Research on Water Environment Improvement in Urban Rivers and Lakes Connected Areas——Taking "Shanghai Fish" Lake as an Example

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Abstract. In order to clarify the spatiotemporal variation patterns of water quality in urban river lake connected areas and improve the regional water environment, this research takes "Shanghai Fish" Lake and its surrounding backbone river network as the research objects. One-dimensional and two-dimensional hydrodynamic water quality model are both used to simulate the regional water quality, turbidity, and water exchange rate of "Shanghai Fish" Lake under three types of improvement facilities: no control, semi control, and full control. The results show that: (1) If no control measures are established, the water quality in the lake will be basically consistent with the peripheral river network, and the total phosphorus, total nitrogen, and turbidity will exceed the standard strictly; (2) If partial controlled, the connection between the lake's water body and the peripheral river network can be appropriately delayed, and the water quality is basically uncontrollable; (3) If fully controlled, it can effectively delay the connection between the lake's water and the peripheral river network, and the water quality can be basically controlled; (4) The construction and control method of building navigation lock combined with overflow weirs can meet the needs of flood control, ecology, and navigation.

Keywords: urban rivers and lakes; improvement of water environment; Shanghai Fish Lake; river and lake connectivity; tidal river network.

1 Introduction

The urban river lake connectivity area is mainly centered around landscape lakes, radiating the surrounding river network and water system. It is a special space that integrates functions such as flood control and drainage, living and living, ecological landscape, tourism and sightseeing. As the relationship between humans and water gradually strengthens, urban river and lake water environmental problems such as

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deteriorating water quality, declining water self purification capacity, and ecological service functions are becoming increasingly severe[1].

In order to improve the overall environment of river lake connected areas and promote urban ecological water conservancy construction, the improvement of urban river lake water environment has become a research hotspot[2-4]. Tu Huawei et al. established an integrated water environment model of "land unit river network lake", simulated and analyzed the water quality improvement effects of various water environment improvement schemes in the Jinshan Lake area of Huizhou City, and showed that implementing source control and pollution interception projects can effectively improve water quality conditions[5]; Zhou Si et al. showed through regular monitoring of the water quality and plankton in Mingxin Lake that real-time ecological governance projects can significantly improve water transparency and reduce eutrophication index [6].

The implementation of water environment improvement projects or ecological management projects can only treat point and surface sources as well as internal sources within the connected areas of rivers and lakes, and cannot effectively deal with a large number of external pollution sources after the connection of rivers and lakes. The actual application effect of water environment improvement in urban river and lake connected areas is not significant. The improvement of water environment relies more on water conservancy engineering facilities[7,8]. Therefore, this article takes the "Fish of Shanghai" lake and surrounding water systems in Fengxian District, Shanghai as an example, and proposes a series of engineering facility schemes based on reality. Through one and two-dimensional hydrodynamic water quality models, the water quality changes in the region under each scheme are simulated to reveal the impact of different engineering schemes on the improvement of water environment in the connected areas of rivers and lakes.

2 Information of research area

“Shanghai Fish” Lake, also known as Jinhai Lake, is located in the central part of Fengxian District, Shanghai. The current lake is connected to the Daqing River on the northeast side, as shown in Figure 1. The scheme needs to be further connected to the south side of the Punan Canal, the east side of Jinhui River, and the north side of Qixian River. The water diversion and drainage are all regulated by the water conservancy control area of Pudong, and small boats on the Punan Canal can enter the lake area from the south river.

