

长江口水源地开发的可行性研究

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摘要

随着经济发展和人口增长，上海面临严重的水资源问题。为解决上海的水质型缺水问题，政府将加快开发长江口第二水源地。本论文采用 MIKE 21 模型（包括水动力、对流扩散和水质模块）对长江口水量、水质以及北支盐水倒灌对淡水资源的影响进行模拟和分析，为水源地的开发、建设和保护提供依据。

对长江口水动力特征和盐度分布的模拟结果显示，为控制北支盐潮倒灌所提出的各整治工程方案对盐潮有不同程度的控制，其中以建挡盐潮闸最为有效。同时，模型基于现状并改变污水排放、处理以及边界水质等条件，对水质作出一系列预案分析。结果表明长江口水源地符合供水水质标准。此外，论文根据模拟结果对潜在的水污染问题提出了相应控制策略，以保证上海在社会和经济可持续发展过程中有充足的优质水源地和良好的水环境。

The Feasibility Study on Shanghai Water Resources Development in Yangtze Estuary

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ABSTRACT

With rapid economic development and population increasement, Shanghai faces a serious water resources problem. The government is therefore exploring possible water resources for the future, in particular the Yangtze Estuary. This study is mainly interested in the water quality of the planning Shanghai water resources areas in the Yangtze estuary as well as the influence of saline water intrusion on these areas. MIKE 21 models, including the hydrodynamic (HD), advection-dispersion (AD), and water quality (WQ), were set up to calibrate and simulate the hydrodynamic characteristics, salinity distribution and water quality in the study area.

Under the consideration of the proposed engineering activities in the North Branch of the estuary, several scenarios are conducted to evaluate their influences on current pattern and salinity distribution changes. The simulated results show that the proposed activities can protect the water resources areas in the estuary from salinity intrusion in different degrees, especially the gate construction. Furthermore, a group of scenarios for water quality are specified from the following aspects: outfall discharges, wastewater treatment, boundary condition changes, etc. It shows that the water resources areas in the estuary are sufficient with good water quality and could be additional sources for Shanghai City, alleviating the water supply pressure of the Huangpu River. Meanwhile, some possible pollutions are addressed and various strategies on water pollution control are recommended as well.

1 INTRODUCTION

Along with a rapid development of economic and population, the Huangpu River as the main water source of Shanghai cannot meet the huge amount of water demand. Therefore Shanghai is exploring other possible water resources, in particular the Yangtze Estuary which has plenty good freshwater.

The water quality in the Yangtze Estuary is normally Class II or III of the Chinese surface water standard, but during dry season salty water intrusion is becoming a crucial problem for water resources development in this area. Therefore, the feasibility study on the Shanghai water resources from the Yangtze estuary should be carried out, which focuses on two aspects, i.e., the salinity distribution and the water quality in the estuary.

In this study, MIKE 21 models, including the hydrodynamic (HD), advection-dispersion (AD), and water quality (WQ), were set up to calibrate and simulate the hydrodynamic characteristics, salinity distribution and water quality in the study area.

2 HYDRODYNAMIC STUDY

The Yangtze River segment from DaTong to the coast is shown in Fig 1. Near the end, the River is split into two branches by ChongMing Island, and the south branch is further split into two branches by ChangXing Island near the end of the Yangtze River. The three branches of the Yangtze River at the eastern end are named as North branch, Middle branch, and South branch, respectively. To study the hydrodynamic characteristics, salinity distribution and water quality situation of the Yangtze River estuary, a 2D regional hydrodynamic model (named M1) in the estuary area was set up firstly. The model domain covers both Yangtze Estuary and Hangzhou Bay. In order to get a detail and reliable simulation result, especially for the scenarios' simulations in salinity distribution and water quality, another 2D model (named M2) with finer grids and smaller area was set-up simultaneously. Figure 2 as a snapshot of Mike Bathymetry Editor shows the locations of the computation area of the models.

