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Hydrological Variation Characteristics of Rivers in Humid Region: Oujiang River, China

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Abstract

Oujiang River was selected as the case study, and a dataset of daily flow series at Xuren Station was used to explore the hydrologic characteristics of rivers in humid areas, by using the 'Indicators of Hydrologic Alteration' approach and 'Range of Variability Approach'. Results showed that the overall alteration of the hydrological regime for *Oujiang River* belonged to the low alteration category, and some key eco-hydrological characteristics should be protected in certain key periods to maintain the integrality and health status of river ecosystems.

Keywords: humid area; Oujiang River; IHA; RVA; hydrological indicator; statistical characteristics

1. Introduction

Understanding of the hydrological characteristics is vital for ecological protection in humid areas. As for Oujiang River in East China, it is necessary to coordinate between ecological protection and economic development [1]. The results will provide foundations for ecological protection and water management for Oujiang River and other rivers of this kind in humid region.

2. Materials and Methods

Oujiang River is a rainfall-fed river in Zhejiang Province, China. The mainstream of the river flows 384 km, covers a drainage area of 18,100 km^2, and ultimately dumps into East China Sea. The upstream

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of the river, covering the drainage of 13,500 km^2, was the study area; and hydrological variations of Xuren Station can reflect the general regime of the upper-middle reaches of the river. The large and medium hydropower development grew up after 1980s, with the representation of Jinshuitan Hydropower Station [2]. The dataset of daily flow series (1957-2002, with 1990 was missing) was divided into two by the impoundment time (1986) of the reservoir to assess the hydrological alteration induced by anthropogenic influence. The 'Indicators of Hydrologic Alteration (IHA)' approach [3] and 'Range of Variability Approach (RVA)' [4] (namely the IHA-RVA method [5]) were used to analysis the hydrological characteristics and assess the hydrologic alteration.

3. Results

3.1. Characteristics of inter-annual and intra-annual variations

Fig.1(a) showed the annual flow of Oujiang River, there was slight fluctuation with characteristics of alternately variations among wet, normal and dry years, and the annual flow experienced an increasing trend after 1980. The average flow is 436 $m^3 \cdot s^{-1}$, the ratio of the runoff in wettest year to that in driest year (extreme ratio, K) reaches 3.4, and the coefficient of variation (Cv) is 0.25. Fig.1(b) showed the uneven distribution of monthly flows, there were alternations between wet and dry period, and especially, the wettest month occurred in June and the driest month in December. The ratio of the average flow in June to that in December reached 11.4 for the pre-period, 6.7 for the post-period. Furthermore, it showed a uniformly increasing trend from January to June and a decreasing trend from June to December, especially in the pre-period. The proportion of the runoff from April to June to the total runoff of the whole year in the pre-period reached 50.8%, while it was 45.2% in the post-period.

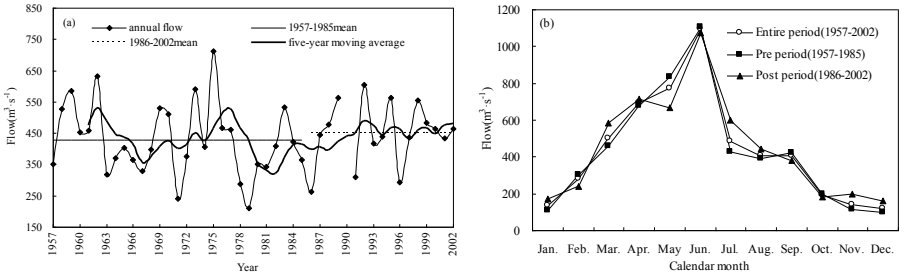

Fig.1. Flow variations of Oujiang River at Xuren Station (a) Inter-annual variation; (b) Intra-annual distribution

3.2. Statistical characteristics with various consecutive periods

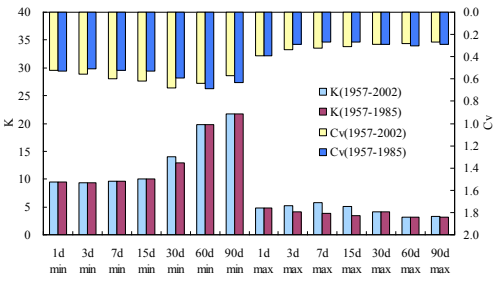

Fig.2. Characteristic flow series with various consecutive periods of Oujiang River at Xuren Station

Both in periods of 1957-2002 and 1957-1985, K and Cv for characteristic flow series of 1d min, 3d min, 7d min, 15d min, 30d min, 60d min and 90d min were all greater than those for characteristic flow series of 1d max, 3d max, 7d max, 15d max, 30d max, 60d max and 90d max; and especially in the minimum characteristic flow series, values of K and Cv for 30d min, 60d min and 90d min series were greater than those for the other series (Fig.2). These features indicated that, the inter-annual variation for the minimum characteristic flows was greater than that for the maximum characteristic flows; and particularly, for series of minimum characteristic flow, the inter-annual variation for characteristic flows with longer consecutive periods was greater than that with shorter consecutive periods.

