ASSESSMENT OF ENVIRONMENTAL FLOW FOR SARYU RIVER IN UTTARAKHAND

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

IRRIGATION WATER MANAGEMENT

By

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CANDIDATE'S DECLARATION

I hereby certify that the dissertation work entitled **"ASSESSMENT OF ENVIRONMENTAL FLOW FOR SARYU RIVER IN UTTARAKHAND "** in partial fulfilment of the requirements for the award of **Master of Technology** in **Irrigation Water Management** and submitted in the Department of Water Resources Development and Management of Indian Institute of Technology, Roorkee is an Authentic record of my own work carried out during a period from July, 2012 to June, 2013 under the supervision of **Professor S.K.Mishra** and **Professor Devadutta Das** of Water Resources Development and Management Department at Indian Institute of Technology Roorkee.

The matter presented in the dissertation has not been submitted by me for the award of any other degree of this or in any other Institute.

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This is to certify the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

Environmental flow refers to the flow regime required for maintaining all river ecosystem functions. The environmental flow, in general, should at least include the water required for the assimilation of pollutants, evaporation, groundwater conservation, and aquatic-habitat conservation. An environmental flow is the provision of water within rivers and groundwater systems to maintain downstream ecosystems and their benefits, where the river or groundwater system is subject to competing water uses and flow regulation. Since flow can be regulated directly through infrastructure (like on-stream dams/weirs/barrages) as well as through diversions of water from the system (for example by pumping water away), there are different ways in which environmental flows can be provided.

The study Area includes the Saryu River Basin in Bageshwaer district of Uttarakhand. A large number of people (about 259,840; Census 2011) rely on the Saryu Rive in terms of their various functions including biodiversity and conservation, irrigation and domestic water supply and so on. Hence the rivers and streams need to be healthy to provide these functions. The natural flow in River Saryu is highly variable. It has periods of both very low and very high flows. Flows in the river vary seasonally with the higher flows usually occurring in the monsoon months. The Environmental Flow Guidelines need to identify those components of flow from this variable flow regime necessary to maintain stream health. The purpose of this project is to determine the minimum flow for the river and to describe the process and methodology used in order to facilitate Environmental Flow Assessment. This study evaluated the minimum flow requirements in the river, i.e. the environmental flow, by using different Hydrologic Methods at different sites of Saryu River and suggested suitable environmental flows at various locations of the river.

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ABBREVATIONS

AAF	Average Annual Flow
BBM	Building Block Methodology
BOD	Biological Oxygen Demand
BS	British Standards
CSIR	Council for Scientific and Industrial Research
DO	Dissolved Oxygen
DRIFT	Downstream Response to Imposed Flow Transformations (known previously as Downstream Response to Intended Flow Transformations)
EAFR	Ecologically Acceptable Flow Regime
EFA	Environmental Flow Assessment (also known as Instream Flow Assessment)
EFR	Environmental Flow Requirement (also known as IFR: Instream Flow Requirement or Ecological Flow Requirement: EFR)
EIA	Environmental Impact Assessment
EPAM	Expert Panel Assessment Method
EVHA	Evaluation of Habitat Method
EWR	Environmental Water Requirements
FDC	Flow Duration Curve
GIS	Geographical Information System
GPS	Global Positioning System
HEP	Habitat Evaluation Procedure
HFR	High Flow Requirements
IFA	Instream Flow Assessment (also known as Environmental Flow Assessment)
IFIM	Instream Flow Incremental Methodology
IFR	Instream Flow Requirement (also known as Environmental/Ecological Flow Requirement: EFR)
IHA	Indicator(s) of Hydrologic Alteration
IWMI	International Water Management Institute
LFR	Low Flow Requirements

MAR	Mean Annual Runoff
MCM	Million Cubic Metres (x $10^6 m^3$)
PHABSIM	Physical Habitat Simulation Model
RSS	River System Simulator
RVA	Range of Variability Approach
S.A.	South Africa
U.N.	United Nations
U.S.	United States
U.S.A.	United States of America
WRC	Water Research Commission
WUA	Weighted Usable Area

LIST OF ANNEXURE

1.1 BACKGROUND

The term Environment flows are also called by different names such as "Environmental Water Requirement"; "Environmental Water Demand"; etc. Environmental flow by (Stewardson, 2000) "refers to the flow regime required for maintaining all river ecosystem functions." Generally The Environmental flow should at least include the water that is required for the incorporation of Pollutants, for evaporation purposes, for conservation of Groundwater. But in most of the studies the Environmental Studies are done for aquatic habitat conservation."An environmental flow is the provision of water within rivers and groundwater systems to maintain downstream ecosystems and their benefits, where the river or groundwater system is subject to competing water uses and flow regulation. Since regulation of flow can occur through direct infrastructure (like on-stream dams) as well as through diversions of water from the system (for example by pumping water away), there are different ways in which environmental flows can be provided". (Jha,2008)

Environmental flows in water resources policies, plans and projects, "Findings and recommendations by Rafic Hirji and Richard Davis,(2008) "are for the equitable distribution of and access to water and services provided by aquatic ecosystems. They refer to the quality, quantity, and timing of water flows required for maintaining the components, functions, processes, and resilience of aquatic ecosystems that provide goods and services to people." The science of environmental flows is relatively new. Environmental Flows are the water that is to be provided in the River regime or in wetlands or coastal lands to preserve the ecosystem that is dependent on the river in spite of the competing water users and the regulated river systems. Environmental flows provide the significant contribution to the health of the River and the economic development and hence, in poverty mitigation. These flows make sure the availability of the continuous flow that for proper health of the river and groundwater, ultimately brings benefits to the society

In India the services and the goods that are provided by various rivers and the ecosystem are getting affected badly due the quality and quantity and the changes in the flow regimes.Increase in the abstraction of the water has given rise to the question of great concern and it is the main challenge to understand the matter of flows. Or we can way How much water a river need to sustain its ecological, cultural and social needs and How can we determine this need.? Environmental flows are important for people and as well as for the plants and the animals.

Now the water resources Engineers re well know the necessity to take care of the resources and to maintain these resources for Long term economic and social benefits. The E- Flows are more or less related to management of integrated catchment. E flow alone does not solve the problem but there are many other factors that are to be look after and they include protecting the natural habitat and the dependent species, managing salinity and decreasing the pollutants. Globally there is much awareness now. that the Environmental flow can give the life to the dying rivers and Now The Environmental flows are acknowledged as a key to the preservation of the ecology of the river and species and their the natural habitat plus goods and services provide by the river.

1.2 EFA - A SCENARIO IN INDIA

In past five decades the Application and development of Environmental Flow Methods has rapidly increased. These Methods serve as a means to sustain and restore the natural aquatic and ecosystem regardless the increasing demand of limited water resources. India faces a number of challenges related to the Environmental Flows and increasing water scarcity and the dispute between the different states for the water. Some of the rivers of southern and western parts are facing the scarcity of water both in economic and physical sense whereas some of the basins of the east experience surplus water leading to recurrent floods. The Environmental Flow Studies has yet not taken pace and needs to be modified in view of managing the proper health of the river and ecosystem. There is a large number of rivers in India characterized by seasonal variations. The entire land is drained by 15 major, 45 medium and 120 minor rivers and various other small streams (Smakhtin 2006).

The issue of Environmental flow was first highlighted by the Supreme Court for Yamuna River in the year199, in which the court has ordered to release at least 10 cumec of water in the river in view of keeping it pollution free. After this several studies were conducted on different rivers. In 2001, Water Quality Assessment Authority was constituted by the government to provide the minimum flow in the rivers to protect the ecosystem. The first attempt to estimate the environmental flow was done in 2005 by for all the River system of India. This study was based on the Global study by Smakhthin in 2004. The total volume of EF came out to be 25% of the total renewable water resource of the country. Then various studies have been carried out for Environmental Flow assessment for various rivers in India. In one of the studies by National Institute of Hydrology, Roorkee, in Barhmani and Baitarani river systems in India, Range of Variability Approach (RVA) method was adopted.

1.2 ENVIRONMENTAL FLOW AND THE ECOSYSTEM

The assessment of the flows is both social and technical process and Environmental flows or E-Flows are multidimensional. They progress both towards the social and technical aspects. The E flows are social at its core because of the dependence of the people on rivers or in simple way what people want a river to do for them. And Rivers in India fulfils people's basic needs as well as to sustain their cultural , spiritual and biodiversity or livelihoods functions and more. Secondly the Environmental flows are technical process as the process itself requires a wide range of specialist investigators and engineers to analyse and the past , present and future scenario of the functioning of the River to maintain these choices. (Jay O'Keeffe, 2012)

The goods and services offered by the river s in India are seriously getting damaged due to the change in the amount, quality and the changes in the flow regimes of the rivers. There is increase in the abstractions of water from the river for various purposes like agriculture, domestic needs, industrial purposes, and for hydropower generation from last few years. This outcome of this is the rivers running dry and lot of pollution in the water of the river. Therefore it has become necessary to check the status of each river and provide the minimum flow in the river.

Environmental flows are "the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated. Environmental flows provide critical contributions to river health, economic development and poverty alleviation. They ensure the continued availability of the many benefits that healthy river and groundwater systems bring to society. Environmental flows are vital for healthy functioning of river systems, which in turn is critical for attracting investment, achieving long term economic prosperity and the conservation of biodiversity" (Megan,2003)

1.4 OBJECTIVE OF THE STUDY

The present study is carried out with the following specific objectives:

- To describe the importance of the environmental flow and review the environmental flow techniques.
- To describe different methodologies of Environmental Flow Assessment (EFA) and their advantages and disadvantages.
- To determine EF for Saryu River using hydrological approaches.
- To suggest the appropriate environmental flow for River Saryu.

1.5 ORGANIZATION OF DISSERTATION WORK

The dissertation is organized into five chapters as follows:

Chapter 1: This chapter introduces the dissertation work and sets the objectives of the study.

Chapter 2: This chapter presents a brief review of the Hydrological Methods and gives the literature available on the topic.

Chapter 3: This chapter presents different hydrological techniques for estimation of environmental flows for a river system.

Chapter 4: This chapter describes the location and physical features of the study area, such as topography and location details of the river under study. It also describes the data and materials used for the study.

Chapter 5: This chapter discussion of application results of EFA.

Chapter 6: This chapter concludes the study.

2.1 GENERAL

Assessment of environmental flow is quite a complex problem as it involves the multidimensional fields of engineering. Environmental flow as such represents the flow regime of a river useful for maintaining all the functions of the ecosystem. The environmental flow, certainly, should at least include the water required for the incorporation of pollutants, groundwater conservation and management, evaporation of water and aquatic-habitat conservation. Thus, it is the provision of water within rivers and groundwater systems to maintain downstream ecosystems and their benefits, where the river or groundwater system is subject to competing water uses and flow regulation. The following text provides a brief review of the literature available on the subject.

2.2 AVAILABLE EFA TECHNIQUES

There is no single standardized method for estimating environmental flows in any country. Rather, there are many methods available, which are usually tailored to meet the specific requirements of each assessment. Environmental flow assessments have been undertaken for a number of rivers and streams, using the most appropriate methods available at the time. Previously, these assessments have focused largely on minimum flow requirements in stream for fauna (such as fish and invertebrates). However, new holistic methodologies that incorporate natural variability in stream flow, and the high flow water requirements of entire riverine ecosystems. The process of assessing and implementing E-Flows deals not just with maintaining some flow in rivers, but also with managing the magnitude, frequency, duration, timing and rate of change of flow events, so that the mosaic of hydraulic habitat conditions is maintained over time and space, to provide opportunities for the range of species, processes, structures and functions that are characteristic of the natural biodiversity of the river. Generally, the application of an intensive E-Flows assessment method will lead to recommend flows with a higher confidence level (from the perspective of accuracy and clarity), and more detailed motivations which provided clear consequences for the biodiversity, livelihoods or other aspects.

As the conditions of river systems are deteriorating globally, environmental flows are increasingly engaging attention of the planners and designers. There is also increasing demand for the entering the environmental flow criterion through appropriate legislation. The science of advising on environmental flows is relatively young (about 50 years), but about 207 different methodologies within 44 countries (Tharme, 2003) have been reported to exist for such assessments for sustainable water resource management. Generally, these can be classified into four categories (Jay 2012)

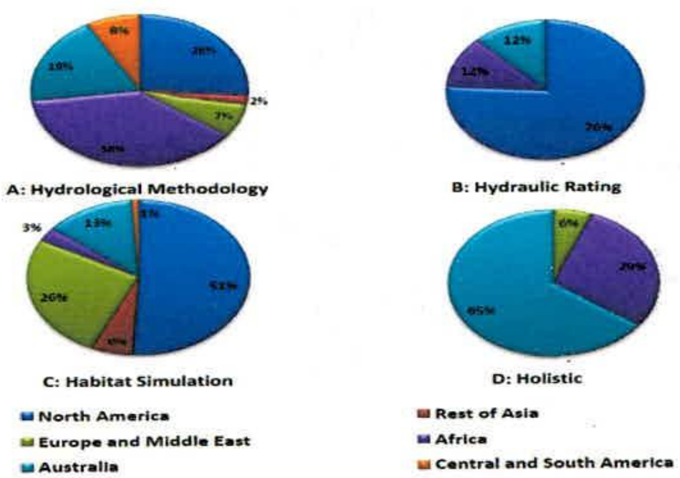
- Hydrology-based and look-up table approaches
- Hydraulic rating methodologies
- Habitat simulation methodologies
- Holistic methodologies

The following actions are less commonly taken:

- "See what happens" method
- "Upside down" or "Onus on the user" approach

Though there are wide range of applications of the methods based on hydrology for the estimation of environmental flows, like Tennant method (1976), an approach based on desktop reserve model range of variability and environmental flow which is based on environmental management class (EMC) and estimation is not responsible for the various components of the environmental flow, and henceforth the application of these methods have been very less and restricted for a highly intercepted river, receives discharge of waste water, and historical records are not noted and are not available. On the other side, in the fourth classification, a less number of studies have been done and undertaken. Geographical distribution of application of various methodologies over the globe is shown in Figure 2.1.

Fig 2.1 Geographical Distribution of Application of Various EF Estimation Methodologies



2.3 HYDRAULIC RATING METHODOLOGIES

It uses changes in simple hydraulic variables (e.g. wetted perimeter) across single river cross-section which is used as a surrogate for habitat factors limiting to target biota. The changes in the available hydraulic habitat such as wetted perimeter, depth, velocity, etc. are measured using hydraulic rating methods based on a single cross-section of the river that measures the shape of the channel. For biological habitat this cross-section is used as a surrogate, and allows a probability of the changes that would occur in that habitat as a result of changing flows. By an assessment of the habitat the required flows can be inferred form available for sensitive, or "indicator" species.

Strengths and deficiencies

- Can incorporate ecological habitat information.
- Relatively according to available data.
- Suitable for assessments at the reconnaissance/medium level.
- Simplistic assumptions exploring from single cross section.
- Low to medium confidence, difficult to defend.

2.4 HABITAT SIMULATION METHODOLOGIES

Assess e-flows on basis of modelling of quantity and suitability of physical habitat available to target species under different flow regimes (integrated hydrological, hydraulic and biological response data)

Habitat rating simulation methodologies combine hydraulic rating with the characterization of habitat preferences of target species. In a hydraulic model cross sections which are multiple rated are used to simulate the different conditions in a river range, depth and velocity and again based on wetted perimeter. Indicator species which are biologically sampled, together with measurements of the hydraulic properties where they are found, are employed to populate the habitat part of the river model. Then the area of preferred habitat available for the indicator species at different flows, and can be used to infer the required flows are then calculated by combined hydraulic/biological model. Particularly the Instream Flow Incremental Methodology (IFIM) mentioned in this method, a kind of habitat methodology which can be simulated, has been used very widely especially in the United States of America, and recommendations of flow have been successfully defended in court based on it.

Strengths and deficiencies

- High resolution characterization of habitat availability.
- Flexible for assessment of different flow section.
- In frequent use, high degree of scientific acceptability.
- Largely confined to target species.
- Limited to transferability between rivers.
- Low resolution of other aspects.
- Advanced technical support

2.5 HOLISTIC METHODOLOGIES

Identify important flow events for all major components of river, model relationships between flow and ecological, geomorphological and social responses, and use in inter disciplinary team approach to establish recommended e-flow regime/implications of flow scenarios (bottom-up or top-down)

Holistic Methodologies are concerned with whole systems rather than with the analysis or dissection of systems into parts. This is another method to measure environmental flow in a river. These are various methodologies based on the input of different specialists working in different disciplines to reach a consensus regarding setting of flow to meet a pre-defined set of environmental objectives, and to describe the consequences of different levels of modifications to the flow regime.

In this methodology we use multi-disciplinary team including a hydrologist and a hydraulic engineer who provide baseline flow data and hydraulic conditions, a freshwater biologists who gives characteristics of biotic requirements i.e how to restore longitudinal and lateral connectivity by providing fish passes or altering the configuration of levee banks on a flood plain and also for plants etc. , a geomorphologies who can predict the quantity of sediment changes and channel maintenance in different stages of flowing river, a water quality specialist who gives view in quality of water, and a socio-economist.

2.6 HYDROLOGIC APPROACHES

The hydrologic Methods are the simplest and most extensively used EFA methods. These Methods are also called desk-top or look-up table methods and they primarily rely on historical flow records. These are the simplest and original of the environmental assessment types. Methods based on hydrology are dedicated to the use of simulated or existing available flow data, long-term virgin or naturalised, historical monthly or daily records. These methods are based on the predictions that some percentage of the natural flow will which is maintained provide for the interest of environmental issues. As these are based on historical flow data, these are also referred as historic flow methods. Hydrological methods are considered as rapid and less-resource intensive and appropriate at the planning level of water resource development. Since these methods are simple and straight forward, these make up the largest proportion (about 30%) of environmental flow methodologies developed. Hydrological methods often seek for specified minimum flow, and there are many regionalization techniques to derive results for gauged and ungauged rivers. The most frequently used methods include the Tennant Method (Tennant, 1976) and RVA both developed in USA. These methods are most appropriate in low controversy situations where they may be used as preliminary estimates.