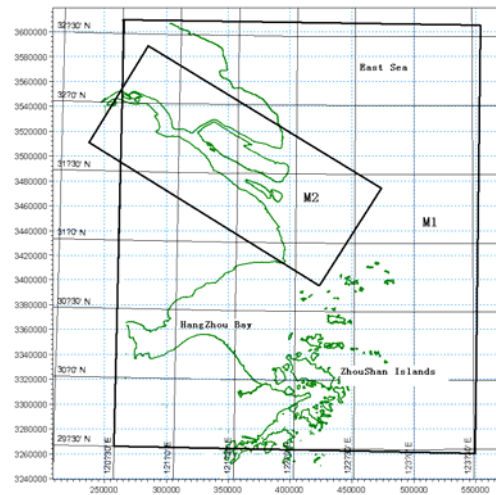


Fig 1 The study area including downstream Yangtze River segment. Fig 2 The geographic range of models M1 and M2.

The M1 model receives its upstream boundary from a 1D river model (from DaTong to the coast), and other ocean boundaries from tidal predictions. The tide data of totally 13 tidal measure stations are involved, either as boundary conditions or as verification data in the HD modelling. For the M2 model, the west open flux boundary condition at XuLiuJing is calculated from the 1D model, and the other three open sea boundary conditions are extracted from the results of the M1 model. Based on the predicted surface elevations at tidal stations within the model area, the hydrodynamic calibration parameters, eddy viscosity and bed resistance, can be determined for both models. The HD modelling results show the simulated surface elevations match the predicted results quite well generally at all stations, especially for those in the mouth of the Yangtze estuary.

3 SALINITY STUDY

3.1 Advection-dispersion Modelling

As the Yangtze Estuary is suffered from salinity intrusion, one important objective of the study is to study the influence of salinity distribution on the planning Shanghai water resources in the Yangtze estuary. Figure 3 shows the present and proposed water resources in the Yangtze estuary, including ChenHang reservoir (present), Qingchaosha reservoir, Chongming Mingzhu reservoir, and Momaosha reservoir. Dynamically coupled with the HD model, the advection-dispersion (AD) model was set up for the salinity distribution simulations.

Another main purpose of the AD modelling is to determine the dispersion coefficients for the water quality modelling. In M1 model, the dispersion coefficients in X and Y directions are respectively optimised as $50\text{m}^2/\text{s}$ and $40\text{m}^2/\text{s}$, with respect to the measured historical data in 1998. While, the dispersion coefficients of $30\text{m}^2/\text{s}$ and $20\text{m}^2/\text{s}$ are applied in M2 model. The comparisons of simulated salinity distributions and those in the reference studies indicate the AD model is well calibrated.

3.2 Salinity Scenarios Analyses

According to the measurements, it shows that, during the dry season, the saline water could inflow from the North branch and into the South branch. Thus, the area of the water intake for Shanghai in the Yangtze estuary, say, the ChenHang reservoir, will be affected by the saline water.

To reduce the salinity invasion from the North Branch of the estuary, several engineering activities were proposed in the Yangtze estuary, including reclamation and gate construction in the North Branch. These engineering considerations bring topographical changes in the estuary and certainly affect the current pattern. Such current pattern changes will inevitably lead to the salinity distribution changes. In order to investigate the influence of proposed engineering activities on saline water intrusion on the water resources areas, a few scenarios are studied by using the present AD model. One thing should be mentioned is that the M1 model with a grid size of 500m is too rough for the salinity distribution study. Therefore, the M2 model is used for the scenarios' simulations on the salinity distribution. The simulations for the scenarios are carried out with dry season conditions.

The results show that both the small and big narrowed North branch could reduce the salinity intrusion from the North branch a little, while the gate construction could totally change the situation, i.e., no salinity intrusion from the North branch. In order to learn more about the phenomenon of the salinity intrusion in the North branch, the longitudinal salinity distributions in the North branch are studied. Figure 4 shows the longitudinal positions and Fig 5 shows the longitudinal salinity distributions from different scenarios. Figure 6 shows the salinity variations in the Chenhang reservoir area. It is clear from Fig 6 that the maximum salinity at the Chenhang reservoir area is about 0.65‰ for baseline scenario, while for Scenarios with small and big narrowed North branch, the maximum salinity at the same position could be 0.49‰ and 0.37‰, respectively.



Fig 3 Positions of the water resources areas in the Yangtze estuary.

