THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Environmental Flows Assessment of Eastern Ramganga River, India, by Drought Analysis

Lt. Col. Manish Kothari
P.G. Scholar, Department of WRD & M, IIT Roorkee, Roorkee, India
S. K. Mishra
Professor, Department of WRD & M, IIT Roorkee, Roorkee, (UK), India

Abstract:
Environmental Flows (EFs) have been accepted as one of the most important factors deciding the survival of a river. This concept is fairly well understood in few developed countries however, in developing countries like India, EFs consideration in river water resource development and management poses great challenges. In this paper, EFs variability was estimated using Tennant's method, Hughes and Munster method and further comparing it with drought severity of study area using SPEI (Standerized Precipitation Evapotranspiration Index). The computed values further helps to establish a link between EF and drought severity and as a results helps to assess the health EF condition of the river basin. The estimated results could be used in future water resource and river health assessment in the basin.

Keywords: *Environmental flows, SPEI, drought, tennant method, hughes and munster method*

1. Introduction

Environmental flow (EF) is referred as the amount of water required for maintaining the ecosystem of the river. A critical part of this approach is the assessment and maintenance of Environmental Flows – 'sufficient water to sustain the integrity and functioning of aquatic ecosystems and the associated socioeconomic and cultural functions' (UN, 2005).

Most of the rivers are excessively exploited to fulfill ever increasing demand for power, agricultural, industrial and municipal sectors. Damming of rivers or tributaries is the root cause of river obstructions causing severe modifications and perturbations to the river flow, velocity, depth, substratum, pools, ecology and fish habitats.

Each river system has an individual flow regime with particular characteristics such as seasonal pattern of flows, timing, frequency, predictability and duration of extreme events(e.g. floods and droughts), rates of change and other aspects of flow variability.

Accounting for natural differences in flow variability among rivers, and understanding its importance for the protection of freshwater biodiversity and maintenance of goods and services that rivers provide, is a daunting challenge for water managers and scientists.

The assessment of water requirements of freshwater-dependent ecosystems represents a major challenge due to the complexity of physical processes and interactions between the components of the ecosystems.

With the rise in concern about the impact of dams and flow regulation on river biota, more than 200 methods were developed for assessment of "minimum flow" or the "environmental flows" .

It is important to note that maintaining environmental flows helps a river system to maintain the ecological balance of river regime.

The study area is Eastern Ramganga river. It is a tributary of Sarju River.It originates from the Ramganga glacier in Northern Himalayas. The river flows south in its upper course and gradually turns towards west to meet with Sarju at Rameswar Ghat(29º31'N and 80º07' E)in Pithoragarh district in the state. The upper catchment of the river comprises with steep slopes that descends from height right up to the water channel. In the middle and lower courses, the river is augmented along with deep gorges and V-shaped valleys. Some small snow fed tributaries joins the river at different locations. It is Perennial River. The river catchment is 1354.60sq km.

There are various small hydropower station (<25MW) on the entire river courses. In monsoon the river flow is sufficient, however during non monsoon season the aquatic species survival becomes questionable and even the requisite head is not achieved for the hydropower stations. Hence, assessment of EF is of prime importance on the basin.

2. Review of Literature

A number of methodologies are in practice worldwide to estimate EFR of rivers. Tharme (2003) discussed the existence of more than 243 methodologies .In India limited numbers of studies have been reported.

Jha et al., 2008 carried out a appraisal for estimation of EF's and their utilization in two river system of India. In this method hydrological methods using daily discharge data and flow duration curve were used. The study calculated the value of environmental flow at different reaches of river. The result of the study concluded environmental flow values for maintaining the desired ecological flow of the river.

Kumara et al., 2010 carried out a study on EF in Bhadra River. The study carried Desktop analysis method and field investigation for the estimation of EF. The study had been carried two modules i.e. Biophysical assessment and Socio Economic assessment. The study had been done to show how the people have affected by specified flow river alternations.