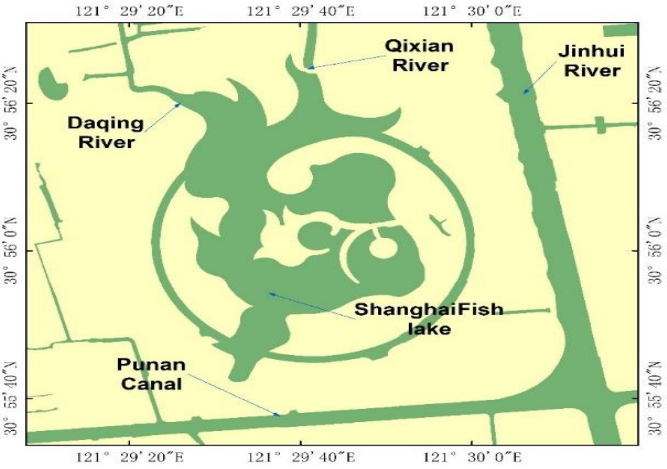


Fig. 1. Schematic diagram of "Shanghai Fish" Lake and surrounding water systems.

At present, the water body of "Shanghai Fish" Lake is transparent, and the water quality is at the level of Class III in the lake. There are large areas of submerged plants planted in the lake, and the ecological function is good. The total nitrogen and turbidity of the water system near the research area exceed the standard severely. The total nitrogen is classified as inferior to Class V, with the highest turbidity exceeding 20 NTU for a long time and up to 50 NTU. The other water quality indicators are between Class III-IV. Once the lake area is connected to the peripheral river network, it can cause water environmental problems such as turbidity and excessive nitrogen and phosphorus in the lake area in a short period of time, leading to a decline in ecological function and a significant increase in eutrophication risk.

3 Model building and scheme design

This research is based on a one-dimensional river network hydrodynamic water quality model to generate a two-dimensional model calculation boundary, and uses a two-dimensional hydrodynamic water quality model to simulate the impact of various hydraulic engineering combination schemes on the water quality of the study area.

3.1 One-dimensional hydrodynamic water quality model

Based on the previous research results of our research group [9-11], a refined one-dimensional hydrodynamic water quality model of the river network in Shanghai was constructed. The model summarized all the district level and above rivers in the city, and also included a large number of branch level rivers. The final model consists of 1979 rivers with a total length of 6065km, 29470 river network nodes, and 124 water diversion gates (Figure 2).

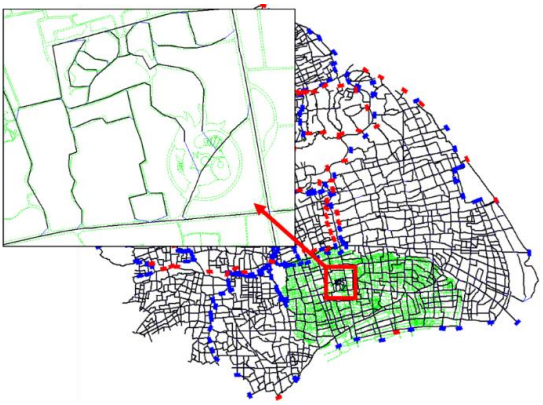
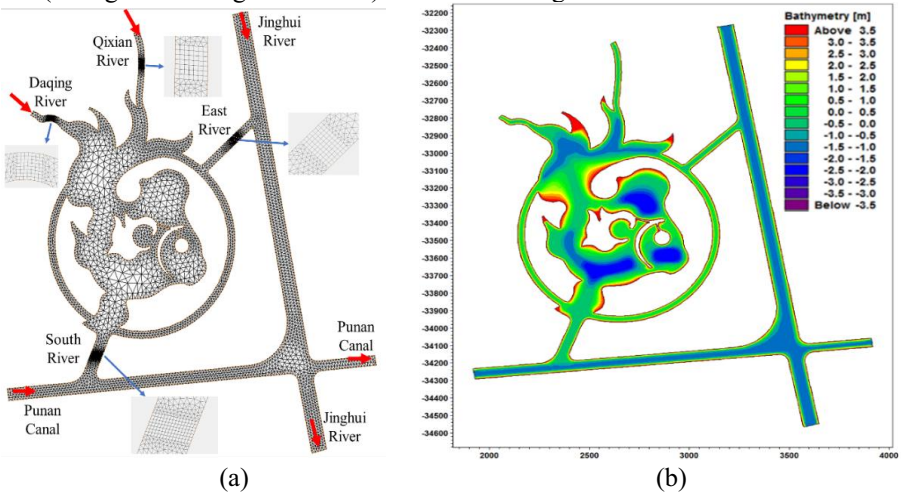


Fig. 2. Schematic diagram of the range of one-dimensional river network hydrodynamic water quality model for "Shanghai Fish" Lake and surrounding water systems.

