during the monsoon season (June to October) the average flow is about 897 m^3/s. Water level and discharge hydrograph of Dudhkumar river at Pateswari is shown in Fig,2 and Fig. 3 respectively. The sediment size, d_{50}, at Pateswari and Tangonmari is found to be 0.21 mm and 0.16 mm respectively. The average slope of the river is about 10 cm/km.

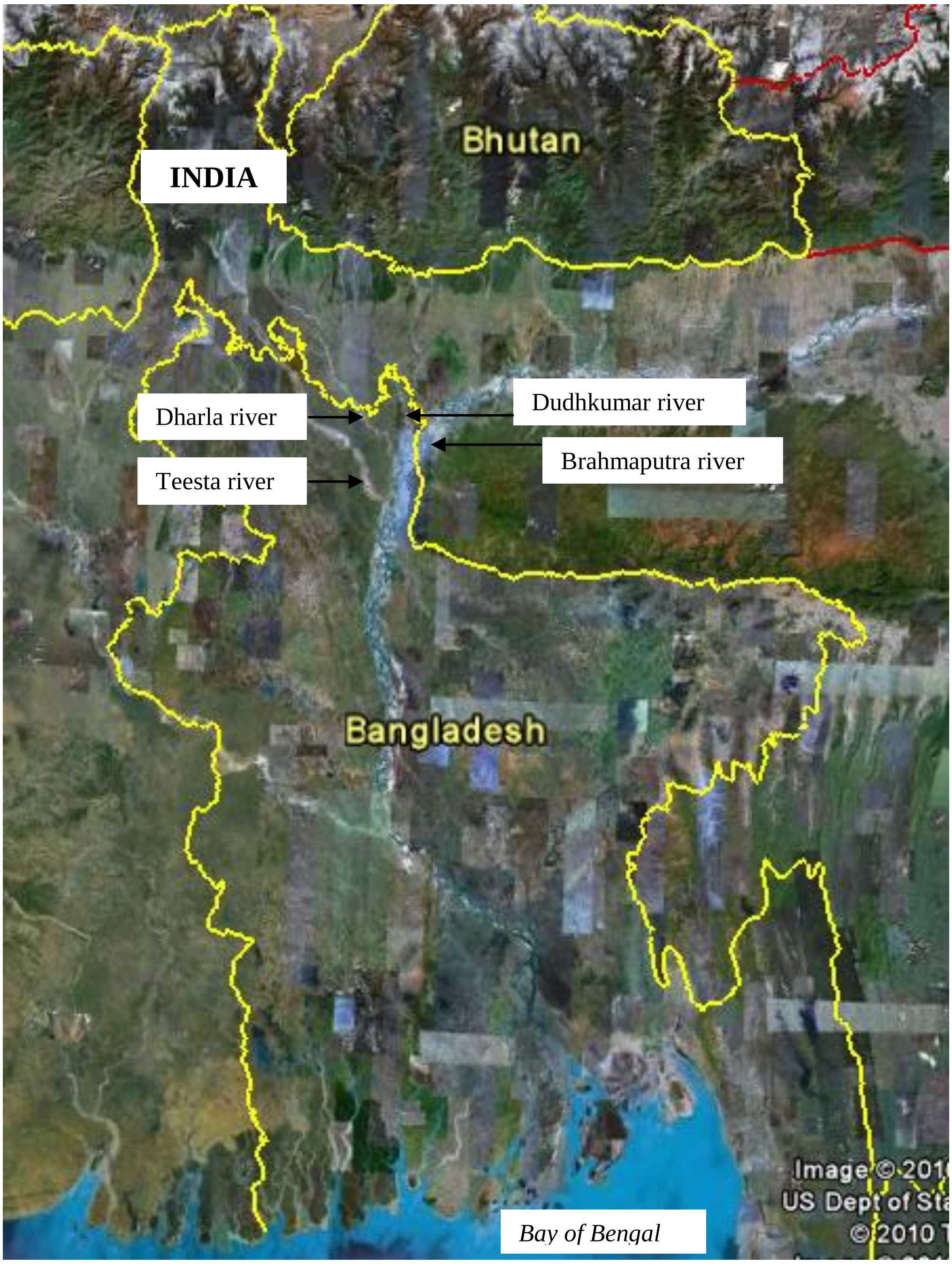

Figure1: Location Map of Dudhkumar River

This high slope makes Dudhkumar a flashy type river during rainy season when onrush of surface runoff due to monsoon rain cause flooding to the flood plain of the river causing bank erosion and destruction of houses and settlement of the people living on both banks.

