Regulation research on flow backward of Poyang Lake

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Abstract. The main factors affecting the water level of Poyang Lake include the inflow, outflow, precipitation and flow backward, etc. The Hydrological Alteration Diagnose System was used to analyze the water level series of Hukou Station to uncover the alteration point, and the alteration point was taken as the basis to divide the time series as before the alteration point and after the alteration point, in order to study the alteration regulation of flow backward. The results show that, compared with the flow backward series before the alteration point, the water level and discharge of flow backward after the alteration point were much more intensity, and the tendency of flow backward discharge was decreasing, the times and lasting period of flow backward were much more reduced at the same time. The regulation appeared above may be one of the reasons that cause the water level decreasing, and dry season advancing of Poyang Lake.

1. Introduction

River water backward flow is a typical feature of lakes connected to rivers, providing the function of regulating and storing flood from the Yangtze River, maintaining lake water level, ensuring safe utilization of water resources at lake areas and promoting the ecological evolution of marshlands and wetlands. Due to the impact of the changing relations between rivers and lakes, river water backward flow also exhibits a number of new change rules. Current research on the relations between rivers and lakes is mostly concentrated on the correlation between lake water level and silt in the changing environment. Guo Hua, *et al* [1], based on data analysis for 2004-2008, believe that the large storage of water in the Three Gorges Reservoir in October substantially reduces the frequency of action of the Yangtze River on Poyang Lake, resulting in reduced let-down flow of the river and affecting the water level of the lake to some extent. Wang Yingchun, *et al* [2] use the coupling hydrodynamic model of rivers and lakes at the middle reaches of the Yangtze River for simulation, which indicates that the water storage of the Three Gorges Reservoir will result in reduced water level at Duchang station of Poyang Lake by 0.09-1.11 m. Fang Chunming, *et al* [3] predict that due to the application of the Three Gorges Reservoir and under the combined action of river channel erosion and water storage, the dry season of Poyang Lake will occur about one month earlier; and they also propose simplified conditions to determine the occurrence of backward flow at Hukou station, i.e. daily increased amount of the flow of Jiujiang River exceeds the flow of Hukou of the previous day. Hu Chunhong [4], Zhu

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Lingling, *et al* [5] carried out a research on the change of sediment accumulation of mainstream channels of the Yangtze River and Poyang Lake after the Three Gorges Project was put into operation and they pointed out that the operation of the project reduced the speed and volume of sediment accumulation of the lake and increased the river channel erosion.

To sum up, a number of scholars regard the operation of the Three Gorges Reservoir as the node of change regarding the river-lake relations of Poyang Lake but they often fail to carry out further hydrological alteration analysis and the selection of the node lacks theoretical basis; secondly, river water backward flow plays a very obvious role in the replenishment of water for lakes connected to rivers and is susceptible to environmental change; and the backward flow volume and duration are also changing quietly but currently there is a lack of research on the change rule. In view of the above problems, this paper takes backward flow of river water with regard to lakes connected to rivers as the research object and adopts the hydrological alteration diagnosis system to carry out alteration diagnosis of the water level at Hukou station of Poyang Lake; and, based on the diagnosis result, the paper conducts a systematic sorting and analysis regarding the annual change rule of river water backward flow prior to and after the alteration.

2. Database and hydrological alteration diagnose system

2.1. Data sources

Water level of lakes is one of the key factors that affect lake ecological safety. It is the comprehensive reflection of the integrity of the structure and function of lake ecological system and it should reflect the river-lake relations between Poyang Lake and the Yangtze River. Therefore, this paper takes the water level sequence of Hukou station of Poyang Lake as the river-lake relations change node analysis sequence; at it uses the actual runoff sequence of the station to analyze the annual change rule of the river water backward flow prior to and after the alteration.

2.2. Hydrological alteration diagnosis system

The hydrological series composed by definite composition and stochastic composition [6], the Hydrological Alteration Diagnosis System (HADS) was put forward by XIE to diagnose the alteration of jump and trend, by the investigation of the actual conditions, the alteration style will be confirmed at last.

3. Water level series of Hukou station alteration

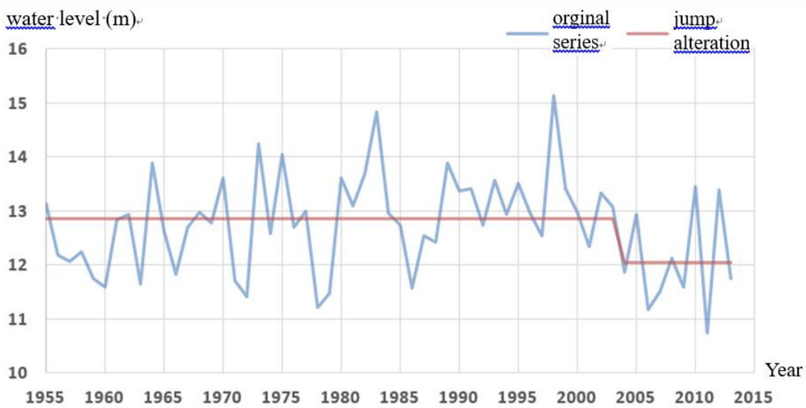

Figure 1. Annual average water level series and jump alteration figure.

