

Hydrology method for environmental flows assessment of Johor river basin under regulated and non-regulated conditions

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Abstract

This paper evaluates the capability of hydrology method for environmental flow (Eflow) assessment of Johor river basin under non-regulated and regulated conditions due to dam construction. Daily river flow data from 1971 to 2017 was used for the assessment. Generalized extreme value distribution was applied in order to estimate exceedance probabilities associated with historical observation data at different return periods. Environmental water allocations of the river at different ecological conditions were estimated using the intra-annual and inter-annual flows. This study has estimated the hydrological yearly conditions (very dry, dry, average and wet) for the river basin. Moreover, the method has also successfully proposed the environmental water allocations to achieve the desired ecological conditions, which are very good ecological (Eflow class A), good ecological (Eflow class B), medium ecological (Eflow class C), and deficient ecological conditions (Eflow class D). In general, the proposed method has been capable and acceptable for the assessment of Eflow of Johor river basin in line with sustainable water management goal.

Keyword :

Environmental flow, water allocation, sustainable water management

1 Introduction

Recently, some rivers in the world are under extreme pressure especially in terms of water resources possibly due to rapid urbanization and over exploitation of the natural resources (Bassi et al., 2014; Lani et al., 2018a; Lani et al., 2018b). It is noted that an increased proportion of impervious surface would lead to shorter lag times between onset of precipitation and subsequently higher runoff peaks and total volume of runoff in receiving waters (Shuster et al., 2005). Therefore, changes in river flows can influence chemical, physical, and biological aspects of rivers (Van Niekerk et al., 2019).

Environmental flow is a conventional approach employed to provide nature with an equitable share of water to keep rivers alive and flowing (Hough et al., 2019). Flow regimes such as flow magnitude, flood frequency, duration, timing, depth, and velocity are essential to ecosystem health (Arthington et al., 2018).

In addition, they are also high dependent on water quality, including temperature, concentration of nutrients, and other chemical and biological properties (Crespo et al., 2019). Therefore, management of environmental flow is very crucial to sustain the fresh water environment and to avoid catastrophic effects (Sabzi et al., 2019; Tachamo et al., 2020)

In Malaysia, a comprehensive study on environmental flow characteristics of rivers is still lacking. In closing the research gap, this study aims to provide procedure for determining environmental flow based on hydrology perspective. Since environmental flows have been approved as an important for ecosystem health, they have also the potential to provide communities with an essential reserve against climate change and shifting human needs for sustainable water management goal.

2 Methodology

2.1 Data and study site

Environmental flow analysis was carried out using historical flow data (observed at Rantau Panjang station) of Johor river basin ranging from 1971 to 2017. The Johor river is the main river located in the state of Johor, Malaysia. It has 122.7 km in long with a catchment of 2285 km². In this work, rating curve measurement and water demand data are provided by the National Hydraulic Research Institute of Malaysia (NAHRIM).

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Flow frequency analysis Flow frequency distributions (maximum and low flows) can be described using generalized extreme value (GEV) distribution. Basically, it is a family of continuous probability distributions developed within extreme value theory to combine the Gumbel, Fréchet, and Weibull families also known as type I, II and III extreme value distributions. It is mathematically expressed as:

$$F(x) = \exp \left[- \left\{ 1 + \zeta \left(\frac{x-\mu}{\sigma} \right) \right\}^{-1/\zeta} \right] \quad (1)$$

where χ is the observed discharge data, μ is the location parameter, σ is the scale parameter, and ζ is the shape parameter.

2.2 Intra-annual and inter-annual flows

Intra-annual flow was analyzed based on ordinary seasonal flows at monthly scale. It shows the seasonal pattern of the flow regime within a year according to the whole series of flows record available. Therefore, flows at percentiles 0, 10, 25, and 75 was defined as very dry, dry, average, and wet conditions, respectively (See Table 1).

Table 1 Range of flows for very dry, dry, average, and wet conditions

Percentile	Condition
0	Very dry
10	Dry
25	Average
75	Wet

2.3 Environmental water allocation estimation

A river is considered in a very good ecological condition (Eflow class A), if it can maintain 20% of its wet year flows, 50% of its average year flows, 20% of its dry year flows, and 10% of its very dry year flows as presented in Table 2. In addition, a river can be categorized in a good ecological condition (Eflow class B) when it is able to maintain 10% of its wet year flows, 40% of its average year flows, 30% of its dry year flows, and 20% of its very dry year flows. A river is in a medium ecological condition (Eflow class C) when it falls under 0% of its wet year flows, 20% of its average year flows, 40% of its dry year flows, and 40% of its very dry year flows. On other hand, a river is categorized under a deficient ecological condition (Eflow class D) when it recorded 0% of its wet year flows, 0% of its average year flows, 40% of its dry year flows, and 60% of its very dry year flows.