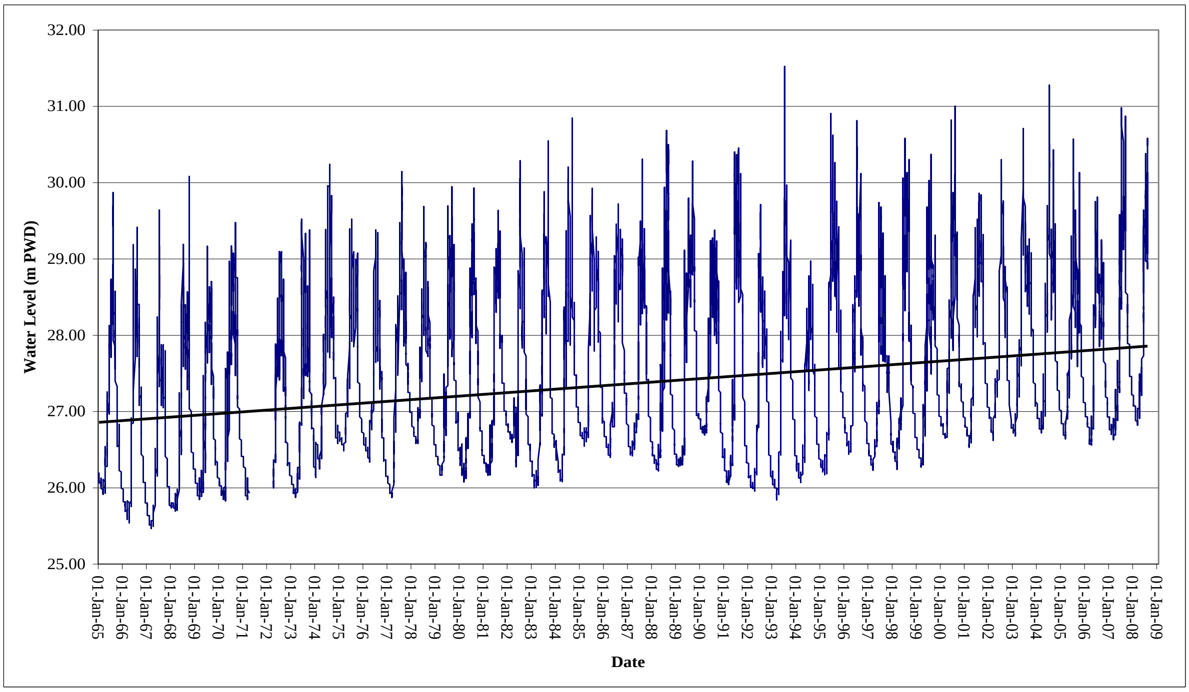

Figure-2: Water Level Hydrograph of Dudhkumar river at Pateswari

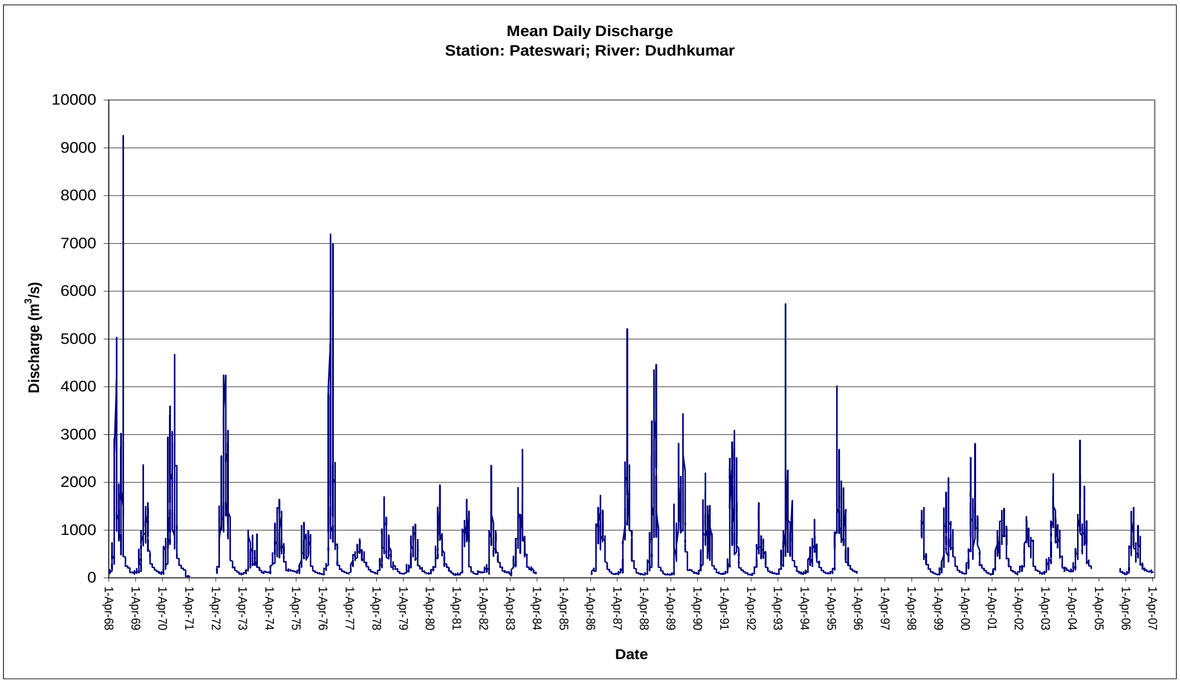

Figure 3: Discharge Hydrograph of Dudhkumar river at Pateswari

2. REVIEW OF LITERATURE

Tharme traced the evolution of environmental flow methodologies worldwide [4]. He noted that the United States of America was at the forefront of research in this field even in the late 1940s and a series of more formally documented techniques emerging in the late 1970s. In most other parts of the world, Environmental Flow Assessment (EFA) processes became established far later. Early on and still today in some countries, the focus of environmental flow assessment is the maintenance of economically important freshwater fisheries [5]. Other notable works on instream flow assessment that are based on use of water for fish, wildlife, ecological processes and other environmental, recreational and aesthetic purposes have been published many investigators [6], [7], [8].Table-1 illustrate that Instream Flow Incremental Methodology (IFIM) became the most widely used method in the United States, followed by other simpler method which are suitable for minor schemes and basin wide planning.

Table 1 Various Methods and the Number of States using them for assessing IFR in the U.S.A.

Method	Number of States using the method
Instream Flow Incremental Methodology (IFIM)	38
Tennant Method	16
Wetted Perimeter	6
Aquatic Base Flow	5
7-day, 10-year Low Flow (7Q10)	5
Professional Judgment	4
Single Cross-section (R-2 CROSS)	3
USGS Toe-width	2
Flow records/duration	2
Water Quality	2
Average Depth Predictor (AVDEPTH)	1
Habitat Quality Index	1
Oregon fish-flow	1
US Army Corps of Engineers	1
Hydraulic Modelling (HEC-2)	1

Source: [8]

