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Hydrological Method to Evaluate Environmental Flow (Case Study: Gharasou River, Ardabil)

Mehdi Fuladipanah, Mehdi Jorabloo

***Abstract*—**Water flow management is one of the most important parts of river engineering. Non-uniformity distribution of rainfall and various flow demand with unreasonable flow management will be caused destroyed of river ecosystem. Then, it is very serious to determine ecosystem flow requirement. In this paper, Flow duration curve indices method which has hydrological based was used to evaluate environmental flow in Gharasou River, Ardabil, Iran. Using flow duration curve, Q90 and Q95 for different return periods were calculated. Their magnitude were determined as 1-day, 3-day, 7-day and 30 day. According the second method, hydraulic alteration indices often had low and medium range. In order to maintain river at an acceptable ecological condition, minimum daily discharge of index Q95 is 0.7 $m^3.s^{-1}$.

***Keywords*—**Ardabil, Environmental flow, Flow Duration Curve, Gharasou River.

I. Introduction

THE construction of dams and subsequent downstream changes to both flow and sediment regime is one of the most profound anthropogenic impacts upon river ecology. Changes to the hydrologic regime include a decrease in flow volume, decrease in the magnitude, frequency and duration of flood discharges, a reduction and/or attenuation in seasonality of flows and change in the variability and predictability of flows [1]. Goals of inflow management extend from preservation of the extant aquatic system to its enhancement, and occasionally include restoration of the ecosystem that existed prior to human impacts. Such management goals require a means of determining the requisite environmental flows, based upon stream hydrology and the responses of aquatic organisms to their hydrological environment. Worldwide, an imposing literature has developed addressing various aspects of the technical problem of establishing a cause-and-effect connection of specific classes of organisms to specific characteristics of the hydrology of a stream [2]-[5]. The methods of environmental flow assessment are categorized in four groups which hydrological (desktop estimates) group is one of them. There are numerous methodologies in hydrological group as: Rapid Reserve Determination, Flow Duration Curves percentiles (FDCs), Range of Variability approach (RVA), VHI, BWE, Ecotype-based Modified Tennant Method [3]. One of the common hydrological methods is Flow Duration Curve (FDC) which is a convenient way of presenting hydrological frequency characteristics of a river flow. FDCs are widely used in hydrological practice. Vogel and Fennessey refer to several early studies related to the theory and application of FDC [6]. Searcy was possibly the first to summarize a number of FDC applications including the analysis of catchment geology on low flow, hydropower and stream water quality studies [7]. Male and Ogawa advocated the use of FDCs in the evaluation of the trade-offs among various characteristics involved in determination of the capacity of waste-water treatment plants including flow, flow duration, water quality requirements and costs [8]. Alaouze developed the procedures based on FDC, for estimation of optimal release schedule from reservoirs, where each release has a unique reliability [9], [10]. Estes and Osborn illustrated the use of FDC for the assessment of river habitats in estimation of instream flow requirements [9]. Hughes et al. developed an operating rule model which is based on FDCs and is designed to convert the original tabulated values of estimated ecological instream flow requirements for each calendar month into a time series of daily reservoir releases [11]. A review of numerous possible applications of FDCs in engineering practice, water resources management and water quality management is given by Vogel and Fennessey [12]. According to the lockage of related information, four above mentioned hydrological methods were used to evaluate environmental flow in Gharasou River, Ardabil, Iran (Fig. 1).

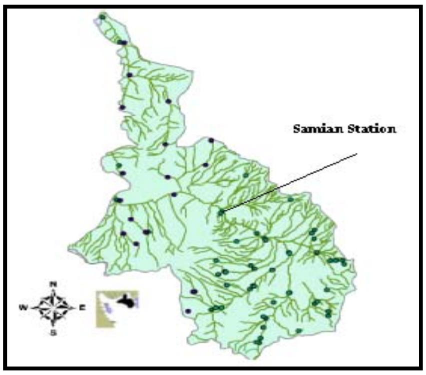

Fig. 1 Gharasou catchment and Samian hydrometric station

II. Materials and Methods

A. Flow Duration Curve Indices Method

Flow duration curve is a graphical presentation of river discharge from low flows to flood events. On the other hand, it shows the relationship between magnitude and frequency of flow discharges. Various indices may be extracted from FDC.

