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Estimation of environmental water requirements via an ecological approach: A case study of Bakhtegan Lake, Iran

Saeid Sajedipour[a,*], Heidar Zarei[b], Somayeh Oryan[c]

[a] MSc of Civil and Environmental Engineering, Faculty of Water Science Engineering, Shahid Chamran University of Ahvaz, Iran
[b] Faculty of Water Science Engineering, Shahid Chamran University of Ahvaz, Iran
[c] Department of Environmental Education, Payame Noor University (PNU), Tehran, Iran

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ABSTRACT

As a critical environmental issue, destruction of wetlands could adversely affect several aspects of ecosystem cycles in the world, including declining the biotic diversity and ecological services of wetlands, as well as contributing to climate change and global warming. Ecological studies, engineering methods and statistical analysis could be employed to investigate the causes and compensate this impact in the most effective approach, so that in addition to sustaining one of the most important ecological sources, water resource management could be reached through estimation of water requirements. Bakhtegan Lake, one of international wetlands in Iran, with critical regional role and diverse habitat values, was chosen as the case study in the present research. An ecological approach was followed in order to estimate the environmental water requirements. As a result of deep investigation into socio-economical, physicochemical, biological and ecological factors, the Greater Flamingos were chosen as the main estimation indicator. The relationship between the number of Flamingos and the surface area of the lake was studied with the aim of estimating the lake's environmental water requirements, with special focus on Flamingo's survival. The analysis revealed water requirements need to be kept at 680 and 1870 million cubic meters as the minimum and desirable levels, respectively. After investigating the water balance of Bakhtegan Lake, the amount of required water entering the lake through Kor River was calculated. The approached employed in the current study could be generalized to the other wetlands by accounting for the contributing factors, and the results might be used in catchment studies.

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1. Introduction

Wetlands, pivotal component of our environment and the cradles of biodiversity, cover approximately 5%–8% of the world's land surface (7–10 million km^2) and must be preserved for their significant functions as natural habitats and global carbon cycling (Dorau et al., 2015; Garg, 2013; Gibbs et al., 2016; Song et al., 2012). According to the past studies, the annual value of inland wetlands' services is estimated at 14,785$ (Costanza et al., 1997). Research has further shown that the ecosystem service values of wetland is 24 times more than forests and 9 times more than shrublands (Ingraham and Foster, 2008).

Meanwhile, Wetlands throughout the world have been extremely exposed to serious threat of destruction (Audet et al., 2013; Garg, 2013; Martinez-Martinez et al., 2014). Studies estimate that approximately 50% of wetlands have been lost (Cui et al., 2009; Song et al., 2012).

Human exploitation and changes in wetlands and lakes significantly affect ecosystem processes in the world (i.e. declining the biotic diversity and ecological services of wetlands) and contribute to climate change and global warming (Gunderson et al., 2016; Song et al., 2012; Wentzell et al., 2016).

Iran has 250 wetlands with an area of 2.5 million hectares. 24 wetlands with a total area of 1486,438 ha have been registered in Ramsar Convention's List of International Wetlands. Among theses, 6 wetlands including Bakhtegan Wetland (Neyriz & Kamjan), Shadegan, Anzali and Shurgol are in Montreux Records. The Montreux Records contain wetlands which suffered severe ecological changes or are on the verge of these changes. In terms of the highest number of wetlands on the list, Iran is the world's second country (Ramsar Convention, 2016). The countries whose wetlands are

Abbreviations: EWRs, environmental water requirements; IBA, Important Bird Area; DEM, digital elevation model.

* Corresponding author.
E-mail addresses: saeid.sajedipour@yahoo.com, saeid.sajedipour@gmail.com (S. Sajedipour).

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listed in Montreux records must try in order to solve the problems of wetlands and to promote their situation to an ideal one, otherwise, the Convention may penalize these countries (Rafii et al., 2011). So, taking into account the principles of integrated water resources management in water projects, it is necessary to consider environmental components as legal water consumer in politics and management principles in order to reduce the effects of river flow regulation on natural conditions and other dependant ecosystems (i.e. wetlands and lakes) (Oryan et al., 2014). This becomes more crucial given the exacerbating drought and the importance of protecting and restoring aquatic ecosystems in these circumstances.

By definition, Environmental Water Requirements (EWRs) are water regimes needed to survive and maintain the ecological sustainability in the minimal risk level (ARMCANZ and ANZECC, 1996). Another definition says, Environmental Flow (EF) means the water regime provided for a river, wetland or coastal zone to protect the biophysical components, ecological processes, and the health of aquatic ecosystems and ecological services, when there are competing uses and flows have been adjusted (Arthington et al., 2003; Dyson et al., 2003; Yang and Yang, 2014). So, allocating EWRs of wetlands and lakes is an effective approach in order to achieve these significant objectives (Gibbs et al., 2016; Oryan et al., 2014).

Studies examining the EWRs initially conducted by the U.S. Wildlife Service and with revealing the negative effects of dams on aquatic ecosystems, from 1940 to 1970 in this country. Formal environmental flow law in 1970 as a result of Water Resources Planning Document (1956) instructions and the National Environmental Policy (1969) has been registered (Tharme, 2003). The major work done in this field focused more on rivers with specific attention to fish habitat, the rivers and other relevant issues such as ecosystem cycles protection and on ecosystems such as wetlands (Davis et al., 2001).

