After the Three Gorges Project to use the impact analysis by scouring and silting in Poyang Lake control engineering area

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Abstract: Lake control project of Poyang lake is a large scale with a complex operation scheduling, which has an effect on the flood control and environment near the connected area between Poyang lake and Yangtze river. This paper combines one-dimensional and two-dimensional water and sediment mathematical model to calculate and analyze it. The application of a long reach and long term one-dimensional mathematical model from Yichang to Datong provides boundary conditions for the two-dimensional model. Two-dimensional model between part of Yangtze river and Poyang lake is used to calculating the influence caused by lake control project to the bed erosion and deposition between the river and lake after the operation of Three Gorges Reservoir. The research result shows that after a 10-year operation of lake control project, riverbed scouring takes place on a large scale near the connected area as long as the point bar which used to be deposit, and the deepest erosion on bed groove reaches about 1.3m. Sediment scouring takes place on the Yangtze river under the lower Zhangjiagiazhou channel, but the upper channel changes less relatively.

1. Overview

The Yangtze River Basin is a comprehensive water system with many tributaries. The main stream is divided into upper, middle, and lower reaches by Yichang City in Hubei Province and Hukou City in Jiangxi Province with Hukou being the boundary point between the middle and lower reaches of the Yangtze River. The area of the main stream of the Yangtze River near Hukou is bounded by Hukou (Bali River), with the area up to Dashuxia being called the Jiujiang River section (hereinafter referred to as the Jiuhu section), which is 51.6 km long while the area down to Xiaogushan being called the upper and lower Sanhaozhou River section (hereinafter referred to as Shanghe section), which is 40.3 km long. Hukou is connected to the Yangtze River and Poyang Lake, whose hydrological and sediment are distinctive and influential to each other.

Poyang Lake is located in the northern part of Jiangxi Province, connecting the Five Rivers of Gan, Fu, Xin, Rao and Xiu. The water level is affected by the Five Rivers and the Yangtze River, leading to serious flood disasters. The water level and volume in the dry and the flood seasons are very different. The shape of the river is wide in the south and narrow in the north. It is 173 km long from north to south, with its widest point from east to west being 74 km and the narrowest point of the river channel being 2.8 km.

In order to effectively prevent the flood disasters of Poyang Lakerationally develop and utilize its abundant water and soil resources, it is proposed to build a multi-functional comprehensive water...
conservancy project called the Poyang Lake Hukou Control Project. This Project is huge in scale and complicated in operation and dispatching due to the fact that the hydrological and sediment characteristics of Poyang Lake are quite different from those of the Yangtze River, which leads to complicated movement of sediments near the Hukou and the jacking effect between rivers and lakes. In addition, the construction of the Three Gorges Project has also influenced the water and sand conditions to some extent. This paper analyzes the impact of the Lake Control Project on the river bed erosion and deposition in the vicinity of the Project after the construction of the Three Gorges Project by adopting numerical simulation.

1.1. Overview of Poyang Lake Control Project
It is planned to build a hydro-junction for comprehensive utilization of flood control, power generation, shipping and water supply between Changling and Pingfeng Mountain.

Dispatching mode: set the flood control mode of the initial Poyang Lake Control Project according to the proposed flood control level and drainage level of the inner lake as follows: (1) When the water level of the Yangtze River is lower than the drainage level of the inner lake, open the gate so that the two levels can be the same;
(2) When 20.00 m ≤ Yangtze River water level < 22.50 m, close the gate and turn on the pump to drain the Five Rivers as much as possible;
(3) When the water level of the Yangtze River ≥ 22.50 m and still has an upward trend, gradually open the gate and pour the water in the Yangtze River into the lake, so that the water level of the Yangtze River can be maintained at 22.50 m. the sequence of using flood basin is Fenglin Mountain, Changshan Mountain and Kangshan Mountain and Huayang River sub-storage areas.

Scheduling operation principle: before the flood is the power generation period. On April 1st, the dead water level is 16.0 m. As the water from the lake increases, the water volume in the lake is larger than that required for maximum power generation, and the water level of the dam rises to 18.0 m, the highest power generation level; when the water level of the dam is greater than 18.0 m, the power generation is stopped, the gate is opened to level the upstream and downstream level of the dam. If the water level rises further to 20.0 m, the gate is closed to enable the pump to drain the inner lake water to control it at 20.0 m, and if the water volume is larger than that required for pumping, store the excess water in the lake. When the water level on the dam rises to 21.0 m (or 21.50 m), use the existing flood storage in the lake to maintain the maximum water level lower the water level. The water level in the inner lake is maintained at 18.0 m for power generation. During the dry season of the Yangtze River, increase power generation to lower the water level in the lake until it reaches the dead water level of 16.0 m at the end of March.

1.2. Hydrological and sediment characteristics
The Yangtze River Basin is rich in water resources. The average annual flow of Hankou Station is 22,600 m³/s, and its average annual runoff is 7147×10⁸•m³. The average annual flow of Datong Station is 28,600 m³/s, and the average annual runoff is 9030×10⁸•m³.