Environmental flow is calculated by using daily measured discharge values. These values may be analysed using various curves and tables to determine flow at different conditions. The results may not be very precise but they can be obtained in short time. This category of methods is accepted to be convenient for planning stage of water related projects. Under this category, there are number of methods developed for estimation of environmental flow, some of them include

1. Tennant Method (also known as Montana method)
2. Modified Tennant Method
3. Hughes & Münster Method
4. 7Q10 Method
5. Seasonal Method

Hossain (2011) described the Environmental Flow requirements for the River Dudhkumar, shared by Bhutan, India, and Bangladesh. In-stream flow requirement of Dudhkumar River were determined using three methods of hydrological approaches, the Mean Annual Flow, Flow Duration Curve, and Constant Yield method. The study showed that for most of the months during low flow season, there was a shortage of water in the river, while during flood season most of the demands could be met and duration of deficit period was shorter. No method provided a 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 influenced the result.

A reservoir operation simulation study was carried out to analyze the impact of alternative scenarios of a hydropower system operation on energy production and natural flow regime in the La Nga river basin in Vietnam by Babel (2011). The Da Mi hydropower plant on the river is a run-off-the-river scheme, located downstream of Ham Thuan reservoir. Hydrologic Method, Flow Duration Curve (FDC) Method, and Range of Variability Approach (RVA) were proposed. The proposed operation policy caused severe hydrologic alternation in the natural flow regimes represented by 32 parameters of RVA. The result indicated that the system operation could be improved with increased power production while maintaining the EF requirement for downstream ecosystems.

Mullick (2010) analyzed the flow characteristic of the Teesta River in Bangladesh based on 40 years historic flow data and further estimated the environmental flow requirements for the river by different hydrological methods considering initial stage of the research at the river. Three different hydrologic methods were used - Tennant method, Flow Duration Curve (FDC) method and Range of Variability Approach (RVA). The results were consistent. The results suggested some flows for the dry months because of the difference in the flow pre and post barrage periods. The results from the study provide the necessary information for the Water Management Authorities in managing River in more efficient manner.

Toriman (2010) evaluated the existing flow characteristics and then estimated EF due to the diversion structure in Sg Pelus. Daily river flow were recorded at different stations and then these flows are used to estimate the lowest 7 day average probability of recurring at 10 years interval. The Flow Duration Curve studies were prepared for the two sites and the 50% exceedence flow was determined. The results obtained in this model are important to manage the river at least in Class II after river diversion project.

Kumar (2010) analyzed water flow status of Bhadra River for thirty years. This covers complete livelihood dependent fishermen communities and command area dependent agricultural communities. The upper catchment of the river was covered with good vegetation, the downstream of the river for 40 km has shrunken in its river bed due to Bhadra dam, and that the river flow is completely irregular over a period of years. It has changed the natural flow, leading to massive loss of riparian, aquatic habitat and water quality. The study was been carried out using both desktop analysis and field investigations covering two modules for the assessment of the environmental flows (EF). These include - Biophysical assessment and Socio-economic assessment which was carried out by the survey for the people depending on the river on the downstream of the River. In Biophysical assessment 30 years data of inflow and outflow was analyzed and compared with the present flow status. This comparison was done using French fisheries Law Method and Tennant Method. The Results showed that the irregular dry season and water level fluctuation impacted the communities and affected riverine vegetation, birds, reptiles and various aquatic life forms whose lifecycles.

River basins, important water surplus basins in Orissa State in India. Brahmani River is the 2nd largest river in the State of Orissa, The Baitarani River is one of the medium sized east flowing rivers, having catchment area of 14218 sq. km. The length of the river is 360 km before it joins the Bay of Bengal, while Brahamani covers a drainage area of 39116 sq. km. They emphasized an urgent need for the water planners and stakeholders to assess environmental flows at various locations of the river systems for best management practices of available water resources. They critically evaluated the applicability of existing approaches, provided values of environmental design flows at different locations of these river systems, and suggested a suitable scientific approach for the assessment of environmental flows. The flow duration curves (FDC) are a useful tool for illustrating and evaluating the relationship between the magnitude and frequency of daily stream flow, with the probability of exceedance corresponding to Q95. The 7Q10 FDC was found appropriate as environmental design flow during normal precipitation years and drought years/low flow periods. They suggested to apply 7Q10 flow for regulation purpose: 1) protection or regulation of water quality from waste load allocations or wastewater discharges, 2) protection of habitat during drought conditions, 3) criteria for aquatic life, and 4) a local extinction flow.

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Smakthin (2006) debated on environmental flows, which is only beginning to receive attention and recognition in India. It is one of the small part of the National River Linking Project. He first examined the emerging trend in environmental flows work in India and reviews desktop methods of environmental flows assessment. The method takes into account the limitations of available hydrological and ecological information in India at present, but ensures that elements of natural flow variability are preserved in the estimated environmental flows time series, as required by the contemporary hydro-ecological theory. The method is based on the use of a flow duration curve - a cumulative distribution function of monthly flow time series. The flow duration Curve is established and then analysed for various aquatic ecosystem. Then the required environmental flow volumes set according to the flow variability. Then further the illustration has been given to convert these curves to the Monthly time series of E flows using simple interpolations. At last the E-Flows are presented in two forms of Flow duration curve and Monthly flow series. E Flows are then estimated for other rivers including Cauvery, Krishna, Godavari, Narmada and Mahanadi. The method is suggested for longer term E Flow programmes.

Rai (2001) determined a different technique for estimation of the Yamuna River environmental flow, as "highlighting advantages and disadvantages of various methodologies for EF estimation. The study includes comparison of various hydrologic methods like Tennant Method, Modified Tennant Method and EMC based Techniques." Comparison and evaluation of results acquired revealed that the proposed methodology gave much higher values than the other two used methods, and when the river morphology is also considered it seems practical.

2.7 OTHER METHODS

The **"See what happens"** approach involves water releasing down the river, and the results are continuously monitored to see if they fulfil specified objectives. The advantages of this method is not requiring any sophisticated probabilities of the effects of the water flow, and of being able to provide instant results which are related to real experience. Though, this method does require either some form of available storage from the experimental work or Environmental Flows of water that can be released and is allowed to flow downstream which requires the user to be prepared to forego the allocated water flow. Willingness by the user on the part of river management agencies is always required to release the flows without a detailed and demonstrated justification, which often creates problems in contested environments (Jay O'Keeffe, 2012).

The **"Upside down" or "Onus on the user" approach** the burden of proof is reversed, and demonstration is required by the potential user that the proposed river's resources use will not degrade the resource in such a way that is unacceptable, or "impair the public trust" in the constitutional sense in the United States of America, for a long time where this methodology has been pioneered (as yet unsuccessfully). A long-term goal for the protection of water resources is probably the adoption of this approach, since it is linked and associated with the other forms of EIA methodologies where the potential user is on the pressure to determine and demonstrate that the proposed work and development is not flawed fatally, and is better than any alternatives, and that impacts will be mitigated as far as possible (Jay O'Keeffe, 2012).

Vladimir Smakhtin (2008) attempted to identify, locate and quantify coastal erosion and deposition processes in Krishna river basin in India. It is done by using a time series of Landsat images with a spatial resolution. In this process time series of river flow, sediment discharge and sediment storage in the basin were analyzed. The results suggested that coastal erosion in the Krishna Delta progressed over 25 years, but slowly. The results showed some negative environmental impacts such as saltwater intrusion, and the potential rise in sea level caused by future climate change may significantly increase the erosion.

2.8 SELECTION OF EFA APPROACH

The most important aspects to be considered in the selection of the appropriate Method are:

- Availability and quantity of data
- Location and extent of the Study Area
- Prevailing time and financial constraints
- Level of confidence required for the final output

In general the project in which involve the trade-offs and in environmental and considerable negotiation development issues, can be considered controversial or large projects. Such projects require more comprehensive approach and deep studies

Table 2.1 General requirements for each generic type of assessment method.

Assessment Type	Requirements	Time	Costs Required	Confidence
Look-up tables	Hydrology	1 day	Low	Low
Hydrological Models	Hydrology	1 day	Low	Low
Extrapolation Model	Hydrology	1 day	Low	Low
Habitat Analysis	Hydrology/Hydraulics /Ecology	Months	High	Fairly High
Holistic Method	Hydrology/Hydraulics /Ecology/Geomorphology/Social/Water Quality	Months/ Years	High	High
See What Happens	Controlled flow releases	Weeks	Low	Fairly High
Upside-down	Change in policy	Unknown	Unknown, but long	High but Large

In cases of the interactive approach like Holistic and Habitat simulation, the data collection and the field survey has to be acquired from the sites itself and hence the methods become time taking, large fund extracting and expertise requiring. On the other hand the other hydrologic approaches are much used.

In brief, it can be seen from the above review that hydrologic approaches can be most advantageously employed for a rapid and reasonable environmental flow assessment.

3.1 GENERAL

The methods used in this study are based on hydrologic approach. In these methods the environmental flow is usually given as a percentage of the Annual Average Flow (AAF) or as percentile of the Flow duration curve, on annual or seasonal or monthly bases. The methods used are described below.

3.2 TENNANT METHOD

The Tennant Method simply focuses on requirements of the stream flow. These requirements are based on the observation of aquatic-habitat condition of the rivers. The method usually based on the assumption that The conditions of aquatic-habitat are similar in rivers carrying the same proportion of the Average Annual flow (AAF) or the Mean Annual Flow (MAF). The method develops the stream flow requirements on the basis of a predetermined percentage of Average Annual Flow. The Tennant Method is less significant for the Lean Seasons or we can say low flows because the flow requirements are calculated from the Mean annual Flow statistics which are mostly determined by the high flows.

The Tennant method was originally called the "Montana method". The method was discovered by Donald Tennant . Tennant used the stream data from the Montana region (Tennant 1975).The method was discovered through measurements and field observations. The data were collected on 58 cross sections on 11 different streams within Montana, Nebraska, and Wyoming. Tennant collected the different hydraulic parameters of the these different streams from these three regions and then He studied the different aspects of the aquatic species in relation with the hydraulic parameters of the streams (Figure 3.1). He studied this by considering the different proportion of the Average annual flows. Tennant suggested that "the stream flow requirements on the observation that aquatic-habitat conditions are similar in streams carrying the same proportion of the Mean Annual Flow (MAF)" (Rai,2001) He gave the predetermined percentages of the Average annual flow and associates the different aquatic habitat conditions for these percentages. Table 3.1 shows the different aquatic habitat conditions with the different percentages of the AAF. The stream flow requirements with 40, 30, 20 and 10 percentages of AAF shows good ,fair and poor habitat conditions respectively.

He further suggested that at 30 % of AAF, most part of the river substrate is submerged under water where as at 10% the half or more than half part can remain above the water surface level. (Tennant, 1976). 10 % of AAF is suggested to be used for the summer months when the flow available is already quit low in the river. At last to account for the seasonal variation in the flow Tennant gave different percentages of annual average flow(Table 3.1) for Low flow and high flow months.(Tennant 1976)

Figure 3.1 The relationship between the depth, width and velocity to percentages of AAF for 11 streams of Montana, Wyoming and Nebraska (Tennant 1976)

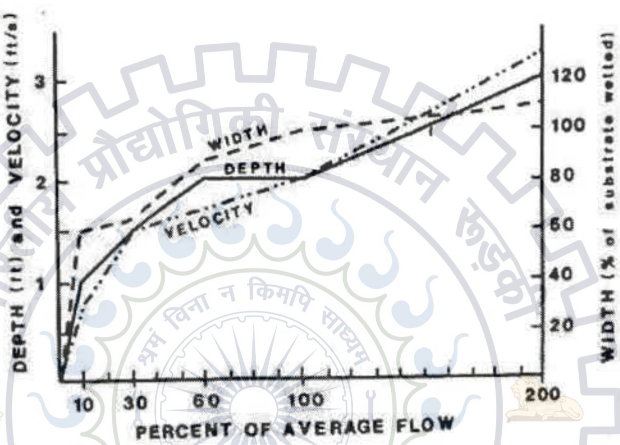


Table 3.1 Relations between aquatic-habitat conditions and mean annual flow described by the Tennant method for small streams (Tennant 1976)

Narrative description of general condition of flow	% MAF monsoon season (June–Sept)	% MAF non-monsoon season (Oct–May)
Flushing or maximum	200%	200%
Optimum range	60 – 100%	60 – 100%
Outstanding	40%	60%
Excellent	30%	50%
Good	20%	40%
Fair or degrading	10%	30%
Poor or minimum	10%	10%
Severe Degradation	<10%	<10%

3.3 MODIFIED TENNANT METHOD

The large variability of the flow in Indian River system leads to the inadequacy of the above method. The constant allowance of the Flow on the basis of the AAF is unsatisfied for the variable or seasonal flowing rivers which shows high flows during monsoon months and very low flow in non- monsoon periods. It result into the revision of methodology. In modified Tennant Method the the estimated E-Flows are temporally distributed taking into account temporal variation in the stream flow. The method consider the relative percentage distribution of the monthly flow. The application of the methodology is explained in chapter five for the study river.

3.4 FLOW INDEX METHOD

The flow Index Method gives the value of the minimum instream flow (MIF) that must be maintained downstream water diversion to maintain vital conditions of ecosystem functionality and quality. The method is based on Q_{355} .Q_{355} is the flow not exceeded more than 355 days per year. Means on average, the natural flow is less than Q355 value only for 10 days in a year (Maran 2007):

$$MIF = Q355\ K_a\ K_b\ K_c$$

Where K_a = Corrective coefficient for different environmental sensitive of the required river stretch (0.7 to 1.0), K_b = 1 (since 2005 when the rule was supposed full play) and Kc = Corrective coefficient to account for different level of protection due to the naturalistic value of the required area (1.0 to 1.5).

The daily discharge data is important data while using this method. This daily average data may be converted into average monthly flow of at least ten years. The research must extend to collection of data for the different environmental sensitive of the interested river stretch so as to know the value of the corrective coefficient (K_a) which generally ranges from 0.7 to 1.0. The information on different levels of protection due to the naturalistic value of the interested area must be ascertained in order to know the value of corrective coefficient (K_c). The corrective coefficient ranges from 0.1 to 1.5.

When the slope of the FDC is flat, or Q90 $\geq$ 30% of AAF, the flow in the river is very stable throughout the year, and the ecosystem is getting used to have a constant rate of flow in the river most of the time. This type of ecosystem is more sensitive to any change in river flow regime and the value of Ka will be taken as 1. When the FDC slope is steep, say Q90 < 10% of AAF, the river flow is very unstable and present high extreme values (floods and droughts). Under this condition, the ecosystem is getting used to water scarcity during some periods of the year; therefore this ecosystem is less sensitive to changes in flow regime, because the river naturally presents a wide variability in flow regime. In this case, the value of Ka can be taken as 0.7. The implementation factor refers to upgrade or degraded river condition, in which the quantity of water in the river is very low, due the abstractions made for different purposes (domestic, industrial, agriculture, etc.). The recovery of natural conditions of the river flow must to be done gradually, because another uses of water will be affected. In this case, the value of Kb could be 0.25. In the case of no significant abstractions, the value of Kb will be 1. The K_c factor increases the value of MIF, for protection of special conditions in the river ecosystem like naturalistic and tourism values, fisheries development and medicinal or religious issues.

3.5 HUGHES & MUNSTER METHOD

The Hughes and Munster Method is one of the Hydrological based method in which the estimation of the Environmental flows includes the portions of base flow as well as quick flow. These flows add to maintain the dynamics and productivity of fresh water ecosystem. These flows then are given the term Environmental Low Flow Requirement (LFR) and Environmental High Flow Requirements (HFR). LFR or Low Flow Requirement is the Minimum water by the fishes and other aquatic species for their sustainability throughout the year. Whereas the High Flow Requirements are the wter required for the maintenance of the river channel for various purposes like spawning and migration, for floods, establishment of the riverine vegetation.

The total Environmental Flow is thus given by the summation of LFR and HFR as shown in the equation (1) below.

$$EWR = LFR + HFR \quad \text{...} \quad (1)$$

Environmental Water Requirements (EWR) is estimated from the time series of monthly river flows. For estimation of total EWR Mean Annual runoff of the long period of the river is required.

The Low flow Requirement i.e. LFR is believed to be the to the monthly discharge of the stream which will exceed 90 percent of the time on an average throughout the whole year. This is denoted by Q_{90}. This flow in simple language can be said that the discharge that will exceed 9 out of 10 times. This flow corresponds to the low flow that is widely used in hydrology and water resource sciences.

For the estimation of HFR the table 3.2 given below. The value HFR is set by different threshold range of LFR and the average flow.

In the rivers with variable flows which have high base flow forms high LFR and Low HFR and the LFR forms higher contribution to total flows .Whereas the rivers which are highly variable flow for different time periods, the contribution by base flow is less hence low LFR and consequently high HFR. In such case the total flow is dominated by the High flows.

Table 3.2 Estimation of environmental high-flow requirement (HFR)

Low Flow Req. (Q_{90})	HFR	Comment
If $Q_{90} < 10\%$ MAR	Then HFR = 20% MAR	Basins with very variable flow regimes. Most of the flow occurs as flood events during short wet season
If 10% MAR $\leq Q_{90} <$ 20% MAR	Then HFR = 15% MAR	-
If 20% MAR $\leq Q_{90} <$ 30% MAR	Then HFR = 7% MAR	-
If $Q_{90} \geq 30\%$ MAR	Then HFR = 0	Very stable flow regimes. Flow is consistent throughout the year. Low-flow requirement is the primary component.

3.6 7Q10 METHOD

The 7Q10 means "seven-day, consecutive low flow with a ten year return frequency; that would be expected to occur once in ten years," the lowest stream flow for seven consecutive days. The Method is used for most of the river in U.S. and is the second most widely used hydrological method used for environmental flow estimation. This method can be interpreted as the 7-day low flow with a 10-year return using daily discharge data. (Feaster,2010)

This method has been used for various purposes in various countries. The method is adopted mostly for -

- Prevention and Maintenance of the quality of the water mainly from waste water discharges and waste water allocations.
- Protection of the Habitat during the drought periods
- For the prevention of aquatic life.

3.7 SEASONAL METHOD

The seasonal method used in this study follows the principle of Building Block Methodology, which is based on the identification of different natural flows regimes; and their magnitudes, timing and duration as well as their interaction with surrounding biota. The EF so constructed satisfies the water requirements in the river for maintaining a desired condition.

The Seasonal Method used for the estimation of Environmental Flow reproduces the natural conditions in the river so as to fulfil the different flow regimes required throughout the year. Thus the river channel structures and physical features of the ecological being is maintained by the assimilation and identification of these derived flow characteristics. For using this method is important to identify the different seasons throughout the year. These seasons are described below-.