With the first degree and second degree of confidence: α=0.05 and β=0.01, the water level series from the year of 1955 to 2013 of Hukou station was diagnosed by HADS. The result shows that the water level of Hukou station experienced a moderate alteration in a leap-down manner in 2003. The mean value of the water level for 1955-2003 before the alteration is 12.85 m and the mean value for 2004-2013 is 12.05 m. The annual water level decrease of Hukou station after the alteration is 0.8 m as shown in the figure 1.

4. Alteration regulation analysis of flow backward

On the basis of the result of the alteration diagnosis of the water level sequence of Hukou station, the river water backward flow sequence of the station for 1958-2012 is divided into two parts, i.e. 1958-2003 before alteration (hereinafter referred to as before alteration,) and 2004-2012 after alteration (hereinafter referred to as after alteration), and the annual change rule of river water backward flow for Poyang Lake is analyzed.

4.1. Water level and discharge alteration regulation of flow backward

With the number of days of backward flow as the sample, analysis is carried out regarding the overall sample water level and flow in the first place.

Based on the measured data of Hukou Station, the time of flow backward was 574 days before the alteration, and 82 days after the alteration, shown in figures 2 and 3 below.

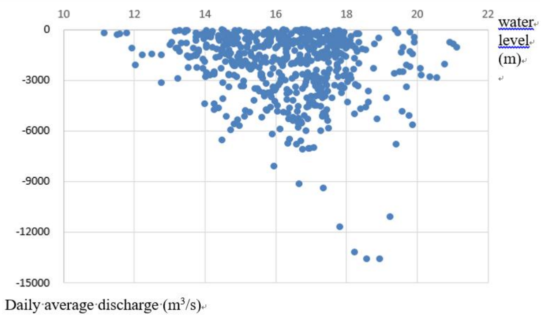

Figure 2. Daily average discharge of Hukou Station before jump alteration.

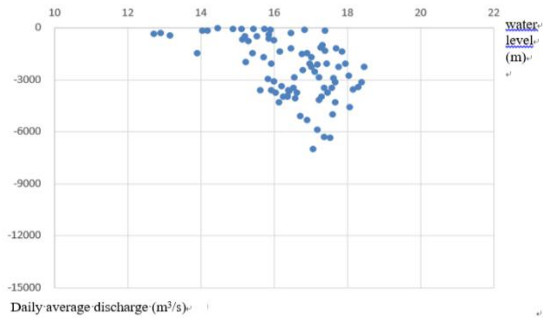

Figure 3. Daily average discharge of Hukou Station after jump alteration.

Table 1. Flow backward water level and discharge border variation before and after the alteration.

Item	Minimium Waterlevel (m)	Maxium Waterlevel (m)	Maxium daily average discharge (m^3/s)
BA	11.16	21.12	13600
AA	12.73	18.46	7000

Notes: "BA" means Before Alteration; "AA" means After Alteration; same as follows.

Table 2. Flow backward water level distribution zones variation before and after the alteration.

Water level of flow backward (m)	BA		AA	
	Times	Probability	Times	Probability
Less than 12	5	0.87	0	0.00
12-14	39	6.79	4	4.88
14.01-16	175	30.49	21	25.61
16.01-18	288	50.17	51	62.20
18.01-20	59	10.28	6	7.32
Bigger than 20	8	1.39	0	0.00
Sum	574	100	82	100

The extreme value of water level and discharge of Hukou Station when the flow backward happened before and after the alteration were shown in table 1.

From table 2, it can be seen that the water level and maximum daily average flow in case of backward flow of river water experiences substantial changes before and after water level alteration of Hukou station. First, the water level distribution interval in case of river water backward flow after alteration is more concentrated, only at the interval of 12.73-18.46 m, a decrease of 4.23 m compared to the value of 11.16- 21.12 m before alteration; secondly, the maximum value of daily average backward flow decreases remarkably from 13,600 m^3/s to 7,000 m^3/s, representing a decrease rate of 48.5%.

The total flow backward water level samples were satisfied, shown as the table 2.

From table 3, it can be seen that the water level distribution interval in case of river water backward flow of Hukou station experiences some change. First, the water level distribution after alteration is more concentrated, the probability of occurrence at 16.01-18 m increases to some extent compared to that before alteration and the water level interval decreases; secondly, at the interval of water level less than 12 m and more than 20 m after alteration, there is no river water backward flow.