The annual runoff of the main stream of the Yangtze River is relatively stable, with little change from year to year. The annual runoff of the regions of Yichang and above, the middle reaches of Hankou, and Poyang Lakeaccounted for 48.5%, 79.2%, and 16.6% respectively of the annual runoff of Datong. The distribution features of the Yangtze River runoff is similar to that of precipitation during the year, which is mainly concentrated in the flood season and tops in July and August while the largest runoff of Poyang Lake water appears from April to July. The flood season and dry season of Poyang Lake are about one month ahead of that of the Yangtze River. In July and August, the Yangtze River flow reaches the maximum while the Poyang Lake flows backward due to the influence of the Yangtze River. Therefore, the negative flow appears mostly in July, August and September. In October, the water level of the Yangtze River decreases and the gradient and outflow rate near the outlet increases. Therefore, the average annual flow of the lake in October was greater than that in September.
The sediment in the middle and lower reaches of the Yangtze River mainly comes from the areas of Yichang and above. The sediment transport from May to October in Datong Station accounts for 87.8% of that in the whole year and the average monthly sediment transport rate in Poyang Lake reaches its highest in March, accounting for 27.4% of the annual sediment transport. In July, August and September, backward flow leads to the negative sediment transport rate at Hukou Station. The amount of sand flowed backward from July to September is -10.2% for the whole year. The average annual sediment transport of Hukou Station accounts for 2.4% of Datong Station, much smaller than the 16% of runoff.

2. Calculate and analyze to Mathematical Models
Poyang Lake is closely related to the main stream of the Yangtze River. Hukou, with complicated sediment movement while connecting the rivers and lakes is located in the lower part of Nanjing, Zhangjiakou. The supporting effect of rivers and lakes is obvious. The Three Gorges Reservoir has changed the water and sand conditions of Yangtze River downstream. The riverbeds in the lower reaches of the dam will be washed up from the top to the bottom for a long time, which will also have a certain impact on the riverbed erosion and flood control in the vicinity of Hukou. Therefore, this paper builds a long-reach long-time one-dimensional constant water and sediment mathematical model and a two-dimensional flood evolution mathematical model in Poyang Lake area and local two-dimensional water and sediment mathematical model in Hukou District in order to calculate and analyze the water-sand relationship and riverbed erosion and sedimentation changes in the rivers and lakes.

2.1. One-dimensional model calculation and analysis of the influence of lake control project on riverbed erosion and sedimentation in the mainstream of the Yangtze River and the relationship between rivers and lakes

2.1.1. Calculation conditions
Calculation range: The 1123 km-long middle and lower mainstreams of the Yangtze River from Yichang to the Datong section below the Hukou; the diversion channel below the three entrances of Jingjiang, the Dongting Lake area and the Poyang Lake area.

Water and sand conditions for inlet and outlet: conduct sedimentation calculation of the Three Gorges Reservoir of the three-phase cofferdam water storage operation of the Project during construction and its normal water storage operation plan. The water and sediment process and numerical values of the reservoir are taken as the inlet condition of downstream scouring calculation while the outlet is controlled by the water level flow relationship of Datong Station in the lower reaches of the Yangtze River.

2.1.2. Influence on riverbed erosion and deposition in the main stream of the Yangtze River
After the long-distance riverbed adjustment of the sediment of the Three Gorges Reservoir, the sand carrying capacity of the Wuhan section is obviously weakened. After the completion of the Three Gorges Reservoir for 1 to 20 years, the sediment of the Three Gorges Reservoir is recharged along the way. As it enters Wuhan section, scouring and siltation both exist, with siltation as the dominant one. After 30 years of completion, the erosion of the riverbed above the Wuhan section leads to some coarser riverbeds, less recharge of outlet sediments, and bigger sand carrying capacity of the water in this section. Scouring began to become the dominate phenomenon in the riverbed.

After the implementation of the Poyang Lake Control Project, the water and sediment in the lake area entering the main stream of the Yangtze River was reduced and the supporting effect of the main stream of the Yangtze River was enhanced, which will lead to higher lake level and larger volume of sediments of the riverbed from the Wuhan to Jiujiang River, less sediment in the lake inlet and its reaches and riverbeds downstream and larger amount of scouring. In the early stage of the implementation of the project (1~10 years), the riverbed scourled 1.669×10^8 m^3 more sediment than
2.1.3. Influence on river bed erosion and siltation in the vicinity of the Yangtze River

Table 1: Table of cumulative changes in riverbed erosion and sedimentation near the outlet (Suspension volume)

| Location                      | 10y   | 20y   | 30y   | 40y   | 50y   |
|-------------------------------|-------|-------|-------|-------|-------|
| Wuhan-Jiujiang                | 0.349 | 0.345 | 0.282 | 0.359 | 0.448 |
| Jiujiang-Datong               | -1.669| -3.669| -4.776| -4.033| -2.746|
| Xinzhou-Zhangjiazhou          | 0.168 | 0.102 | 0.124 | 0.162 | 0.174 |
| Left branch of Zhangjiazhou   | -0.221| -0.318| -0.374| -0.326| -0.168|
| Right branch of Zhangjiazhou  | -0.361| -0.508| -0.567| -0.554| -0.502|
| Zhangjiazhou-GePaizhou        | -0.725| -1.072| -1.086| -0.900| -0.632|