The Season I: Season 1 is a period of heavy rainfall and varies from place to place. This season is incorporated with the high monsoon and hence is high flow season. With the context of Indian climate this season covers the months from May to September. The minimum flow for this season is found to be 30 percent of the average flow or 90% dependable flow of the corresponding period. The discharge data that is used can be 10 daily flow data or monthly flow data.

Season II: It is the season of period of average flow covering the month of October. The minimum flow for this season is considered as 20 percent of average flow or 90% dependable flow of the corresponding period. The October month is considered as the changeover or transition period between wet and dry periods.

Season III: Season II is a period of lean season or dry flow period. It includes the months from November to March. The minimum flow considerations for these months were taken as 15 percent of the average flow or 90% dependable flow of the corresponding period.

Season IV: This is also an average flow period as Season II, covering the months of April and the minimum flow considerations are 20 percent of the average flow or 90% dependable flow of the corresponding period. Again it is a transition period between the dry and wet season.

All these four groups of the flow are estimated by average monthly flow or for the 90 percent dependable year flows.

4. 1 GENERAL

The study area includes the Saryu River Basin in Bageshwar district of Uttarakhand. The details of the Study area are given below-

4.2 LOCATION

Saryu River is a tributary of Mahakali River which in turn is a tributary of River Ganga. The Saryu River flows through the Bageshwar and Pithoragarh districts of the Uttarakhand State. Saryu River originates from Kautela Dhar range of Himalyas at an elevation of 4114 m above the mean sea level. The area of study that comprises Saryu River Basin is shown in Figure 4.1.

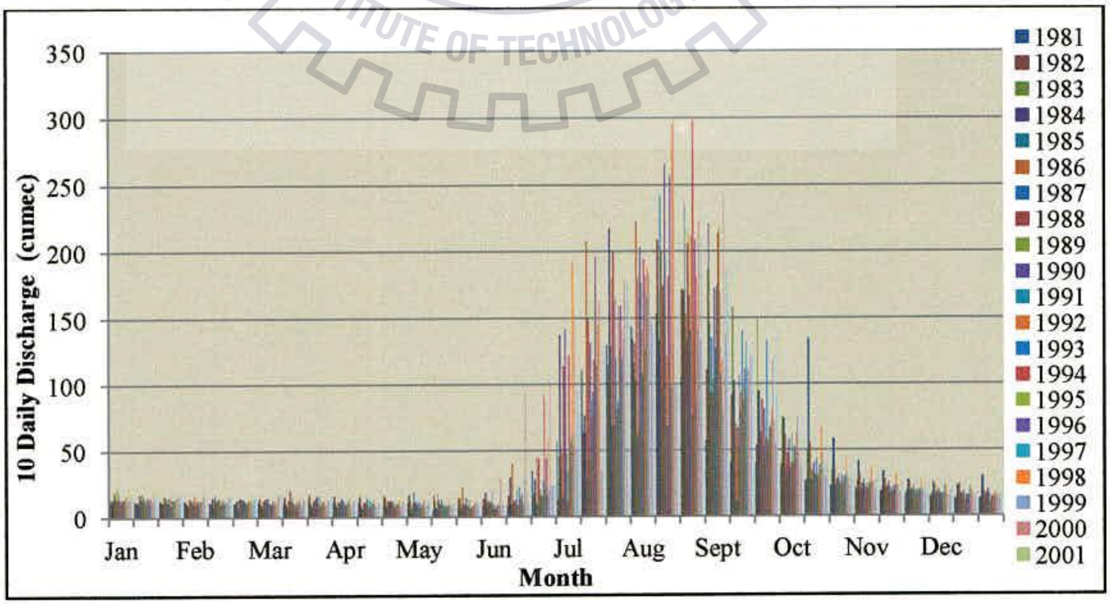
Fig. 4.1: Saryu River in District Bageshwar in Uttarakhand

The river flows through Kapkot, Bageshwar, and Sheraghat in a south-easterly direction to join Eastern Ramganga river, flowing on its eastern boundary at Rameshwar (456 m MSL) and flows with the name of Saryu in a southeasterly direction to join River Mahakali downstream of Ghat. At the origin it is known as Saryu. During the flow through the Central plateau the river meets with the larger tributaries viz. Gomti and Pannar. Upstream of the project site the river meets another tributary known as Revti Ganga and then it is known as Saryu.

The total length of Saryu River from its origin up to its confluence with Eastern Ramganga at Rameshwar is approximately 126 km. The longitudinal section of the River Saryu from Loharkhet Weir to Seraghat is shown in Figure 3.0. The basin of the river is endowed with dense mixed jungle and the river flows in its upper reaches through Dhakuri Reserve Forest. The river is generally rain-fed. However, during summer, the snow in the higher reaches which have fallen during the previous winter, melt to maintain a perennial flow in the river. Further, the river flow is augmented by springs and drainage from the subterranean aquifers in the mountain ranges along the river course.

A very small area in the river lying above 3000 m MSL receives snow fall. The snow melt during summer contributes to the river flow. The river is fed mainly by rain during the monsoon and from seepages through the mountains along its course and partially by snow melt. The river is thus perennial.

Fig.4.2 Graph showing 10 Daily Avg. Flow of the Saryu river using 25 years discharge data



The district of Bageshwar is located in the northern parts of province of Uttarakhand State in India. It encompasses an area of 2310 sq. km and situated between 29° 42' 40" to 30° 15' 56" Latitude and 79° 23' to 80° 90' E Longitude. The river is generally rain-fed, however during summer, the snow in the higher reaches which have fallen during the previous winter melt to maintain a perennial flow in the river. Further the river flow is augmented by springs and drainage from the subterranean aquifers in the mountain ranges along the river course. The region is inconspicuously different from the plains of India due to its topography, soil, climate, relief, vegetation, language, culture and historical background.

4.3 LAND USE

The land use pattern of the entire catchment of Bageshwar district is presented in Table 4.1.

Table 4.1 Land Use Pattern in the Catchment

Class	Area Sq. Km	Percentage
Builtup/Rural	0.24	0.01
Agricultural/ Crop Land	138.73	6.17
Forest/Evergreen/Semi Evergreen	1221.8	54.30
Forest, Scrub forest	71.77	3.19
Barren/Unculturable/Wasteland	15.61	0.69
wetlands/Water bodies	18.96	0.84
Builtpu/Mining	1.38	0.06
Agricuture/Fallow	205.16	9.12
Forests/Decidious	100.5	4.47
Grass Gazing	179.45	7.98
Barren/ Unculturable/Wasteland	67.03	2.98
Snow/Glacier	229.38	10.19
Total	**2250**	100

4.4 AREA AND POPULATION

The district has a geographical area 2310 sq. km and supports the total population at 259,840 (Census 2011) of which male and female were 124,121 and 135,719 respectively. The population density per sq. km., as per 2011 census of Bageshwar was 110 in 2001, now increases to 116 in 2011. As per 2011 census, 96.50 % population of Bageshwar districts lives in rural areas of villages. The total Bageshwar district population living in rural areas is 250,749 of which males and females are 119,402 and 131,347 respectively. Out of the total Bageshwar population for 2011 census, 3.50 percent lives in urban regions of district.

4.5 DATA USED

The hydrologic data of 25 years (1981-2005) derived from the Khutani site, a site identified for locating a small hydropower station from the discharged data gauged at the Bageshwar site of the Central Water Commission (CWC). The flow data for other sites are obtained by proportioning the available flow data of Khutani site. For example the catchment area ratio of Loharkhet site with respect to the representative site. The catchment area details and the other features of the sites are given in Table 5.1. The catchment area ratio for Loharkhet, Khutani, Balighat and Seraghat comes out to be 0.56, 0.508, 1.0 and 0.96, respectively.

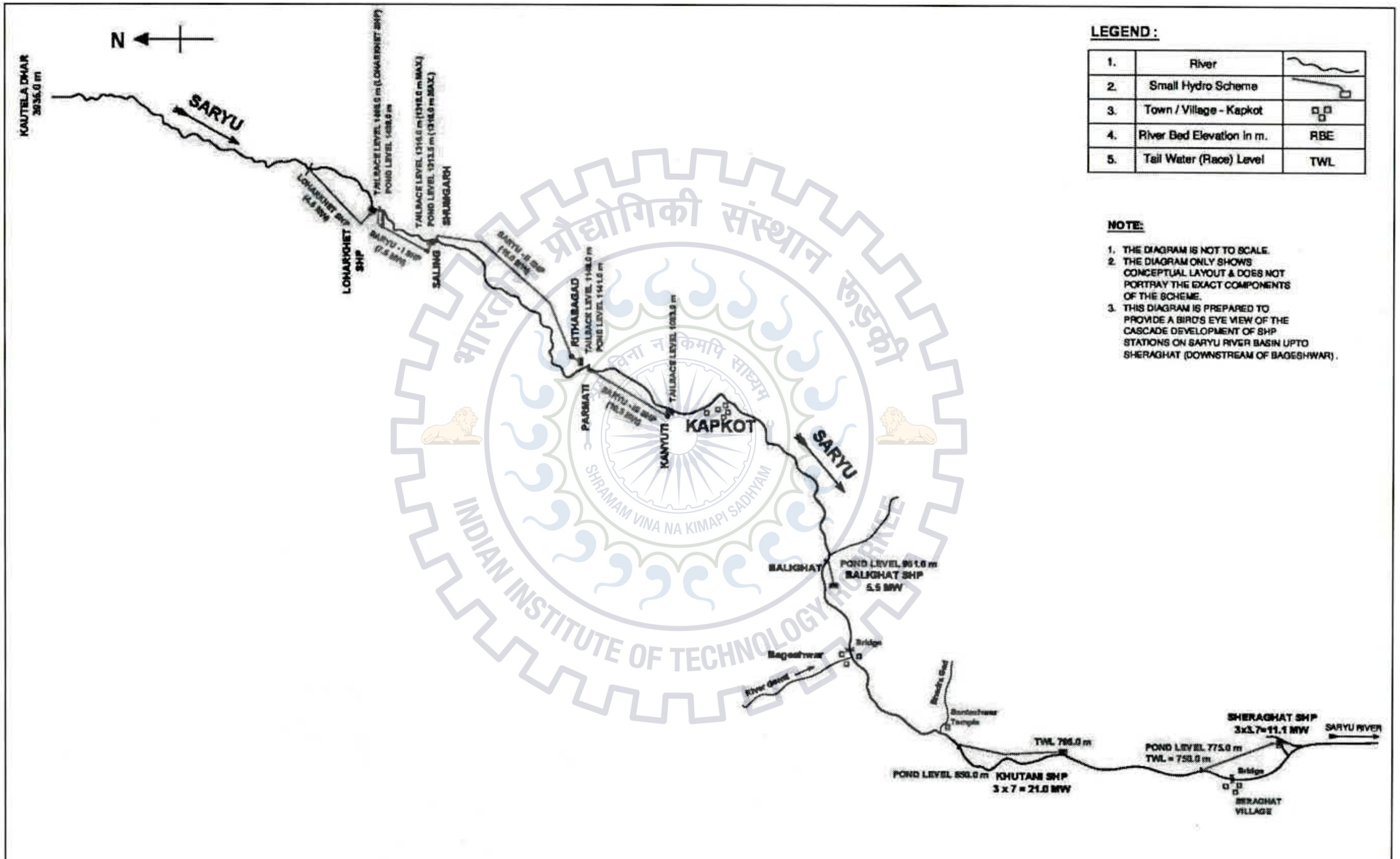


FIGURE 3 : LOCATION OF SMALL HYDRO PROJECTS EXISTING & PROPOSED ON SARYU RIVER - SCHEMATIC LAYOUT PLAN

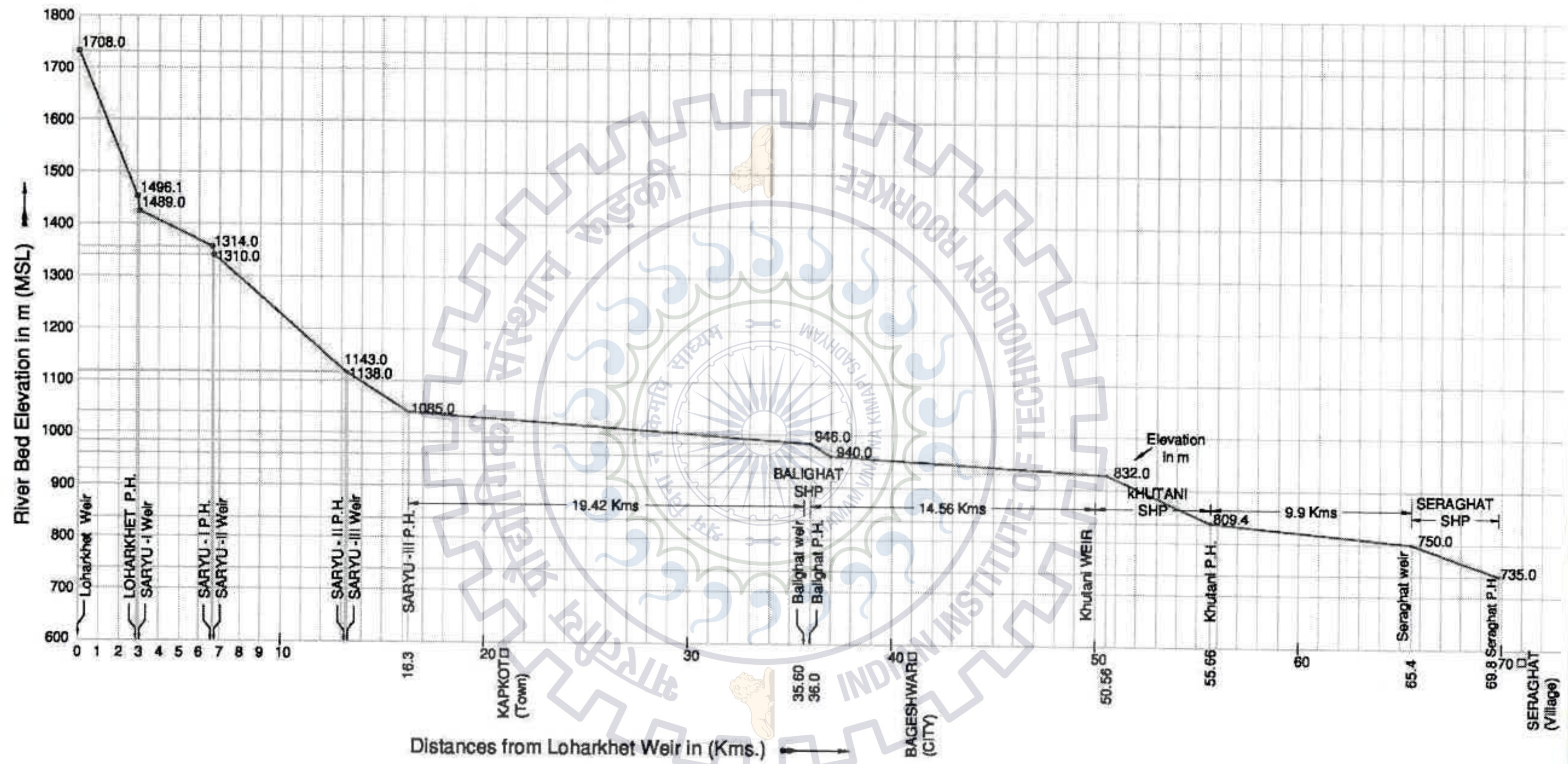


FIGURE 4 : LONGITUDINAL SECTION OF RIVER SARYU FROM LOHARKHET WEIR TO SERAGHAT SHOWING ELEVATION(MSL) OF VARIOUS SHP'S (UNDER OPERATION,UNDER CONSTRUCTION)

CHAPTER 5 : ANALYSIS AND DISCUSSION OF RESULTS

5.1 GENERAL

The environmental flow for the Saryu River has been assessed using six hydrologic methods described in Chapter 3. First of all the entire river reach is divided into four numbers of gauged sites. The features of these sites are given in Table 5.1. The longitudinal section of the river basin from Loharkhet weir site to Seraghat and the details of different hydro-project are shown in Figures 3 and 4. The reaches that are considered to estimation of environmental flow for the Saryu River are as under:

i. From Origin to Loharkhet Weir Site
ii. From Loharkhet Balighat Weir Site
iii. From Balighat Weir Site to Khutani Weir Site
iv. From Khutani to Seraghat

Table 5.1 Salient features of the different Sites of the Sarju River Basin

Salient Features	Name of the Site			
	Loharkhet	**Balighat**	**Khutani**	**Seraghat**
District	Bageshwar	Bageshwar	Pithoragarh	Pithoragarh
Village	Loharkhet	Balighat	Khutani	Seraghat
Geographical coordinates	79° 57' 30" E & 30° 2' 00" N	79° 51.7' E & 29 52° 78'N	79° 49'25" E & 29° 47' 03" N	79° 53'42" E & 29° 42' 49" N
River bed Elevation (MSL) m	1708	946	832	750
Total Catchment Area(sq.Km)	780	713.5	1402	1461

5.2 EFA USING TENNANT METHOD

In Tennant Method, the Average Annual Flow (AAF) is determined for each year. Months for the AAF are now grouped into two. The formulation of these groups depends on the availability of flow from low flow to high flow, and from high flow to extreme high flow. For example, in India, the extreme low to medium or moderate flows are during October to May and EF will be in the group of 10, 20 and 30% of AAF. The next group is from high to extreme high flows during the months of June to September. In this group EF will be 10, 30 and 50% of AAF.

10% of the flow is the minimum instantaneous flow that reflects the short term survival of the species and the river depth and velocities are reduced to one third and all the fishes will be crowed in the deeper pools and the gravel bars are dewatered. The flow of 30% is found to be satisfactorily as depth and velocity are maintained at this flow and more number of fish could pass the riffles. Subsequently other habitat conditions give better depths and velocities. In this case the "good" aquatic habitat condition is recommended for the stream.

In this study the 10-daily discharge data of 25 years for the period of 1981–2005 have been used. The Mean Annual Flow (MAF) of various sites of the river (Tables 5.2-5.5) is first calculated. The Minimum Flow Requirement For high flow seasons according to different aquatic-habitat conditions, and also MAF for both flow seasons is given in Table 5.6 derived using Tennant recommendations (Table3.2) with respect to different aquatic-habitat conditions.