The total flow backward discharge samples were satisfied, shown as table 3.

Table 3. Flow backward discharge distribution zones variation before and after the alteration.

Discharge of flow backward (m^3/s)	BA		AA	
	Times	Probability	Times	Probability
Less than 1500	271	47.21	28	34.15
1500-3000	152	26.48	22	26.83
3001-4500	77	13.41	24	29.27
4501-6000	54	9.41	5	6.10
6001-7500	12	2.09	3	3.66
Bigger than 7500	8	1.39	0	0.00
Sum	574	100	82	100

From table 4, it can be seen that the river water backward flow distribution interval before and after water level alteration experiences some change. Before alteration, about half of the backward flow is distributed within the range less than 1,500 m^3/s and, with the increase of backward flow, the probability of occurrence decrease accordingly, showing substantial regularity; after alteration, only about one third of the backward flow is distributed within the range less than 1,500 m^3/s and the distribution probability in the interval of 1,500-3,000 m^3/s and 4,501-6,000 m^3/s is very close, showing substantial decentrality of backward flow.

4.2. Times of flow backward alteration regulation

Table 4. Flow backward annual times variation before and after the alteration.

annual times	BA		AA	
	Years	Probability	Years	Probability
1	7	20.00	2	28.57
2	5	14.29	3	42.86
3	11	31.43	1	14.29
4	7	20.00	1	14.29
5	3	8.57	0	0.00
6	1	2.86	0	0.00
7	1	2.86	0	0.00
Sum	35	100	7	100

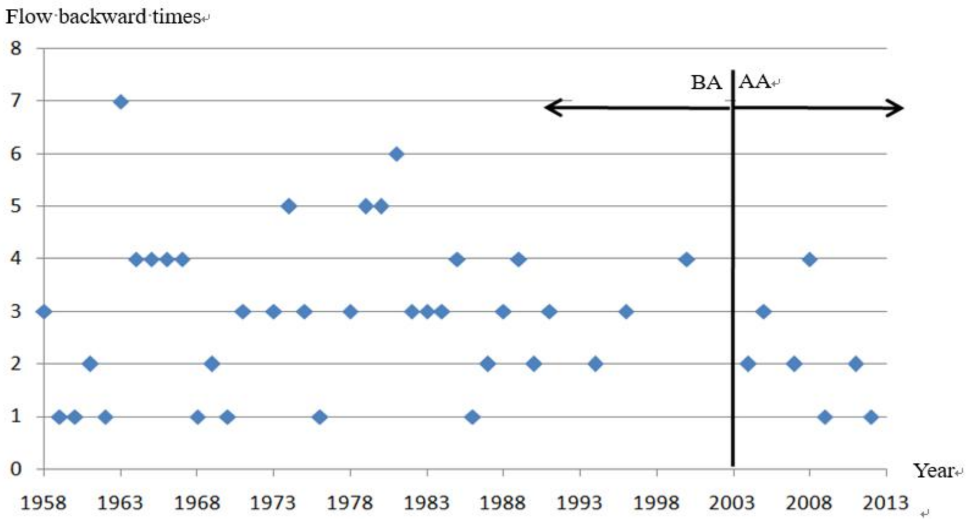

Figure 4. Flow backward annual times distribution before and after the alteration.

With the frequency of backward flow as the sample, analysis is made regarding the annual change rule of the sample water level and flow.

According to the actual backward flow data of Hukou station, river water backward flow occurs in 35 years before alteration, totalling 106 times; and seven years after alteration, totalling 15 times. The number of times of backward flow each year before and after alteration is shown in figure 4 and table 4.

Table 5. Flow backward lasting days variation before and after the alteration.

Lasting days	BA		AA	
	Years	Probability	Years	Probability
1-5	5	14.29	3	42.86
6-10	6	17.14	0	0.00
11-15	7	20.00	1	14.29
16-20	7	20.00	1	14.29
21-25	2	5.71	2	28.57
26-30	6	17.14	0	0.00
31-40	1	2.86	0	0.00
>40	1	2.86	0	0.00
Sum	35	100	7	100

From table 5, it can be seen that when backward flow occurs before alteration, the largest probability is three times per year, totaling 11 years; the probability within four times a year is 85.72%, totaling 30 times. When backward flow occurs after alteration, the largest probability is two times a year, totaling three years and the probability within four times a year is 100%; the number of times of backward flow after alteration decreases substantially compared to that before alteration.

The annual flow backward duration samples before and after the alteration were satisfied, shown as the table 5 and figure 5.

From table 5 it can be seen that when backward flow occurs before alteration, the probability of various durations is relevantly average, with the largest probability not more than 20%. After alteration, the backward flow duration is reduced significantly, with the largest probability within five days and it is distributed in a concentrated manner; in addition, there is no backward flow that lasts for more than 25 days.

