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GEOGRAPHIC ENVIRONMENT CHANGE AND FLOOD CATASTROPHE IN HUAIHE RIVER BASIN DURING LAST 2000 YEARS[①]

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ABSTRACT: During the last 2000 years, flood and waterlogging catastrophes took place quite frequently in the Huaihe River Basin. In the authors' opinion, these natural calamities have a very close relation to the evolution of Hongze Lake. Formed initially within a man-made dyke that was built in the Han Dynasty about 2000 years ago, Hongze Lake brought out headward accumulation developing in the middle reaches of the Huaihe River, with its continuous aggravation on lake-bottom and consequent water-level rise. It was estimated that, on an average, there were 3400×10^4 t sediment per kilometre per year deposited on the river bed from Lutaizi to Bengbu. Therefore, the rising of water-level and the drainage difficulty in the middle reaches of the Huaihe River aggravated local flood and waterlogging catastrophe here.
KEY WORDS: Hongze Lake, headward accumulation, middle reaches of the Huaihe River, flood catastrophe

I. INTRODUCTION

The Huaihe River Basin is an area where flood and waterlogging catastrophes happened very frequently through the history. According to statistics, there were as many as 338 years when flood and waterlogging catastrophes

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once took place recorded in the historical literature from 185 B. C. to 1982. For example, in 1593, the Huaihe River flood overflowed the Hongze Lake Dyke (the Gaojiayan Dyke), the spilled floodwater was several feet deep down to the ground, and one hundred and twenty counties were hit, which occupied two thirds of the number of counties in this river basin. In 1931, the counties hit were more than one hundred, nearly twenty million people suffered from the disaster, two hundred and twenty thousand died. In 1954, the Huaihe River flood hit eighty-five counties, the disaster area was 4.08×10^4 km^2. And in 1991, the area was 3.17×10^4 km^2, fifty two million and four thousand people became victims of the flood catastrophe, making up 37.5% of the population in that river basin, this flood shattered one million nine hundred and thirty one thousand houses, caused 61.8×10^8 kg grain lost, and the corn production decreased 156×10^8 kg in that year, it was estimated that a direct pecuniary loss above 34,400 million yuan (RMB) was caused by this flood catastrophe.

When the Huaihe River flood in 1991 had gone over, specialists had proposed the problem that "the Huaihe River trunk (middle reaches mainly) could not release the floodwater smoothly", it was so serious that the available flow for flood discharge in some courses was 1000 to 1500 m^3/s, even 2000 m^3/s lower than the designed capacity. For example, in 1954, the maximum floodwater-level at Wangjiaba Station was 29.57 m above sea level, while the maximum flood-flow was 9600 m^3/s, but in 1991, they were 29.56 m and 6,630 m^3/s only. At Zhengyangguan Station, it was 26.55m and 12,700 m^3/s in 1954, but 26.51 m and only 7,450 m^3/s in 1991. Compared with historical record, the scale of the Huaihe River flood in 1991 just belongs to up-middle class, however, the floodwater-level along the middle reaches of the Huaihe River maintained at high value for such a long time which last 35 days at Zhengyangguan Station and 25 days at Bengbu Station during which the water-level was keeping above the warning stage.

Meanwhile, some others researched the causes of frequent flood in history and the methods of permanent control of the Huaihe River, they agreed in that the evil consequence of the Huanghe (Yellow) River took the course of the Huaihe River had not been thoroughly done away. By 1855, the Huanghe River had taken the course of the Huaihe River and flowed through North Jiangsu Province into the Yellow Sea for a long time, it silted up and caused the lower reaches of the Huaihe River abandoned, raised the gradient of the middle reaches and deduced the ability of flood discharge along the middle and lower reaches of the Huaihe River[1]. Furthermore, the climatic conditions at that area were believed to play an important role in flood. As a normal in the Huaihe River Basin, the precipitation in summer makes up 60% of the total in a year, and there are two major climatic factors that bring plenty of rain, one is the monsoon in June and July, the other is typhoon, coming mainly in August.

Based on other studies and focuses on the research why the flood and waterlogging catastrophes came about so frequently in the Huaihe River Basin in history, especially along the middle reaches of this river, this paper analyzed the effect of the geographic environment of this area in detail, and the authors hope that it is useful to formulate a long-range plan to bring the Huaihe River under control.

II. THE HUAIHE RIVER FLOOD DURING THE LAST 2000 YEARS

So far, the study on the change of geographic environment in the Huaihe River Basin is relatively weak, it is because too many natural events took place there which fragmentated the deposition sequence, among which, the flood and waterlogging catastrophes are two of the most prominent disasters.