3.3. Hydrological alteration of Oujiang River

Table 1 showed the 33 IHA parameters and hydrologic alteration assessment. There were eight parameters belonging to the moderate category, one parameter in to the high category, and the rest in the low category; especially, the value 0 for 'number of zero-flow days' indicated no zero-flow for Oujiang River. Additionally, the overall alteration degree of hydrological regime for Oujiang River can be calculated as approximately to 29%, which indicated that it was just in the low alteration category.

Table 1. Summary of 33 IHA parameters and hydrologic alteration assessment for Oujiang River

HI	January	February	March	April	May	June	July	August	September	October	November
HA	3.6	8.8	20.8	43.1	4.9	-23.7	-34.1	13.3	18.2	10.3	-4.0
AR	L	L	L	M	L	L	M	L	L	L	L
HI	December	1d min	3d min	7d min	30d min	90d min	1d max	3d max	7d max	30d max	90d max
HA	-29.5	-2.4	-9.4	-13.0	-37.3	15.3	-4.6	-42.8	-48.2	-5.1	-1.1
AR	L	L	L	L	M	L	L	M	M	L	L
HI	Number of zero days	Base flow index	Date of mini	Date of max	Rise rate	Fall rate	Number of reversals	Low pulse count	Low pulse duration	High pulse count	High pulse duration
HA	0	-34.1	-9.4	0.7	-18.4	15.3	-91.8	-48.2	-50.6	-0.3	-5.1
AR	L	M	L	L	L	L	H	M	M	L	L

Notes: HI, HA, and AR indicates Hydrological indicators, Hydrologic alteration (unit: %), and Assessment result; L, M, and H indicates Low, Moderate and High alteration category.

3.4. Variation characteristics of flow pulse and flow change rate

The high flow pulses occurred from March to August, the low flow pulses occurred from October to the next January (Fig.3). Pulses are defined as those periods in which the flow either rises above the 75th percentile or drops below the 25th percentile of daily values. Frequency and duration were employed to portray the pulsing behavior; the reversal was used to indicate the intra-annual fluctuation. According to Table 1, the alteration degrees for both the count and duration of high pulse belonged to the low category; while, alterations for low pulse and reversal were in the high category. The average number of the low pulse count increased from 6.7 in the pre-impact period to 8.8 in the post-impact period, with the degree of hydrologic alteration was 48.2%; while, the mean duration of low pulse decreased from 17 to 5 days, with the degree of hydrologic alteration was 50.6%, the mean of the number of reversals increased from 99 to 161, with the degree of hydrologic alteration reached 91.8%.

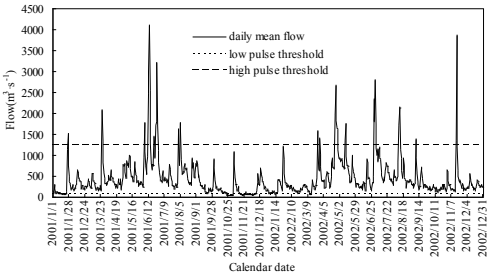

Fig.3. Mean daily flow and flow pulse characteristics of Oujiang River at Xuren Station

4. Conclusion

For rivers like Oujiang River in humid areas, there is no zero flow, the inter-annual variation of flow shows a slightly fluctuant trend, and the intra-annual distribution is uneven. The inter-annual variation for minimum characteristic flows is greater than maximum characteristic flows; among minimum characteristic flows, variations of flows with consecutive 30-day, 60-day and 90-day are more severe than others. In addition, there is one IHA parameter in the high category, eight in the moderate category; the overall alteration of hydrological regime is in the low category. In order to maintain the integrality and healthy status of river ecosystems, some key eco-hydrological characteristics should be protected, especially in extreme water conditions. The results will provide foundations for ecological protection and water management for Oujiang River, and other rivers of this kind in humid areas.

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