Study and development of emergent dispatching system for sudden water pollution accidents

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Abstract. Because of the frequent incidents of water pollution in China, the ecological environment and the socio-economic along the river are threatened seriously. In order to improve the ability of dealing with sudden water pollution accidents, the emergency dispatching system of sudden water pollution accidents is constructed by using data mining, database, GIS and other technologies combined with reservoir operation model, hydrodynamic model and water quality model. The main functions of the system include that the information management, scheme generation, simulation of water quality and quantity, emergency dispatch, and three-dimensional simulation. Applied research is carried out in Songhua River basin, which can provide technical support and decision-making platform for sudden water pollution accidents.

1. Introduction
According to statistics, sudden water pollution accidents occur frequently in China. In recent years, nearly 900 water pollution accidents occur every year, with an average of 2-3 per day. For example, the Songhua River water pollution incident in November 2005, the Beijiang river cadmium pollution incident in December 2005, the Taihu cyanobacteria water pollution incident in May 2007, and the Shanxi aniline leakage incident in December 2012, etc., all these caused significant socioeconomic losses, and even threatened urban water supply safety and ecological security. For this reason, the research and development of emergency dispatching models and systems for multi-hydraulic projects facing sudden water pollution accidents have strong practical significance for improving the ability to respond to sudden water pollution accidents, reducing socioeconomic losses, and protecting the ecological environment.

Since the Songhua River water pollution incident in 2005, all big rivers in China have established emergency plans or measures to respond to sudden water pollution accidents, providing a basis for emergency management. However, through the recent pollution incidents, it can be seen that the current emergency system has the following problems[1~6]: 1) Lack of identification and prevention of risk sources; 2) Lack of timely information acquisition and data mining; 3) Lag in model calculation and auxiliary decision-making; 4) Low efficiency of on-site emergency response and coordination. Therefore, it is urgent to build a set of emergency management systems with functions such as information monitoring, data mining, model calculation, and scheme simulation. In response to the above problems, this paper has developed an emergency dispatching system for sudden water pollution accidents in the Songhua River Basin, providing a fulcrum for risk prevention and...
emergency management in the basin, and providing technical support for the Songhua River Basin and other large rivers to respond to sudden water pollution accidents support.

2. System architecture
The system uses a three-layer structure designed: the data layer, the application base layer, and the application layer. The specific architecture is shown in Figure 1.

3. Emergency dispatching model
A set of modelling technologies such as water quantity simulation model, water quality simulation model, and emergency dispatching model were constructed in the system. A multi-hydraulic project emergency dispatching model based on the water quality and quantity simulation model for water pollution emergencies is also constructed.

3.1. One-dimensional hydrodynamic model of water quality and quantity
One-dimensional Saint-Venant system of equations are used to describe the river network flow model. Based on this, a mathematical model of river network water quality is constructed by using the one-dimensional longitudinal displacement discrete equation under unsteady conditions. For the hydrodynamic equations, the Preismann format is used to discretize the de Saint-Venant system of equations, and the matrix equations can be obtained. Then, apply chase and iterative methods to solve matrix equations. For each equation in the model, the corresponding matrix equation can be obtained by discretizing according to the principle of conservation of matter in the equilibrium domain. A certain boundary treatment method is used for the equation to obtain the solution expression at the boundary, so that a complete solution matrix can be formed for each equation, and the chase method is used to solve. In the above solution, the BOD, COD, and NH₃-N equations can be discretely formed into independent solution matrices. For the DO equation, the concentration value must be passed to the DO solution equation based on the above concentration solution.
3.2. Reservoir operation model
Reservoir operation for sudden water pollution accidents must not only consider water quality safety, but also be constrained by targets such as flood control, water supply, power generation, and shipping. Therefore, reservoir operation must fully consider existing dispatching rules, instructions of dispatching decision makers, Optimization of various goals and other issues. Reservoir operation is based on the water balance equation, and uses the water level ~ storage, water level ~ discharge relationship curves for dispatching calculation. The dispatching methods include plan dispatching, simulation dispatching (discharge control dispatching and gate dispatching) and target dispatching. The water quality of the reservoir area adopts a zero-dimensional water quality model, which means that the pollutants are uniformly mixed.