Up to now, more than one hundred culture relics developed in the New Stone Age and in history age, had been excavated along the Huaihe River, among them, most of the New Stone Age ones were built on some "terrace-shaped high mound", which had been buried by later flood deposition. The same phenomena were also found in South Jiangsu Plain, the Jianghan Plain and the Dongting Lake area. In fact, the so-called "terrace-shaped high mound" is the remnants of low-lying river terrace, to live there was of great advantage for people to avert flood. In addition, it was mentioned in those historical records before the Qin Dynasty, such as "the Meng Zi", "the Mo Zi" and so on, that the Great King Yu ever regulated the Huaihe River and its tributaries, the Ruhe River, the Yinghe River and the Sihe River. So, it can be concluded that as early as thousands of years ago, flood disasters had happened along the Huaihe River.

Classified by traces of flood discharge, the above-mentioned 338 floods can be divided into three types. Type A was caused mainly by torrential rain or successive rainfall, its floodwater came from the Huaihe River system only, just few exceptions took place in the Xinghe — Sihe — Muhe River Basin the north of the lower reaches of the Huaihe River without effects on the middle reaches of the Huaihe River. Type B was caused by floodwater coming from the Huanghe River and the Huaihe River together, taking the flood in 1593 for example, in May, firstly from the bursts of the Huanghe River dyke at Huanggu, Shanxian County, submerged some spaces, and then from some tributaries of the Huaihe River overflowed, the Wuhe City and the Sizhou City along the Huaihe River, and the Gaojia Dyke was burst at 22 sites. Type C was because that the Huanghe River broke down its dyke firstly, then flood spread over the Huaihe River basin, for example, in 1938, when the Huanghe River dyke was breached at Huayuankou for some man-made reasons which resulted in a flood area larger than 5.0×10^4 km^2, affected about 12.5 million people, left a so-called "the Yellow River flood area" about 2.0×10^4 km^2 with no sign of human habitation.

It is shown in Table 1 that, the frequency of flood and waterlogging catastrophes had a rising tendency, it had increased from several times to twenty to thirty times per hundred years, and reached the maximum value of sixty in the Yuan Dynasty. There were thirteen times of flood runoff from 1949 to 1985, but it was not a certainty that every flood runoff produces a heavy damage (loss), obviously, it was the water conservancy project to play an important role in natural disaster reduction.

Table 1 Heavy flood catastrophes occurring in the Huaihe River Basin during the last 2000 years

Time range	Dynasty	Total of heavy flood catastrophes	Frequency (times/100a)	Times of type A and B	Times of type C
185—219	The Han	11	2.7	9	2
220—280	The Three Kingdoms	2	3.3	2	0
281—419	The Jin	11	7.9	11	0
420—580	The Northern and Southern	12	7.5	12	0
581—617	The Sui	3	8.3	3	0
618—906	The Tang	46	16.0	43	3
907—959	The Five	12	23.1	1	11
960—1278	The Song	90	28.3	50	40
1279—1367	The Yuan	57	64.8	17	40
1368—1643	The Ming	34	12.4	17	17
1644—1911	The Qing	38	14.2	23	15
1912—1948	The Republic of China	9	25.0	7	2
1949—1985		13	36.1	13	0
Total 2170a		338	15.58	208	130

* Source: Wang Zulie, 1987.

The frequency change of the above-mentioned three types of flood and waterlogging catastrophes happened in the Huaihe River Basin during the last 2000 years are illustrated in Fig. 1, among them, the frequency of type A and type B increased alternately before 1367, their rising rate was lower than that of type C. After 1368, all of the three types changed irregularly. The maximum frequency of type A and B was 26. 8 times or years per hundred years from 1901 to 1982, the second one was 16 times or years per hundred years, in the 17th century. Moreover, the former (type A and B in all) had a reverse-ratio relation to the latter (type C only), and it suggests that in the Huaihe River Basin, besides the factor that "the evil consequence of the Huanghe River taking the course of the Huaihe River had not been thoroughly done away", there must have some other ones worked together and caused the flood and water logging catastrophes to happen, at least, conditions of climate and river channel belong to the latter.