Unit: 10^8t

After the implementation of the Poyang Lake Control Project, the amount of sand discharged from the lake was greatly reduced. Both scouring and siltation existed in the upstream riverbed, with siltation being the dominant one compared with the former situation. The Zhangjiazhou branch is dominated by scouring with that in the upstream larger than that in the downstream. It can be seen from Table 1 that after the implementation of the Project, the reaches and riverbeds below the Hukou suffered from erosion to different extent compared with before. When the construction of the Three Gorges Reservoir has been completed for 60 years, left riverbed of Zhangjiazhou accumulated 0.156×10^8•m^3 more than before; that of the upper and lower riverbed of the right riverbed of Zhangjiazhou accumulated 0.346×10^8•m^3 and 0.164×10^8•m^3 respectively more than before; that of the tail of Zhangjiazhou to the head of GePaizhou accumulated more than 0.408×10^8•m^3, less than that of the Zhangjiazhou. In addition, the more downstream, the smaller the scouring range, indicating that the farther away from the outlet, the smaller influence of the Project on the riverbed erosion and siltation.

2.2. Two-dimensional model calculation and analysis of the influence of Lake Control Project on river bed erosion and deposition in the river section near Hukou

2.2.1. Analysis of scouring and silting distribution

With the application of the Lake Control Project taken into consideration, a large area of the water channel in the lake suffered from scouring with the general scouring depth in the deep groove being 0.2 to 1.0 m and the maximum depth being 1.3 m. The original sedimentation area of the marginal bank also suffered from scouring with generally with the general scouring depth being 0.1 to 0.5 m. The lower section of the Yangtze River main stream, the lower section of the Zhangjiazhou ramp and the confluence sections below Hukou showed phenomenon of scouring compared with before while that of the diversion section of the upper section of the Zhangjiazhou and above showed relatively less change.

From the comparison diagram of the Project after 10 years of operation, it can be seen that due to the reduction of the discharged sand volume, the Pingfengshan-Hukou section mainly suffered from scouring the initial 10 years with wider and deeper groove. In addition, the diara and the margin bank

Before the implementation of this project, part of the sediment was deposited in the reservoir with fewer amounts of sediment discharged and more serious scouring. When the Project has been operated for 30 years, the riverbed in the Jiujiang-Datong section scoured 4.76×10^8•m^3 more than before. As the sedimentation in the reservoir area tended to be balanced, the amount of sediment discharged from the reservoir gradually increased with less impact on the downstream scouring and less cumulative amount of sediment in the downstream riverbed. When the Project has been operated for 60 years, the cumulative scour amount from Jiujiang to Datong was only 1.88×10^8•m^3 than before.
also suffered from scouring.

2.2.2. Analysis of the amount of scouring and silting
The staged scouring and silting scale shows that in the absence of Lake Control Project, the whole Yangtze River main stream and the inlet sections suffered from a small amount of scouring. After 10 years of the operation of the Project, the total amount of scouring and sediment was $-0.067 \times 10^8$ t and $-0.030 \times 10^8$ t, respectively. Therefore, the Lake Control Project led to a little increase in the scouring amount of the main stream of the Yangtze River ($-0.120 \times 10^8$ t) and a large increase in the scouring of the lake section ($-0.303 \times 10^8$ t).

3. Summary
In order to analyze the influence of Poyang Lake Hukou Control Project on the river bed erosion and siltation of Poyang Lake and the junction area near Hukou, this paper combines one-dimensional and two-dimensional water and sand mathematical models to calculate and analyze the amount of erosion and siltation of the area near the Project and its junctions after its implementation.

The one-dimensional water and sand mathematical model is used to conduct long-term long-reach calculation from Yichang to Datong, providing the boundary conditions for the two-dimensional mathematical model of water and sediment. Apply the two-dimensional sediment mathematical model to select some parts of the Yangtze River mainstream and the Poyang Lake waterway section for calculation with the impact of the implementation of the Lake Control Project after the completion of the Three Gorges Reservoir on the river bed scouring and silting in the lake section and the main section of the Yangtze River taken into consideration.

The result shows that, with the Project taken into consideration, the amount of scouring in the lake inlet at the end of 10-year operation obviously increased; that of the main stream of the Yangtze River increased a little. From the distribution of scouring and silting, a large area of the lake inlet suffered from scouring with general scouring depth of the groove being 0.2~1.0 m and its maximum of 1.3 m. The original sedimentation area of the margin bank also suffered from scouring, with general scouring depth of the groove being 0.1~0.5 m. The lower section of the Zhangjiazhou and the confluence section below Hukou suffered a little scouring while the change in the upper section of the Zhangjiazhou and above was relatively small.

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