2.1. Review on Instream Flow Requirement (IFR) in Indian subcontinent

In Indian water resources planning and management culture, water flowing to the sea was, and predominantly still is, regarded as waste. The water development approach was to harness river water through dams, barrages or other structures to the extent technically feasible. National Water Policy of India [9] ranks 'ecology' as the fourth item in the list of priorities for water allocation. As the degradation of water related environment started to manifest itself, the environmental concerns have started to gain strength. Nowadays, the term 'minimum flow' is understood as a flow, which is needed, to be released downstream of the dams for environmental maintenance. The first scientific attempt to assess environmental water demand for the entire India has been recently done [10]. This estimate is based on the global study conducted by Smakhtin et al [11] and was made separately for major river basins/drainage regions of India. The estimate turned out to be about 476 km^3 which constitutes approximately 25% of the total renewable water resources in the country. This was not an estimate of environmental flows per se, but rather an estimate of the total volume of environmental flows.

In Bangladesh, flood control and irrigation development have been the main focus of water resources management without due attention to the low flow and instream flow management. Historically water has been managed from supply perspective with an emphasis on maximizing the economic return from its use. Flood Action Plan studies emphasized on water management taking into consideration the environmental perspective of water resources management. Environmental implication of water resources development has been recognized in the National Water Policy and the National Water Management Plan [12]. In Bangladesh no systematic study and research has been done for defining the environmental flow requirement. The instream requirement set forth in different Plan and project related studies, until now, has been on an ad-hoc and empirical basis. From a river management point of view, scientifically justified methods and guidelines are needed for determining flow requirement to safeguard the aquatic environment, livelihood of subsistence users and requirement of downstream users. In this regard water management in Bangladesh lags behind in the development of appropriate management tools for recommending the flow regimes considering environmental and ecological aspects [13].

3. DATA COLLECTION

Necessary data required for the present study of Dudhkumar river at Pateswari station have been collected from Bangladesh Water Development Board (BWDB). A summary of the data collected as well as those used in the present study is presented in Table-2.

Table 2 Summary Status of Collected Data

Station ID and Name	Type of Data	Period of Data Collected	Period of Data used after quality checking
River: Dudhkumar Station: Pateswari Station ID: SW81	Daily Water Level	January 1965 to August 2008	April 1968 - March 2007
	Daily Discharge	April 1968 to December 2006	April 1968 - March 2007

From Table-2 it can be seen that availability of discharge data is less compared to that of water level data. Discharge data is available upto December 2006 whereas water level data is available upto August 2008. Considering a common period of data availability, water level and discharge data for the period April 1968 to March 2007 has been used in the present study.

3.1. Data Quality

Quality of the water level data (WL) has been checked by visual inspection of the yearly WL hydrograph. Since there is no other WL measurement station on the Dudhkumar river upstream and downstream of Pateswari, it was not possible to assess the consistency of WL data of Pateswai by comparing with neighboring station. Like water level data, discharge data has also been checked to identify data gap and data quality. Discharge data quality has been checked by visual inspection by comparing the variation of water level and discharge data for the same period. Where it is found necessary to fill missing discharge data of a particular period, missing data has been filled by using rating curve. A hydrograph of the discharge data is shown in Figure 3.

4. INSTREAM FLOW ASSESSMENT

Instream flow requirement for Dudhkumar river at Pateswari has been assessed using three methods of the hydrological approach. The methods are (i) Mean Annual Flow (MAF) method, (ii) Flow Duration Curve (FDC) method and (iii) Constant Yield (CY) method. All the methods belong to hydrological approach and use historical flow data.

4.1. Mean Annual Flow Method

This method is widely known as Tennant method. It is perhaps the most widely known and used method of similar categories. It is the second most popular method in the USA and is used or recognized by 16 states [14]. According to this method, IFR is set at different percentage of the mean annual flow. The percentages vary from 10% to 200% of the mean annual flow. The percentage is set considering the desired habitat quality. The different percentages that have been used for assessing

IFR for various habitat qualities are shown in Table-3.