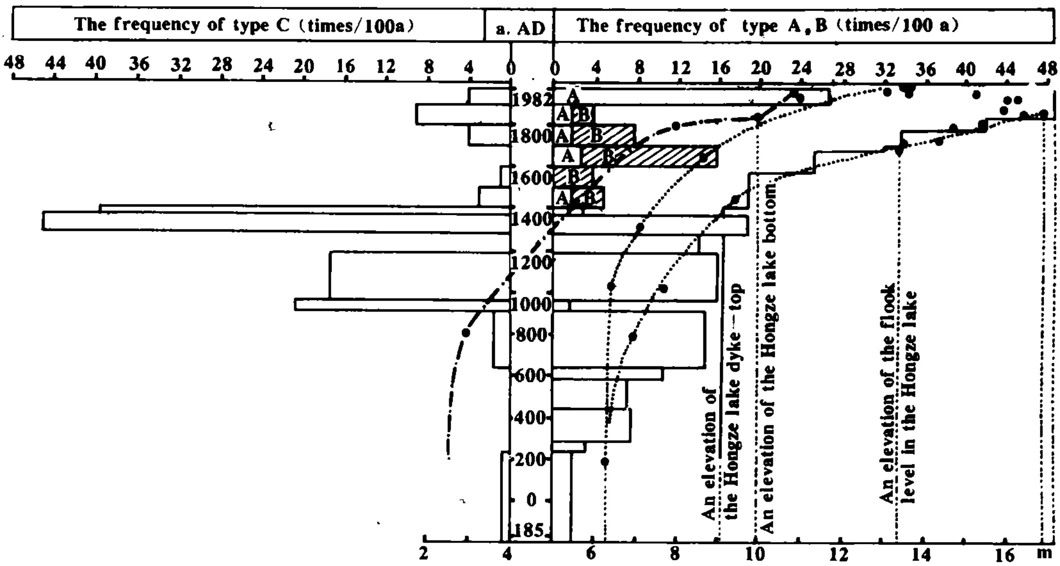

Fig. 1 Change of frequency of heavy flood and waterlogging damages in the Huaihe River Basin during the last 2000 years

III. EVOLUTION OF THE HONGZE LAKE DURING THE LAST 2000 YEARS

In fact, Hongze Lake was a reservoir that developed initially within a man-made dyke, before which there was the part of the wide valley of the Huaihe River which flowed out from hilly land. Based on the historical literature, in the Han Dynasty, there were several smaller lakes in Hongze Lake area, Fuling Lake, Pofujian Lake, Baishuitang Lake and Nidun Lake, they were all located at the tributary outlet of the Huaihe River, subordinated to the lateral levee lake probably. However, in the same period, there were the low-lying land along the Lixia River and a series of coastal bars paralleled, lying to the east of Hongze Lake. Still in the Han Dynasty, fishery and salt production along the sand bar zone had been highly developed, but in 168 B. C. and 132 B. C. (within the Han Dynasty still), the Huanghe River twice breached its dyke and took the course of the Huaihe River. For this reason, the Huaihe River could not flow fluently into the sea, and most of its runoff threatened the security of that region lying to the east of Hongze Lake. Under this condition, with Chen Deng as the leader, who was the president of the Guangling State in 200, the local people built dykes to intercept the floodwater from the Huaihe River, and formed a lake there gradually.

Evolution of Hongze Lake is closely relevant to that of its dyke, which can be put as "heighten the dyke with rising water-level, and water-level rise with heightened dyke in a round". Recently, after having studied a large magnitude of historical data, Xu Shichuan (1984) had found out the evolution of Hongze Lake Dyke (the Gaojia Dyke) being heightened and consolidated in history. On the basis of calculation, the elevation of the dyke-top increased from 9. 77 m above sea level in 1415 to 17. 20 m in 1826, and that of the Zinian Dyke from 14. 32 m in 1678 to 19. 00 m in 1826. Calculated by Xu Shichuan, too, in 200, the elevation of the lake-bottom was around 2. 7 m above sea level, in 800, it was higher than 3. 0 m, and 10 m in 1855. According to Nanjing Institute of Geography and Limnology, the Chinese Academy of Sciences[2], when the Huanghe River Dyke was burst at Huayuankou and flood spread southward from 1938 to 1947, the lake-bottom of Hongze Lake silted up 0. 5 m to 1 m high, the average elevation of the lake-bottom was 10. 4 m above sea level in 1954,and the total volume of sediment deposited in Hongze Lake from 1960 to 1965 was $4,321 \times 10^4$ t.