3.2 Two-dimensional hydrodynamic water quality model

Two-dimensional hydrodynamic water quality model is established by using the Saint Venant equation system to describe the two-dimensional hydrodynamic process[12], fully considering the convection, diffusion, and degradation of water pollutants. The model covers the "Fish of Shanghai" Lake, four planned connected rivers (Daqing River, Qixian River, East River, and South River), as well as the Jinhui Port and Punan Canal connected to the East and South River, and the grid of the connected locations is locally encrypted. The model grid and the terrain elevation of the study area (Shanghai Wusong benchmark) are shown in Figure 3.



(a) (b)

Fig. 3. Schematic diagram of two-dimensional hydrodynamic water quality model grid range and river (a) and terrain elevation (b).

3.3 Scheme design

The research area is affected by tides and has a certain amount of reciprocating flow, with most of the time flowing in a counterclockwise direction. The main water channels in the lake area are Daqing River, Qixian River, and Jinhui River, and the main outlet channel is the Punan Canal. Among them, Daqing River and Qixian River have good water quality and low turbidity; The water quality of Jinhui River and Punan Canal is poor, with high turbidity. The South River has navigation function and cannot be closed for a long time. This article comprehensively considers the actual needs of flood control, water quality, and navigation, and proposes three engineering schemes: no control, semi control, and full control (Table 1, Scheme 1-3). At the same time, considering that the South River is the main outlet channel, a set of gates can be set up for navigation based on tides; The water quality of Daqing River and Qixian River is good, and overflow weirs can be set up to ensure flood control function is not affected while reducing daily lake inflow. Two engineering schemes are proposed (Table 1, Scheme 4-5).

Table 1. Engineering combination scheme design details table.

Scheme number	Type	Engineering combination
1	No construction	null
2	Partial construction	Daqing River and Qixian River remain connected, and control gates will be constructed on the East and South Rivers, South control gate opens and closes twice a day
3	Fully construction	Control gates will be constructed on Daqing River, Qixian River, East River, and South River, South control gate opens and closes twice a day
4	Fully construction	Construction of control gates on Daqing River, Qixian River, and East River, and construction of ship locks on South River
5	Partial construction	Construction of overflow weirs on Daqing River and Qixian River, construction of control gates on East River, and construction of set gates on South River

4 Results and discussions

No construction (Scheme 1), the lake area is completely directly connected to the external river network. Within 3 days, the replacement rate of fish tails and the central and western regions of the lake reaches over 90%, and within 14 days, the water body in the lake is basically replaced (Figure 4). The peripheral dirty water seriously pollutes the water quality of the lake area. Within 7 days, the turbidity in most areas of the lake area is above 20 degrees (NTU). Afterwards, the pollution will gradually spread to the entire lake, and the water quality in the lake is basically uncontrollable (Figure 5). There is a significant correlation between the deterioration of water quality in lake areas and the replacement rate of water bodies.

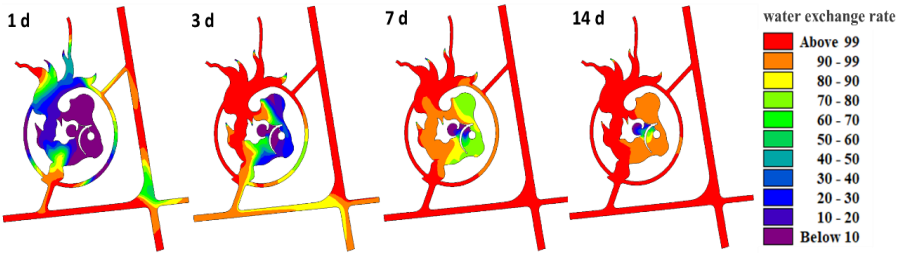


Fig. 4. Simulation results of water exchange rate for 1-14 days (Scheme 1).

