Sigma J Eng & Nat Sci 36 (3), 2018, 861-870

Sigma Journal of Engineering and Natural Sciences
Sigma Mühendislik ve Fen Bilimleri Dergisi

Research Article

URMIA LAKE ENVIRONMENTAL WATER RIGHT FROM GADAR RIVER

Saeid Habibi ALAGOZ*[1], Mehdi YASI[2]

[1]*Urmia University, Department of Water Engineering, Tabriz-IRAN;* ORCID:0000-0002-7914-1724
[2]*University of Tehran, Dept. of Irrigation and Reclamation Eng., Karaj-IRAN;* ORCID:0000-0002-2512-2317

Received: 20.04.2017 Accepted: 06.03.2018

ABSTRACT

The main aim of the present study was to use different Hydro-Ecological methods to determine the environmental Water Right in a typical perennial river, the Gadar River, the Urmia Lake Basin, Iran for saving Urmia Lake. The ecological needs of the Gadar River were investigated in two different reaches along the river. Three Eco-Hydrological methods (1- FDC shifting, 2- DRM, 3- Q Equation) were used for the assessment of the river environmental flow requirements. In order to maintain the Gadar River at minimum acceptable environmental status (i.e. ClassC of environmental management), average annual flows of 3.28 , 3.25 m^3/s are to be allocated along the river in Naqadeh Bridge and Bahramlu Bridge Stations (located 40 and 18 km upstream from the Urmia Lake), respectively. The potential monthly flow rates are also proposed in order to preserve the riverine lives. For example, in the Naqadeh Bridge Station, the mean annual flow is proposed 3.28 m^3/s, and the monthly flows vary from 0.4 m^3/s (in Sept.) to 10 m^3/s (in May).
Some more important results that have to be noticed are: 1) Evaluation of Environmental flows for each of the ten rivers entering the Urmia Lake has to be evaluated based on the potential flows from the basin and the upstream reasonable needs and water rights; 2) Monitoring the Environmental flows flowing is necessary along the rivers to make sure that the recipient water body, the Urmia Lake, benefits from the right to be restored; 3) By this way, it is anticipated to provide the Urmia Lake with more than 1 billion cubic meters of water from its 10 surrounding rivers.
Keywords: Environmental flows, eco-hydrological methods, river management, Gadar river, Urmia lake.

1. INTRODUCTION

Urmia Lake is one of the biggest saltwater lakes in the world. This lake basin is one of the few watershed in the world that 10% of its area is covered by water. Unfortunately, for various reasons the Urmia Lake was much closed to die. It has attracted the world's attention to itself. Why the worlds attend to this issue?

Without doubt shriveling of the Urmia Lake will effect on its basin and neighbors. There are some methods to rescue the Urmia Lake. But which one is useful?

It is clear that the Urmia Lake basin Rivers have the most important role on its rescue plan. It is obvious that if all rivers flows reach into the Urmia Lake, it will be saved earlier but it is known that several harvest is done along the rivers and prevent to reach water into the Urmia Lake. There is a concept as river environmental flows (EFs) to resolve this problem. EFs is Minimum flow to

* Corresponding Author: e-mail: sayid.habibi@gmail.com, tel: +989354462358

keep the rivers alive that ca used to keep the Urmia Lake alive. Methods designed to quantify minimum ‘in-stream flows’ to sustain fish appeared in the United States in the late 1940s. With increasing concern about the impact of dams and flow regulation on river biota, the scientific field of ‘environmental flows’ prospered to produce more than 200 methods that can be grouped into four categories: hydrological rules, hydraulic rating methods, habitat simulation methods, and holistic methodologies.(Tharme 2003).

The vast majority of Environmental Flow Requirement (EFR) methodologies available globally have focused almost exclusively on riverine systems (Jiang et al. 2006). Among these methods, the best known is the Tennant hydrological method, developed in the USA, which identifies various levels of minimum flows based unspecified proportions of the mean flow (Tennant 1976).

More recently, the range of variability approach (RVA) is an advanced hydrological procedure which evaluates flow regimes based on a correlation of 33 flow statistics for the regulated and natural flow regime (Richter et al. 1998). A new framework named as ecological limits of hydrologic alteration (ELOHA) was recently presented (Poff et al. 2010).