Table 3 Percentage of MAF for various Habitat Qualities

Habitat Quality	Percent of Mean Annual Flow (MAF)	
	Low Flow Season	High Flow Season
Flushing or maximum	200	200
Optimum	60-100	60-100
Outstanding	40	60
Excellent	30	50
Good	20	40
Fair	10	30
Poor	10	10
Severe degradation	<10	<10

Source: [13]

For determination of IFR using the MAF method, mean annual flow of Dudhkumar river at Pateswari has been computed. The computed mean annual flow for each year as well as for the whole period of data availability was conducted. Mean annual flow of Dudhkumar River at Pateswari varies from 246 m^3/s to 808 m^3/s with an average of 475 m^3/s. This average flow (475 m^3/s) has been used to assess the IFR using the MAF method. The computed values are shown in Table-4.

4.2. Flow Duration Curve Method

According to the FDC method, IFR has been set at the 50th (for high flow season) and 90th (for low flow season) percentile flow of the monthly flow duration curve. For this purpose, flow duration curve for each month of the year has been constructed. The flow duration curve shows the percentage of time during which a specified flow is equaled or exceeded.

4.3. Constant Yield Method

According to the Constant Yield method, instream flow requirement for the Dudhkumar river has been set at 100% of the median monthly flows for each month. For this purpose, median monthly flow for each month has been computed in two different ways. According to the 1st method, the median flow of each month has been computed considering the data availability period. In the 2nd method, median monthly flow for each month of each year has been computed separately. Thus, several median values are obtained for each month, and then the median of these values has been taken as the median for the given month over the entire period of record.

Since Dudhkumar river is an unregulated river and the drainage area exceeds 130 km^2 and the availability of flow record is more than 25 years, median monthly flows can serve as the datum for assessment of instream flow requirement. Thus the instream flow requirement for each month has been taken as 100% of the average of the median monthly flows computed according to the two different methods. In Bangladesh, this procedure has been used for assessment of instream flow requirement for Surma, Kushiyara, Teesta and Gorai river [13] and for the Ganges river [15].

5. RESULTS AND DISCUSSION

A summary of the instream flow requirement for the Dudhkumar river at Pateswari computed by the Mean Annual Flow method, Flow Duration Curve method and Constant Yield method is presented in Table-4 as well as in Figure-4. For the MAF method two different scenarios have been considered. Option-**I** comprises of ‘good’ habitat quality for the low flow season and ‘flushing’ habitat quality for the high flow season. In Option-**II** ‘outstanding’ habitat quality has been considered for the low flow season keeping the habitat quality for the high flow season same as that of Option-I.

From a review of Table-4 and Figure-4, it may be seen that, according to the MAF method, under Option-I, IFR varies from 95 m^3/s in the low flow season to 950 m^3/s in the high flow season whereas under Option-II of the MAF method, it varies from 190 m^3/s in the low flow season to 950 m^3/s in the high flow season. According to the FDC method IFR varies from 72 m^3/s in the low flow season to 1190 m^3/s in the high flow season and according to the CY method the IFR varies from 89 m^3/s in the low flow season to 1032 m^3/s in the high flow season. It is also seen that, out of these three methods, highest (1190 m^3/s) and lowest (72 m^3/s) IFR occurs in the Flow Duration Curve method.

Table 4 Summary of IFR computed by the three Methods

Months	Season	Instream Flow Requirement (m^3/s)			
		Mean Annual Flow Method		Flow Duration Curve Method	Constant Yield Method
		Option-I	Option-II		
April	Low Flow	95	190	82	106
May		95	190	140	207
June	High Flow	950	950	580	536
July		950	950	1190	1032
August		950	950	1180	918
September		950	950	1060	799
October		950	950	675	435
November	Low Flow	95	190	190	234
December		95	190	125	167
January		95	190	100	128
February		95	190	82	98
March		95	190	72	89

It may be pointed out that for Option-I, ‘Good’ and ‘Flushing’ habitat quality is assumed for low and high flow season respectively. For Option-II, ‘Outstanding’ and ‘Flushing’ habitat quality is assumed for low and high flow season respectively.

