Original Research Article

Research progress in the application of hydrodynamic model of lake and reservoir based on MIKE 21

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Abstract: The MIKE 21 hydrodynamic model is a reliable means to study surface water movement. The simulation of two-dimensional flow motion by digital model is of great significance for water condition transformation, hydrologic process calculation and flow trend prediction. MIKE 21 model has been widely used in lake and reservoir area by experts at home and abroad, and has achieved good results. In this paper, the application of MIKE 21 model is reviewed, including the application of two-dimensional hydrodynamic model, coupled one-dimensional hydrodynamic model and water quality model in lake, reservoir and other areas. This paper summarizes the key points in the current application of the model, and grasps the research trends of the MIKE 21 hydrodynamic model in order to provide new ideas for the application and research of the model.

Keywords: MIKE 21; Two-dimensional hydrodynamic mode; Lake; Reservoir; Coupling

1. Introduction

Nowadays, numerical simulation of surface flow has become a research hotspot, and accurate simulation of surface flow movement can provide firm support for decision-making, engineering feasibility, flood prediction and other work[1,2]. Nowadays, there are many kinds of hydrodynamic numerical models, commonly used are MIKE[3], EFDC[4], Delft 3D[5], SMS[6]. Among them, the MIKE model has been widely used by domestic and foreign scholars due to its simple use, accurate and clear results[7-8]. MIKE software is a mathematical simulation software developed by the Danish Hydraulics Institute (DHI), in which MIKE 21 is a two-dimensional hydrodynamic simulation software. It is commonly used to simulate sediments, currents and environmental fields in lakes, estuaries and oceans, providing the design conditions and parameters required for engineering applications and planning.

The application objects of MIKE 21 hydrodynamic model at home and abroad mainly include river simulation, flood risk prediction, and influence of water conservancy project construction Previous studies have reviewed the application of MIKE software in domestic flood simulation and basin hydrological model. This paper reviews the application of MIKE 21 two-dimensional hydrodynamic model in lake and reservoir, and summarizes the limitations in the application of the model. The application and research trends are mainly discussed in order to provide reference for the development of hydrodynamic numerical models.

2. Application research of two-dimensional hydrodynamic model

The MIKE 21 model is a numerical simulation model, which takes the average vertical flow as the research object to calculate the changes of the plane flow field. It has powerful functions in two-dimensional numerical simulation and can be used to simulate a variety of water environments. Therefore, the general lake is suitable for MIKE 21 software because of its wide and shallow structure.

The hydrodynamic module (HD) is the core plate of MIKE 21, which is the basis of convective flow and water quality propagation The feedback information of water level and flow in the simulation results can provide reference for project decision-making. For example, in the hydrodynamic model of the South Lake, because the South Lake is a newly built artificial lake, the long series data are not enough. Only the water balance method can be used to analyze the rationality of the flow field simulation results, and the accuracy of long-term simulation cannot be compared and verified. Wang Ping et al. analyzed the impact of Poyang Lake water conservancy project on wetland vegetation habitat, but the research results were based on the scenario of typical year of high, flat and low, and lacked the support of long-term observation data. Therefore, there may be some uncertainty about the effects in different years and different climatic conditions. At the same time, the simulated working conditions cannot be completely consistent with the actual working conditions. The actual working conditions should consider Coriolis force, tidal force, wave, thermal effect, wind, evapotranspiration and other factors, but also according to the simulation time to set ice, rain and other physical phenomena. Therefore, when setting the model, it is necessary to reasonably depict the important influencing factors based on the local actual situation.

In water resources management, the capacity of incoming water, replenishment and water exchange of lakes is very important. By setting specific boundary conditions and terrain assignment, it can provide basis for water replenishment scheme and engineering design. For example, in the relevant studies on Baiyangdian Lake, Zeng Qinghui et al., Liang Dong et al. and Bai Jie et al. established the hydrodynamic model of Baiyangdian Lake to explore the replenishment scheme and the demolition scheme of embankment. These research results are of great significance to the improvement of Baiyangdian ecological environment and water environment and the coordinated development of XiongAn New Area ecological environment. However, through comparison, it can be found that even in the same research area, there will be some differences in the model body because of the different model construction methods. It is mainly reflected in the construction of computational grid, that is, the construction of distorted grid under complex terrain. Therefore, the reasonable construction method is the key factor affecting the model, and the convergence analysis of the degree to which the grid construction can achieve the optimal balance between the two factors of calculation speed and terrain accuracy needs to be perfected.

3. Application research of coupled MIKE module

When dealing with the complex flow evolution in the study area, the MIKE 21 model can well describe the time, scope, speed, depth distribution and other information of flood inundation[7], but it is not applicable to all working conditions and scenarios. Therefore, the coupling function between the MIKE 21 model and other models is increased. In the Mike software, it can be coupled with the MIKE 11 and MIKE URBAN models, which synthesizes the advantages of the MIKE 21 model and other models, and gives full play to the advantages of the two modules. It can also effectively avoid the problems of accuracy and step size encountered in separate simulation, expand the scope of application, and gradually change from a single model to a coupled model is also the development trend of numerical simulation research.