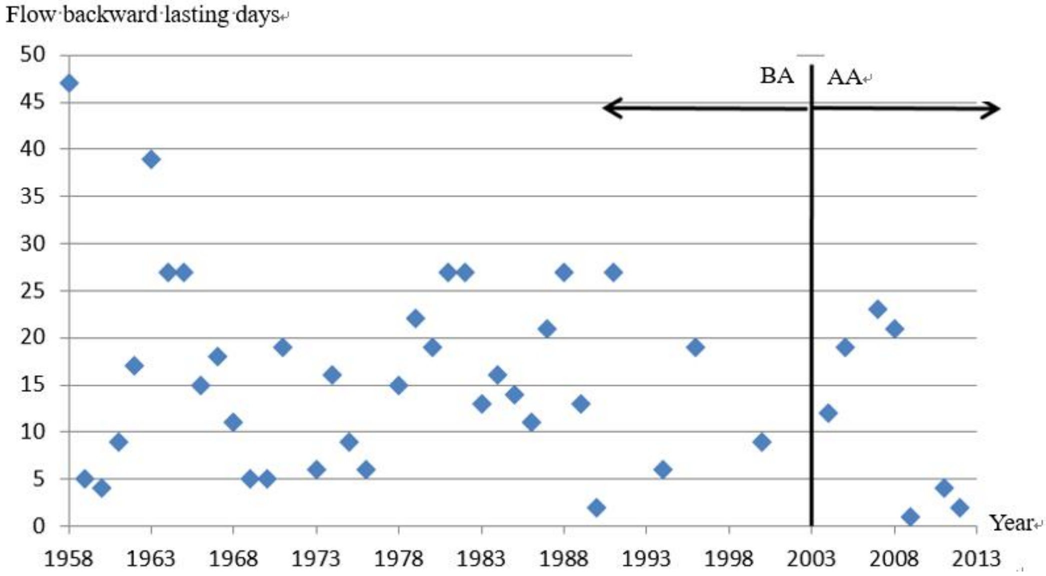

Figure 5. Flow backward annual lasting days distribution before and after the alteration.

5. Conclusions and discussions

5.1. Conclusions

Hydrological alteration diagnose system was used to diagnose the series of measured water level of Hukou Station, and based on the alteration results, the year of 2003 was taken as the point to divide the series as before alteration and after alteration, therefore, the alteration regulation could be studied, the main conculsions as follows:

- The water level of Hukou station experienced a moderate alteration in a leap-down manner in 2003. The mean value of the water level for 1955-2003 before the alteration is 12.85 m and the mean value for 2004-2013 is 12.05 m. The annual water level decrease of Hukou station after the alteration is 0.8 m.
- Based on the measured data of Hukou Station, the time of flow backward was 574 days before the alteration, and 82 days after the alteration. The water level became much more concentrate after the alteration, only at the interval of 12.73-18.46 m, a decrease of 4.23 m compared to the value of 11.16- 21.12 m before alteration. The maximum discharge decreasing apparently, from 13,600 m^3/s to 7,000 m^3/s, representing a decrease rate of 48.5%. The backward flow distribution interval before and after water level alteration experiences some change. Before alteration, about half of the backward flow is distributed within the range less than 1,500 m^3/s and, with the increase of backward flow, the probability of occurrence decrease accordingly, showing substantial regularity; after alteration, only about one third of the backward flow is distributed within the range less than 1,500 m^3/s and the distribution probability in the interval of 1,500-3,000 m^3/s and 4,501-6,000 m^3/s is very close, showing substantial decentrality of backward flow.
- According to the actual backward flow data of Hukou station, river water backward flow occurs in 35 years before alteration, totaling 106 times; and seven years after alteration, totaling 15 times.

When backward flow occurs before alteration, the largest probability is three times per year, totaling 11 years; the probability within four times a year is 85.72%, totaling 30 times. When backward flow occurs after alteration, the largest probability is two times a year, totaling three years and the probability within four times a year is 100%; the number of times of backward flow after alteration decreases substantially compared to that before alteration.

When backward flow occurs before alteration, the probability of various durations is relevantly average, with the largest probability not more than 20%. After alteration, the backward flow duration is reduced significantly, with the largest probability within five days and it is distributed in a concentrated manner; in addition, there is no backward flow that lasts for more than 25 days.

5.2. Discussion

There still exist some problems needing to be studied in the next step.

- Although the alteration happened in the year of 2003 at Hukou Station, the attribution degree of the Three Gorges needs to be studied in the next step.
- Compared with the series before the alteration point, the flow backward times, duration, and the water quantity are all decreasing after the alteration, that maybe one of important reasons that result in the low water level in the dry season, but the attribution degree and countermeasures according need to be studied in the next step.

Acknowledgments

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