IMPACTS OF THE SOUTH-TO-NORTH WATER DIVERSION PROJECTS (MIDDLE ROUTE) ON THE WATER ENVIRONMENT OF THE MIDDLE AND LOWER REACHES OF THE HANJIANG RIVER

FAN Bei-Lin, WAN Jian-Rong, ZHANG Jie and LIN Qiu-Sheng

(Yangtze River Scientific Research Institute, River Research Deparment, Wuhan 430010, China)

Abstract: In this paper, according to the rule of unbalanced sediment transport and the analysis of field data, different water diversion schemes were theoretically studied, including the erosion and sedimentation trend as well as their impacts on the environment of the middle and lower reaches of the Hanjiang River. The results showed that the $95 \times 10^8 m^3$ water diversion scheme will cause less erosion and water level decrease than the $15 \times 10^8 m^3$ water diversion scheme. Using a water diversion scheme of $95 \times 10^8 m^3$, the decrease of water quantity can impact the river hydrodynamic regime substantially and the environments of the middle and lower reaches of the Hanjiang River will be greatly affected. It is therefore necessary to develop new water resources or build projects to meet the need of the environment and the needs for navigation.

Key words: South-to-North Water Diversion Project; River regime; Water environment; Mathematical model

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The Hanjiang River is the most important tributary of the Changjiang River, which has a length of 1570 km. The confluence of the river with the Yangtze River is at Wuhan city. From the Danjiangkou to the Nianpanshan extends the middle reach of the Hanjiang River, which is 240 km long and represents a fork river section, having tributaries such as the Bei River, the Nan River, the Tangbai River, and others. The lower reach extents from Nianpanshan to the estuary, stretching over 409 km., This stretch is a curved river section, having tributaries such as the Zhi River, the Tianmen River, the Yun River, and other smaller ones. It also has a branch named Dongjing River (Fig. 1).

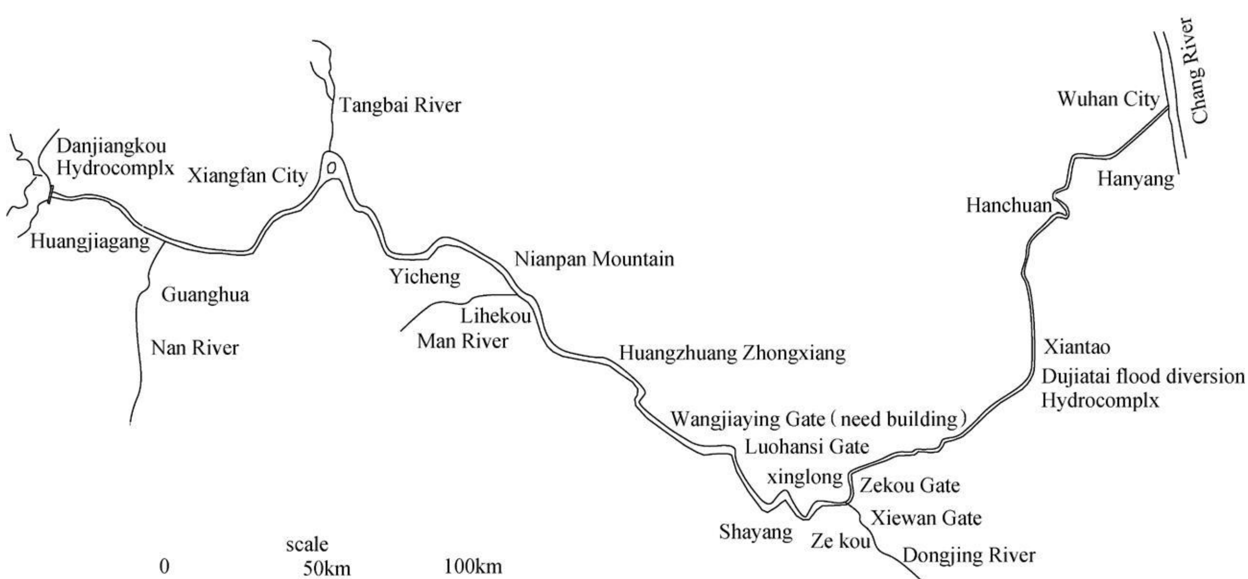

Fig. 1 Schematic diagram of river channels in the middle and lower reaches of the Hanjiang River