Table 5.2 MAF data of Loharkhet Site of Saryu River for the years 1981-2005

Month	Days	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
AAF (Cumec-day)		217023.7	215928.2	246651	284079.1	341858.4	314501	327484	179086.4	313583.4	211393.3	343624.1	262227.9	234612.9
AAF (Cumec)		594.6	591.6	675.8	776.2	936.6	861.6	897.2	489.3	859.1	579.2	941.4	716.5	642.8
Month	**Days**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	
AAF(Cumec-day)		332485.8	275449.7	331890.7	245614.4	359306.5	268423.8	391751.2	292751.6	220918.5	314492.1	303081.2	323668	
AAF (Cumec)		910.9	754.7	906.8	672.9	984.4	735.4	1070.4	802.1	605.3	861.6	828.1	886.8	
Mean AAF		**783.2**												

Table 5.3 MAF data of Khutani Site of Saryu River for the years 1981-2005

Month	Days	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
AAF (Cumec-day)		387542.3	385586.1	440448.2	507284.1	610461.5	561608.9	584792.9	319797.1	559970.3	377488	613614.5	468264.1	418951.7
AAF (Cumec)		1061.76	1056.4	1206.71	1386.02	1672.5	1538.65	1602.17	873.76	1534.17	1034.21	1681.14	1279.41	1147.81
Month	**Days**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	
AAF(Cumec-day)		593724.6	491874.4	592661.9	438597.2	641618.8	479328.2	699555.7	522770.7	394497.4	561593	541216.4	577978.6	
AAF (Cumec)		1626.64	1347.6	1619.29	1201.64	1757.86	1313.23	1911.35	1432.25	1080.81	1538.61	1478.73	1583.5	
Mean AAF		**1399**												

Table 5.4 MAF of Balighat Site of Saryu River for the years 1981-2005

Month	Days	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
AAF (Cumec-day)		232525.4	231351.7	264268.9	304370.4	366276.9	336965.3	350875.8	191878.3	335982.2	226492.8	368168.7	280958.4	251371
AAF (Cumec)		637.1	633.8	724	831.6	1003.5	923.2	961.3	524.3	920.5	620.5	1008.7	767.6	688.7
Month	**Days**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	
AAF(Cumec-day)		356234.7	295124.7	355597.2	263158.3	384971.3	287596.9	419733.4	313662.4	236698.4	336955.8	324729.8	346787.2	
AAF (Cumec)		976	808.6	971.6	721	1054.7	787.9	1146.8	859.3	648.5	923.2	887.2	950.1	
Mean AAF		**839.2**												

Table 5.5 MAF of Seraghat Site of Saryu River for the years 1981-200

Month	Days	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
AAF (Cumec-day)		403044	401009.6	458066.1	527575.4	634879.9	584073.3	608184.6	332589	582369.1	392587.5	638159	486994.6	435709.7
AAF (Cumec)		1104.2	1098.7	1255	1441.5	1739.4	1600.2	1666.3	908.7	1595.5	1075.6	1748.4	1330.6	1193.7
	Days	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	
AAF(Cumec-day)		617473.6	511549.4	616368.4	456141	667283.6	498501.3	727538	543681.5	410277.3	584056.7	562865	601097.8	
AAF (Cumec)		1691.7	1401.5	1684.1	1249.7	1828.2	1365.8	1987.8	1489.5	1124	1600.2	1537.9	1646.8	
Mean AAF		**1455**												

Table 5.6 Recommended Mean Annual Flow for different sites of Saryu River

Description of flow for Aquatic-habitat	Recommended flow regime(in Cumec) (% of MAF) June to Sept				Recommended flow regime(in Cumec) (% of MAF in cumec) Oct to May			
	Loharkhet	Balighat	Khutani	Sheraghat	Loharkhet	Balighat	Khutani	Sheraghat
Flushing or Maximum	1566	1678	2798	2910	1566	1678	2798	2910
Optimum range	470-783	503-839	839-1399	873-1455	470-783	503-839	839-1399	873-1455
Outstanding	470	503	839	873	386	420	700	727
Excellent	386	420	700	727	313	336	560	582
Good	313	336	560	582	157	168	280	291
Fair or Degrading	235	252	420	436	78	84	140	145
Poor or Minimum	78	84	140	145	78	84	140	145
Severe Degradation	<78	<84	<140	<145	<78	<84	<140	<145

5.1 EFA USING MODIFIED TENNANT METHOD

In Modified Tennant Method the temporal variation of river flows is considered and thus the required environmental flows will also be temporally distributed. To this end, 10-daily discharge data for the period of 1981–2005 and estimated mean annual flow (MAF) for the four reaches are shown in Tables 5.2 to 5.5.

Table 5.7 shows the allocation of environmental flow volume with respect to various aquatic-habitat conditions. The monthly flow distribution of MAF for the reaches was derived based on mean monthly flows, as in Table 5.7. This table also provides the mean monthly environmental flow requirements.

Table 5.7 Estimated environmental flow allocation for the site of Saryu River

S.No.	Reach/ Site name	MAF (cumec)	Aquatic Habitat Condition			
			Poor 10% MAF	Fair 25% MAF	Fair 30% MAF	Good 40% MAF
1	**From Origin to Loharkhet Weir Site**	805	80.50	201.25	241.5	322.0
2	**From Loharkhet Balighat Weir Site**	867	86.70	216.75	260.1	346.8
3	**From Balighat Weir Site to Khutani Weir Site**	1448.00	144.80	362.00	434.4	579.2
4	**From Khutani to Seraghat**	1503	150.30	375.75	450.90	601.2

Table 5.8 shows the estimated monthly distribution of MAF. Using the appropriate monthly distribution with respect to the site, monthly volume of environmental flows for different aquatic-habitat conditions (Table 5.8) is obtained, as shown in Tables 5.9-5.12. The tables 5.9 to 5.12 gives the minimum monthly environmental flow requirements for the different reaches of the River.

Table 5.8 Monthly percent distribution of MAF for different sites/reaches of the Saryu River

Month	Discharge Sites of the Saryu River			
	Loharkhet(%)	Balighat(%)	Khutani(%)	Seraghat(%)
JAN	2.64	2.64	2.64	2.64
FEB	2.15	2.15	2.15	2.15
MAR	2.27	2.27	2.27	2.27
APR	2.01	2.01	2.01	2.01
MAY	1.95	1.95	1.95	1.95
JUN	3.69	3.69	3.69	3.69
JUL	20.02	20.02	20.02	20.02
AUG	31.00	31.00	31.00	31.00
SEP	18.81	18.81	18.81	18.81
OCT	7.94	7.94	7.94	7.94
NOV	4.23	4.23	4.23	4.23
DEC	3.30	3.30	3.30	3.30

Table 5.9 Environmental Flows for Loharkhet site using modified Tennant method

Month	% Distribution	Poor : 10 % MAF		Fair : 25% MAF		Fair : 30% MAF		Good : 40% MAF	
		MCM	Cumec	MCM	Cumec	MCM	Cumec	MCM	Cumec
JAN	2.64	2.13	0.82	5.31	2.05	6.38	2.46	8.50	3.28
FEB	2.15	1.73	0.67	4.33	1.67	5.19	2.00	7.45	2.88
MAR	2.27	1.83	0.71	4.57	1.76	5.49	2.12	7.88	3.04
APR	2.01	1.61	0.62	4.04	1.56	4.84	1.87	6.96	2.68
MAY	1.95	1.57	0.61	3.93	1.51	4.71	1.82	6.77	2.61
JUN	3.69	2.97	1.15	7.42	2.86	8.91	3.44	12.79	4.94
JUL	20.02	16.12	6.22	40.30	15.55	48.36	18.66	69.44	26.79
AUG	31.00	24.96	9.63	62.39	24.07	74.87	28.88	107.51	41.48
SEP	18.81	15.14	5.84	37.86	14.60	45.43	17.53	65.23	25.17
OCT	7.94	6.39	2.47	15.99	6.17	19.18	7.40	27.55	10.63
NOV	4.23	3.41	1.31	8.52	3.29	10.22	3.94	14.68	5.66
DEC	3.30	2.65	1.02	6.63	2.56	7.96	3.07	11.43	4.41
TOTAL	100.01	80.51	31.06	201.28	77.65	241.53	93.18	346.19	133.56

Table 5.10 Environmental Flows Balighat Weir Site using modified Tennant method

Month	% Distribution	Poor : 10 %MAF		Fair : 25% MAF		Fair : 30% MAF		Good : 40%MAF	
		MCM	Cumec	MCM	Cumec	MCM	Cumec	MCM	Cumec
JAN	2.64	2.29	0.88	5.72	2.21	6.87	2.65	9.16	3.53
FEB	2.15	1.86	0.72	4.66	1.80	5.59	2.16	7.45	2.88
MAR	2.27	1.97	0.76	4.92	1.90	5.91	2.28	7.88	3.04
APR	2.01	1.74	0.67	4.35	1.68	5.22	2.01	6.96	2.68
MAY	1.95	1.69	0.65	4.23	1.63	5.07	1.96	6.77	2.61
JUN	3.69	3.20	1.23	8.00	3.08	9.60	3.70	12.79	4.94
JUL	20.02	17.36	6.70	43.40	16.74	52.08	20.09	69.44	26.79
AUG	31.00	26.88	10.37	67.20	25.92	80.64	31.11	107.51	41.48
SEP	18.81	16.31	6.29	40.77	15.73	48.92	18.88	65.23	25.17
OCT	7.94	6.89	2.66	17.22	6.64	20.66	7.97	27.55	10.63
NOV	4.23	3.67	1.42	9.17	3.54	11.01	4.25	14.68	5.66
DEC	3.30	2.86	1.10	7.14	2.76	8.57	3.31	11.43	4.41
TOTAL	100.01	86.71	33.45	216.78	83.63	260.14	100.36	346.85	133.81

Table 5.11 Environmental Flows for Khutani Weir Site using modified Tennant method

Month	% Distribution	Poor : 10% MAF		Fair : 25%MAF		Fair : 30%MAF		Good : 40%MAF	
		MCM	Cumec	MCM	Cumec	MCM	Cumec	MCM	Cumec
JAN	2.64	3.82	1.47	9.56	3.69	11.47	4.42	15.29	5.90
FEB	2.15	3.11	1.20	7.78	3.00	9.34	3.60	12.45	4.80
MAR	2.27	3.29	1.27	8.22	3.17	9.87	3.81	13.16	5.08
APR	2.01	2.90	1.12	7.26	2.80	8.71	3.36	11.62	4.48
MAY	1.95	2.82	1.09	7.06	2.72	8.47	3.27	11.30	4.36
JUN	3.69	5.34	2.06	13.35	5.15	16.02	6.18	21.36	8.24
JUL	20.02	28.99	11.18	72.47	27.96	86.97	33.55	115.96	44.74
AUG	31.00	44.88	17.32	112.21	43.29	134.65	51.95	179.54	69.27
SEP	18.81	27.23	10.51	68.08	26.27	81.70	31.52	108.93	42.03
OCT	7.94	11.50	4.44	28.75	11.09	34.50	13.31	46.00	17.75
NOV	4.23	6.13	2.36	15.32	5.91	18.38	7.09	24.51	9.46
DEC	3.30	4.77	1.84	11.93	4.60	14.32	5.52	19.09	7.36
TOTAL	100.00	144.80	55.86	362.00	139.66	434.40	167.59	579.20	223.46

Table 5.12 Environmental Flows for Seraghat site using modified Tennant method

Month	% Distribution	Poor : 10%MAF		Fair : 25% MAF		Fair : 30% MAF		Good : 40% MAF	
		MCM	Cumec	MCM	Cumec	MCM	Cumec	MCM	Cumec
JAN	2.64	3.97	1.53	9.92	3.83	11.91	4.59	15.87	6.12
FEB	2.15	3.23	1.25	8.08	3.12	9.69	3.74	12.93	4.99
MAR	2.27	3.41	1.32	8.54	3.29	10.24	3.95	13.66	5.27
APR	2.01	3.01	1.16	7.54	2.91	9.04	3.49	12.06	4.65
MAY	1.95	2.93	1.13	7.33	2.83	8.80	3.39	11.73	4.52
JUN	3.69	5.54	2.14	13.86	5.35	16.63	6.42	22.18	8.56
JUL	20.02	30.09	11.61	75.24	29.03	90.28	34.83	120.38	46.44
AUG	31.00	46.60	17.98	116.49	44.94	139.79	53.93	186.38	71.91
SEP	18.81	28.27	10.91	70.68	27.27	84.81	32.72	113.09	43.63
OCT	7.94	11.94	4.61	29.85	11.51	35.81	13.82	47.75	18.42
NOV	4.23	6.36	2.45	15.90	6.13	19.08	7.36	25.44	9.82
DEC	3.30	4.95	1.91	12.38	4.78	14.86	5.73	19.81	7.64
TOTAL	100.01	150.32	57.99	375.80	144.99	450.96	173.98	601.28	231.98

The Saryu River water is regulated by upstream uses due to the presence of hydroelectric plant and weir, and hence the flow is not virgin. In such situation the first two conditions (poor and fair classes) should be avoided. They are not recommended for the study river. Thus, the "Fair Class (i.e., 30% MAF)" aquatic-habitat condition has been considered. The mean annual flow volumes in different months are shown in Figures. 5.1-5.4.

Fig 5.1: Mean Monthly E flow rates for Loharkhet Site using Modified Tennant Method

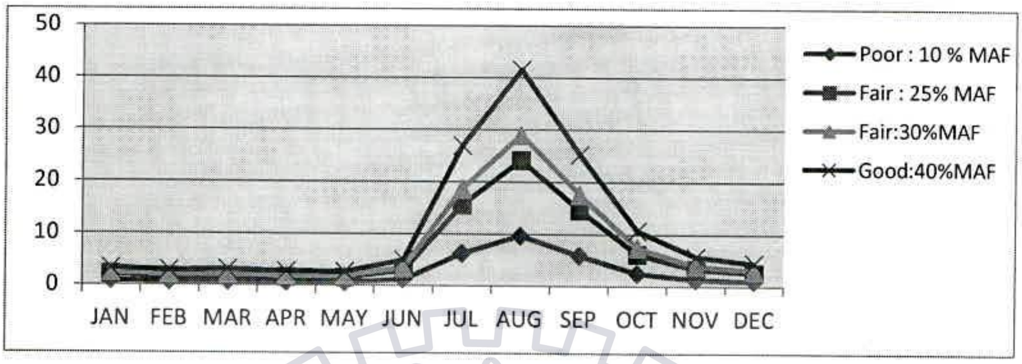


Fig 5.2: Mean Monthly E flow rates for Balighat Site using Modified Tennant Method

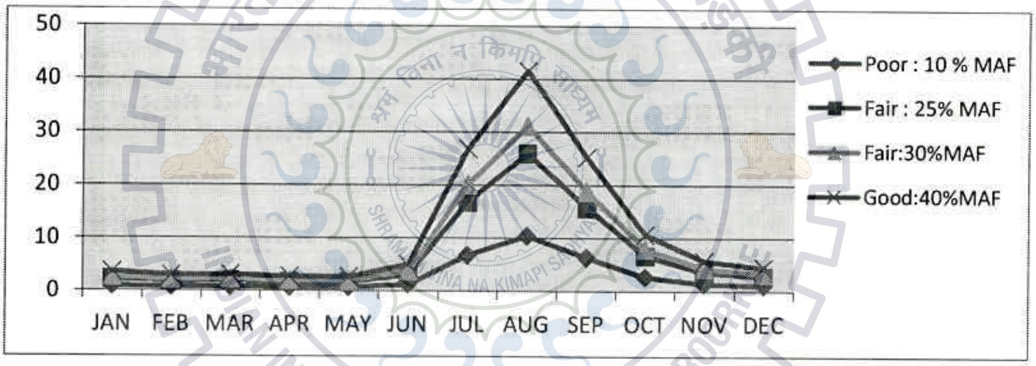


Fig 5.3: Mean Monthly E flow rates for Khutani Site using Modified Tennant Method

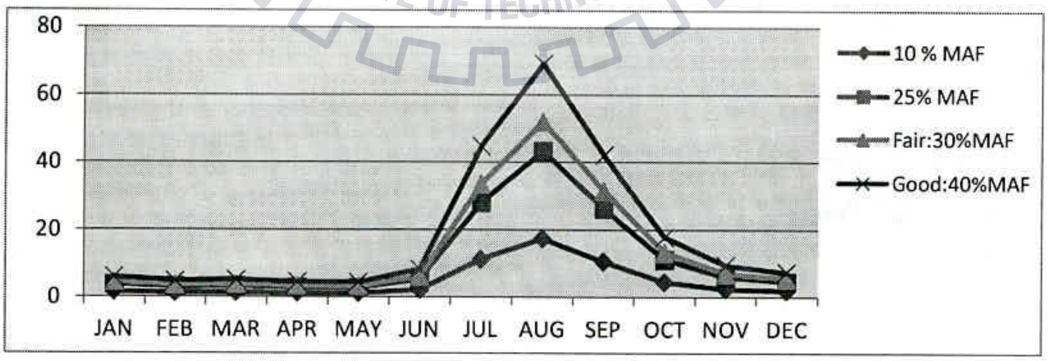
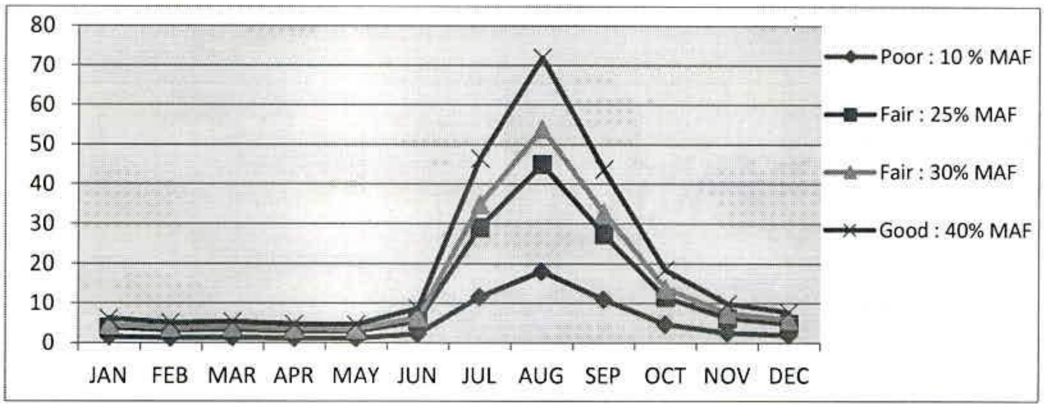


Fig 5.4: Mean Monthly E flow rates for Seraghat Site using Modified Tennant Method



5.2 EFA USING INDEX FLOW METHOD

Q_{355} is estimated corresponding to the flow not having exceeded more than 355 days in a year. This value is determined from the flow-duration curve (Figure 5.5) Then the corrective coefficients K_a, K_b & K_c are determined. The concept of "environmental sensitive" is linked with FDC. From FDC (Figure 5.5) Q_{355} corresponds to 97.3%. It is determined from the FDC and is given in Table 5.13 for all the four sites of the river. The value of K_a is then estimated through the values of Average Annual Flow and Q_{90}. In this case the Q_{90} falls between 10% to 30% of Average Annual Flow. The Value of the corrective Coefficient K_a is 1 for Q90 $\geq$ 30% of AAF and is 0.7 for Q90 < 10% of AAF. K_a for different sites is calculated below, K_b is taken as 1, and K_c as 1.5 assuming that the naturalistic value of interest area is high and the desire level of protection is maximum.