This framework is a combination of some existing hydrologic manners and EFR methods that are currently being used to different degrees and that can keep up widespread regional flow management. One the most popular model in hydraulic-habitat models group is instream flow incremental methodology (IFIM) (There 2003). The influence of water quality was incorporated in the EFRs assessment (Tchobanoglous et al. 2003).

Much attention has been paid to the analysis of eco-hydrological data for developing a better understanding of how flow regimes influence the structures and functions of riverine ecosystems (Tsai et al 2016). Olden et al (2012) provided with a framework for hydrologic classification of different methods and their applications in eco-hydrology. McClain et al (2014) examined the relationship between potential annual flow regimes and selected riverine species in three gauging stations on the Mara River in Kenya and Tanzania. The results were compared with available knowledge of the life histories and flow sensitivities of the aquatic and riparian communities, and a dynamic environmental flow regime was determined to protect ecosystems in the region. Modeling of complex relationships between variable biological and flow indicators is a major challenge (Zhang et al 2015). Freshwater fish communities are acknowledged as indicators that can be adopted to assess the ecological conditions of rivers. Tsai et al (2016) examined the relationship between flow regimes and fish communities at 38 locations in 12 rivers in Taiwan, using soft computing techniques (i.e. self-organizing feature map and clustering methods). Results indicated that the flow regime characteristics at midstream reaches are critical for the population and diversity of fishes. The hydraulic methods and their uncertainties in determining environmental flow requirements were investigated by Shokoohi (2015).

Various methods have been acquired over the last decades. These methods are not necessarily on similar hypothesis, data base, approaches, and not following an identical river management target. Most of them have been developed independently with no further modification over the time. In the literature, there is no general agreement on which method should well be adapted to any specific river environment.

The newly developed methods are not still justified as the more appropriate ones. Therefore, the predetermination of a best fitted method does not seem to be an appropriate approach. The main aim of the present study was to provide with a framework to determine EFRs of a typical perennial river in different reaches. For this, the Gadar River is selected.

Three different ecological and eco-hydrological methods were tested in two reaches of the river. The comparison of the selected methods is correlated with the evaluation of conformity of the methods based on ecological and eco-hydrologic circumstances in Gadar River.

2. MATERIALS A ND METHODS

Study area: The Gadar River is a perennial river located in the West Azerbaijan, west of Iran and it is one of the most important rivers in the Urmia Lake basin. This river passes the city of Oshnavieh, Naqadeh and Mohammadyar in north-west of Iran, then joins to the Urmia Lake. The Gadar River basin covers an area about 2100 km^2 (36°45′–37°10′ N, 44°42′–45°41′ E) and the volume of annual runoff of 375 millions of cubic meters (MCM). Two river reaches were selected along 100 km of the Gadar River from upstream to downstream, where two existing hydrometric stations (Naqadeh Bridge and Bahramlu Bridge) represent the flow regime at these two sites. There is no instream dams on Gadar River but already there is an offstream dam (Hassanlu Dam) that filling by a canal. Naqadeh Bridge is in upstream and Bahramlu Bridge is in downstream of this dam. An overview of the study area is presented in Figure 1. General information of these two river reaches and corresponding hydrometric stations are shown in Table 1.

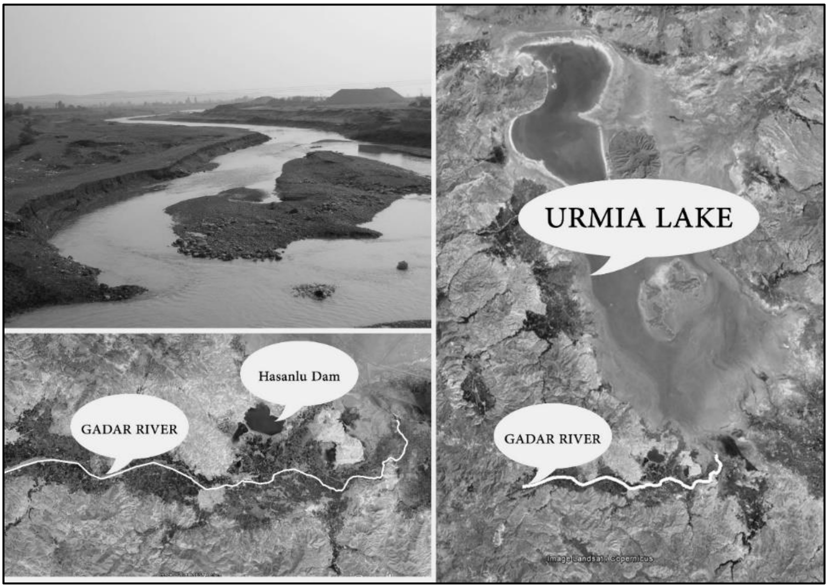

Figure 1. A landscape of the Gadar River in the study area.