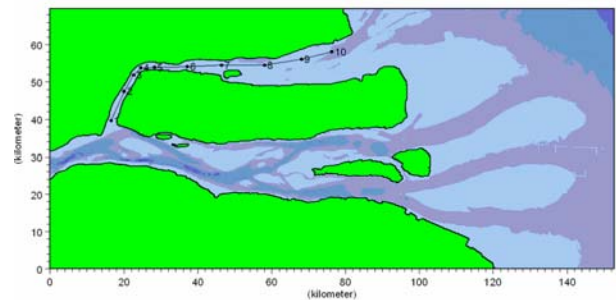


Fig 4 The longitudinal positions in the North branch.

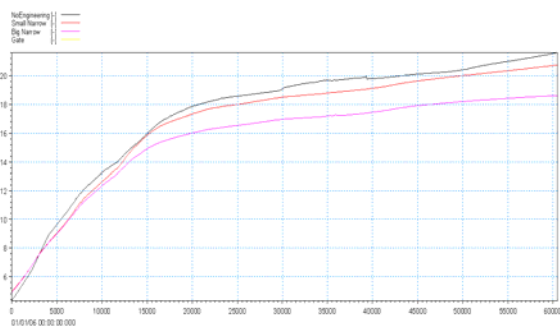


Fig 5 The longitudinal salinity distributions in the North branch.

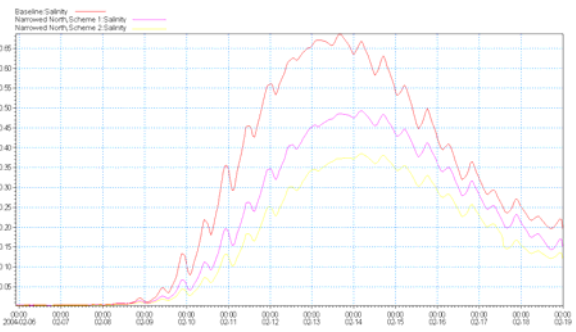


Fig 6 Salinity variations at Chenhang reservoir area.

4 WATER QUALITY STUDY

4.1 Present Water Quality Situation

To study the environmental impact in the Yangtze estuary, the 2D WQ model was set up. The water quality conditions in the estuary are dependent on the seasonal variation, the influences of hydrodynamic conditions as well as the loading from the rivers and outfalls within the study area. The main analysed pollutant parameters in the present study are Dissolved oxygen, COD, BOD, Ammonia, Nitrate and Phosphorous.

The pollution loading involved in M1 modelling includes 3 Rivers (Qiantang, Huangpu, and Liuhe) and 7 Outfall from local WWTPs and industrial outfall. The geographical locations of these pollution sources (except for Qiantang) within M2 model area are shown in Fig 7. The discharges at different sources in 2004, and the pollutant concentrations from each source in both dry and wet seasons are collected as model inputs.

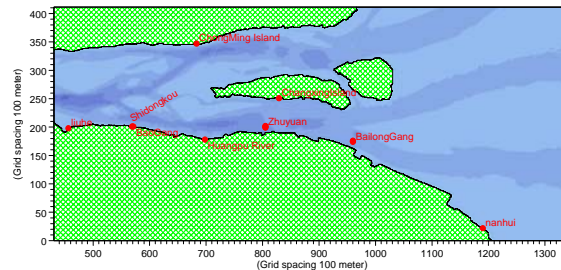


Fig 7 Locations of pollution sources in the Yangtze estuary within M2 model.

The western WQ boundary in the M1 model is estimated on the measured data at Xuliujing. While the other ocean boundaries' water quality can meet the values between Class I and II of seawater quality standard (GB3097-1997). For the water quality part, there are many calibration parameters including degradation constants, temperature dependency coefficients, etc. Since there is little measured information in the M2 model, the water quality model calibration was carried out within the M1 model, with regard to the measurements of six water quality measurement stations along the Yangtze estuary for the dry and wet seasons. The comparisons show that the average simulated concentrations of all the pollutant components in the dry and wet seasons have a good agreement with the measurements in most situations.