Kaushal, 2008, carried out the study for environmental flow assessment of the upper stretch of river Ganga. The objective was to develop and apply EFA methodology in the Upper Ganga Basin and also EF analysis was done for a large river basin.

Certain notional locations were chosen in Ganga Basin (representing certain stretches). Recommended flows were calculated by different working group i.e spiritual, geomorphology biodiversity, and livelihood group. Each group found out and recommended flow for maintenance and drought year.

Even for drought there are more than 150 drought indices exists and many more new indices come into account in the last decades.

As per the Ministry of Agriculture, 2009, the drought index value is typically a single unit less number for decision making. The Government of India, State Governments and the scientific community uses a number of indices to measure the intensity, duration, and spatial extent of drought. It is useful to also refer to these scientific indices for monitoring drought situation at the National and State levels.

Shukla and Wood et al., 2008 derived standardized runoff index (SRI) which incorporates hydrologic processes that determine the seasonal loss in stream flow due to the influence of climate. As a result, on month to seasonal time scales SRI is a useful complement to SPI for depicting hydrological aspects of droughts.

Thus, it is clearly reflected that although the computation of EFR and drought is done on individual basis, but none of the study directly links them together to develop a inter relation between these two aspects.

In this paper, we are computing the EFR and drought individually for the selected area of study and hence on the basis of the attained values trying to link these two parameter, to develop a link between EF and drought.

The study is validated on the basis of two basins after checking that whether the achieved results for EF and drought severity indicate some pattern of resemblance.

3. The Study Area

3.1. The Eastern Ramganga River Basin

It originates from the hills of Nandakot. The main tributaries are Jakula and Saryu that join it in its course. Thereafter, this river is called Saryu before it joins river Kali, which originates from Milam glacier in Kumaon region.

The Eastern Ramganga is a tributary of Sarju River.It originates from the Ramganga glacier in Northern Himalayas.The river flows south in its upper course and gradually turns towards west to meet with Sarju at Rameswar Ghat (29º31'N and 80º07' E) in Pithoragarh district in the state.

The upper catchment of the river comprises with steep slopes that descends from height right up to the water channel. In the middle and lower courses, the river is augmented along with deep gorges and V-shaped valleys. Some small snow fed tributaries joins the river at different locations. It is Perennial River. The river catchment is 1354.60sq km. The area has a high altitude land with hilly terrain.

The Birthi and Burthing sites are located in the Thal-Minsiyari road, at a distance of about 40km and 1 km, respectively, from Thal town. The nearest rail head is situated at a distance of 240 km at Tanakpur from both sites.

Figure 1: Satellite Image of Eastern Ramganga River

The discharge in the Eastern Ramganga River is being gauged by the Central Water Commission (CWC) at the gauging site near Thal since 1985.The daily discharge data of Eastern Ramganga River was collected at the Thal dam site on basis of 10 daily inflow of Sarju River at Chamgad.

Five gauging sites were chosen for collection of data on Eastern Ramganga River for EF assessment. They are Birthi, Burthing, Phulibagar, Balgad, and Thal.

SI No.	Site Name	Longitude	Latitude	Catchment Area(Sq.Km)
1	Birthi	80º9'19"E	30º02'24"N	06
2	Burthing	80º9'26"E	30º02'41"N	38
3	Phulibagar	80º9'03"E	30º02'22"N	69
4	Balgad	80º9'37"E	29º51'45"N	605
5	Thal	80º08'27"E	29º49'36"N	650

Table 1: Location of gauging sites in Eastern Ramganga River

4. Methodology

In this conceptual approach, linking of Tennant Method, Hughes and Muster method along with drought severity indices in catchment area of river is done.

The Tennant's method was developed in 1976 (Tharme 2006).The recommended EF should follow the "excellent" condition (i.e. 30% and 50% of mean flow for the months October to March and Apr-Sept).