Table 1. The information of the two selected river reaches in the Gadar River

River reach (gauging station)	Distance from the Urmia Lake (km)	Length of the reach (m)	Elevation (m)	Statistical period	Mean annually runoff (MCM)	Average flow (CMS)
Naqadeh Bridge	42	23.5	1340	1965-2014	375	11.9
Bahramlu Bridge	18.5	18.5	1283	1957-2014	320	10.11

Hydrologic methods Smakhtin & Anputhas (2006) developed the flow duration curve shifting (FDC Shifting) hydrological method. According to this procedure, six environmental management classes (EMCs) have used (ShaeriKarimi et al. 2014). The EMCs are similar to those described in department of water affairs and forestry (DWAF 1997).

Table 2 presents description for a typical environmental management class C. In this study, global environmental flow calculator (GEFC) was used to analyze the data and to estimate EFRs (GEFC software).

Table 2. Characteristics of selected classes of EMCs in FDC Shifting method

EMC	Most likely ecological condition	Management perspective
C (moderately modified)	The habitats and dynamics of the biota have been disturbed, but basic ecosystem functions are still intact; some sensitive species are lost and/or reduced in extent; alien species present	Multiple disturbances (e.g., dams, diversions, habitat modification, and reduced water quality) associated with the need for socioeconomic development

Desktop reserve model (DRM) is a hydrology-based, planning-type EFR methodology developed in South Africa by Hughes &Hannart (2003).

The parameters of DRM model have been determined empirically for South African rivers, and DRM parameter values must be modified for other conditions.

In computing the results, the model assumes that the primary dry-season months are June to August and the primary wet season months are January to March, as occurs over much of South Africa. This assumption cannot be altered within the model (ShaeriKarimi et al. 2012).

In the case of the Gadar river basin's climatology, March to May and August to October represent the wet and dry seasons, respectively. To reflect these key months, the input data were shifted by 2 months (i.e. January became March and so forth) and then the results were readjusted.

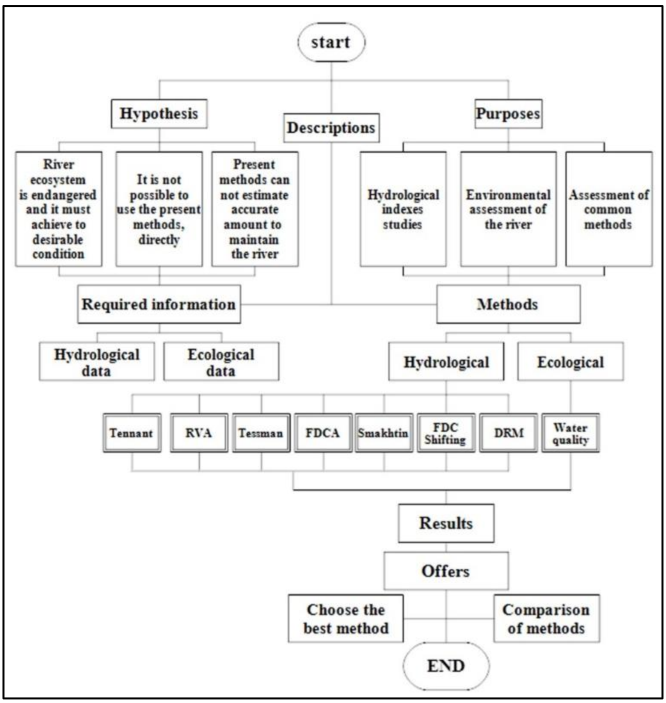

Figure 2. Step-by-step flowchart for determination of environmental flows in this study

To determine the influence of water quality parameters in determining EFs, the Q equation (Equation (1)) was used for assessing the efficiency of this procedure in EWRs assessment

(Tchobanoglous et al. 2003). Different water quality parameters were considered using this equation such as TDS, DO, BOD, COD, pH, etc.

$$(Q_1 + Q_c) \times C_0 = (Q_2 \times C_2) + (Q_1 \times C_1) \quad (1)$$

where, Q1 and Q2 are the initial and secondary discharges; C1 and C2 are corresponding concentration of each of the quality parameters; and Co is the interested concentration value of the parameter. The water chemical statistics of the Gadar River were investigated in the three gauging stations. Among different parameters, COD was selected as representative of water quality, and the EPA standard was used as the reference for acceptable values of COD. The step-by-step methodology for the determination of environmental flows from different eco-hydro approaches in this study is presented in Figure 2.