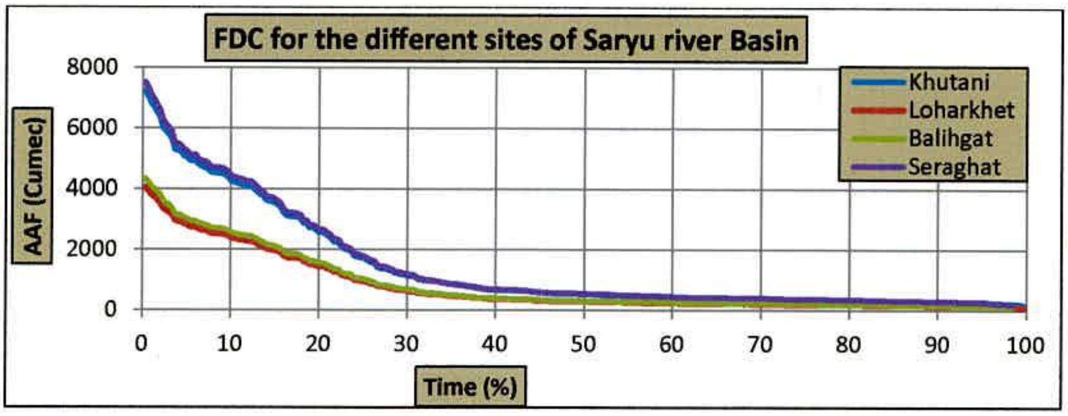
Table 5.13 Calculation of MIF by Index Flow Method

Site	Mean AAF	Q_{90}	Condition	K_a	K_b	K_c	Q_{355}	MIF
Loharkhet	783	171	30% AAF > Q90 > 10%AAF	0.877	1	1.5	144	189.432
Balighat	839	184	30% AAF > Q90 > 10%AAF	0.879	1	1.5	154	203.049
Khutani	1399	306	30% AAF > Q90 > 10%AAF	0.878	1	1.5	257	338.469
Seraghat	1455	318	30% AAF > Q90 > 10%AAF	0.878	1	1.5	268	352.956

5.3 EFA USING HUGHES & MÜNSTER METHOD

Q_{90} which is the LFR value determined from FDC, which is a plot of discharge vs. percent of time that a particular discharge was equalled or exceeded. The area under the FDC gives the average daily (or monthly) flow or mean annual runoff (MAR). From Figure 6.5, Q_{90} is derived for different reaches of the River and shown in Table 5.14.

Fig. 5.5 Flow duration Curve for different sites of the Saryu River Basin



With the values of Q_{90} and MAR and Table 3.2 HFR is computed. In this case, Q_{90} lies between 20% to 30% of MAR for each site and hence the value of HFR comes out to be 7% of MAR. Table 5.14 shows the calculation of HFR for each site of the river. This occurs in rivers with stable flows throughout the year. From Fig.5.5, the slope of FDC is very small and this is indicator of a stable flow regime, in which Q_{90} constitutes a large portion of MAR. Further, a "steep" FDC is a representation of a highly variable regime and low flow contributions (Q_{90}) are very small or zero.

Table 5.14 Calculation of HFR for four sites of Sarju River

Site	Loharkhet	Balighat	Khutani	Seraghat
MAFor AAF (Cumec)	783	839	1399	1455
LFR = Q^{90} (Cumec)	171	184	306	381
HFR = 7% MAF (Cumec)	55	59	98	102
EVR (Cumec)	226	243	404	483

5.4 EFA USING 7Q10 METHOD

Tables 5.2-5.5 show the computed Mean Annual Flows for each site of the river. The ten year return period is taken as 1991 and this year flow is taken as the environmental flow. But the formula intends to determine the lowest 10 daily average data. In this problem, if it is assumed that 70 % of this lowest monthly flow is minimum 10 daily flows, then the environmental flow can be considered to be 70% of the flow of 10-year return period. Table 5.15 gives the environmental flow for the four reaches of the Saryu River by 7Q10 Method.

Fig.5.6 Minimum Flow For four sites of Saryu River basin using 7Q10 Method

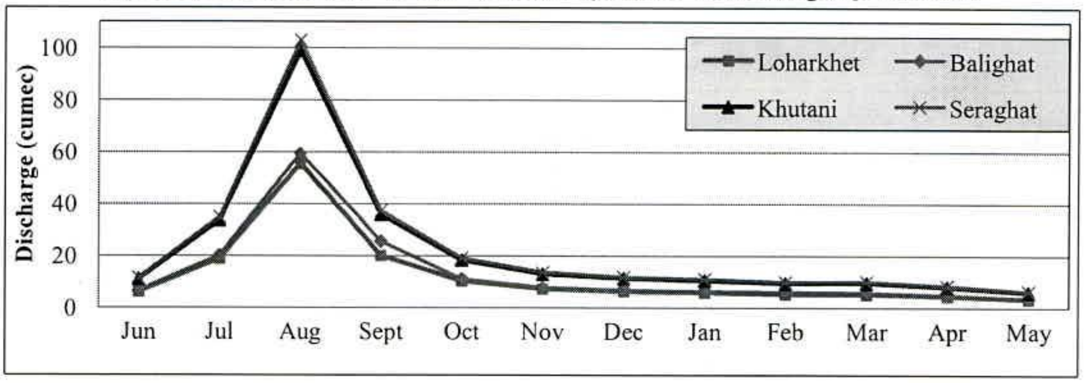


Table 5.15 E-Flow For different sites of Saryu River basin using 7Q10 Method for the 10 year return period (1991)

S.N.	Months	Min. Required Flow (Cumec)			
		Loharkhet	Balighat	Khutani	Seraghat
1	Jun	6.19	6.64	11.06	11.5
	Jul	18.79	20.13	33.55	34.79
	Aug	55.38	59.34	98.9	102.85
	Sept	20.08	25.51	35.85	37.29
2	Oct	10.26	11	18.33	19.06
	Nov	7.28	7.8	13	13.52
	Dec	6.38	6.84	11.4	11.85
	Jan	5.93	6.35	10.58	11.01
	Feb	5.33	6.12	9.52	9.9
3	Mar	5.24	5.79	9.65	10.03
	Apr	4.53	4.86	8.09	8.42
	May	3.42	3.67	6.11	6.36

5.5 EFA USING SEASONAL METHOD

There are two cases of arranging data for the Seasonal method of environmental flow estimation and they are outlined below:

i) Case 1: 10 day average flow data is considered

ii) Case 2: 90 % dependable year is considered

Next the collected flow data is arranged into seasons. Data is arranged as per definition of the seasons and percentages attached as follows: Season 1 is a period with heavy rainfall and varies from place to place. Season I is a season is incorporated with the high monsoon and hence is high flow season. With the context of Indian climate this season covers the months from May to September. The minimum flow for this season is found to be 30 percent of the average annual flow. The discharge data that is used can be 10 daily flow data or monthly flow data. Season II is the season of period of average flow covering the month of October. The minimum flow for this season is considered as 20 percent of average flow. The October month is considered as the changeover or transition period between wet and dry periods. Season III is a period of lean season or dry flow period. In includes the months from November to March. The minimum flow considerations for these months were taken as 15 percent of the average flow. Season IV is also an average flow period as Season II, covering the months of April and the minimum flow considerations are 20 percent of the average flow. Again it is a transition period between the dry and wet season

The proposed minimum flows are estimated for the two cases:

I. For case in which 25 years (1981 up to 2005), 10 daily average flow data is considered.
II. For 90 % dependable year (1981)

Case 1 – 10 daily Average Flow data is considered

The data was analysed and Annual Average and average daily discharges were determined from the historic data as shown in Table 5.2 -5.5 and Annexure I respectively Since the weather pattern is different in India, three seasons only will be considered with Season 1 from May to September, Season 2 from October to February, and Season 3 from March to May. The minimum flow using Seasonal Method (Case 1) for all the reaches of the Saryu River is shown in figure 5.7.

Case 2: 90% dependable flow is determined

Average 10 daily flow is determined for the four sites of the river basin (Table 5.2-5.5) to determine the 90 % dependable year(Table 5.16). The 90% percent dependable year is determined as 1981. Figure 5.7 and 5.8 show different proportions of the minimum flow requirement, and the variation of daily discharge and minimum flow for different sites of the Saryu River basin. Table 5.17 shows the minimum flow for Khutani site by Case 1 and Case 2 of the Seasonal Method. Similarly the minimum flows for all the other sites are evaluated.

Table 5.16 Calculation of 90 % dependable year for Khutani site

YEAR	MAF	RANK	Probability =(n/m+1)*100
2000	62.14	1	3.85
1998	56.95	2	7.69
1984	54.39	3	11.54
1990	53.96	4	15.38
1996	52.47	5	19.23
1994	52.38	6	23.08
1986	51.83	7	26.92
2005	51.48	8	30.77
2003	49.71	9	34.62
1988	48.93	10	38.46
1985	48.55	11	42.31
2004	47.77	12	46.15
2001	46.00	13	50.00
1983	45.04	14	53.85
1995	43.74	15	57.69
1999	42.53	16	61.54
1991	41.71	17	65.38
1997	39.05	18	69.23
1982	38.90	19	73.08
1993	38.71	20	76.92
1992	37.72	21	80.77
2002	35.22	22	85.78
1981	34.28	23	90.02
1989	33.79	24	92.31
1987	28.78	25	96.15

Table 5.17 Estimation of Min. flow for Khutani Site Using Seasonal Method for Case 1 & Case 2.

S.N.	Month		TEN DAILY BLOCK	No. of days in a Block	Percentage	10 days Avg. Discharge (cumec)	Min flow (cumec)	Discharge in 90% Dependable year (1981) (cumec)	Min flow (cumec)
						CASE 1		CASE 2	
1	Jun	I	1 10	10	30%	11.52	3.45	8.48	2.54
		II	11 20	10	30%	19.34	5.80	8.33	2.50
		III	21 30	10	30%	30.84	9.25	34.60	10.38
	Jul	I	1 10	10	30%	71.86	21.56	56.87	17.06
		II	11 20	10	30%	109.27	32.78	110.07	33.02
		III	21 31	11	30%	139.78	41.93	129.90	38.97
	Aug	I	1 10	10	30%	153.69	46.11	143.77	43.13
		II	11 20	10	30%	179.23	53.77	153.77	46.13
		III	21 31	11	30%	168.72	50.61	104.09	31.23
	Sept	I	1 10	10	30%	143.47	43.04	57.01	17.10
		II	11 20	10	30%	94.02	28.21	40.48	12.14
		III	21 30	10	30%	77.11	23.13	40.19	12.06
2	Oct	I	1 10	10	10%	52.06	5.21	36.61	3.66
		II	11 20	10	10%	45.77	4.58	26.31	2.63
		III	21 31	11	10%	31.83	3.18	22.72	2.27
	Nov	I	1 10	10	10%	26.50	2.65	21.70	2.17
		II	11 20	10	10%	23.46	2.35	18.19	1.82
		III	21 30	10	10%	20.82	2.08	15.48	1.55
	Dec	I	1 10	10	10%	19.01	1.90	15.19	1.52
		II	11 20	10	10%	17.50	1.75	13.31	1.33
		III	21 31	11	10%	16.92	1.69	12.54	1.25
	Jan	I	1 10	10	10%	15.16	1.52	13.34	1.33
		II	11 20	10	10%	14.06	1.41	12.35	1.24
		III	21 31	11	10%	13.58	1.36	13.53	1.35
	Feb	I	1 10	10	10%	13.08	1.31	12.76	1.28
		II	11 20	10	10%	12.91	1.29	10.98	1.10
		III	21 28	8	10%	12.45	1.24	10.73	1.07
3	Mar	I	1 10	10	20%	12.32	2.46	11.43	2.29
		II	11 20	10	20%	12.22	2.44	10.87	2.17
		III	21 31	11	20%	12.24	2.45	12.53	2.51
	Apr	I	1 10	10	20%	11.53	2.31	12.18	2.44
		II	11 20	10	20%	11.17	2.23	11.19	2.24
		III	21 30	10	20%	10.85	2.17	9.82	1.96
	May	I	1 10	10	20%	10.85	2.17	11.21	2.24
		II	11 20	10	20%	10.26	2.05	5.09	1.02
		III	21 31	11	20%	10.47	2.09	6.56	1.31

Note: Case 1: Base discharge considered for the 10 day block is the average discharge calculated considering the number of years for which discharge data is available . In this case the discharge data over a period of 25 years have been considered i.e. (1981-2005)

Case 2: In this method, the base discharge data has been considered as that observed during 90 % dependable year.

Fig 5.7 Min. flow requirements for the different sites of the Saryu River basin Using Seasonal Method (Case 1)

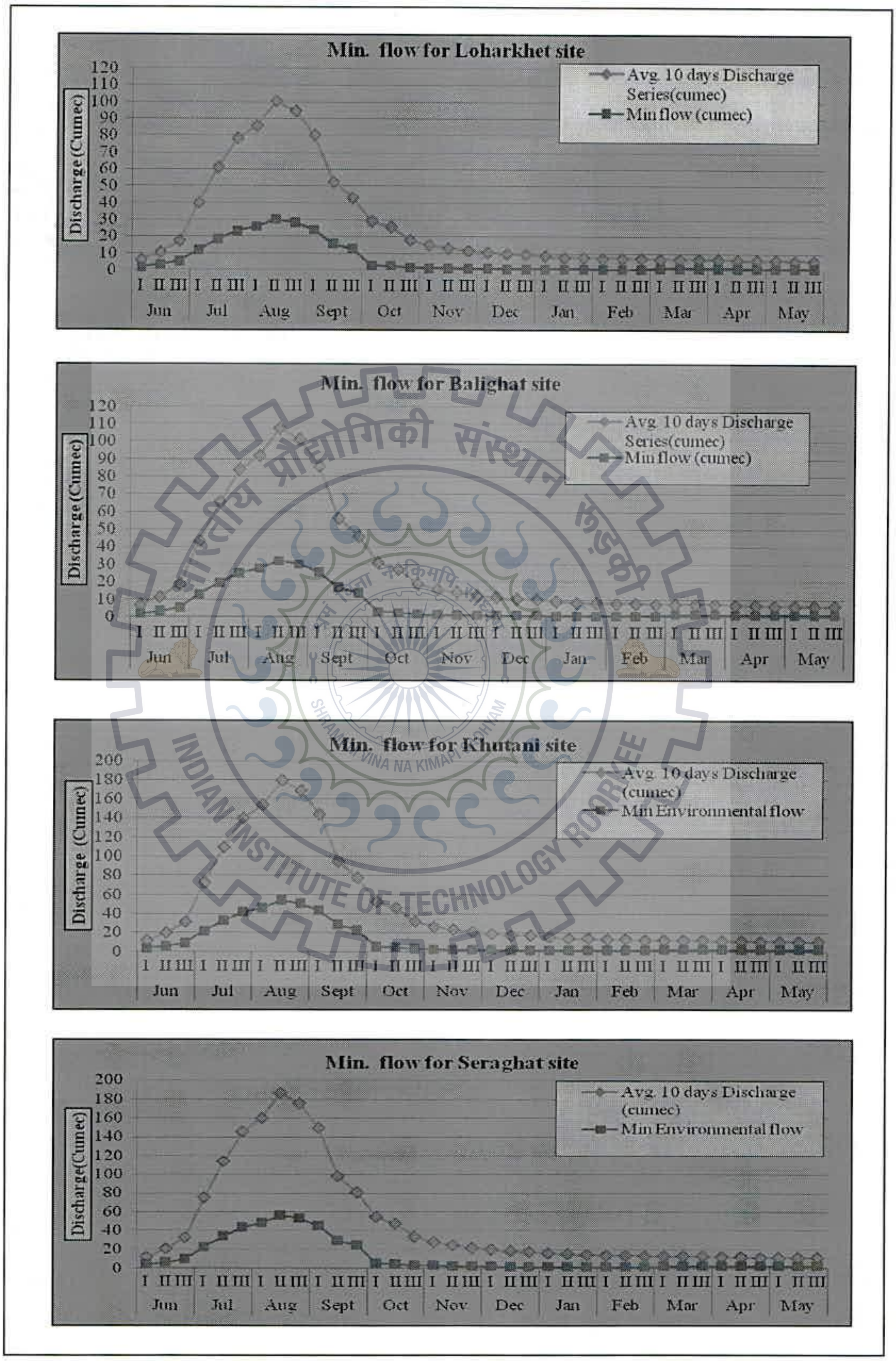
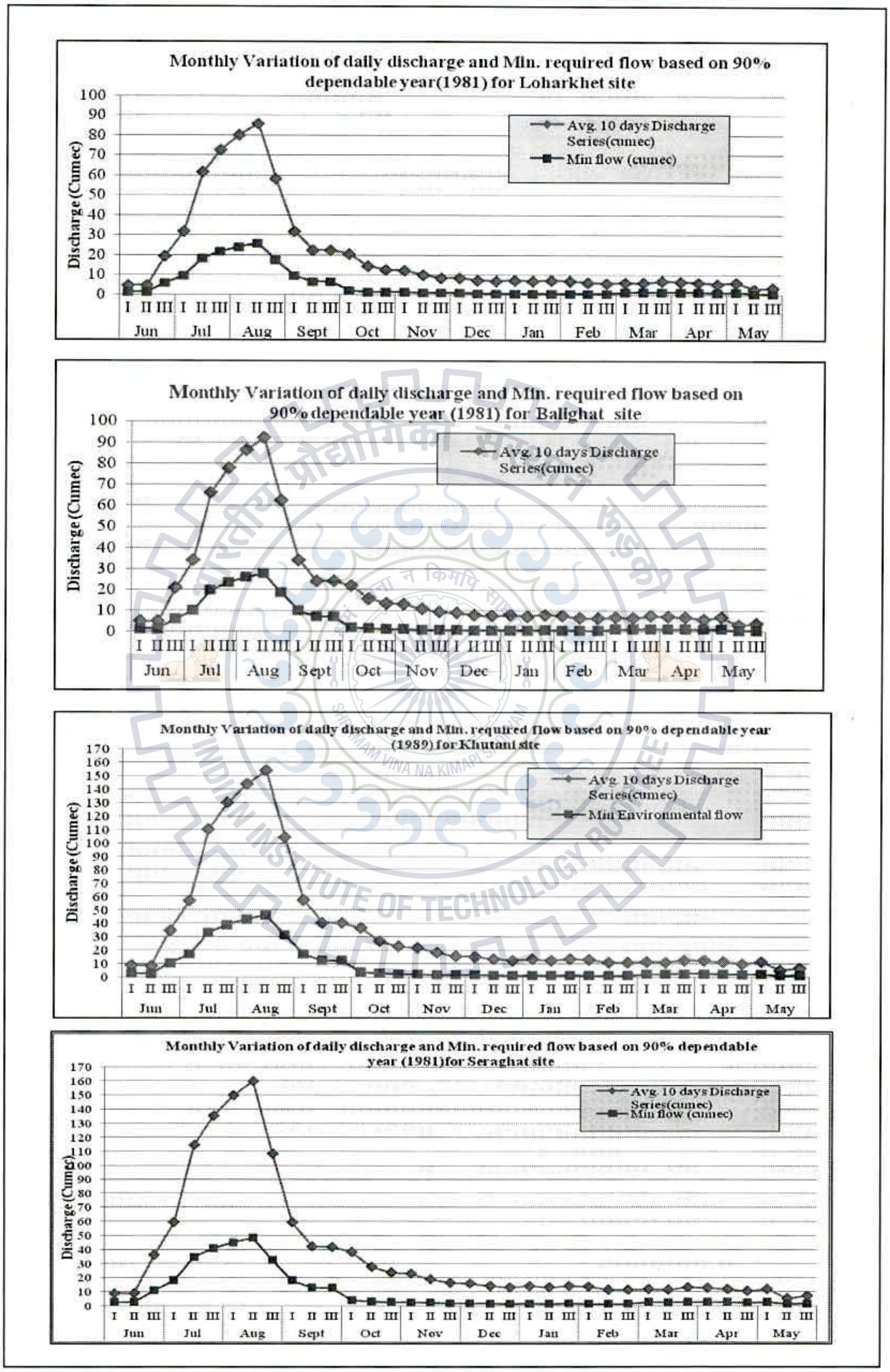