With the uninterrupted increase of the lake-dyke elevation and the silt thickness on lake-bottom, the water-level of Hongze Lake rose too. In his another paper, Xu Shichuan estimated that at the beginning when the Gaojia Dyke was built, the local floodwater-level was 6. 39 m, in 792 it reached 6. 98 m, then it was 7. 10 m in 1307, 9. 47 m in 1441, 8. 64 m in 1696, 13. 41 m in 1683, 13. 51 m in 1706, 14. 40 m in 1742, 14. 63 m in 1786, 15. 49 m in 1808, 16. 42 m in 1851, 16. 00 m in 1921, 16. 25 m in 1931, 15. 23m in 1954, 13. 66 m in 1963, 13. 17 m in 1968, 13. 59 m in 1977, 13. 45 m in 1982 and 14. 21 m in 1991. Before the 1850s, the annual maximum water-level had a high-rate rising trend, after then, the burst of the Sanhe Dyke in 1851 caused the Huaihe River flow southward through Gaoyou Lake into the Changjiang River. The Sanhe floodgate was built in 1952, used to control the discharge of the Huaihe

River flood, its flow of flood discharge was 10,700 m^3/s in 1954 and 8,000 m^3/s in 1991.

IV. RELATION OF EVOLUTION OF HONGZE LAKE AND FLOOD CATASTROPHE IN THE HUAIHE RIVER BASIN

Before being discussed in this paper, the impact of evolution of Hongze Lake on the flood catastrophe in the Huaihe River Basin had been noticed by some scholars already. For example, Wang Zulie's appraisal (1987) was "forming the vast and mighty Hongze Lake, raising trunk water-level of the Huaihe River, affecting flood discharge and intensifying flood and waterlogging catastrophes along the upper and middle reaches of that river." Fig. 1 illustrates the interaction of evolution of Hongze Lake and flood catastrophe in the Huaihe River Basin, from which we could deduce that the alternative or irregular changes of flood frequency may be affected by the climatic change and the unequal flood flow of the Huaihe River.

Evolution of Hongze Lake influenced the flood catastrophe in the Huaihe River basin in many respects. Firstly, it caused headward accumulation developing in the Huaihe River above Hongze Lake, which silted up on the flood plain, narrowed the cross section of river channel, forced floodwater level rise. Secondly, it brought about meander developing in this course of the Huaihe River, which increased the river curvature, caused impeded releasing flood. Finally, because of the two effects above, the function of the Huaihe River channel there had changed from releasing flood only to storing floodwater while discharging, once comes an over-volume flood runoff, flood catastrophe is easy to take place.

The headward accumulation which, developed in the Huaihe River channel above Hongze Lake, and caused by silting up on the lake-bottom and rise of the lake water-level, had a time lag to induced factors. According to Nanjing Institute of Geography and Limnology, the Chinese Academy of Sciences[2], from 1963 to 1973, because against by highwater level of Hongze Lake, the Huaihe River silted on the bed of its stream outlet (flow into Hongze Lake) up to a maximum depth of 5 to 6 meters and a minimum value of 3 meters, average rate of deposition was 0.5 meter per year.

Calculated by Zhao Jialiang, et al. (1992), from 1950 to 1979, the average annual volume of suspended load of the Huaihe River deposited on the river bed was 361×10^4 t along the course from Wangjiaba to Lutaizi and 209×10^4 t from Lutaizi to Bengbu, which can be converted into 2.57×10^4 t sediment per kilometre per year that there deposited on the bed from Wangjiaba to Lutaizi and 3.48 X 10^4 t from Lutaizi to Bengbu. Further more, the total magnitude of sediment deposited along the course between Lutaizi and Bengbu from 1950 to 1990 was $9,550 \times 10^4$ t, in other words, the average rate of deposition in this period was 3.882×10^4 t per kilometre per year, it was larger than that of 3.48×10^4 t from 1950 to 1979. This comparison indicated that headward accumulation is still in progress. If estimate with these values of deposition rate, we can say that $3,400 \times 10^4$ t per kilometre deposited on the bed from Lutaizi to Bengbu since the construction of Hongze Lake Dyke, and at the high-lying flood plain located at Diaoyutai, Bengbu, there had silted up 3.9 m thick since $2,370 \pm 50$a B.P. (by ^{14}C)[3].

If we neglect the change of meander length from Bengbu to Hongze Lake and estimate further with these above-mentioned deposition rates, we will discover that the river gradient of high floodwater-level in this course had decreased 26.6% during the last 2000 years. If the change of meanders is considered, the decrease range will be higher, namely, the ability of flood discharge of that course had come down a lot, so, aggravation on the river bed went intensively even more.

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