3. RESULTS AND DISCUSSION

The main aim of the present study is to highlight the potential use of different methods, and the importance of choosing the most appropriate method, given the nature of the river and the data available to propose the environmental water right of Gadar River for saving Urmia Lake. The results of calculating environmental flows from different echo-hydrologic methods at two reaches of the Gadar River are presented in Table 3.

Table 3. Estimation of EWRs from different methods, Gadar River

Method	Classes	Naqadeh Bridge		Bahramlu Bridge	
		%MAR	EWR (cms)	%MAR	EWR (cms)
FDC shifting	Class A	68.6	8.16	81.5	8.23
	Class B	43.1	5.12	51.7	5.22
	Class C	27.6	3.28	32.2	3.25
	Class D	18.1	2.15	19.9	2
	Class E	12.2	1.45	11.8	1.19
	Class F	8.3	0.98	6.5	0.65
DRM	Class A	48.39	5.75	47.37	4.78
	Class A/B	40.62	4.83	39.88	4.03
	Class B	33	3.92	32.48	3.28
	Class B/C	27.64	3.28	27.24	2.72
	Class C	21.95	2.61	21.67	3.3
	Class C/D	18.05	2.14	17.82	1.8
	Class D	14.31	1.7	14.14	1.42
Water quality		21.6	2.58	29.8	3.01

The DRM calculates the EFR by considering ecological characteristics of the study area in different ecological management categories. The evaluated EFs by DRM method (ver. 2) in different management classes are presented in Table 4. In the study area of the Gadar River, the ecological class B/C was selected as EMC.

Table 4. Estimation of EFs as MAFs% for different EMCs in DRM method, Gadar River

Long-term EFR (percent of MAF) at different EMCs								
River reach	MAF (CMS)	Class A	Class A/B	Class B	Class B/C	Class C	Class C/D	Class D
Naqadeh Bridge	11.9	48.39	40.62	33	27.64	21.95	18.05	14.31
Bahramlu Bridge	10.1	47.37	39.88	32.48	27.24	21.67	17.82	14.14

Calculation of the environmental flows with FDC Shifting method was made using GEFC software (ver. 1). The MMFs of the period of 1974–2012 were introduced to this model. The EWRs in each of the two river reaches were investigated based for different ecological classes (class A to class F), and presented in Table 5. The ecological management class C is chosen based on the field study of ecological values of the river, and current water resources development projects. Figure 3 shows typical derivation of the environmental FDCs for different EMCs in the Naqadeh Bridge river reach.

Table 5. Estimation of EFs as MAFs% for different EMCs in FDC Shifting method, Gadar River

Long-term EFR (percent of MAF) at different EMCs							
River reach	MAF (CMS)	Class A	Class B	Class C	Class D	Class E	Class F
Naqadeh Bridge	11.9	68.6	43.1	27.6	18.1	12.2	8.3
Bahramlu Bridge	10.1	81.5	51.7	32.2	19.9	11.8	6.5

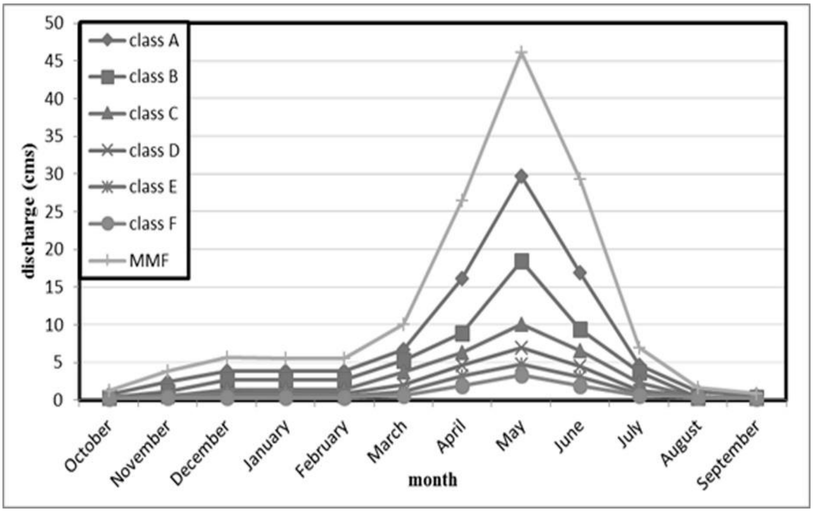

Figure 3. Comparison of FDC-Shifting Classes for the Gadar River at the Naqadeh Bridge Station