Table 2 Calculation of environmental water allocation based on seasonal flows

Environmental management class	Ecological desired state	f frequency of			
		Wet	Average	Dry	Very dry
A	Very good	0.2	0.5	0.2	0.1
B	Good	0.1	0.4	0.3	0.2
C	Medium	0.0	0.2	0.4	0.3
D	Deficient	0.0	0.0	0.4	0.6

Therefore, environmental water allocation can be estimated using the following equation:

$$Tv = f_W x v_W + f_A + v_A + f_D + v_D + f_{VD} x v_{VD} \quad (2)$$

where Tv is the total volume of ordinary seasonal flows, f is the occurrence frequency of a regime i , and v is the occurrence frequency of a regime i . In addition, W, A, D , and VD refer to the wet, average, dry, and very dry, respectively (see Table 2).

3 Results and discussion

3.1 Flow frequency analysis

As shown in Fig. 1, annual maximum flow for the river basin at return periods of 2, 5, 10, 20, 25, 50, and 100 years prior to the dam construction were 216.16, 345.15, 444.64, 552.23, 589.08, 711.63, and 847.99 m^3/s , respectively. After the completion of the dam, the corresponding values were 139.01, 243.67, 351.61, 498.66, 556.91, 782.03, and 1,094.35 m^3/s . The minimum 1-day low flows at the same return periods were 6.31, 4.22, 3.37, 2.82, 2.69, 2.36, and 2.13 m^3/s , respectively. After the dam, the corresponding values were 7.48, 5.03, 3.96, 3.23, 3.04, 2.57, and 2.23 m^3/s . The minimum 7-day low flows at the same return periods were 7.14, 4.77, 3.83, 3.21, 3.06, 2.70, and 2.45 m^3/s , respectively. After the dam, the corresponding values were 10.01, 6.81, 4.95, 3.33, 2.86, 1.47, and 0.23 m^3/s . Increase in 1-day and 7-day minimum flows after dam construction are probably due to the regulation of streamflow.

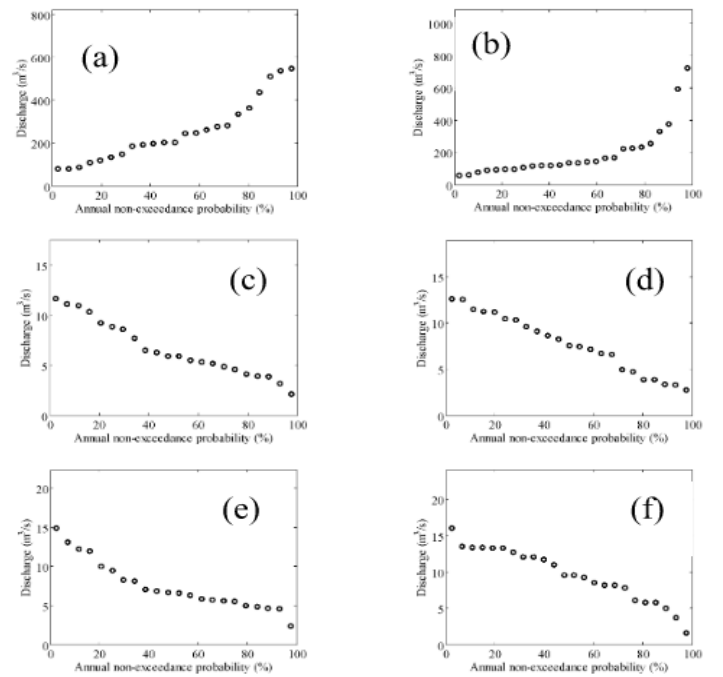


Figure 1 Annual non-exceedance probability and return period of (a-b) maximum flows, (c-d) the minimum 1-day low flow, and (e-f) the minimum 7-day low flow (a-b) before and after the dam constructions, respectively

3.2 Environmental water allocation

Environmental water allocations represent four categories i.e. Eflow class A, Eflow class B, Eflow class C, and Eflow class D. The Johor river basin falls under Eflow class A by maintaining the flows ranging from 14.15 to 32.41 m^3/s . In addition, the Johor river basin can be categorized as the Eflow class B, Eflow class C, and Eflow class D by maintaining the flows ranging from 12.05 to 26.59, 9.46 to 20.08, and 8.47 to 18.67 m^3/s depending on the related months. Sg Johor is difficult to achieve environmental flow class A by using the current water demand (2322 MLD). The river can only achieve environmental flow class B only for December. In addition, the river can achieve environmental flow classes C and D only for December-January. Demand management and additional strategies such as providing alternative water resources and flow management are recommended to improve environmental flow classes of the river.

4 Conclusion

The concept of Green marketing mix which consists of green product, green price, green place and green promotion together has a positive and significant effect on product purchasing decisions. The green product variable has a positive and significant effect on purchasing decisions for Tupperware products that and which are considered by consumers to have product quality is durable, hygienic, green eco-design and environmentally friendly. Green promotion variables have a positive and significant effect on product purchasing decisions are committed to creating products provide solutions for healthy ways to consume drinks and promote 'green living' (green lifestyle).

Declaration of competing interest

The authors declare no known competing interests that could have influenced the work reported in this paper.

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