With the calibrated WQ parameters, M2 model was employed to provide a detail water quality result. The water quality boundary conditions in western boundary - Xuliujing in the M2 model is the same as in M1 model, while other three open sea boundary conditions are extracted from the M1 water quality results. According to all the simulations, the general water quality in the Yangtze estuary area belongs to Class II ~ III of the Chinese surface water standard. The proposed water resources areas and the three largest outfalls (Shidongkou, Zhuyuan and Bailonggang) within the M2 model area are selected, and some discussions on the maximum simulated concentrations on these points are drawn as below:

- The general pollutant concentrations around the Chenhang Reservoir are similar to the concentrations around the Chongming Island and the Qingcaosha Water Resource area, and belong to Class II ~ III of the Chinese surface water standard.
- The simulated water quality around Qingcaosha shows that BOD and COD meet Class II of the Chinese surface water standard; while Ammonia and TP meet Class III of the Chinese surface water standard.
- The water quality (in the far field from the immediate discharging) around the three largest outfalls is worse than the water quality in the upstream area. In the dry season, the water quality there can meet Class II with respect to COD, but falls in Class III for Ammonia and Phosphorus.

4.2 Anticipated water quality situation

Furthermore, to evaluate the possible influence of the water quality at the potential water resources areas, a group of scenarios are specified from the following aspects: outfall discharges, wastewater treatment, boundary condition changes, etc. Since the water quality in the dry season is generally worse than that in the wet season, all the scenarios will be simulated with the conditions in the dry season in the M2 model:

- **S100-** Present situation in the dry season (2004).
- **S101-** Increasing the wastewater discharge to the final designed value in Shidongkou, Zhuyuan, Bailonggang, Chongming, Changxing Island and Nanhui, but keeping the present treatment process.
- **S102-** With the final designed discharges but without treatment process in Shidongkou, Zhuyuan and Bailonggang WWTPs.
- **S103-** With the final designed discharges and advanced secondary treatment process in Shidongkou, Zhuyuan and Bailonggang's WWTP, ie Ammonia: 5mg/l, Nitrate: 10mg/l, BOD: 20mg/l, TP: 0.5mg/l, and COD: 50mg/l. /1/
- **S104-** The water quality boundary conditions at Xuliujing degrades to one class down compared to the 2004 condition (from Class II to Class III)

The discharges from the outfalls for different scenarios are described in Table 1. (/2/ and /3/) The pollution loading and the treatment technology of the wastewater treatment plants for S100 and S102 are respectively shown in Tables 2 and 3. (/1/)

Table 1 Discharge at point sources in different scenarios.

| Name | S100, S104 Discharge (m ³ /s) | S101, S102, and S103 Discharge (m ³ /s) |
|--------------------------|--|--|
| Huangpu River | 350 | 350 |
| Liuhe | 19.47 | 19.47 |
| Shidongkou Outfall | 3.12 | 9.26 |
| Zhuyuan Outfall | 15.85 | 27.78 |
| Bailong Gang Outfall | 11.53 | 40.51 |
| Nanhui Outfall | 0.58 | 1.16 |
| Chongming Island Outfall | 0 | 3.01 |
| Bao Steel Outfall | 0.27 | 0.27 |
| Changxing Island Outfall | 0 | 0.58 |

Table 2 The discharging concentrations from the three largest WWTPs' in S100 (unit: mg/l).

| WWTP | Ammonia | Nitrate | BOD | TP | COD | Process |
|-------------|---------|---------|-----|----|-----|----------------------------|
| Shidongkou | 10 | 10 | 30 | 2 | 100 | Secondary treatment |
| Zhuyuan | 30 | 1 | 60 | 2 | 150 | Enhanced primary treatment |
| Bailonggang | 30 | 1 | 70 | 2 | 180 | Enhanced primary treatment |

Table 3 The discharging concentrations from the three largest WWTPs' in S102 (using influent concentrations) (unit: mg/l).

| WWTP | Ammonia | Nitrate | BOD | TP | COD | Process |
|-------------|---------|---------|-----|----|-----|-------------|
| Shidongkou | 30 | 1 | 180 | 5 | 400 | Without WWT |
| Zhuyuan | 30 | 1 | 120 | 5 | 250 | Without WWT |
| Bailonggang | 30 | 1 | 130 | 5 | 320 | Without WWT |

Take BOD as exemplification, the averaged concentrations over the most interested area for different scenarios are shown in Figures 8-11 as below.