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Corresponding author: Fan Bei-Lin, E-mail: fbl0907@yahoo.com

The Danjiangkou Reservoir was built in 1958 and was put into use in November 1967. After the reservoir began to fill up with water, the water and sediment conditions of the mid- to lower reaches of the Hanjiang River changed greatly. Firstly, low sediment concentrations occurred, which means a low sediment carrying capacity, causing intensely spatial erosion dominating sedimentaion, while the river bed became gradually coarse, while the water level decreased and the water slope became gentle, leading to reduce water velocity. These changes are beneficial to the stability of the river bed. However, series of regulation works in the middle and lower reaches are also helpful for a stable river regime. The navigation conditions of the mid- to lower reaches have greatly improved since than and also before the construction of Danjiangkou Reservoir. Because of the reservoir's flood regulation capacity, it allows for more discharge in the dry seasons and less discharge in the flood seasons, thereby the annual inflow of the hydrographic systems tends to be more evened out. Therefore, the possibility of deluge becomes less. However, due to the reservoir's limited regulation capacity, if the south-to-north water diversion project's middle route is added, the capacity for deluge flood control will be improved further.

1 Methods

In this paper, for impact researches on the Hanjiang River's middle and lower reaches and its water environment, based on the rule of unbalanced sediment transport, 1-D heterogeneous sediment mathematical model was developed and validated.[1,5]

The simulated river stretch is 649km long, starting from the Danjiangkou to the estuary. The simulated period was 11 years, from 1978 to 1988, and the simulated initial land form was 1/1000 mapped in 1978. The total reach was divided into 336 sections, which means each part was 1.93km long. The validated results are presented in Tab. 1. From Tab. 1, according to the total flushed sediment quantity, the calculated value was $1.45 \times 10^8 m^3$, and the field data was $1.35 \times 10^8 m^3$, which indicates the difference is 7%. The sectional differences between model results and field data were less than 18%.

Tab. 1 Comparison of flushed sediment quantities between observed data and calculated value in the middle and lower reaches of the Hanjiang River (unit: $10^4 m^3$)

River reach	Field data	Calculated value	Difference (%)
Guanyinge~Huangzhuang	-4146	-3527	14.9
Huangzhuang~Xincheng	-3291	-3788	15.1
Xincheng~Xiantao	-6103	-7184	17.7
Guanyinge~Xiantao	-13540	-14499	7.0

Note: The simulated period is from 1978 to 1988

2 Calculating conditions

Calculating schemes were made meeting the need of design, based on the following rule: Safety, ecology, water diversion, and power generation. Water diversion scheme of $95 \times 10^8 m^3$ was emphasized after Danjiangkou dam had been heightened. The representative hydrological years for the model predictions are going to be 2010 and 2030. For each year, less water inflow into the reservoir and the subsequent anticipated impacts on the water and sediment conditions of the mid- to lower reaches of the river are taken into account. The following aspects were considered: (a) how will water demand in the mid- to lower reach areas change, (b) how to improve water supply capacities by building compensating projects, and (c) what will be the tributaries' water inflow into the mid- to lower reaches of the Hanjiang River in each hydrological year. The tributaries inflow is mainly concentrated between June and December.

3 Results and discussion

3.1 Quantity of erosion and sedimentation

The estimated quantitative volumes of erosion and sedimentation of sediment in the mid- to lower reaches of the river is shown in Tab. 2. At the end of 2040, the erosion for $95 \times 10^8 m^3$ water diversion scheme is $1.09 \times 10^8 m^3$, while the erosion for $15 \times 10^8 m^3$ water diversion scheme is $2.09 \times 10^8 m^3$. For river reaches from Huangjiagang to Xiangfan and from Xiangfan to Huangzhuang, under $95 \times 10^8 m^3$ water diversion scheme, the erosion is less than 4% of total, which means these river reaches are nearly silt-stable channels. While for the river reach between Xiangfan and Huangzhuang, the erosion under the $15\times10^8m^3$ water volume diversion scheme is anticipated to reach about 4 times of that of the $95\times10^8m^3$ water diversion scheme. The river reach from Huangzhuang to Xiantao is 220 km, about 1/3 of the total length, and the estimated erosion levels under the two schemes are both above 55% of the total, which means that most of the quantity of the erosion volume will come from this reach. The erosion volume from Xiantao to the estuary will be about 30% of the total under the two proposed diversion schemes.