Fig. 5.8 Variation of 10 daily discharge and minimum flow for different sites of the Saryu River based on 90 % dependable year (1981)



5.5 DISCUSSION OF THE RESULTS

The Hydrological techniques which are based on historical flow data and 90% dependable flow in their computations are used to determine the minimum flow for the river. The obvious benefit of these methods is that flow requirements are set without expensive field data collection or processing.

The Tennant method is considered a standard setting method, meaning that it uses a single, fixed rule as a minimum base flow. It gives the Environmental flow on the bases of roughly assumed aquatic habitat conditions. For example 10% of Mean Annual Flow shows poor habitat condition. These percentages are based on mere assumptions which can be changed to suit the available flow. On the other hand this method is easy to apply to any situation without collecting lots of data or being expensive.

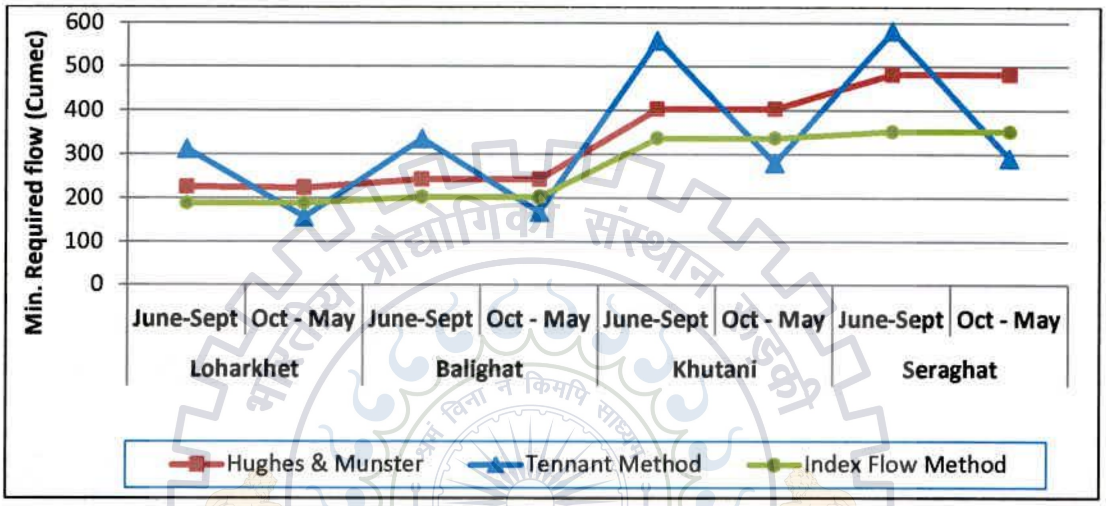
For Indian rivers the Tennant method was modified by distributing the evaluated environmental flow throughout the year considering similar monthly flow distribution patterns. The results of the Tennant Method are given in Table 5.6. The Good habitat condition is appropriate for the Environmental flow of 40% and 20% for monsoon (Jun to Sept) and non-monsoon (Oct – May). But the Modified Tennant Method gives clearer E-Flow for each month (Table 5.7 and Table 5.9 to 5.12). As it is a regulated river due to the construction of weirs and powerhouses the environmental flow of Fair (30%) or good (40%) can considered. The Tennant method has been used to estimate the environmental flow for the number of streams in the world. The method gives the changes in the stream depth and the velocity of the steams. The depth and velocity in turn directly affect the sustainability of the aquatic and other species.

The values of EF due to Hughes and Munster Method are obtained as 90% dependable flow of 90% dependable year. These values must be taken as limiting values, since the values are minimum flows in the river during stress period along historical flow records and they represent the extreme values. The final value of EF must be derived from using 90% dependable flow of whole hydrology data series which take into account the wet years as well as dry years.

Table 5.18 Comparison of EF for three Hydrological Methods

Methods	Loharkhet		Balighat		Khutani		Seraghat	
Tennant Method	June-Sept	Oct - May	June-Sept	Oct - May	June-Sept	Oct - May	June-Sept	Oct - May
	313	157	336	168	560	280	582	291
Hughes & Munster	226		243		404		483	
Index Flow Method	189.43		203		338		353	

Figure 5.9 Variation of Min. required flow using three methods



Initially the 7Q10 Method was used for the stream water quality standards for regulating the pollution. But the method is now used to estimate the E-Flow also due to its simplicity and less data requirement. 7Q10 Method gives the highest values for EF among all the methods also these high values are difficult to maintain in the river. The summery of the E-flow for Balighat, Seraghat and Khutani site are shown in Table 5.20

In seasonal Method case 1, the E-flows are estimated as percentages of the mean flows. The EF values so obtained are quite acceptable as these values are lower than 90% dependable flow. In case 2 the Flow is estimated by 90% dependable year (1981) .In both the cases of the Seasonal method the seasonal variation of the flow is taken under consideration. Hence the method is recommended.

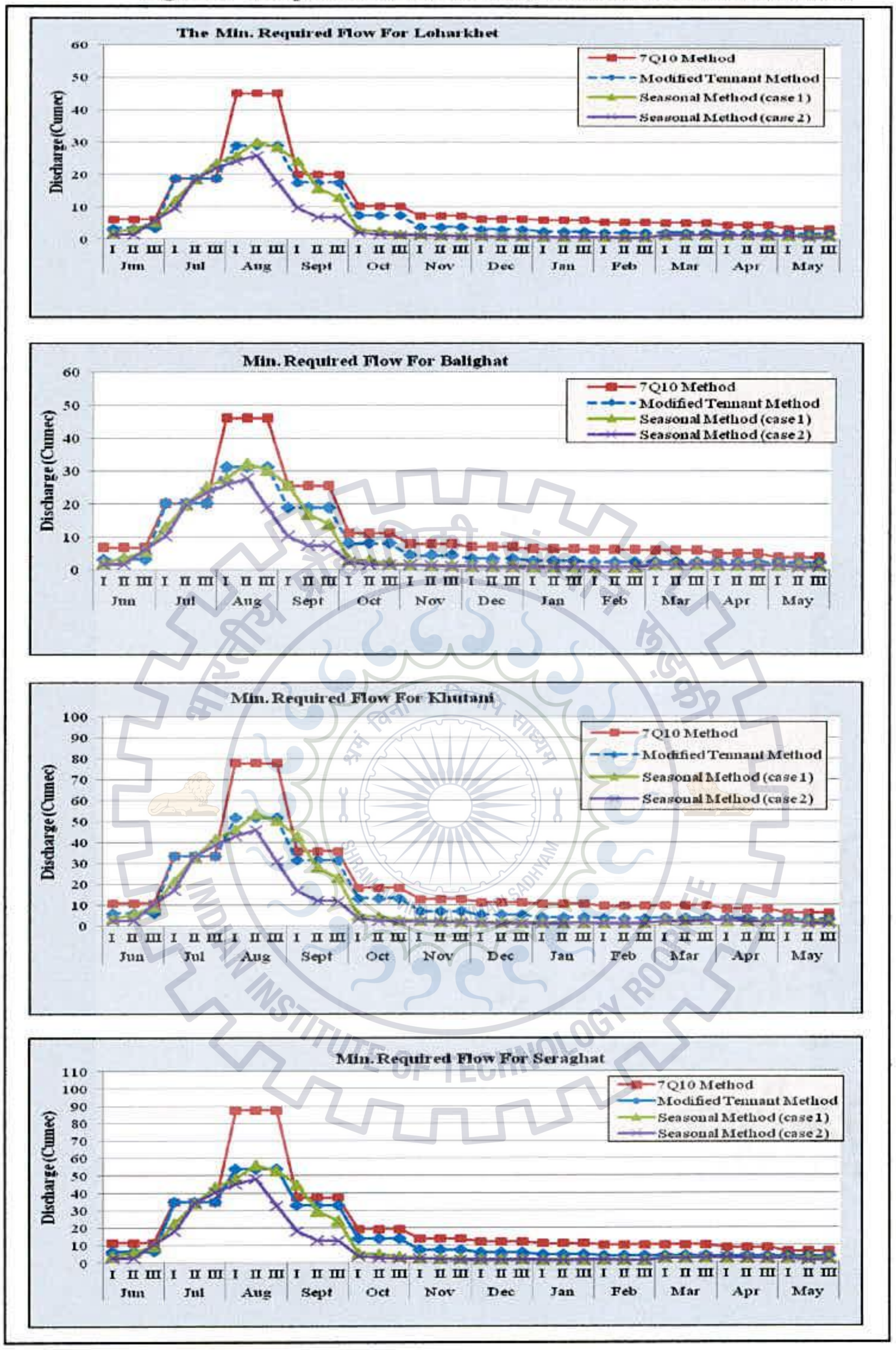
Table 5.19 The Q_{90} flows, Q_{50} flows and the Minimum flows(in cumec) by four methods for Khutani site.

Month		Q_{90}	Q_{50}	Seasonal Method		Modified Tennant Method	7Q10 Method
				Case 1	Case 2		
jun	I	8.48	14.85	3.45	2.54	11.06	6.18
	II	8.33	22.36	5.80	2.50		
	III	34.60	31.52	9.25	10.38		
jul	I	56.87	49.54	21.56	17.06	33.55	33.55
	II	110.07	187.17	32.78	33.02		
	III	129.90	246.77	41.93	38.97		
aug	I	143.77	170.12	46.11	43.13	98.9	51.95
	II	153.77	234.35	53.77	46.13		
	III	104.09	149.31	50.61	31.23		
sep	I	57.01	77.08	43.04	17.10	35.85	31.52
	II	40.48	56.55	28.21	12.14		
	III	40.19	40.33	23.13	12.06		
oct	I	36.61	32.20	5.21	3.66	18.33	13.31
	II	26.31	26.36	4.58	2.63		
	III	22.72	23.77	3.18	2.27		
nov	I	21.70	21.09	2.65	2.17	13	7.09
	II	18.19	19.66	2.35	1.82		
	III	15.48	18.97	2.08	1.55		
dec	I	15.19	17.56	1.90	1.52	11.4	5.52
	II	13.31	16.30	1.75	1.33		
	III	12.54	15.97	1.69	1.25		
jan	I	13.34	16.79	1.52	1.33	10.58	4.24
	II	12.35	15.24	1.41	1.24		
	III	13.53	15.03	1.36	1.35		
feb	I	12.76	14.14	1.31	1.28	9.52	3.60
	II	10.98	11.41	1.29	1.10		
	III	10.73	12.97	1.24	1.07		
mar	I	11.43	12.59	2.46	2.29	9.65	3.80
	II	10.87	11.88	2.44	2.17		
	III	12.53	12.25	2.45	2.51		
apr	I	12.18	11.65	2.31	2.44	8.09	3.36
	II	11.19	10.99	2.23	2.24		
	III	9.82	9.57	2.17	1.96		
may	I	11.21	9.43	2.17	2.24	6.11	3.26
	II	5.09	10.23	2.05	1.02		
	III	6.56	9.92	2.09	1.31		

Table 5.20 The Min. Required Flow (in Cumec) for the four sites of Saryu River by different Methods

Month		Seasonal Method		7Q10 Method	Modified Tennant Method	Seasonal Method		7Q10 Method	Modified Tennant Method	Seasonal Method		7Q10 Method	Modified Tennant Method	Seasonal Method		7Q10 Method	Modified Tennant Method
		Case 1	Case 2			Case 1	Case 2			Case 1	Case 2			Case 1	Case 2		
		Loharkhet				Balighat				Khutani				Seraghat			
Jun	I	1.93	1.42			2.07	1.53			3.45	2.54			3.59	2.65		
	II	3.25	1.40	6.19	3.43	3.48	1.50	6.64	3.07	5.80	2.50	11.06	6.18	6.04	2.60	11.5	6.42
	III	5.18	5.81			5.55	6.23			9.25	10.38			9.62	10.80		
Jul	I	12.07	9.55			12.93	10.24			21.56	17.06			22.42	17.74		
	II	18.36	18.49	18.79	18.65	19.67	19.81	20.13	20.09	32.78	33.02	33.55	33.55	34.09	34.34	34.79	34.83
	III	23.48	21.82			25.16	23.38			41.93	38.97			43.61	40.53		
Aug	I	25.82	24.15			27.66	25.88			46.11	43.13			47.95	44.86		
	II	30.11	25.83	55.38	28.88	32.26	27.68	59.34	31.11	53.77	46.13	98.9	51.95	55.92	47.98	102.85	53.93
	III	28.34	17.49			30.37	18.74			50.61	31.23			52.64	32.48		
Sep	I	24.10	9.58			25.82	10.26			43.04	17.10			44.76	17.79		
	II	15.80	6.80	20.08	17.52	16.92	7.29	25.51	18.88	28.21	12.14	35.85	31.52	29.34	12.63	37.29	32.72
	III	12.95	6.75			13.88	7.23			23.13	12.06			24.06	12.54		
Oct	I	2.92	2.05			3.12	2.20			5.21	3.66			5.41	3.81		
	II	2.56	1.47	10.26	7.40	2.75	1.58	11	7.97	4.58	2.63	18.33	13.31	4.76	2.74	19.06	13.81
	III	1.78	1.27			1.91	1.36			3.18	2.27			3.31	2.36		
Nov	I	1.48	1.22			1.59	1.30			2.65	2.17			2.76	2.26		
	II	1.31	1.02	7.28	3.80	1.41	1.09	7.8	4.25	2.35	1.82	13	7.09	2.44	1.89	13.52	7.36
	III	1.17	0.87			1.25	0.93			2.08	1.55			2.17	1.61		
Dec	I	1.06	0.85			1.14	0.91			1.90	1.52			1.98	1.58		
	II	0.98	0.75	6.38	3.07	1.05	0.80	6.84	3.31	1.75	1.33	11.4	5.52	1.82	1.38	11.85	5.73
	III	0.95	0.70			1.02	0.75			1.69	1.25			1.76	1.30		
Jan	I	0.85	0.75			0.91	0.80			1.52	1.33			1.58	1.39		
	II	0.79	0.69	5.93	2.46	0.84	0.74	6.35	2.65	1.41	1.24	10.58	4.24	1.46	1.28	11.01	4.59
	III	0.76	0.76			0.82	0.81			1.36	1.35			1.41	1.41		
Feb	I	0.73	0.71			0.78	0.77			1.31	1.28			1.36	1.33		
	II	0.72	0.61	5.33	2.00	0.77	0.66	6.12	2.16	1.29	1.10	9.52	3.60	1.34	1.14	9.9	3.74
	III	0.70	0.60			0.75	0.64			1.24	1.07			1.29	1.12		
Mar	I	1.38	1.28			1.48	1.37			2.46	2.29			2.56	2.38		
	II	1.37	1.22	5.24	2.11	1.47	1.30	5.79	2.28	2.44	2.17	9.65	3.80	2.54	2.26	10.03	3.96
	III	1.37	1.40			1.47	1.50			2.45	2.51			2.55	2.61		
Apr	I	1.29	1.36			1.38	1.46			2.31	2.44			2.40	2.53		
	II	1.25	1.25	4.53	1.86	1.34	1.34	4.86	2.01	2.23	2.24	8.09	3.36	2.32	2.33	8.42	3.49
	III	1.21	1.10			1.30	1.18			2.17	1.96			2.26	2.04		
May	I	1.22	1.26			1.30	1.35			2.17	2.24			2.26	2.33		
	II	1.15	0.57	3.42	1.81	1.23	0.61	3.67	1.96	2.05	1.02	6.11	3.26	2.13	1.06	6.36	3.39
	III	1.17	0.73			1.26	0.79			2.09	1.31			2.18	1.36		

Fig. 5.10 Comparison of E Flows obtained from different Methods



The recommendations for the stream flow found to be are higher in summer than in winter. Similarly in Saryu River during the Monsoon (June to September) high flow occur and for the rest of the year low flow condition is achieved. Maximum values for the environmental flow comes out for the monsoon months of July-September whereas the minimum values are for January to May. This is due the fact that the Saryu River is totally a rain-fed river where maximum of its flow occurs in Monsoon months.