The influence of water quality in determining EFs was investigated in the two reaches using the Q equation (Equation (1)). Targeting values of COD were set to adapt to the national standard of surface water quality in Iran. The results are indicated in Table 3.

Monthly distribution of EFRs are also presented and compared in Figures 4 and 5 for two reaches of Gadar River (Naqadeh Bridge & Bahramlu Bridge), respectively. Comparative results indicate that the estimation of EFs from FDC-Shifting method, considering the river management class C, is sufficiently adapted with the monthly variability of the natural flow regime, the desired water quality, and the resilience of the reduction of water usage for agriculture with minimum socio-economic tension in the river basin.

Considering that Naghadeh Bridge hydrometric station shows the Gadar River's flow potential and after this point many water harvest done by agricultural canals and Hassanlu Dam canal, therefore this station is chosen as main station and its Efs have to be available in the last point of downstream (The Urmia Lake). It means that passed flow from Naqadeh Bridge station have to be more than proposed Efs as much as agricultural water right in downstream.

The values of annual EFs from the selected method (i.e. FDC Shifting- Class C) is proposed 3.28 cms (equivalent to 27.6% of MAF=annual 100MMC) in Naqadeh Bridge. According to the results of Q equation (at least 2.58 cms) proposed flow is acceptable.

In figure 6 the values of the mean monthly flows (MMF) in the Naqadeh Bridge station with proposed EFs (FDC Shifting- Class C) is presented.

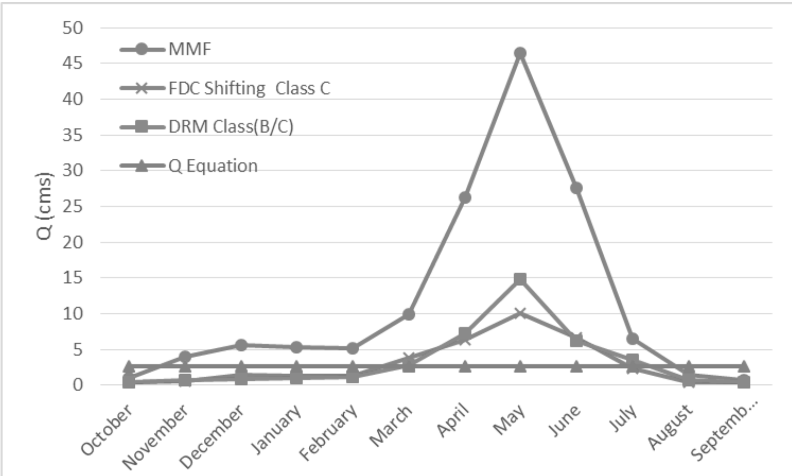

Figure 4. Comparison of EFs methods for the Gadar River at the Naqadeh Bridge Station

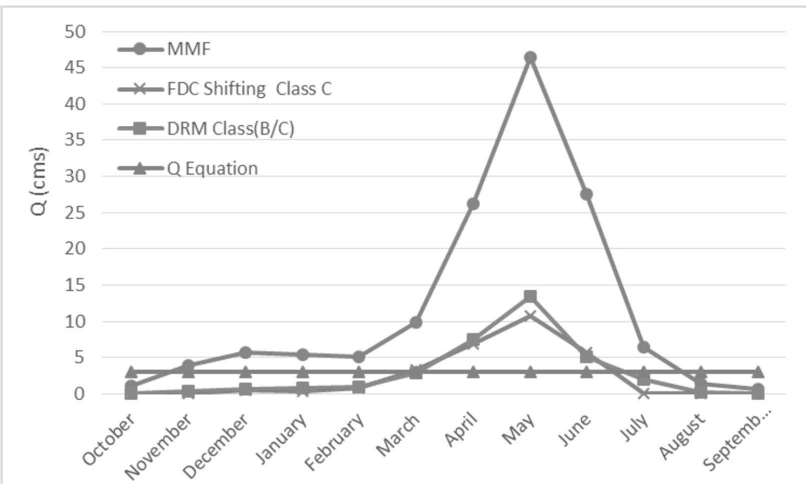

Figure 5. Comparison of EFs methods for the Gadar River at the Bahramlu Bridge Station