Mudgway et al. (1996, Kerang in Australia, hydrological approach), Roberts et al. (2000, Australia, ecological approach), Davis et al. (2001, Australia, hydrological, ecological & holistic approach), Liu & Yang (2002, Haihe-Luanhe basin in China, hydrological & ecological approach), Dong et al. (2008. Hongze & Nansi Lakes in China, hydrological approach), Yang et al. (2011, Baiyangdian Lake in China, hydrological approach), Murray-Darling Basin Authority (2012, Hattah Lakes in Australia, holistic approach), Yang et al. (2016, Baiyangdian Wetland in China, Holistic approach) and Gibbs et al. (2016, Hawdon Lake in Australia, hydrological approach) have done researches on EWRs of wetlands.

From the research conducted in Iran, we can refer to the works of Sima & Tajrishy (2006, Shadegan Wetland, ecological approach), Abbaspour & Nazaridoust (2007, Urmia Lake, ecological approach), Piri (2010, Hamun Wetland, ecological approach) and Sarhadi & Soltani (2013, Gavkhoni Wetland, hydrological approach).

In a simple and practical classification to estimate the EWRs, we can divide inland river wetlands into two categories, namely floodplain wetlands and terminal wetlands. The lakes are one of the terminal wetland types (Arthington and Zalucki, 1998; Davis et al., 2001).

Bakhtegan international Lake is one of the major habitats of the country that a large part of it was dried in the summer of 2007 and also it was dry in recent years. The major causes of this drying incidents can be summarized as: the extension of agricultural land and converting tens of thousands hectares of catchment land into agricultural lands, human origin and climatic drought and water dams of Molla Sadra (411 MCM) and Seyvand (142 MCM) on the rivers feeding the lake (Kor & Seyvand), and therefore lack of environmental water rights by the Regional Water Authority (Rafii et al., 2011). Drying of the lake will be followed by adverse effects, such as the loss of forest cover surrounding areas, up dust with salt from the dried bed of the lake, lake-related and certain species of animals' death. In total, 46 species of mammals, 218 species of birds, 36 species of reptiles and 23 species of fish have been identified within the Bakhtegan, which are valuable attraction for tourists and researchers (Tangestani et al., 2013). If the amount of water needed by the lake is provided, it may revive and return to its past condition. Given the importance of Bakhtegan Lake as an international wetland and its inclusion in the Montreux Record, the necessity of this research is clearer, especially when we know that the ratio of costs of saving ecosystems to the benefits of doing so range from 1:10 to 1:100 (van Roon, 2012).

In a research using lake bottom topography, Teimouri et al. (2011) estimated 1592 million cubic meters water needed to fill the entire surface of Tashk & Bakhtegan Lakes. In another study, Rasi Nezami et al. (2011), calculated the EWRs of Bakhtegan Lake using the water balance equation (Hydrological approach) and the amount for 2006 estimated 313.7 MCM per year.

Given the importance of ecological values of the lakes and that this important issue has not been considered in previous studies, and the lack of comprehensive research that has examined the lake's circumstances, in the present study we have tried to estimate Bakhtegan Lake EWRs with respect to the maximum effective elements i.e. the ecological state, lake's bottom topography and hydrological conditions.

2. Materials and methods

2.1. Study site

Bakhtegan Lake is one of the riverine, terminal wetlands. This great lake with 77 km length, width average of about 10 km and an area of about 750 km^2 is the is second great lake of Iran, following Urmia Lake and located in the east of Fars province, at a distance of 50–160 km from the East of Shiraz, 14 km north of Estahban and 18 km West of Neyriz, in Eastern lengths 53° 4′–54° 2′ northern latitudes 29° 2′–29° 6′ (Fig. 1). The maximum depth of the lake during wet seasons is 3 m and its average depth is between 0.3–0.5 m. Bakhtegan is flooded with saline water and at summer the lake water evaporates to a large degree (Jokar Arsanjani et al., 2015; Tangestani et al., 2013).

The lake basin is 31,458 km^2 and the main water supplies are Kor & Seyvand. Another lake water sources are drainage channels of Kamjan & Karbal area, permanent springs around the lake and winter-time floods caused by heavy rainfall (Teimouri et al., 2011). Currently, the lake water needs are provided only through atmospheric fallout and seasonal flooding input, and the lake is completely dry except for the few rainy months of the year. Bakhtegan Lake is located at Wildlife Sanctuary and National Park of Bakhtegan and is one of the most important places of breeding birds that is recognized as Important Bird Area (IBA) by Bird Life International. also in 1975 has been registered in the list of international wetlands in Ramsar Convention as the fourth International Wetland in Iran (Rafii et al., 2011).

2.2. Method

Approaches to determining the EWRs of wetlands, include hydrological, ecological and holistic three approaches (Haas, 2002). An overview of advantages and disadvantages of these approaches are shown in Table 1.

In this study, the "Calculation of Wetlands Water Requirements Instruction" has been used that has been developed in form of "Guide and Method of Wetlands Water Requirements" (Conservation Of Iranian Wetlands Project, 2013). This guideline offers a holistic approach, but gives the authority to the researchers to take into account the importance of wetlands as well as the basic available information and to use the either hydrological, ecological

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