4. Main functions
The entire system is developed from the bottom layer, based on the .net framework, using VS2013 and SQL server2010 for development and data management. The bottom layer of the 3D scene is the topographic and landform model in the spatial area constructed from remote sensing image data and digital elevation data, and the basic 3D simulation of water conservancy physical elements and virtual reality environment. Then through the seamless docking of GIS and remote sensing images, a 3S integrated platform was formed, which realized the 3D simulation of pollution mass movement and emergency dispatch. The main functions of the system include information service, generation scheme, emergency dispatch, water quality and quantity simulation calculation, 3D simulation, etc. The main interface is shown in Figure 2.

4.1. Information service
After efficiently organizing and managing the basic data and results data of water pollution incidents, this function can realize the comprehensive service of multi-source information through different layer overlays and information correlation technology, including pollution sources (characteristics, nature, major hazards and conventional countermeasures, etc.), hydrology, water quality, water conservancy projects and conditions, risk sources, affected areas and protection targets. There are two types of query methods: database query and query in 3D GIS scene.

4.2. Scheme generation
1) Preliminary event assessment
According to the basic information of pollution emergencies (time, place, type of pollutants, quantity of pollutants, hydrological conditions, hydraulic engineering conditions, etc.), based on data mining technology and pollution information database, this function can information on the characteristics and main hazards of the pollutants incident, the possible affected areas, the key protection targets, and countermeasures are provided to provide a basis for formulating an emergency dispatch plan. And this function can automatically identify the emergency response level that needs to be activated and the emergency plan that needs to be activated according to the judgment conditions of the emergency plan.

2) Generation of preliminary emergency dispatch plan

Based on the basic information of the excavated pollutants, the scope of possible impacts, the protection objectives and the projects that can be dispatched, a preliminary emergency dispatch plan can be automatically generated according to the scheme library, including reservoir dispatching methods, drainage and other physical and chemical measures and many more.

4.3. Emergency water dispatch

As the reservoirs in the study area are managed by different departments, and the reservoirs have normal operation dispatching rules or flood control dispatching rules, for this paper, three methods are used for simulated dispatching: 1) the initial dispatching is based on the existing dispatching chart of each reservoir; 2) Based on the preliminary simulation, combined with the dispatching experience and administrative instructions, this function can adjust the dispatching plan and modify the discharge flow and plan of the reservoir; 3) Compensation dispatching. Which means, the discharge flow from the reservoir can be reversed according to the flow conditions at the downstream section of the reservoir. First select a preliminary scheme, set the dispatching start and end time, set the input and initial conditions, set the dispatching goals and rules, then start dispatching and simulation calculations. Users can modify the dispatching scheme and perform rolling dispatching based on the dispatching results.

4.4. Simulation

According to the calculation results of the dispatch, the water quantity and water quality process of each river section (1km) is calculated through the one-dimensional hydrodynamic model of the river. And then the numerical difference calculation is performed, including the vertical difference and the horizontal difference. The ratio of the concentration of the object to the depth of the water is used to calculate the attenuation, that is, the center line of the river is the calculation result. The difference between the two banks is calculated based on a certain coefficient (decay coefficient based on experimental data). Mapping relationship with density, color the grid points, and then use the color information of the three vertices for smooth rendering in units of triangles to achieve the conversion of density information into image information. Multiple groups of density values are mapped into an image sequence. These true-color images are sequentially played into animation at intervals, that is, the simulation of the diffusion and evolution of pollutants in the process of water pollution is realized. The simulation results of pollution mass and water flow are shown in Figure 3.
5. Conclusion
The system constructed in this study achieved three main functions: 1) Display and query various basic information, pollution event information, and simulation and dispatching results; 2) Perform joint simulation of water quality and quantity on the movement process of the pollution mass under the given initial conditions and the boundary conditions of pollution control measures; 3) Give the recommended dispatching measures and results, and analyze various emergency dispatching plans. The system provides a platform for emergency decision-making and management of sudden water pollution incidents, and provides a starting point for improving the ability to respond to sudden water pollution incidents.

Due to the suddenness of pollution emergencies and hydrological uncertainty, the simulation and calculation of hydrodynamic models and emergency dispatch models require a large amount of data. In order to meet the requirements of emergency dispatch real-time and fast, some boundary conditions have adopted historical typical year data or multi-year average data. At the same time, corresponding parameters have been generalized and simplified. This processing method will be considered and improved in subsequent research.

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