M. Fuladipanah is with the Department of Civil Engineering, Ramhormoz Branch, Islamic Azad University, Ramhormoz, Iran (corresponding author; Tel: +986143532009; e-mail: fuladipanah@gmail.com).
M. Jorabloo is with the Department of Water engineering, Garmsar Branch, Islamic Azad University, Garmsar.

The flows within the range of 70-99% time exceedence are usually most widely used as design low flows. Design low flow range of FDC is in the 70% to 99% range or the value of probability of exceedance corresponding to the Q70 to Q99 range. According to Table I, Q95 and Q90 flow indices have been used globally by researchers for various cases. In this method, FDC is developed for various return periods using the characteristics of distribution of probability plots of stream, calculated by the Weibull plotting formula, at suitable time intervals from 0 to 100 percent on the time axis. The following steps are considered for this approach:

1. After construction of an FDC for each year, read values of daily discharge at every 5% probability of exceedance.
2. Make separate table for each year discharge versus probability of exceedance.
3. Rank discharge values in ascending order and read from each flow duration curve of a given N year term.
4. Calculate the plotting position with the following Weibull plotting formula, select the type probability paper to be used, and plot the data on the probability paper:

$$P=\frac{m}{N+1}\times 100$$

where P is the probability of all events less than or equal to a given discharge value, m is the rank of the event, and N is the number of events in the record.

5. Visually fit a straight line through the estimated values.
6. Using a straight line equation, get the discharge value down from the best fit line for the chosen probability value for various return periods (1 year, 2 year, 5 year, 10 year, 20 year, 50 year and 100 year).
7. Repeat steps 3 to 6 at suitable time intervals from 0 to 100 percent of the time axis (in the present case it is taken at every 5%).
8. Plot probability daily discharge values read at suitable intervals and draw a smooth FDC of return period of 1 year, 2 year, 5 year, 10 year, 20 year, and 50 year.

TABLE I
APPLICATION OF Q90 AND Q95 FLOW INDICES TO ASSESS ENVIRONMENTAL FLOW

Index	Application	Researchers
Q95	Commonly used low flow index or indicator of extreme low flow conditions	[3]
	Minimum flow to protect the river	[5]
	Minimum monthly condition for point discharges	[3]
	Licensing of surface water extractions and effluent discharge limits assessment	[3]
	Biological index for mean monthly flow	[3]
	Used to maintain the natural monthly seasonal variation used to optimize environmental flow rules	[4]
Q90	Commonly used low flow index	[5], [6]
	Monthly value provides stable and average flow conditions	[3], [6]
	Monthly value gives minimum flow for aquatic habitat	[3]
	Used to examine discharge-duration patterns of small streams	[7]
	Threshold for warning water managers of critical stream flow levels	[7]
	Describes limiting stream flow conditions, and is used as a conservative estimator of mean base flow	[8]

III. RESULTS AND DISCUSSION

Daily flow discharges were used to develop flow duration curve and to generate flow requirements in Samian station. Figs. 2-5 show the results of FDC indices method. Using Weibul plotting formula, no results were obtained for flow index Q95 for 30-day and flow indices Q90 and Q95 for 90-day. In these figures, linear trendline has had acceptable correlation coefficient. As it clear, good agreement has been occurred in low return periods u to 5 years. On the other words, these relations can estimate environmental flow in mean situation of river. According to fitting curve equation, the magnitudes of the low flow indices for different return periods are presented in Table II.