CHAPTER 6 : CONCLUSION

The following conclusions can be derived from the study:

- Six hydrological approaches were used for EFA of Saryu River basin. Among these, Modified Tennant Method and Seasonal Method are recommended.
- In Modified Tennant Method the 30% of AAF or "fair" Aquatic habitat condition is recommended. At this flow the depth, width and the velocity in the downstream of the stream are likely to be satisfactory.
- The Seasonal methods gives a certain percentage for the average 10 daily flow 90% dependable flow for each month of the year taking into account the flow variations for each month. Seasonal Methods are integrated by a modified flow hydrograph which assure the proper water requirements for the River.

Scope and Limitations

- The scope of the study includes the application of the EFA techniques using extended Ten-daily flows records from the gauge station near to the area of the study. History flow records were completed and transferred by area proportion methodology to those locations where the data is missing or not available.
- The cross-section details of the river should be used for description of flow variables such as depth and velocity of flow. The ecological components of the river are huge and it is practically impossible to address the impact of flow modification on all the elements of the river system.
- In this study the hydrological flow data is the only index of EFA.

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Annexure I

Ten daily Average discharge data of the year 1981 – 2005 (25 years) River Saryu for Khutani weir Site

S. No.	Month	Ten Daily	Days	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
				Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec
1	Jan	1 10	10	13.34	11.52	14.39	13.39	14.45	19.44	17.51	13.95	22.06	13.62	20.06	14.58	11.83
		11 20	10	12.35	10.77	11.02	11.78	10.17	17.83	17.03	13.98	18.53	12.53	16.29	14.02	10.69
		21 31	11	13.53	11.29	12.68	11.03	9.72	16.35	15.55	12.90	14.67	11.42	15.12	15.61	9.47
2	Feb	1 10	10	12.76	11.79	10.70	10.37	9.03	14.51	13.94	11.71	13.59	11.13	14.58	16.49	9.59
		11 20	10	10.98	11.52	10.25	14.62	8.29	14.57	16.52	11.74	12.97	13.85	13.95	13.99	10.21
		21 28	8	10.73	10.65	10.15	12.80	7.02	14.06	14.20	14.47	12.50	13.77	13.60	11.95	12.30
3	Mar	1 10	10	11.43	14.43	9.94	9.77	6.76	12.48	12.90	14.02	11.70	14.97	13.78	10.82	10.92
		11 20	10	10.87	15.63	10.22	9.42	6.56	13.30	12.62	20.17	11.53	12.87	15.56	10.51	10.77
		21 31	11	12.53	17.03	11.25	9.32	6.29	12.81	11.99	13.98	11.87	16.34	15.29	10.55	15.79
4	Apr	1 10	10	12.18	16.19	10.12	8.91	6.67	12.30	11.20	12.47	11.20	14.29	13.36	9.07	11.44
		11 20	10	11.19	15.15	16.95	8.36	6.57	10.97	10.10	11.90	9.82	14.17	14.06	9.36	12.66
		21 30	10	9.82	16.13	14.82	8.47	5.86	13.13	11.68	12.27	9.34	12.49	11.56	9.90	11.46
5	May	1 10	10	11.21	16.55	12.80	7.58	5.89	10.33	18.98	11.95	9.02	11.71	10.00	9.19	12.13
		11 20	10	5.09	16.92	12.59	7.32	6.77	18.04	13.28	10.49	9.93	13.79	10.84	7.91	9.02
		21 31	11	6.56	14.51	14.39	6.56	9.60	22.68	10.08	9.24	8.62	14.69	8.73	9.49	13.23
6	Jun	1 10	10	8.48	13.66	10.89	18.14	9.03	12.58	10.40	11.28	10.04	11.03	20.20	7.80	10.04
		11 20	10	8.33	16.19	11.05	30.24	9.52	39.93	9.62	12.30	9.24	12.48	21.35	9.35	22.27
		21 30	10	34.60	12.72	17.76	28.17	9.65	45.17	9.15	43.71	16.82	20.43	15.80	15.77	27.46
7	Jul	1 10	10	56.87	12.54	45.32	137.65	38.04	48.27	14.90	113.48	22.90	142.07	47.93	11.79	33.94
		11 20	10	110.07	64.03	25.96	76.67	62.79	208.13	27.11	149.38	43.63	131.67	88.14	74.93	93.73
		21 31	11	129.90	114.17	100.38	217.64	128.33	179.84	68.93	199.31	69.39	163.88	120.78	80.90	86.00
8	Aug	1 10	10	143.77	134.39	115.98	130.52	101.97	222.36	60.43	179.53	67.38	202.77	176.82	141.26	107.46
		11 20	10	153.77	208.77	172.30	133.49	242.16	200.76	96.84	174.40	163.40	265.70	196.38	121.44	68.02
		21 31	11	104.09	171.47	170.00	170.86	236.09	153.11	132.72	205.89	216.86	167.11	141.28	211.18	75.98
9	Sept	1 10	10	57.01	110.26	185.91	220.82	146.35	93.54	134.93	92.40	102.62	172.51	127.10	170.58	174.87
		11 20	10	40.48	91.71	158.24	102.25	102.25	69.86	11.61	66.70	53.87	106.78	80.59	93.70	140.54
		21 30	10	40.19	53.48	148.62	94.57	94.57	63.51	61.12	87.90	43.67	80.84	51.22	58.38	132.78
10	Oct	1 10	10	36.61	39.26	74.94	73.92	73.92	61.79	32.88	47.71	35.17	58.03	36.85	39.99	62.06
		11 20	10	26.31	27.25	50.32	134.51	134.51	55.37	27.06	34.85	32.65	39.94	31.17	31.87	43.29
		21 31	11	22.72	23.02	35.05	58.46	58.46	37.34	22.84	27.68	27.77	31.75	26.18	24.40	30.84
11	Nov	1 10	10	21.70	19.92	27.02	41.62	41.62	31.39	20.69	24.40	24.16	27.06	22.82	20.30	24.79
		11 20	10	18.19	19.04	22.37	33.74	33.74	27.85	19.69	22.36	21.50	25.07	21.02	17.77	21.39
		21 30	10	15.48	17.75	19.59	27.40	27.40	25.77	18.46	20.07	19.52	23.33	18.57	15.82	20.09
12	Dec	1 10	10	15.19	14.94	17.19	25.01	25.01	23.37	16.83	18.45	17.52	20.28	17.76	14.82	16.94
		11 20	10	13.31	12.62	16.02	22.67	22.67	24.27	17.31	16.68	15.75	18.23	16.28	11.72	15.44
		21 31	11	12.54	13.10	14.36	29.95	29.95	18.70	14.83	17.73	15.31	19.96	16.48	10.59	14.13
MEAN ANNUAL DISCHARGE(cumec)				34.28	38.90	45.04	54.39	48.55	51.83	28.78	48.93	33.79	53.96	41.71	37.72	38.71

Annexure I

S. No.	Month	Ten Daily	Days	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Avg. 10 days discharge
				Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec	Cumec
1	Jan	1 10	10	12.72	14.42	14.40	12.57	17.25	16.58	12.58	16.79	14.43	13.51	15.73	17.86	15.16
		11 20	10	14.23	13.84	15.67	12.35	15.11	15.46	12.20	15.24	15.55	12.52	15.02	17.34	14.06
		21 31	11	13.80	12.61	13.81	12.98	13.79	15.00	11.23	15.03	15.35	12.57	15.29	18.79	13.58
2	Feb	1 10	10	13.09	11.80	12.41	11.32	13.21	13.56	12.76	14.14	15.77	13.92	14.22	20.65	13.08
		11 20	10	10.98	14.16	12.42	10.64	12.91	11.74	11.89	11.41	14.69	15.23	13.04	20.19	12.91
		21 28	8	10.34	12.56	13.29	10.80	14.01	11.87	10.17	12.97	13.32	14.54	11.11	18.04	12.45
3	Mar	1 10	10	9.68	11.45	12.62	10.27	13.34	11.15	9.81	12.59	17.45	16.13	11.45	18.02	12.32
		11 20	10	8.79	11.15	12.27	9.90	14.57	10.22	9.63	11.88	13.47	13.35	11.16	19.03	12.22
		21 31	11	8.60	12.80	11.82	10.00	13.35	8.80	9.95	12.25	13.18	13.03	10.62	16.61	12.24
4	Apr	1 10	10	9.20	11.73	11.13	12.70	14.44	9.22	9.17	11.65	12.36	12.68	10.69	13.91	11.53
		11 20	10	7.68	11.17	10.18	11.58	13.41	8.76	8.74	10.99	11.35	11.78	9.68	12.67	11.17
		21 30	10	7.40	10.45	10.10	10.43	13.12	8.54	8.81	9.57	11.66	11.81	9.99	12.32	10.85
5	May	1 10	10	7.47	9.64	9.19	10.84	13.20	7.98	9.24	9.43	11.69	11.29	11.18	12.88	10.85
		11 20	10	7.20	9.89	8.20	8.96	13.02	9.50	9.10	10.23	10.16	9.80	7.70	10.68	10.26
		21 31	11	6.83	7.87	7.78	8.31	11.01	9.95	11.38	9.92	10.53	8.74	11.98	9.02	10.47
6	Jun	1 10	10	6.45	7.04	8.10	9.69	9.61	8.43	29.37	14.85	10.09	9.67	11.88	9.14	11.52
		11 20	10	13.23	13.84	17.76	9.99	11.12	29.14	94.21	22.36	18.18	10.26	22.98	8.67	19.34
		21 30	10	90.75	21.20	44.43	16.04	58.57	19.32	102.95	31.52	23.06	23.66	17.52	24.79	30.84
7	Jul	1 10	10	122.27	50.72	57.02	62.15	193.31	53.65	151.66	49.54	50.81	94.79	111.73	73.17	71.86
		11 20	10	118.43	174.66	195.91	113.95	145.42	85.53	162.87	187.17	34.59	121.43	102.75	132.90	109.27
		21 31	11	159.34	126.96	159.53	119.03	140.84	133.32	177.83	246.77	48.84	175.69	187.52	159.30	139.78
8	Aug	1 10	10	194.06	127.14	181.57	166.76	189.25	184.70	180.21	170.12	147.48	145.80	230.29	140.17	153.69
		11 20	10	180.91	120.90	257.49	96.66	295.51	131.69	299.57	234.35	100.88	150.16	245.30	169.91	179.23
		21 31	11	298.50	146.98	208.73	88.78	181.08	142.67	222.36	149.31	132.76	208.39	147.19	134.51	168.72
9	Sept	1 10	10	214.04	218.32	169.58	107.54	118.00	77.78	243.08	77.08	137.90	187.23	81.83	165.45	143.47
		11 20	10	86.63	98.13	110.86	131.98	89.70	112.61	109.59	56.55	121.19	121.02	60.41	133.34	94.02
		21 30	10	55.72	66.39	67.40	70.89	79.91	119.67	71.71	40.33	54.77	93.42	53.62	142.96	77.11
10	Oct	1 10	10	40.44	52.57	52.47	49.74	62.72	74.61	47.87	32.20	38.15	55.95	45.93	75.72	52.06
		11 20	10	29.97	33.56	38.83	38.49	66.07	47.57	34.94	26.36	29.36	39.10	40.05	50.96	45.77
		21 31	11	24.13	26.38	30.20	29.68	45.42	32.12	28.61	23.77	23.84	32.69	33.05	39.29	31.83
11	Nov	1 10	10	20.79	24.37	24.55	24.21	37.63	26.06	25.74	21.09	19.96	28.03	30.10	32.48	26.50
		11 20	10	18.88	21.36	22.16	23.47	31.24	21.30	23.71	19.66	18.10	24.97	28.61	29.24	23.46
		21 30	10	17.42	18.96	20.07	19.56	26.55	17.90	20.90	18.97	14.69	22.51	27.36	26.44	20.82
12	Dec	1 10	10	15.97	17.37	17.79	23.56	23.37	16.20	18.75	17.56	14.76	19.18	23.56	23.94	19.01
		11 20	10	14.98	16.56	15.45	21.94	21.21	15.09	17.67	16.30	14.41	17.94	20.70	22.16	17.50
		21 31	11	14.62	15.68	13.67	17.97	17.79	13.53	16.83	15.97	13.28	16.83	18.52	20.75	16.92
AAF (cumec)				52.38	43.74	52.47	39.05	56.95	42.53	62.14	46.00	35.22	49.71	47.77	51.48	

Annexure II

Estimation of Min. flow for Loharkhet Site Using seasonal Method for Case 1 & Case 2.

S.N.	Month		TEN DAILY BLOCK	No. of days in a Block	Percentage	Avg. 10 days Discharge (cumec)	Min flow (cumec)	Avg. 10 days Discharge (cumec)	Min flow (cumec)
						CASE 1		CASE 2	
1	Jun	I	1 10	10	30%	6.45	1.93	4.75	1.42
		II	11 20	10	30%	10.83	3.25	4.66	1.40
		III	21 30	10	30%	17.27	5.18	19.38	5.81
	Jul	I	1 10	10	30%	40.24	12.07	31.85	9.55
		II	11 20	10	30%	61.19	18.36	61.64	18.49
		III	21 31	11	30%	78.28	23.48	72.74	21.82
	Aug	I	1 10	10	30%	86.07	25.82	80.51	24.15
		II	11 20	10	30%	100.37	30.11	86.11	25.83
		III	21 31	11	30%	94.48	28.34	58.29	17.49
	Sept	I	1 10	10	30%	80.34	24.10	31.93	9.58
		II	11 20	10	30%	52.65	15.80	22.67	6.80
		III	21 30	10	30%	43.18	12.95	22.51	6.75
2	Oct	I	1 10	10	10%	29.15	2.92	20.50	2.05
		II	11 20	10	10%	25.63	2.56	14.73	1.47
		III	21 31	11	10%	17.82	1.78	12.72	1.27
	Nov	I	1 10	10	10%	14.84	1.48	12.15	1.22
		II	11 20	10	10%	13.14	1.31	10.19	1.02
		III	21 30	10	10%	11.66	1.17	8.67	0.87
	Dec	I	1 10	10	10%	10.65	1.06	8.51	0.85
		II	11 20	10	10%	9.80	0.98	7.45	0.75
		III	21 31	11	10%	9.48	0.95	7.02	0.70
	Jan	I	1 10	10	10%	8.49	0.85	7.47	0.75
		II	11 20	10	10%	7.87	0.79	6.92	0.69
		III	21 31	11	10%	7.61	0.76	7.58	0.76
	Feb	I	1 10	10	10%	7.33	0.73	7.15	0.71
		II	11 20	10	10%	7.23	0.72	6.15	0.61
		III	21 28	8	10%	6.97	0.70	6.01	0.60
3	Mar	I	1 10	10	20%	6.90	1.38	6.40	1.28
		II	11 20	10	20%	6.84	1.37	6.09	1.22
		III	21 31	11	20%	6.86	1.37	7.02	1.40
	Apr	I	1 10	10	20%	6.46	1.29	6.82	1.36
		II	11 20	10	20%	6.26	1.25	6.27	1.25
		III	21 30	10	20%	6.07	1.21	5.50	1.10
	May	I	1 10	10	20%	6.08	1.22	6.28	1.26
		II	11 20	10	20%	5.74	1.15	2.85	0.57
		III	21 31	11	20%	5.86	1.17	3.67	0.73

Annexure II

Estimation of Min.flow for Balighat Site Using Seasonal Method for Case 1 & Case 2.