Objective	Recommended percentage of AAF	
	Autumn(Oct-Mar)	Spring-Summer(Apr-Sept)
Flushing or max flow	200%of AAF	200%of AAF
Optimum range of AAF	60-100%of AAF	60-100%of AAF
Percentage AAF required to maintain a river condition		
Outstanding	40%of AAF	60%of AAF
Excellent	30%of AAF	50%of AAF
Good	20%of AAF	40%of AAF
Fair or degrading	10%of AAF	30%of AAF
Poor or minimum	10%of AAF	10%of AAF
Severe or degradation	10%- of AAF to zero flow	10%-of AAF to zero flow

Table 2: Illustration of Tennant method

In Hughes & Munster Method, the low flow requirement (LFR) and high flow requirement (HFR) is computed using this method .Q90 is the 90 % dependable discharge which is the low flow requirement. After comparing the mean annual flow (MAF) values from optimum range (i.e.100%) of Tennant method and 90% dependable discharge, the environmental water requirement (EWR/EFR) for different sites is computed using this methodology. As the catchment area of the basin increases the value of EWR also increases.

Low Flow Requirement	High Flow Requirement
Q90<10%MAF	HFR=20%MAF
10%MAF≤Q90≤20%MAF	HFR=15%MAF
20%MAF≤Q90≤30%MAF	HFR=7%MAF
Q90≥30%MAF	HFR=0

Table 3: A Theoretical Rule for Environmental High Flow Assessment

For Drought severity computation SPEI (GLOBAL DROUGHT MONITOR) software is being used. The Standardized Precipitation Evapotranspiration Index (SPEI) is an extension of the widely used Standardized Precipitation Index (SPI).

The SPEI is designed to take into account both precipitation and potential evapotranspiration (PET) in determining drought. The SPEI values for different boundary conditions are tabulated below.

SPEI Values	Classification/Condition
>2.33	Extreme flood condition(Danger of Flood)
1.65	Wet condition
1.28	Slight surplus
0.84	Near normal
-0.84	Mild drought
-1.28	Moderate drought
-1.65	Severe drought
<-2.33	Extreme drought

Table 4: Classification of SPEI Values

5. Results and Discussions

Using the drought severity, Tennant (or Montana) method and Hughes and Munster method, assessment is done.

EF should be maintained in the river as per the computed values. The computed values of drought severity is compared with SPEI boundary condition, as per the amalgamated table 6, given below and hence the conclusions are drawn.

Description of General Flow Condition (Tennant's Method)	SPEI Values (Standard Values)	Classification/Condition
Flushing or Max	>2.33	Extreme flood
Optimum Range	1.65-2.33	Wet condition
Outstanding	1.28-1.64	Slight surplus
Excellent	0.84-1.27	Near normal
Good	-0.84-0.83	Mild drought
Fair or Degrading	-1.28- -0.84	Moderate drought
Poor or Minimum	-1.65- -1.28	Severe drought
Severe Degradation	<-2.33	Extreme drought

Table 5: Reference Table for Linkage of EF and Drought Severity

The results indicate that from the values of drought severity computed, we can draw the conclusion to ascertain the health condition river and the of EF boundary conditions.

5.1. Computation for Environmental Flow

The values for EF in Mahanadi Basin is computed with help of Tennant's method, Hughes and Munster method, the conclusions are drawn which are reflected in the tables 6 & 7.

General condition of flow (%)	% MAF in cumec from Oct-Mar				
	EF1	EF2	EF3	EF4	EF5
Flushing or max flow	34.53	230.17	421.98	3567.61	3834.6
Optimum range of AAF	10.36-17.26	69.05-115.08	126.59-210.99	1070.28-1783.81	1150.38-1917.30
Outstanding	6.91	46.03	84.40	713.52	766.92
Excellent	5.18	34.53	63.30	535.14	575.19
Good	3.45	23.02	42.20	356.76	383.46
Fair or degrading	1.73	11.51	21.10	178.38	191.73
Poor or minimum	1.73	11.51	21.10	178.38	191.73
Severe or degradation	<1.73	<11.51	<21.10	<178.38	<191.73