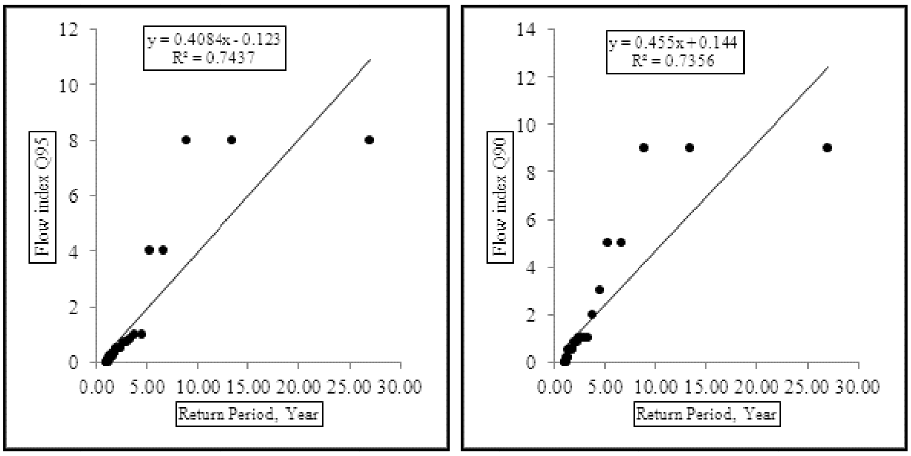

Fig. 2 Return period vs. flow indices Q95 and Q90 for daily discharge

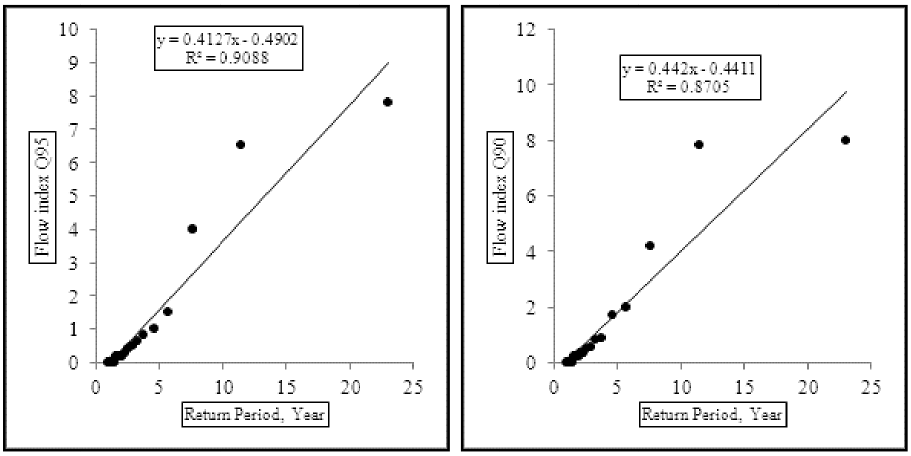

Fig. 3 Return period vs. flow indices Q95 and Q90 for 3-day discharge

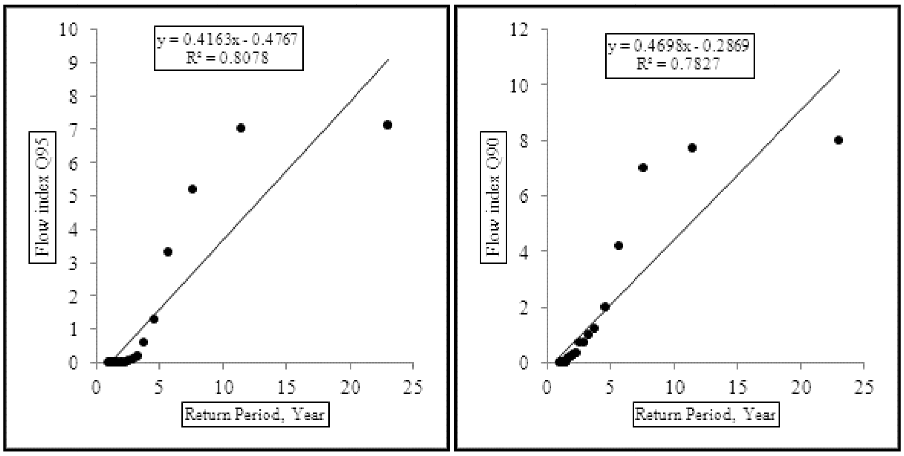

Fig. 4 Return period vs. flow indices Q95 and Q90 for 7-day discharge

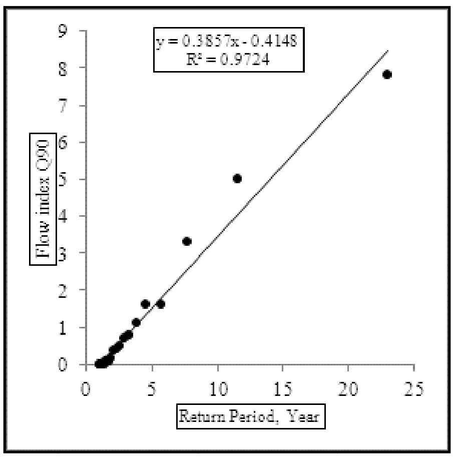

Fig. 5 Return period vs. flow index Q90 for 30-day discharge

IV. Conclusion

In this paper, flow duration curve indices have been applied to calculate environmental flow in Gharasu River, Samian station, Ardabil, Iran. Q90 and Q95 with different return periods are two indices which are used widely to evaluate environmental flow. Based on these indices, different values of environmental flow were calculated. Results showed that direct relation between return period and environmental flow discharge. According to Table II, minimum daily discharge to prevent negative environmental issues is 0.7 cms.

TABLE II
THE RESULTS OF THE FDC INDICES METHOD TO ASSESS ENVIRONMENTAL FLOW FOR SAMIAN STATION

		Return Period					
		2	5	10	25	50	100
1-day	Q90	0.77	2.13	4.40	11.23	22.61	45.35
	Q95	0.70	2.00	4.00	10.00	20.30	40.70
3-day	Q90	0.44	1.77	4.00	10.6	21.6	43.75
	Q95	0.33	1.57	3.6	9.83	20.14	40.8
7-day	Q90	0.65	2.00	4.41	11.45	23.2	46.7
	Q95	0.35	1.60	3.68	9.93	20.34	41.15
30-day	Q90	0.35	1.50	3.44	9.23	18.90	38.15

References

[1] N.L. Poff, J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richeter, R.E. Sparks, and J.C. Stromberg. “The Natural flow regime: a paradigm for river conservation and restoration”. *Bioscience*, 1992, 47 (11): 769-784.