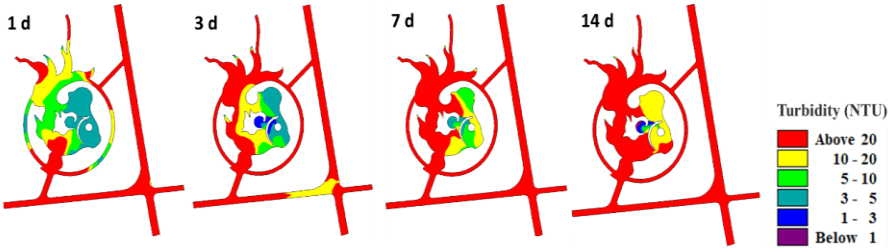


Fig. 5. Simulation results of turbidity for 1-14 days (Scheme 1).

In the absence of control measures (Scheme 2), the replacement rate of water in the lake is lower than that in Scheme 1. Pollution in the lake area comes from the opening of locks by ships entering and exiting the South River, Daqing River, and Qixian River. After 60 days, the replacement rate of water in the lake area generally exceeds 50% (Figure 6), indicating that this scheme can only appropriately delay the pollution rate of water in the lake by the peripheral water system, and the water quality is less controllable. In the case of full construction and control (Scheme 3), the replacement rate of water in the lake is much lower than that without construction and control (Scheme 1). The pollution in the lake area comes from the opening of locks by ships entering and exiting the South River. After 60 days, the replacement rate of water in the lake area near the South River is 40% -60% (Figure 7), indicating that full construction and control can delay the pollution rate of water in the lake by the peripheral water system as much as possible, with a certain degree of controllability, but cannot solve the water quality deterioration caused by ensuring navigation.

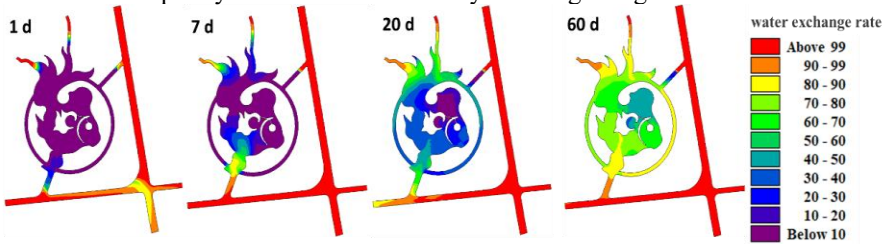


Fig. 6. Simulation results of water exchange rate for 1-60 days (Scheme 2).

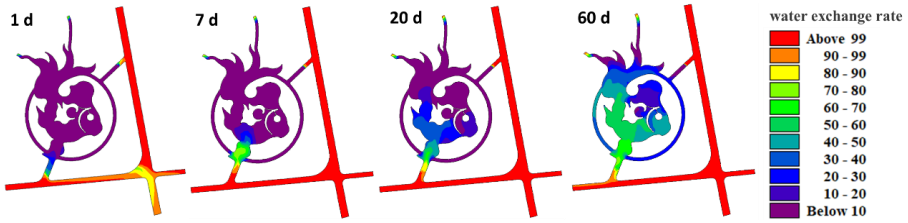


Fig. 7. Simulation results of water exchange rate for 1-60 days (Scheme 3).