Table 6: EF Values during Oct-March

General condition of flow (%)	% MAF in cumec from Apr-Sept				
	EF1	EF2	EF3	EF4	EF5
Flushing or max flow	34.53	230.17	421.98	3567.61	3834.6
Optimum range of AAF	10.36-17.26	69.05-115.08	126.59-210.99	1070.28-1783.81	1150.38-1917.30
Outstanding	10.36	69.05	126.59	1070.28	1150.38
Excellent	8.63	57.54	105.49	891.9	958.65
Good	6.91	46.03	84.40	713.52	766.92
Fair or degrading	5.18	34.53	63.30	535.14	575.19
Poor or minimum	1.73	11.51	21.10	178.38	191.73
Severe or degradation	<1.73	<11.51	<21.10	<178.38	<191.73

Table 7: EF Values during Apr-Sept

The graph's shown underneath have been computed from SPEI and on the basis of the coordinates of the EF gauging sites eastern Ramganga River.

The average value of the drought /low flow severity is computed (1955-2014) and hence the value obtained is compared with the SPEI drought table, therefore the conditions of flow i.e the EF, in the river is being determined.

Thus a fair idea can be made out with the help of computed drought analysis for kind of EF condition in river or with help of computed EF condition's of river, the kind of flow/drought condition (block values) can be ascertained.

Thus, the relation is indicative towards the fact that by help of computation of one value other value can be ascertained.