[2] A. Arthington, S. Bunn, N. Pope, and R. Naiman, “The challenge of providing environmental flow rules to sustain river ecosystems”. Ecological Applications, 2006, 16(4), 1311-1318.

[3] R.E. Tharme. “A global perspective on environmental flow assessment: Emerging trends in the development and application of environmental flow methodologies for rivers”. River Research and Applications, 2003, 19(5-6), 397-441.
[4] P.J. Whiting. “Stream-flow necessary for environmental maintenance”.. Annual Review of Earth and Planetary Sciences, 2002, 30: 181-206.
[5] G.E.Petts “Water allocation to protect river ecosystems”. Regulated Rivers-Research & Management, 1996, 12:353-365.
[6] R.M. Vogel, N.M. Fennessey. “Flow duration curves. I. A new interpretation and confidence intervals. J. Water Resour. Plan. Manag., 1994, 120 (4): 485-504.
[7] J.C. Searcy. “Flow duration curves. United States Geological Survey”, Washington, DC, Water Supply Paper , 1959.
[8] J.W. Male, H. Ogawa. “Tradeoffs in water quality management”. J. Water Resour. Plan. Manag., 1984, ASCE 110 (4): 434–444.
[9] C.M. Alaouze. “Reservoir releases to uses with different reliability requirements”. Water Resour. Bull, 1989, 25 (6): 1163–1168.
[10] C.M. Alaouze. “Transferable water entitlements which satisfy heterogeneous risk preferences”. Aus. J. Agric. Econ., 1991, 35 (2): 197–208.
[11] C. Estes, J.F. Osborn. “Review and analysis of methods for quantifying instream flow requirements”. Water Resour. Bull., 1986, 22 (3), 389-398.
[12] R.M. Vogel, N.M. Fennessey. “Flow duration curves. II. A review of applications in water resource planning”. Water Resour. Bull., 1995, 31 (6), 1029–1039.