3.2 Water level fluctuation in the middle and lower reaches

Because of the anticipated and estimated erosion, the water level will decrease spatially. However, the estimated erosion under the $95\times10^8m^3$ water diversion scheme will be less than under the $15\times10^8m^3$ water diversion scheme. So there will most likely be higher water levels under the $95\times10^8m^3$ than under the $15\times10^8m^3$ water diversion scheme. When the river discharge will be below $400m^3/s$, the difference will reach 0.12—0.47m; however, when the discharge will be about $900m^3/s$, the difference is 0.08—0.43m; and when the discharge is about $1500m^3/s$, the difference is 0.08—0.38m.

Tab. 2 Erosion quantity in the middle and lower reaches of the Hanjiang River (unit: 10^4m^3)

River Reach	$15\times10^8m^3$ water diversion		$95\times10^8m^3$ water diversion	
	Erosion	Percentage(%)	Erosion	Percentage(%)
Huangjiagang~Xiangfan	625	2.9	340	3.12
Xiangfan~Huangzhuang	1635	7.8	410	3.76
Huangzhuang~Xiantao	12508	60.0	6851	62.91
Xiantao~estuary	6135	29.3	3289	30.20
Huangjiagang~estuary	20904	100	10890	100

4 The South-to-North Water Diversion Project (Middle Route) and the potential for algal bloom development in the Hanjiang River

4.1 Potential algal blooms in the middle and lower reaches of the Hanjiang River

With the rapid development of economy along the Hanjiang River, more and more industry and domestic polluted water are produced. Due to multiple reasons, the pace of pollution control will most likely not be the same as that of industrialization and urbanization, which results in the decrease of water quality in the Hanjiang River and its tributaries. Nowadays about 6.89×10^8t of polluted water is produced in Hanjiang River Basin every year, including 3.198×10^8t of industry polluted water and 3.689×10^8t of domestic polluted water. More and more polluted water into the river has caused 4 times of algal bloom incidents (1992, 1998, 2000 and 2003). According to the environmental conditions changes of river ecosystem, these were caused by heavily polluted waters which are enriched with nutrients such as nitrogen and phosphorus. Especially in the dry seasons from February to May, when the river discharge is less than certain value and high water level in estuary influenced by the Changjiang River creates a slow water flow in the river reaches, algae species can grow rapidly in the water under comfortable climate conditions. As a result, algal blooms do occur. The water flow condition is among the main factors causing algal blooms in the middle and lower reaches of the Hanjiang River because nutrient pollution input is less diluted leading to higher concentrations on which algal species can proliferate[2].

4.2 Potential jmpacts of South-to-North Water Diversion Project (Middle Route) on algal bloom development

The $95\times10^8m^3$ water diversion scheme will provide favorable dilution conditions to avoid algal bloom. Firstly, the reservoir's water storage capacity will change from annual to multi-annual cycles. During dry seasons when algal blooms are likely to occur, the river discharge volume will increase, providing some improved dilution. From statistical analysis of the historical hydrological data between 1968 and 1998, it is obvious that there were about 16 years in which the water discharge increased when compared with the data of corresponding periods after the Danjiangkou dam have been heightened. Furthermore, to improve the water environment quality of the mid- to lower reaches, the water diversion project from Changjiang River to Hanjiang River is under planning.[3,4] The project's purpose is to meet the ecological water needs in the river reaches below Xinglong. Statistically, the anticipated diversion flow rate will be nearly $100m^3/s$ during dry seasons when algal blooms are most likely to occur.

5 Conclusion

An increase in water diversion quantity will influence the water volume and sediment inflow amounts into the mid- to lower reaches of the Hanjiang River. Erosion and water level decrease will occur spatially. The water diversion scheme of $95 \times 10^8 m^3$ will result into higher water levels than that employing the $15 \times 10^8 m^3$ water diversion scheme.

To meet the ecological water needs in the mid- to lower river reaches, many engineering projects should be initiated, such as the water diversion from Changjiang River, while also developing new groundwater resources, building cascade projects for navigation, river channel's comprehensive regulation for water use, and other options for diversified management.

Algal blooms are liable to occur during the dry season. After the large $95 \times 10^8 m^3$ water diversion scheme and the water diversion project from the Changjiang River implement, the river discharge in the dry season will increase, then the river's ecological environment will improve in this season and it is hoped that the occurrence of algal blooms can be greatly avoided.

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