In the case of replacing the control gate in scheme 3 with a set gate (scheme 4), after 60 days, the replacement rate of the lake area only exceeded 10% (maximum less than 30%) within 500m north of the gate site, and the turbidity was greater than 3NTU (maximum less than 10NTU). The pollution source was only generated by the exchange of water in the gate chamber (Figure 8), indicating that scheme 4 has little impact on the water quality of the lake area. In scheme 4, the control gates of the two northern rivers were replaced with overflow weirs (scheme 5). The water in the lake area is mainly connected to the peripheral river network through the Daqing River and Qixian River. Due to the influence of water from the north, the replacement rate of water near the South River set gate is less than 10% (Figure 9), indicating that under this scheme, there is only partial pollution at the fish tail in the lake area, and the water quality in most ecological functional areas of the lake area is not affected.

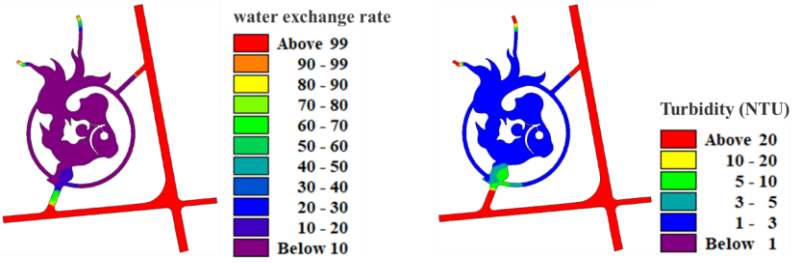


Fig. 8. Simulation results of water exchange rate(a) and turbidity(b) for 60 days (Scheme 4).

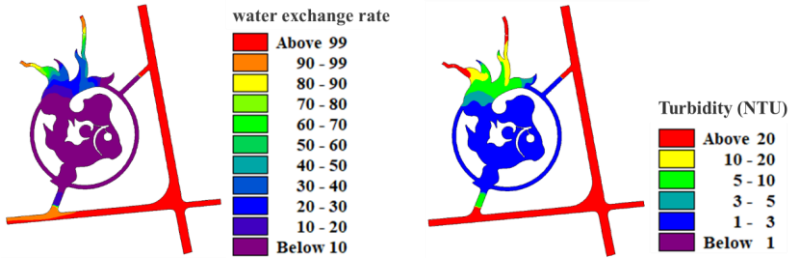


Fig. 9. Simulation results of water exchange rate(a) and turbidity(b) for 60 days (Scheme 5).

The flood control, ecological, navigation guarantee, water quality, and fluidity of each engineering combination scheme are shown in Table 2, indicating that a semi construction control scheme can achieve good flood control benefits; The construction of a ship lock on the South River can achieve significant navigation benefits; Combining the ship lock construction and control scheme can achieve significant ecological benefits; The combination of semi construction control and ship lock (Scheme 5) can simultaneously meet the needs of flood control, ecology, and navigation in the research area.

Table 2. The impact of engineering facility combination scheme on water environment after river lake connection(Simulate 60 days).

Scheme number	Water exchange rate	Turbidity	Flood control benefits	Ecological benefits	Navigation benefits	Liquidity
1	>90%	>20	weak	weak	strong	strong
2	>50%	10-20	strong	weak	weak	strong
3	30%-50%	5-10	strong	strong	weak	weak
4	<10%	1-3	strong	strong	strong	weak
5	<20%	1-5	strong	strong	strong	strong

5 Conclusion

Based on the results and discussions presented above, the conclusions are obtained as below:

(1) There is a significant correlation between water quality deterioration and water exchange rate. Without proper control, the water quality in the lake area can be assimilated by peripheral water systems in a short period of time after the river and lake are connected.

(2) Full construction control can delay the pollution rate of the lake's water from the peripheral water system as much as possible, with a certain degree of controllability, but it cannot solve the water quality deterioration caused by ensuring navigation.

(3) Setting up ship locks can achieve significant ecological benefits while ensuring navigation.

(4) The combination of overflow weir construction and ship locks can meet the needs of flood control, ecology, and navigation in the research area, and provide important technical support for water environment management in this area.

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