S.N.	Month		TEN DAILY BLOCK	No. of days in a Block	Percentage	Avg. 10 days Discharge (cumec)	Min flow (cumec)	Avg. 10 days Discharge (cumec)	Min flow (cumec)
						CASE 1		CASE 2	
1	Jun	I	1 10	10	30%	6.91	2.07	5.09	1.53
		II	11 20	10	30%	11.61	3.48	5.00	1.50
		III	21 30	10	30%	18.50	5.55	20.76	6.23
	Jul	I	1 10	10	30%	43.12	12.93	34.12	10.24
		II	11 20	10	30%	65.56	19.67	66.04	19.81
		III	21 31	11	30%	83.87	25.16	77.94	23.38
	Aug	I	1 10	10	30%	92.21	27.66	86.26	25.88
		II	11 20	10	30%	107.54	32.26	92.26	27.68
		III	21 31	11	30%	101.23	30.37	62.45	18.74
	Sept	I	1 10	10	30%	86.08	25.82	34.21	10.26
		II	11 20	10	30%	56.41	16.92	24.29	7.29
		III	21 30	10	30%	46.26	13.88	24.11	7.23
2	Oct	I	1 10	10	10%	31.24	3.12	21.97	2.20
		II	11 20	10	10%	27.46	2.75	15.79	1.58
		III	21 31	11	10%	19.10	1.91	13.63	1.36
	Nov	I	1 10	10	10%	15.90	1.59	13.02	1.30
		II	11 20	10	10%	14.07	1.41	10.91	1.09
		III	21 30	10	10%	12.49	1.25	9.29	0.93
	Dec	I	1 10	10	10%	11.41	1.14	9.11	0.91
		II	11 20	10	10%	10.50	1.05	7.99	0.80
		III	21 31	11	10%	10.15	1.02	7.52	0.75
	Jan	I	1 10	10	10%	9.10	0.91	8.00	0.80
		II	11 20	10	10%	8.44	0.84	7.41	0.74
		III	21 31	11	10%	8.15	0.82	8.12	0.81
	Feb	I	1 10	10	10%	7.85	0.78	7.66	0.77
		II	11 20	10	10%	7.75	0.77	6.59	0.66
		III	21 28	8	10%	7.47	0.75	6.44	0.64
3	Mar	I	1 10	10	20%	7.39	1.48	6.86	1.37
		II	11 20	10	20%	7.33	1.47	6.52	1.30
		III	21 31	11	20%	7.35	1.47	7.52	1.50
	Apr	I	1 10	10	20%	6.92	1.38	7.31	1.46
		II	11 20	10	20%	6.70	1.34	6.71	1.34
		III	21 30	10	20%	6.51	1.30	5.89	1.18
	May	I	1 10	10	20%	6.51	1.30	6.73	1.35
		II	11 20	10	20%	6.15	1.23	3.05	0.61
		III	21 31	11	20%	6.28	1.26	3.94	0.79

Annexure II

Estimation of Min. flow for Khutani Site Using Seasonal Method
For Case1 & case 2

S.N.	Month		TEN DAILY BLOCK	No. of days in a Block	Percentage	Avg. 10 days Discharge (cumec)	Min flow (cumec)	Avg. 10 days Discharge (cumec)	Min flow (cumec)
						CASE 1		CASE 2	
1	Jun	I	1 10	10	30%	11.52	3.45	8.48	2.54
		II	11 20	10	30%	19.34	5.80	8.33	2.50
		III	21 30	10	30%	30.84	9.25	34.60	10.38
	Jul	I	1 10	10	30%	71.86	21.56	56.87	17.06
		II	11 20	10	30%	109.27	32.78	110.07	33.02
		III	21 31	11	30%	139.78	41.93	129.90	38.97
	Aug	I	1 10	10	30%	153.69	46.11	143.77	43.13
		II	11 20	10	30%	179.23	53.77	153.77	46.13
		III	21 31	11	30%	168.72	50.61	104.09	31.23
	Sept	I	1 10	10	30%	143.47	43.04	57.01	17.10
		II	11 20	10	30%	94.02	28.21	40.48	12.14
		III	21 30	10	30%	77.11	23.13	40.19	12.06
2	Oct	I	1 10	10	10%	52.06	5.21	36.61	3.66
		II	11 20	10	10%	45.77	4.58	26.31	2.63
		III	21 31	11	10%	31.83	3.18	22.72	2.27
	Nov	I	1 10	10	10%	26.50	2.65	21.70	2.17
		II	11 20	10	10%	23.46	2.35	18.19	1.82
		III	21 30	10	10%	20.82	2.08	15.48	1.55
	Dec	I	1 10	10	10%	19.01	1.90	15.19	1.52
		II	11 20	10	10%	17.50	1.75	13.31	1.33
		III	21 31	11	10%	16.92	1.69	12.54	1.25
	Jan	I	1 10	10	10%	15.16	1.52	13.34	1.33
		II	11 20	10	10%	14.06	1.41	12.35	1.24
		III	21 31	11	10%	13.58	1.36	13.53	1.35
	Feb	I	1 10	10	10%	13.08	1.31	12.76	1.28
		II	11 20	10	10%	12.91	1.29	10.98	1.10
		III	21 28	8	10%	12.45	1.24	10.73	1.07
3	Mar	I	1 10	10	20%	12.32	2.46	11.43	2.29
		II	11 20	10	20%	12.22	2.44	10.87	2.17
		III	21 31	11	20%	12.24	2.45	12.53	2.51
	Apr	I	1 10	10	20%	11.53	2.31	12.18	2.44
		II	11 20	10	20%	11.17	2.23	11.19	2.24
		III	21 30	10	20%	10.85	2.17	9.82	1.96
	May	I	1 10	10	20%	10.85	2.17	11.21	2.24
		II	11 20	10	20%	10.26	2.05	5.09	1.02
		III	21 31	11	20%	10.47	2.09	6.56	1.31

Annexure II

Estimation of Min. flow for Seraghat Site Using Seasonal Method
For Case 1 & case 2

S.N.	Month		TEN DAILY BLOCK	No. of days in a Block	Percentage	Avg. 10 days Discharge (cumec)	Min flow (cumec)	Avg. 10 days Discharge (cumec)	Min flow (cumec)
						CASE 1		CASE 2	
1	Jun	I	1 10	10	30%	11.98	3.59	8.82	2.65
		II	11 20	10	30%	20.12	6.04	8.66	2.60
		III	21 30	10	30%	32.07	9.62	35.98	10.80
	Jul	I	1 10	10	30%	74.74	22.42	59.14	17.74
		II	11 20	10	30%	113.64	34.09	114.47	34.34
		III	21 31	11	30%	145.37	43.61	135.10	40.53
	Aug	I	1 10	10	30%	159.84	47.95	149.52	44.86
		II	11 20	10	30%	186.40	55.92	159.92	47.98
		III	21 31	11	30%	175.46	52.64	108.25	32.48
	Sept	I	1 10	10	30%	149.21	44.76	59.29	17.79
		II	11 20	10	30%	97.78	29.34	42.10	12.63
		III	21 30	10	30%	80.19	24.06	41.80	12.54
2	Oct	I	1 10	10	10%	54.14	5.41	38.07	3.81
		II	11 20	10	10%	47.61	4.76	27.36	2.74
		III	21 31	11	10%	33.10	3.31	23.63	2.36
	Nov	I	1 10	10	10%	27.56	2.76	22.57	2.26
		II	11 20	10	10%	24.40	2.44	18.92	1.89
		III	21 30	10	10%	21.66	2.17	16.10	1.61
	Dec	I	1 10	10	10%	19.77	1.98	15.80	1.58
		II	11 20	10	10%	18.20	1.82	13.84	1.38
		III	21 31	11	10%	17.60	1.76	13.04	1.30
	Jan	I	1 10	10	10%	15.77	1.58	13.87	1.39
		II	11 20	10	10%	14.62	1.46	12.84	1.28
		III	21 31	11	10%	14.13	1.41	14.07	1.41
	Feb	I	1 10	10	10%	13.60	1.36	13.27	1.33
		II	11 20	10	10%	13.43	1.34	11.42	1.14
		III	21 28	8	10%	12.95	1.29	11.16	1.12
3	Mar	I	1 10	10	20%	12.81	2.56	11.89	2.38
		II	11 20	10	20%	12.71	2.54	11.30	2.26
		III	21 31	11	20%	12.73	2.55	13.03	2.61
	Apr	I	1 10	10	20%	11.99	2.40	12.67	2.53
		II	11 20	10	20%	11.62	2.32	11.64	2.33
		III	21 30	10	20%	11.28	2.26	10.21	2.04
	May	I	1 10	10	20%	11.29	2.26	11.66	2.33
		II	11 20	10	20%	10.67	2.13	5.29	1.06
		III	21 31	11	20%	10.89	2.18	6.82	1.36

Annexure III

Calculations of Flow-Duration Curve

Motnhly Discharge in Cumec				Rank	%Time	Motnhly Discharge in Cumec				Rank	%Time
Loharkhet	Khutani	Balihgat	Seraghat			Loharkhet	Khutani	Balihgat	Seraghat		
4057	7244	4346	7534	1	0.33	1736	3101	1860	3225	51	16.94
3939	7033	4220	7315	2	0.66	1735	3098	1859	3222	52	17.28
3830	6839	4104	7113	3	1.00	1719	3070	1842	3193	53	17.61
3745	6687	4012	6954	4	1.33	1698	3033	1820	3154	54	17.94
3653	6523	3914	6784	5	1.66	1611	2876	1726	2991	55	18.27
3570	6375	3825	6630	6	1.99	1601	2858	1715	2973	56	18.60
3381	6038	3623	6280	7	2.33	1527	2727	1636	2836	57	18.94
3313	5915	3549	6152	8	2.66	1527	2727	1636	2836	58	19.27
3250	5804	3482	6036	9	2.99	1506	2689	1614	2797	59	19.60
3185	5687	3412	5915	10	3.32	1451	2591	1554	2694	60	19.93
2978	5318	3191	5530	11	3.65	1450	2589	1553	2693	61	20.27
2960	5286	3172	5498	12	3.99	1431	2555	1533	2657	62	20.60
2941	5252	3151	5462	13	4.32	1383	2470	1482	2569	63	20.93
2857	5101	3061	5305	14	4.65	1355	2420	1452	2517	64	21.26
2846	5082	3049	5285	15	4.98	1271	2269	1361	2360	65	21.59
2772	4950	2970	5148	16	5.32	1269	2265	1359	2356	66	21.93
2764	4937	2962	5134	17	5.65	1245	2223	1334	2312	67	22.26
2760	4928	2957	5125	18	5.98	1163	2077	1246	2160	68	22.59
2700	4821	2893	5014	19	6.31	1132	2022	1213	2102	69	22.92
2662	4753	2852	4943	20	6.64	1121	2002	1201	2082	70	23.26
2651	4733	2840	4923	21	6.98	1097	1959	1175	2037	71	23.59
2628	4693	2816	4881	22	7.31	1018	1817	1090	1890	72	23.92
2565	4580	2748	4764	23	7.64	1001	1788	1073	1859	73	24.25
2544	4542	2725	4724	24	7.97	984	1757	1054	1827	74	24.58
2542	4540	2724	4722	25	8.31	974	1740	1044	1809	75	24.92
2541	4537	2722	4719	26	8.64	951	1699	1019	1767	76	25.25
2531	4520	2712	4700	27	8.97	917	1638	983	1704	77	25.58
2510	4482	2689	4661	28	9.30	886	1582	949	1646	78	25.91
2474	4418	2651	4594	29	9.63	882	1575	945	1638	79	26.25
2399	4284	2570	4455	30	9.97	800	1429	857	1486	80	26.58
2377	4244	2546	4414	31	10.30	780	1393	836	1448	81	26.91
2356	4208	2525	4376	32	10.63	779	1391	835	1447	82	27.24
2339	4176	2506	4343	33	10.96	771	1377	826	1432	83	27.57
2329	4160	2496	4326	34	11.30	744	1329	797	1382	84	27.91
2307	4120	2472	4285	35	11.63	734	1310	786	1362	85	28.24
2294	4097	2458	4261	36	11.96	697	1245	747	1295	86	28.57
2293	4095	2457	4259	37	12.29	685	1223	734	1272	87	28.90
2249	4017	2410	4177	38	12.62	677	1209	725	1257	88	29.24
2209	3944	2366	4102	39	12.96	660	1178	707	1225	89	29.57
2144	3828	2297	3982	40	13.29	645	1151	691	1198	90	29.90
2135	3813	2288	3966	41	13.62	640	1143	686	1189	91	30.23
2044	3650	2190	3796	42	13.95	633	1130	678	1175	92	30.56
2022	3611	2166	3755	43	14.29	618	1104	663	1148	93	30.90
2017	3601	2161	3745	44	14.62	575	1028	617	1069	94	31.23
1996	3564	2138	3706	45	14.95	575	1028	617	1069	95	31.56
1948	3478	2087	3618	46	15.28	553	987	592	1026	96	31.89
1922	3432	2059	3569	47	15.61	551	984	590	1023	97	32.23
1807	3227	1936	3356	48	15.95	547	977	586	1016	98	32.56
1758	3139	1883	3264	49	16.28	543	970	582	1008	99	32.89
1738	3104	1862	3228	50	16.61	542	968	581	1007	100	33.22

Annexure III

Motnhly Discharge in Cumec				Rank	%Time	Motnhly Discharge in Cumec				Rank	%Time
Loharkhet	Khutani	Balihgat	Seraghat			Loharkhet	Khutani	Balihgat	Seraghat		
534	954	573	992	101	33.55	302	539	323	560	151	50.17
525	937	562	975	102	33.89	299	533	320	555	152	50.50
514	918	551	955	103	34.22	297	530	318	551	153	50.83
494	882	529	917	104	34.55	295	528	317	549	154	51.16
492	879	527	914	105	34.88	293	524	314	545	155	51.50
482	861	516	895	106	35.22	292	522	313	543	156	51.83
476	851	510	885	107	35.55	289	516	310	537	157	52.16
476	850	510	884	108	35.88	288	514	309	535	158	52.49
474	847	508	881	109	36.21	288	514	308	535	159	52.82
452	806	484	839	110	36.54	287	513	308	534	160	53.16
452	806	484	839	111	36.88	287	512	307	532	161	53.49
444	793	476	825	112	37.21	283	505	303	525	162	53.82
429	766	459	796	113	37.54	281	501	301	521	163	54.15
423	755	453	785	114	37.87	278	496	297	516	164	54.49
423	755	453	785	115	38.21	277	494	297	514	165	54.82
394	704	422	732	116	38.54	274	490	294	510	166	55.15
394	703	422	731	117	38.87	273	488	293	507	167	55.48
386	690	414	717	118	39.20	272	486	291	505	168	55.81
386	689	414	717	119	39.53	272	485	291	505	169	56.15
385	687	412	715	120	39.87	270	483	290	502	170	56.48
382	682	409	709	121	40.20	268	479	288	498	171	56.81
377	673	404	700	122	40.53	266	476	285	495	172	57.14
377	672	403	699	123	40.86	266	475	285	494	173	57.48
374	668	401	695	124	41.20	266	475	285	494	174	57.81
374	668	401	695	125	41.53	263	470	282	489	175	58.14
371	663	398	689	126	41.86	262	469	281	487	176	58.47
365	653	392	679	127	42.19	259	462	277	480	177	58.80
365	653	392	679	128	42.52	258	462	277	480	178	59.14
365	652	391	678	129	42.86	257	458	275	476	179	59.47
362	647	388	673	130	43.19	256	458	275	476	180	59.80
362	646	388	672	131	43.52	254	454	273	472	181	60.13
359	641	385	667	132	43.85	253	453	272	471	182	60.47
349	624	374	649	133	44.19	246	439	264	457	183	60.80
339	605	363	629	134	44.52	245	438	263	456	184	61.13
335	598	359	622	135	44.85	245	438	263	455	185	61.46
334	597	358	621	136	45.18	244	436	262	453	186	61.79
330	588	353	612	137	45.51	243	433	260	451	187	62.13
321	574	344	596	138	45.85	239	426	256	443	188	62.46
320	571	343	594	139	46.18	239	426	256	443	189	62.79
319	569	341	592	140	46.51	238	426	255	443	190	63.12
318	567	340	590	141	46.84	237	423	254	440	191	63.46
318	567	340	590	142	47.18	236	421	253	438	192	63.79
313	559	335	581	143	47.51	236	421	253	438	193	64.12
312	556	334	579	144	47.84	236	421	253	438	194	64.45
310	554	332	576	145	48.17	236	421	252	438	195	64.78
310	553	332	575	146	48.50	235	420	252	436	196	65.12
310	553	332	575	147	48.84	235	419	251	436	197	65.45
309	553	332	575	148	49.17	234	418	251	435	198	65.78
308	549	330	571	149	49.50	233	417	250	433	199	66.11
306	546	328	568	150	49.83	231	412	247	429	200	66.45

__Annexure III__

monthly Discharge in Cumec				Rank	%Time	Motnhly Discharge in Cumec				Rank	%Time
Loharkhet	Khutani	Balihgat	Seraghat			Loharkhet	Khutani	Balihgat	Seraghat		
230	411	247	428	201	66.78	187	334	201	348	251	83.39
229	410	246	426	202	67.11	187	334	200	347	252	83.72
229	410	246	426	203	67.44	186	332	199	345	253	84.05
228	408	245	424	204	67.77	185	330	198	343	254	84.39
226	406	243	422	205	68.11	184	329	198	343	255	84.72
227	403	242	419	206	68.44	184	329	198	343	256	85.05
224	400	240	416	207	68.77	184	329	198	342	257	85.38
223	399	239	415	208	69.10	184	328	197	341	258	85.71
223	399	239	415	209	69.44	183	326	196	339	259	86.05
222	397	238	413	210	69.77	182	325	195	338	260	86.38
221	394	236	410	211	70.10	181	323	194	336	261	86.71
220	394	236	409	212	70.43	181	323	194	336	262	87.04
220	392	235	408	213	70.76	180	322	193	335	263	87.38
219	391	234	406	214	71.10	180	321	192	333	264	87.71
218	390	234	405	215	71.43	178	318	191	331	265	88.04
218	389	233	405	216	71.76	176	314	188	327	266	88.37
217	387	232	403	217	72.09	175	312	187	324	267	88.70
217	387	232	403	218	72.43	174	311	186	323	268	89.04
215	383	230	399	219	72.76	173	309	185	321	269	89.37
214	382	229	397	220	73.09	172	307	184	319	270	89.70
212	379	228	395	221	73.42	171	306	184	318	271	90.03
212	379	227	394	222	73.75	171	306	183	318	272	90.37
209	373	224	388	223	74.09	170	304	183	317	273	90.70
209	373	224	388	224	74.42	170	304	182	316	274	91.03
208	371	223	386	225	74.75	170	304	182	316	275	91.36
205	367	220	381	226	75.08	170	304	182	316	276	91.69
205	366	220	381	227	75.42	166	296	178	308	277	92.03
205	366	219	380	228	75.75	165	294	177	306	278	92.36
204	364	218	379	229	76.08	163	292	175	303	279	92.69
203	363	218	377	230	76.41	163	291	174	302	280	93.02
203	363	218	377	231	76.74	162	289	174	301	281	93.36
202	361	217	376	232	77.08	159	284	171	296	282	93.69
202	361	217	375	233	77.41	159	284	171	296	283	94.02
202	361	216	375	234	77.74	159	283	170	295	284	94.35
202	360	216	374	235	78.07	158	282	169	293	285	94.68
202	360	216	374	236	78.41	158	282	169	293	286	95.02
201	359	216	374	237	78.74	156	279	168	290	287	95.35
200	357	214	371	238	79.07	154	275	165	286	288	95.68
200	357	214	371	239	79.40	150	267	160	278	289	96.01
199	356	213	370	240	79.73	149	265	159	276	290	96.35
199	355	213	369	241	80.07	145	259	156	270	291	96.68
198	354	212	368	242	80.40	144	257	154	268	292	97.01
198	353	212	367	243	80.73	136	243	146	253	293	97.34
197	352	211	366	244	81.06	132	235	141	245	294	97.67
196	350	210	364	245	81.40	130	232	139	241	295	98.01
195	348	209	362	246	81.73	128	229	138	239	296	98.34
194	347	208	361	247	82.06	124	222	133	231	297	98.67
194	347	208	361	248	82.39	124	221	133	230	298	99.00
192	343	206	357	249	82.72	113	202	121	210	299	99.34
187	335	201	348	250	83.06	107	191	115	199	300	99.67