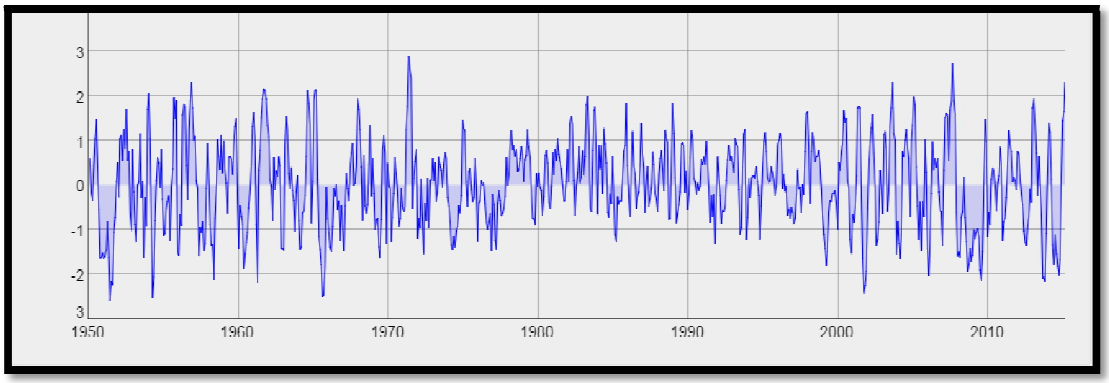

Figure 2: SPEI Drought Analysis at Birthi Avg Value:1.16

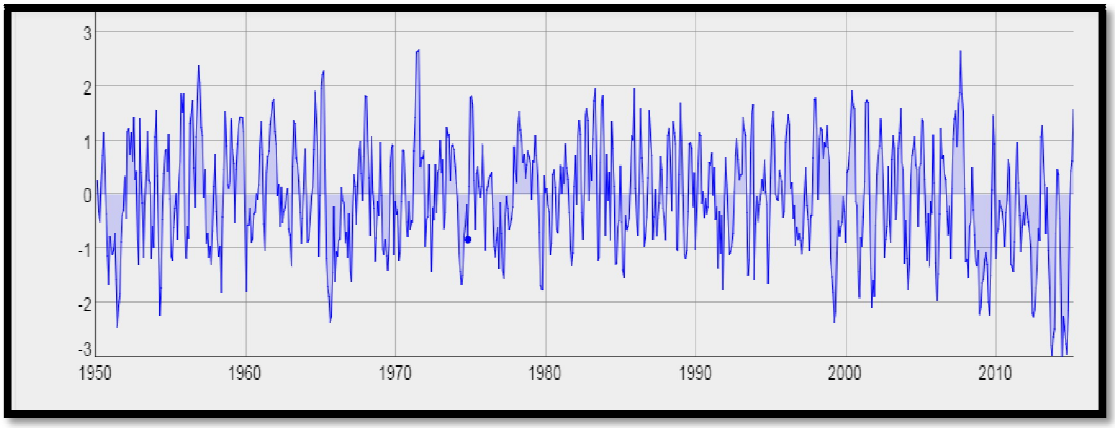

Figure 3: SPEI Drought Analysis at Burthing Avg Value:1.31

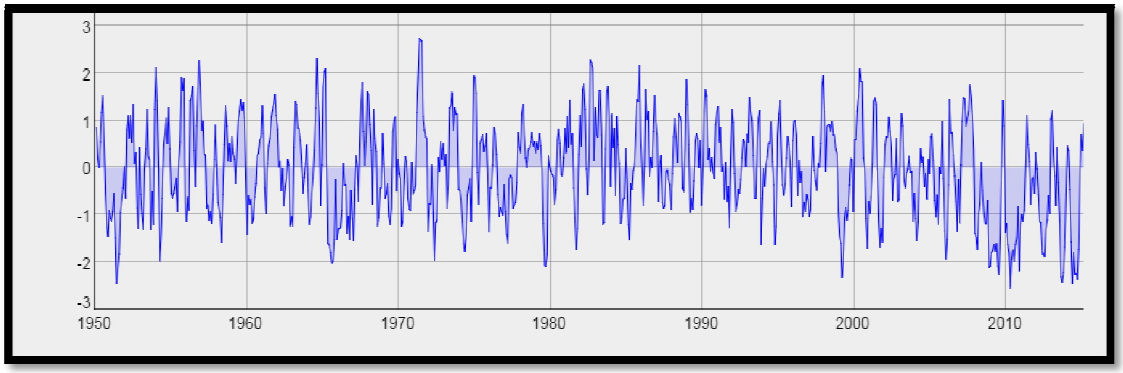

Figure 4: SPEI Drought Analysis at Phulibagar Avg Value:1.38

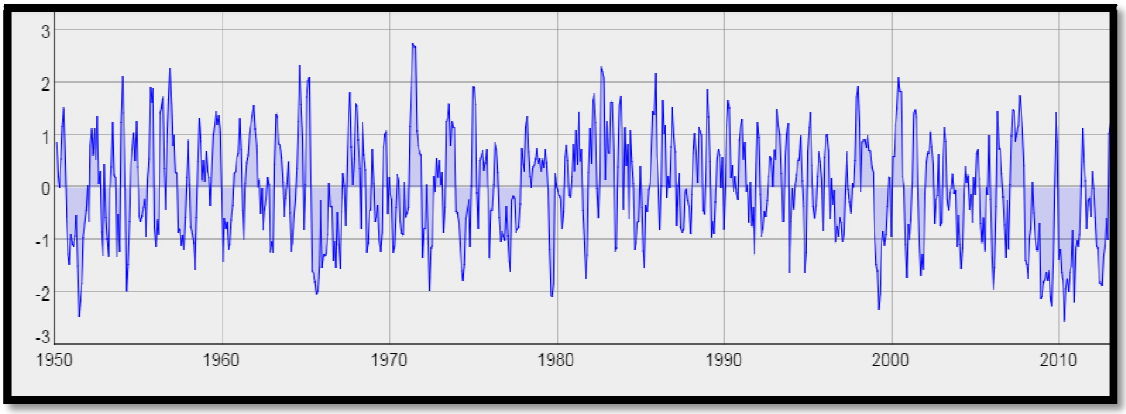

Figure 5: SPEI Drought Analysis at Balgad Avg Value: 1.52

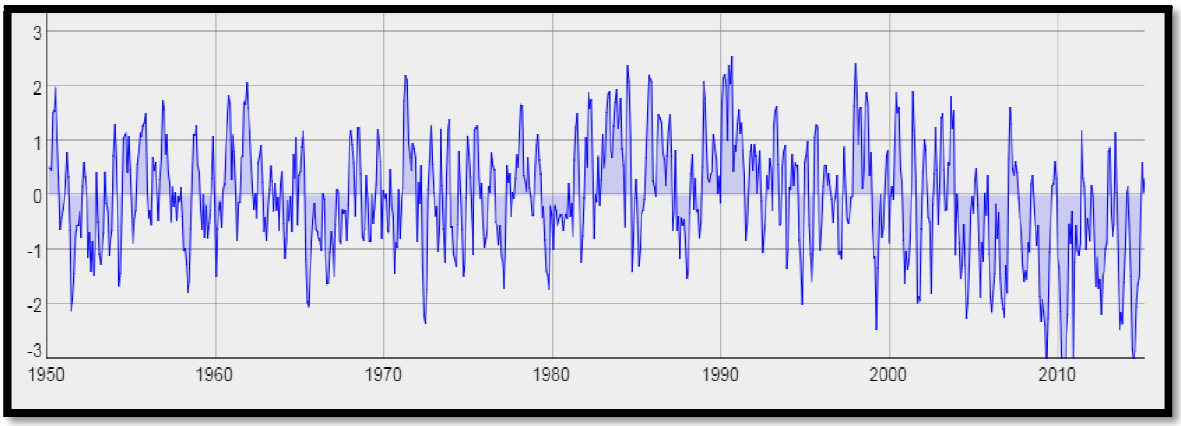

Figure 6: SPEI Drought Analysis at Thal Avg Value: 1.68

The values computed area also checked with the help of Hughes and Munster method. The results obtained are given in table below.

Site	90% Dependable Flow(Q90) in cumec
Birthi	4.19
Burthing	27.92
Phulibagar	51.19
Balgad	432.75
Thal	465.32

Table 8: 90% Dependable Flow Discharge of Different Sites

Thus depending on Q90, computed values of EWR for the given gauging sites of eastern Ramganga river are given in the table below.

Site	EWR in cumec
Birthi	5.40
Burthing	34.52
Phulibagar	63.30
Balgad	557.62
Thal	599.53

Table 9: Values of EWR

The comparative table between Tennant method, Hughes and Munster method is drawn underneath.

Site	Tennant Method Oct-Mar(30%)	Apr-Sept(50%)	Hughes and Munster Method(cumec)	Drought Condition as per SPEI
Birthi	5.18	8.63	5.40	Near normal
Burthing	34.53	57.54	34.52	Slight surplus
Phulibagar	63.30	105.49	63.30	Slight surplus
Balgad	535.14	891.90	557.62	Slight surplus
Thal	575.19	958.65	599.53	Wet

Table 10: Comparative Values of EF and Drought

The values achieved ascertains that the values computed for EF with help of Tennant's method, Hughes and Munster method and values drawn from SPEI are indicating same reference values. Hence the study is affirmed in for this basin.