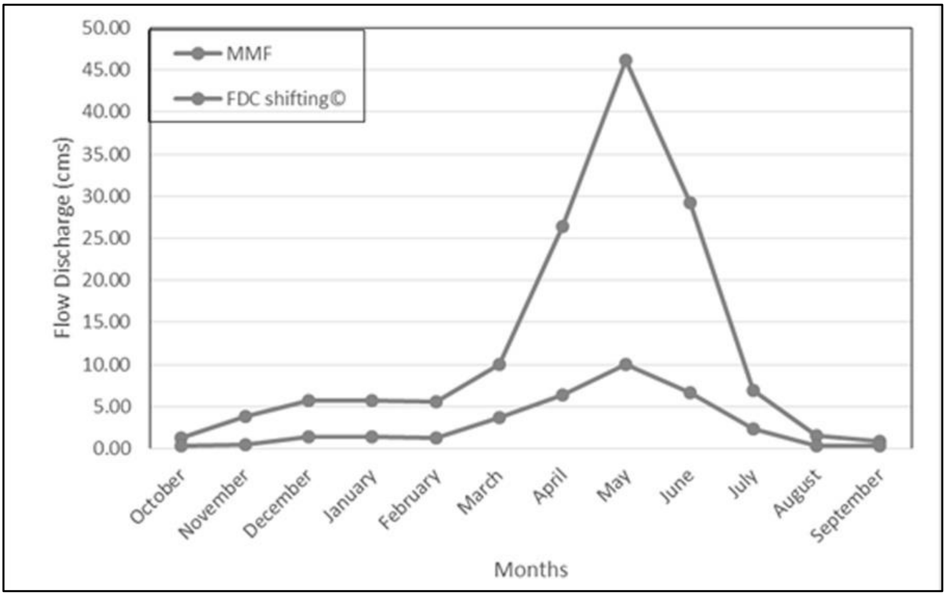

Figure 6. Comparison of distribution of average monthly flows in Naqadeh Bridge station and recommended environmental flows from this study

4. CONCLUSIONS

Urmia Lake is currently suffering from the lack of adequate water to overcome with the loss of surface water due to evaporation. By 2015, the lake had shriveled to a mere 10% of its maximum. The restoration of the Urmia Lake is now a major concern for both the national government and international bodies. The first priority is an action plan to deliver in-basin surface waters from 10 perennial rivers into the lake, and to manage the operation of 24 large dams on the basin with minimum social-economic impacts.

In the lack of specific river-bio data, an emergency attempt was made to provide with a framework for desktop assessment of minimum environmental flow allocation of the rivers using hydrology-based methods.

Some more important results that have to be noticed are: 1) Evaluation of Efs for each of the ten rivers entering the Urmia Lake has to be evaluated based on the potential flows from the basin and the upstream reasonable needs and water rights; 2) Monitoring the Efs flowing is necessary along the rivers to make sure that the recipient water body, the Urmia Lake, benefits from the right to be restored; 3) By this way, it is anticipated to provide the Urmia Lake with more than 1 billion cubic meters of water from its 10 surrounding rivers.

Acknowledgments

Detailed work on the Gadar River is depicted from the M. Sc. thesis of the first author (Saeed Habibi), under the supervision of the second author. The authors would thank the comments from anonymous reviewers for improving this paper.

REFERENCES

[1] Abdi R. &Yasi M. 2015Evaluation of environmental flow requirements using eco-hydrologic-hydraulic methods in perennial rivers. International Journal of Water Science and Technology 72 (3), 354–363.

[2] Ahmadipour Z. &Yasi M. 2014 Evaluation of eco-hydrology-hydraulics methods for environmental flows rivers (case study: Nazloo River, Urmia Lake Basin). Journal of Hydraulics 9 (2), 69-82 (in Persian).

[3] Dyson M., Bergkamp G., & Scanlon J. 2003 The Essentials of Environmental Flows. IUCN, Gland, Switzerland and Cambridge, UK, 118 P.