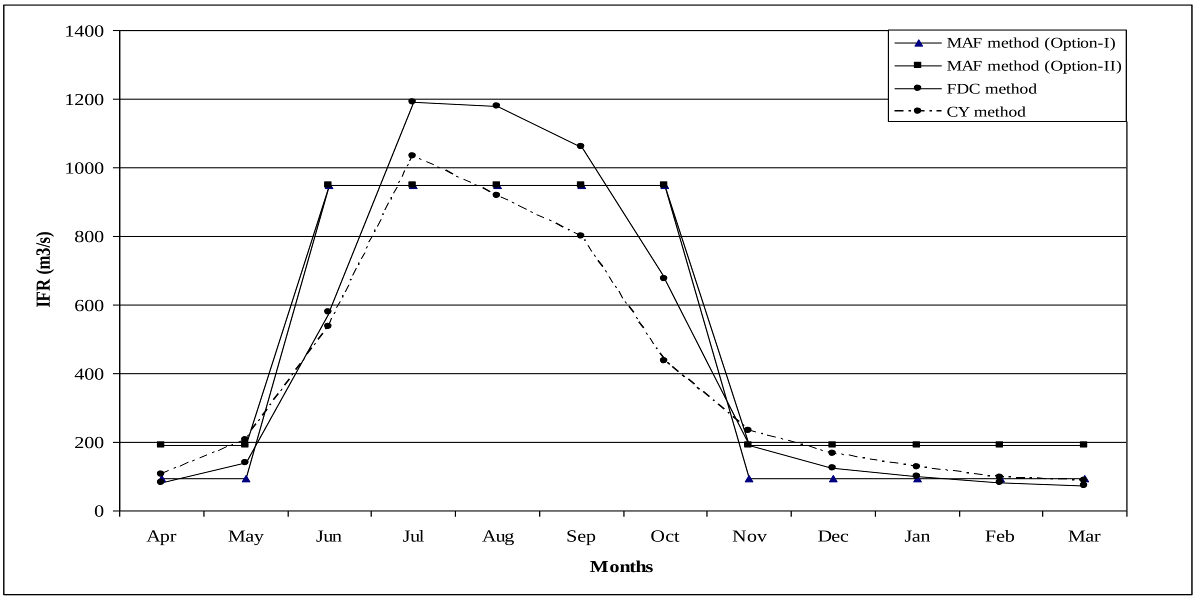

Figure 4 Variation of IFR computed by the three Methods

This wide variation of IFR is due to mainly the variation of habitat quality and flow seasonality. A ‘flushing’ habitat quality requires the largest amount of flow whereas a ‘fair’ habitat quality requires the minimum amount of flow. For the sake of the present study, two different options have been considered. In Option-I, ‘good’ and ‘flushing’ habitat quality has been considered for low flow and high flow season respectively. The corresponding IFR is found to be 95 m^3/s and 950 m^3/s for the low flow months and high flow months respectively. In Option-II, ‘outstanding’ and ‘flushing’ habitat quality has been considered for low flow and high flow season respectively. The corresponding IFR is found to be 190 m^3/s and 950 m^3/s for the low flow months and high flow months respectively. However, if the choice of habitat quality is changed, IFR would also be changed. Similar variation of instream flow requirement of Dudhkumar river for other methods may observed from the above discussion.

6. CONCLUSION

No single method provide an unique value of instream flow requirement of river Dudhkumar in Bangladesh as the hydrological, cultural and morphological conditions as well as habitat condition of the river and the basin influence the result. If other methods are used to assess IFR, the scenario may substantially change. Therefore judgment and experience on the river system plays a vital role in deciding the instream flow requirement of an alluvial river like Dudhkumar in Bangladesh. Since instream flow in Bangladesh is very important, further study on instream flow is recommended.

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