5.2. Advantage of the Concept

1. The EF values recommended and the drought severity computed will help water resource planner and decision makers for development of a new water resources projects such as the design of storage facilities, assessment of water available for municipal, agricultural or industrial purposes and operating rules that satisfy EFs.
2. Will help to compute the value of EF in absence of requisite data, with the help of drought severity analysis.
3. Will help to access the drought severity in the area and further take timely remedial actions for eradication's of implications.

5.3. Disadvantage /Limitation of the Concept

1. It is likely to generate results with low confidence as it is a new concept and requires more refinement in drawing results for various basins.
2. There is no provision to integrate other associated aspects, for instance-the ecology, biodiversity, riverine communities etc.
3. Thus, there is a need for betterment of the methodology, where all the aspects can be integrated to draw the result.

6. Conclusions and Recommendation

The paper presents the initial estimate of EFs recommendation using the conceptual method of drought, Tennant method and Hughes and Munster method. This method is a preliminary approach where insufficient ecological and hydraulic data is available.

The results indicate that in case the values of drought severity is computed (for the given region/basin) we can draw the conclusion to ascertain the values of river health condition or condition of EF as per the recommended percentages as specified by Tennant's method or Hughes and Munster method.

The computation for Eastern Ramganga River is done to draw the link between drought and EF conditions.