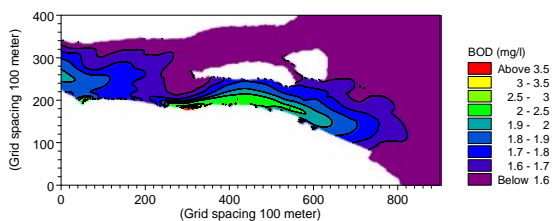


Fig 8 Simulated average concentrations of BOD5 for S100.

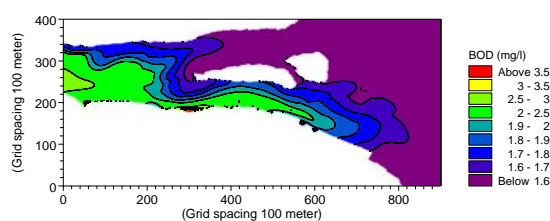


Fig 9 Simulated average concentrations of BOD5 of S104.

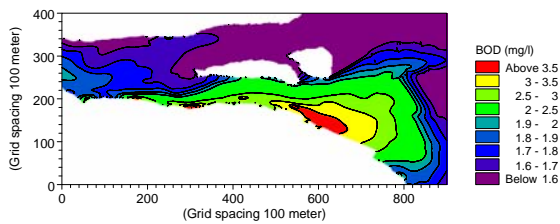


Fig 10 Simulated average concentrations of BOD5 for S102.

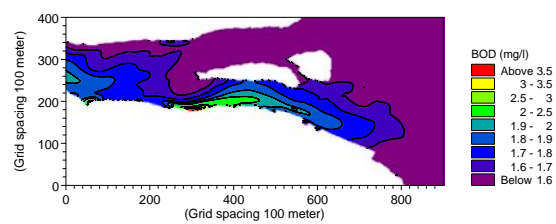


Fig 11 Simulated average concentrations of BOD5 for S103.

From the simulated concentrations at the proposed water resources areas and the three largest outfalls in M2 model area, some discussions are given below:

- There is almost no influence from S101, S102 and S103 on the water quality around the water resource areas, such as Chongming Island water resource, Chenhang reservoir and Qingcaosha water resource.
- It clearly shows that the pollutant concentrations increase around Shidongkou, Zhuyuan and Bailonggang areas due to the outfalls' discharges increase for S101. For example, around Bailonggang, the maximal BOD concentration changes from 3.1mg/l to 6mg/l, and the maximal COD concentration changes from 13mg/l to 20mg/l.
- If without wastewater treatment, S102 simulation shows that the pollutant concentrations increase significantly around Shidongkou, Zhuyuan and Bailonggang, for example, around Shidongkou, maximal BOD and COD could even reach 12.3mg/l and 32mg/l. Fortunately, this influence is only locally and does not reach the water resource areas, according to the simulated results.
- The advanced secondary treatment considered in S103 for all the large WWTPs could improve the local water quality a lot. Comparing the results from S103 with that from S101, with the advanced treatment, the maximal concentration will decrease about 17-52% for BOD, 22-62% for Ammonia, and 24-37% for TP.
- The degradation of the background water quality by one class down at Xuliujing will certainly impact on the water quality around the water resource areas, Chongming Island water resource, Chenhang reservoir and Qingcaosha, where the maximal concentration will increase about 36-44% for BOD, 14-26% for COD, 22-34% for Ammonia and 20-46% for TP.

5 CONCLUSIONS

For the salinity prevention, it is clear that the salinity intrusion in the North branch decreases in different degrees with the different proposed engineering activities, especially the gate construction, which could totally avoid the salinity intrusion. With respect to the water quality, the water resources areas in the estuary are sufficient with good water quality. Thus, the proposed water resources could be additional sources for Shanghai City, alleviating the water supply pressure of the Huangpu River.

On the other hand, some possible pollutions have to be addressed and the corresponding control strategies should be carried out: the pollution from the rivers, such as the Huangpu River, the Chuanyang River and the Dazhi River; the pollution from the outfall discharges along the Yangtze estuary; and the pollution from the Yangtze River upstream. From the present scenario study, it can be seen that the impact of the upstream/background water quality on the water resource areas in the estuary is direct. Therefore, it is very important to protect the upstream/background water quality.

REFERENCE

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