[4] DWAF. 1997White Paper on a National Water Policy for South Africa. Department of Water Affairs and Forestry (DWAF), Pretoria, South Africa.

[5] GEFC Software:http://iwmi.cgiar.org/resources/models-and-software/environmental-flow-calculators/ (accessed 14 April 2016).

[6] Hughes D. A. &Hannart P. 2003A desktop model used to provide an initial estimate of the ecological in stream flow requirements of rivers in South Africa. Journal of Hydrology 270, 167–181.

[7] IWMI. 2004 Environmental flows. In: Environmental Perspectives on River Basin Management in Asia. Vol 1, Issue 1. International Water Management Institute, Colombo.

[8] Jane Sh. K. 2015Assessment of environmental flow requirements for hydropower projects in India. Current Science 108 (10), 1815–1825.

[9] McClain ME, Subalusky AL, Anderson EP et al (2014) Comparing flow regime, channel hydraulics, and biologicalcommunities to infer flow–ecology relationships in the Mara River of Kenya and Tanzania. Hydrol Sci J. 59(3-4):801-819.

[10] Olden JD, Kennard MJ, Pusey BJ (2012) A framework for hydrologic classification with a review of methodologies and applications in ecohydrology. Ecohydrology 5(4):503-518.

[11] Pyrce R. 2004 Hydrological Low Flow Indices and their Uses. Watershed Science Centre. WSC Report No. 04, Trent University, Peterborough, Ontario.

[12] Richter B. D., Baumgartner J. V., Braun D. P. & Powell J. 1998A spatial assessment of hydrologic alteration within a river network. Regulated Rivers: Research Management 14 (4), 329–340.

[13] ShaeriKarimi S., Yasi M. &Eslamian S. 2012Use of hydrological methods for assessment of environmental flow in a river reach. International Journal of Environmental Science and Technology 9, 549–558.

[14] ShaeriKarimi S., Yasi M., Cox J. P. &Eslamian S. 2014Environmental flows. In: Handbook of Engineering Hydrology.Vol. 3:Environmental Hydrology and Water Management. S. Eslamian (ed.), CRC press, Taylor and Francis Group, LLC, NY 10017, USA, pp. 85-104.

[15] Shokoohi A (2015) Sensitivity analysis of Hydraulic models regarding hydromorphologic data derivation methods.

[16] SMADA Software: http://smadaonline.com/DefaultLoggedIn.aspx. (Accessed 14 April 2016).

[17] Smakhtin V. U. &Anputhas M. 2006An Assessment of Environmental Flow Requirements of Indian River Basins. IWMI Research Report 107. International Water Management Institute, Colombo, Sri Lanka, pp. 1–10.

[18] Smakhtin V. U., Revenga C. & Doll P. 2004A pilot global assessment of environmental water requirements and scarcity. Water International 29, 307–317.

[19] Smakhtin V. U., Shilpakar R. L. & Hughes D. A. 2006Hydrology-based assessment of environmental flows: anexample from Nepal. Hydrological Sciences 51 (2), 207–222.

[20] Tchobanoglous G., Burton F. L. &Stensel D. 2003Wastewater Engineering: Treatment and Reuse. McGraw-Hill Education, New York, USA, pp. 558–565.

[21] Tennant D. L. 1976 Instream flow regimens for fish, wildlife, recreation and related environmental resources. Fisheries 1, 6–10.

[22] Tessman S. A. 1980 Environmental Assessment, Technical Appendix E, In: Environmental Use Sector Reconnaissance Elements of the Western Dakotas Region of South Dakota Study. Water Resources Research Institute, South Dakota State University, Brookings, USA.

[23] Tharme R. E. 2003A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. River Research and Applications 19, 397–442.

[24] Tharme R. E. & Smakhtin V. U. 2003 Environmental flow assessment in Asia: capitalizing on existing momentum. In: Proceedings of the First Southeast Asia Water Forum, Vol 2, Chiang Mai, Thailand, November 2003, Thailand Water Resources Association, Bangkok, pp. 301–313.

[25] ULRP 2014 Urmia Lake Restoration Plan, Sharif University of Technology, Tehran, Iran. http://ulrp.sharif.ir//, (accessed 24 April 2016).

[26] Zhang Q, Gu X, Singh VP, Chen X (2015) Evaluation of ecological instream flow using multiple ecologicalindicators with consideration of hydrological alterations. Journal of Hydrology 529:711-722.