Thus, it can be concluded that in case the values for drought severity is known for the river basin, then the EF conditions can be assessed and hence a fair idea can be made out that whether the minimum flow released in the river is adequate to maintain the regime of the river ecosystem or corrective actions are required to be undertaken.

The EF values recommended and the drought severity computed will help water resource planner and decision makers for development of a new water resources projects.

7. References

i. Blake J.H David 2(006) - E-Flows in the Nam Songkhram River Basin IUCN vol. 49 No.1
ii. Brismar A. (2002)- River systems as providers of goods & services:basis for comparing desired & undesired effects of large dams projects. Environmental Management 29:598-609.
iii. Caissie D, El-Jabi N, Bourgeois G. (1998)- Instream flow evaluation by hydrologically based & habitat preference (hydrobiological) techniques. Revue des Sciences de l'Eau 11(3): 347-363.
iv. Flynn R.H. (2003)- A Stream gauging network analysis for the 7-day, 10 year annual low flow in New Hamsphire streams. U.S.Geological Survey Water Resources Investigations Report 03-4023, 31p.
v. Hughes D.A (2001)- Providing Hydrological Information & data analysis tools for the determination of ecological instream Flow requirements for South African rivers. Hydrology Journal 241:140-151.
vi. Jha R, Sharma K.D, Singh V.P (2008)- Critical Appraisal of methods for the assessment of environmental flows and their application in two river systems of India. KSCE journal of civil engineering (2008) 12(3):213-219.
vii. Jha R (2010)- Environmental flow assessment using various techniques in a typical river basin of India. Journal of hydrological research & development vol.25, 2010, INCOH.
viii. Jorde K, Schneider M (1998)- Determining the Instream Flow requirements using the PHABSIM simulation system. Wasser Und Boden 50(4)'45-49.
ix. Keeffe J.O, Kaushal N, Luna B & Vladimir S. (2012)- Assessment of environmental flows for the upper Ganga basin. WWF report IND-12.
x. Kiragu, Home, Mati & Gathenya (2007)- Assessment of suspended sediment loadings & their impact on the environmental flows of upper streams Mara river, Kenya. Ministry of water & Irrigation report KNY/HYD/07/12.
xi. Pyrce R.S (2004)- Hydrological low flow indices and their uses. WSC Report No. 04-2004.
xii. Singh K.P & Stall J.B (1974)- Hydrology of 7day 10 yr low flows. Journal of the Hydraulics division, hy12:1753-1771. International Conference on Innovative Technologies and Management for Water Security 12-14 February 2014,Chennai, India
xiii. Smakhtin V.U(2001)- Low Flow Hydrology: A review Journal Of hydrology 240:147-186.
xiv. Smakhtin V.U & Anputhas M. (2006)- An assessment of environment flow requirements of Indian river basins. Research Report 107, International water management Institute, Sri lanka.
xv. Smakhtin V.U, Shilpakar R.L & Hughes D.A (2006)- Hydrology based assessment of Environmental flows: an example from Nepal. Hydrological Sciences Journal, 51(2), 207-222.
xvi. Smakhtin V.U (2007)- An assessment of Hydrology and Environment Flows in the Walawe River Basin, Sri Lanka, Working paper 103, International Water Management Institute, Sri Lanka.
xvii. Sugiyama H.V, Vudhivanich & Lorsirirat (2003)- Stochastic flow duration curves for the evaluation of the flow regimes of the rivers, J. Am. Water Resources Assoc., Vol. 39, No.1, pp. 47-58.
xviii. Tharme R.S (2003)- A Global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. River Research and Applications Vol.19: 397-441.
xix. Vladimirov A.M & Lobanova H.V (1998)- Classification of Rivers to Assess Low Flow impacts on Water Quality, Hydrology in a changing Environment vol. I. John Wiley and Sons: Baffins Lane Chi Chester W, Sussex PO19 1UD UK; 329-334.
xx. Vogal (1994)- Flow duration curves. I. A new interpretation and confidence intervals.