3.1. Flood model coupled with MIKE 11

MIKE 21 and MIKE 11 or MIKE URBAN cannot be coupled separately, and the coupling relationship needs to be built with the help of MIKE FLOOD model to run the simulation. The coupling of MIKE 21 and MIKE URBAN model is basically applied to urban waterlogging, so it will not be discussed in this paper. This paper mainly discusses the coupling application of MIKE 21 and MIKE 11 models.

The MIKE FLOOD coupling model based on MIKE 21 and MIKE 11 is mainly applied to flood prediction and prediction, and there is sufficient successful experience in this aspect at present. Application scenario one is

flood risk analysis of river course, flood storage area and reservoir. For example, Ye Aimin, relying on the pilot project of national flood risk mapping, used a coupled model to simulate the course of dike burst flood in rivers and lakes in Jiaxing City, Zhejiang Province, under different design rainstorm conditions, and drew flood risk maps. Li Xiaotian et al. selected the area below Changtan of Xitiaoxi main stream as the object and identified the areas with weak flood resistance under the flood scenario in the recurrence period. Yao Siyang et al. built a hydrodynamic model of flood inundate under the combination of dry and tributary rainstorms with different frequencies, considering the difference in precipitation, and the diversity reflected the flood overrunning scenario. The flood coupling model can simulate the flood evolution process more accurately, so as to analyze flood risk elements such as discharge, inundation range, water level and duration. At the same time, through the flood simulation in the flood storage area, water scheduling tests can be carried out and flood storage in the flood storage area can be used. Wu Bo et al. compared several schemes of water transfer measures and engineering measures in Harbin Pangtou flood detention area, and selected the optimal scheme to meet Harbin's flood control safety needs. Meng Changqing et al. in Dujiatai flood separation and storage area of Hubei Province put forward suggestions that the flood diversion capacity of downstream buildings was insufficient or needed to be demolished under large flow water supply. Reasonable flood dispatching can effectively reduce economic losses and dispatch costs, and provide strong support for the formulation of preventive plans.

3.2. Water quality coupling model

With the rapid development of China's economy and society and the acceleration of the urbanization process, water environmental pollution has been increasingly aggravated and worsened, and a large amount of untreated sewage has been discharged into rivers and lakes, and the water environmental problems in China have become increasingly prominent. In order to strengthen the prevention and treatment of lake water environmental pollution and provide a reference for the treatment of water environmental problems in the basin, MIKE 21 can be coupled with the convection diffusion module (AD) or the ECO-LAB module to study the water quality problems of lakes and reservoirs.

Using "MIKE 21" and "water quality" as keywords in the last five years, relevant literatures at home and abroad were searched through the core databases Of CNKI and Web Of Science. There are 52 core literatures in Chinese and 20 in English. Among them, there are 45 papers about the application of MIKE 21 coupled water quality model in lakes and reservoirs, which shows the wide application of coupled water quality model in lakes and reservoirs.

The MIKE 21 coupled water quality model is based on the HD module and runs coupled with the AD module or the ECO-LAB module to simulate the distribution of specified pollution indicators. The first application scenario is to identify the main driving factors of water quality change. For example, Zhou Yanli et al. used the coupled AD module to study the hydrodynamic characteristics and water exchange capacity of artificial lakes, and provided suggestions for ensuring water quality from the perspectives of hydrodynamic and water exchange capacity. Ban Jingya et al. analyzed the effects of rainfall runoff and endogenous release on the water quality of the basin. However, some scholars did not consider the spatial distribution of the initial concentration of pollutants and the degradation of pollutants, which affected the accuracy of the simulation results. The second application scenario is to verify the rationality of dispatching or engineering measures. For example, Ma Tiemei et al. determined the water diversion scheme that is conducive to the improvement of hydraulic power and water quality of Yilong Lake by comprehensively considering the distribution of initial concentration of pollutants, rainfall evaporation and other factors. Niu Xiaoyu et al. studied the relationship between water quality and water quantity by coupling model, and proposed corresponding water diversion regulation methods. Dou Ming et al. selected Longfeng Wetland of Daqing City, added the reduction effect of aquatic plants on water pollutants into the model, and proposed a combination of three engineering measures, such as desilting,

aeration and water replenishing. In the process of simulation, the feasibility suggestions of engineering measures are obtained through qualitative analysis between pollutant conditions and engineering measures, which is a common method of coupling model. However, it focuses on the effect of engineering measures, and cannot reflect some artificial measures, such as the effect of adding activated carbon adsorption, and there are few analysis studies on the relationship between artificial measures and water quality improvement.

4. Summary and prospect

The MIKE 21 two-dimensional hydrodynamics model and its coupling model are mature models in today's application. The application of the single model in the lake has solved a lot of practical problems, and its advantages in flood simulation, scheme optimization, engineering verification and ecological management have been verified. However, the current research trend of numerical model is gradually changing from a single model to a coupled model. The flood model based on MIKE 21 coupling has been applied well. In recent years, the development trend has gradually changed from flood inundation analysis in beach areas to flood risk analysis and flood volume regulation in flood storage areas, and the study on the impact of flood process on ecological vegetation has also been gradually paid attention to. The MIKE 21 coupled water quality model is gradually emerging in the context of current lake ecological governance. Water quality improvement is the main application direction of the coupled water quality model, and it will also be a hot spot in the future. It should be noted that the emphasis is different due to the different modules coupled, and the use should be selected according to the characteristics of the research area.

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