Mechanism and Simulation Evaluation of Urban Rainflood Induced Disasters

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Abstract. The mechanism and simulation evaluation of urban rain and flood disasters are necessary means for the healthy development of cities, and are of great significance for comprehensive urban governance and flood prevention. Based on the mechanism of urban disasters, this paper analyzes and studies the simulation of urban rainwater and flood and disaster risk assessment, and summarizes the methods of urban runoff generation and concentration, domestic and foreign rainwater and flood models, and disaster assessment methods. Combined with the development of computer technology, starting from the current situation of urban flood, and based on multi-source data to improve the simulation accuracy, it is proposed that rainstorm flood simulation evaluation should focus on the research of full physical mechanism model and the application of information technology.

Keywords: urban flooding, Rain and flood simulation, Disaster assessment, Development Trends.

1. Introduction

With dense urban buildings and a large population base, rainstorm events with high intensity and short duration can easily cause serious consequences. In the context of smart city construction, urban flood disaster causing mechanism analysis, urban rainstorm and flood simulation, flood disaster assessment research, etc. are widely used in the decision-making of urban safety management, disaster early warning and forecasting system, municipal planning and other related activities [1]. There is an urgent need for efficient urban rain and flood models that can provide accurate spatio-temporal process information of floods in real time, and more perfect urban disaster assessment methods and technical platforms.

2. The Mechanism of Urban Flooding Induced Disasters

The occurrence of urban rainstorm and flood is closely related to rainstorm, urban underlying surface characteristics and urban drainage pipeline system [2].

2.1. Impact of climate change on urban rainstorm process

Climate change mainly affects evaporation and precipitation through temperature changes, resulting in infiltration, interaction between surface water, soil water, and groundwater, as well as changes in runoff processes, which greatly affect urban hydrological cycles. In recent years, the climate conditions above cities have also been deeply affected by urbanization, leading to changes in rainfall characteristics and frequent occurrence of local heavy rainfall events.

2.2. The impact of urbanization on urban flood processes

Urbanization construction has led to an increase in impermeable areas, changes in the characteristics of underlying surfaces and disaster prone environments, resulting in a decrease in infiltration water volume, weakened river regulation functions, accelerated convergence speed, and increased total confluence. Urban population is dense, the surface is hardened, and the carbon

emissions are high and the heat is difficult to discharge, which has an impact on the urban hydrological cycle and exacerbates the urban flood crisis.

2.3. The impact of urban drainage systems on urban flood processes

when the design standard of drainage pipeline system is lower than the requirements of urban development, it is very likely to increase the vulnerability of urban drainage and waterlogging risk. The development of urbanization has improved the urban drainage system and gradually replaced the original natural drainage channels. The urban water is discharged into the river through multiple pipelines at the same time, which shortens the convergence time and increases the flood intensity of the river channel, resulting in the erosion of the river channel while the sediment in the drainage system will also lead to the pollution of the river channel.

3. Simulation and evaluation of urban rainwater and flood

Cities are heavily influenced by human intervention, which to some extent makes urban hydrological and hydrodynamic processes more complex and variable. It is an important measure for urban flood control and disaster reduction to deduce the process of urban rainstorm and flood inundation by using urban storm flood model according to the predicted rainfall data.

3.1. Calculation of urban production and concentration

The calculation of urban rainstorm and flood mainly includes three modules: runoff generation, surface confluence and pipe network confluence. The runoff calculation module mainly uses statistical methods, including runoff coefficient method, rainfall runoff correlation method, etc; The surface confluence calculation and pipe network confluence calculation modules are mainly based on Hydrology and hydrodynamic methods, of which Hydrology methods include Muskingum method, unit line method and linear reservoir method, and hydrodynamic methods are mainly divided into motion wave, diffusion wave and dynamic wave. The calculation principles and characteristics of different methods also vary, and different methods can be selected based on actual calculation needs.

3.2. Urban Rain Flood Model

Since the 1970s, some countries have gradually recognized the importance of urban rainwater flood models, and urban rainwater flood models have developed rapidly [3]. At present, various urban storm flood models have been developed globally, as shown in Table 1.

Table 1. Rainwater and flood models for major cities at home and abroad

Model name	developer	development time	model type	main features
STORM	US Army Corps of Engineers	1974	hydrologic model	Can be used for combined drainage systems and large-scale planning, able to simulate overflow situations
Wallingford	HR Wallingford UK	1978	hydrologic model	Used for simulation analysis of water circulation processes and simulation of urban rainwater, sewage, and other drainage system capabilities
IFMS/Urban	China Institute of Water Resources and Hydropower Research	2015	hydraulic model	Based on a self-developed GIS platform, achieving one-dimensional and two-dimensional coupled computing
SWMM	US Environmental Protection Agency	1971	Hydrological model/hydrodynamic model	Strong computing power, capable of dynamic rainfall runoff simulation
MIKE Urban or MOUSE	Danish Institute of hydraulics	1984	Hydrological model/hydrodynamic model	Widely used for water flow calculation in urban pipelines and various scenarios
Infowars's	UK HR Wallingford	1997	Hydrological model/hydrodynamic model	High integration, comprehensive functionality, and can be used to simulate drainage overflow in areas
UFDSM	China Institute of Water Resources and Hydropower Research	2000	Hydrological model/hydrodynamic model	Introduce the concept of "clear and narrow gaps", and use unstructured irregular grids for surface generalization

At present, when conducting flood simulation, many buildings have been generalized. With the demand for urban intelligent development, the refinement of flood simulation will be greatly developed [4]; With the continuous improvement of the integrity and reliability of hydrological data and underlying terrain data, and the gradual improvement of data transmission platforms, the coupling model of hydrology and hydrodynamics with clear physical mechanisms has become a hot trend; The integrated intelligent system of data model prediction command can achieve prediction and rehearsal of urban flood processes, and real-time scheduling of urban water systems.

3.3. Urban Flood Disaster Assessment

There are differences in the characteristics of urban flood disasters in different regions, and coupled with different understandings of the risk connotation of flood disasters, there are also differences in risk assessment methods under changing environments. The theory of urban rainfall and flood simulation and flood disaster assessment has developed to this day, and a relatively complete conceptual framework and process have been formed, as shown in Figure 1.

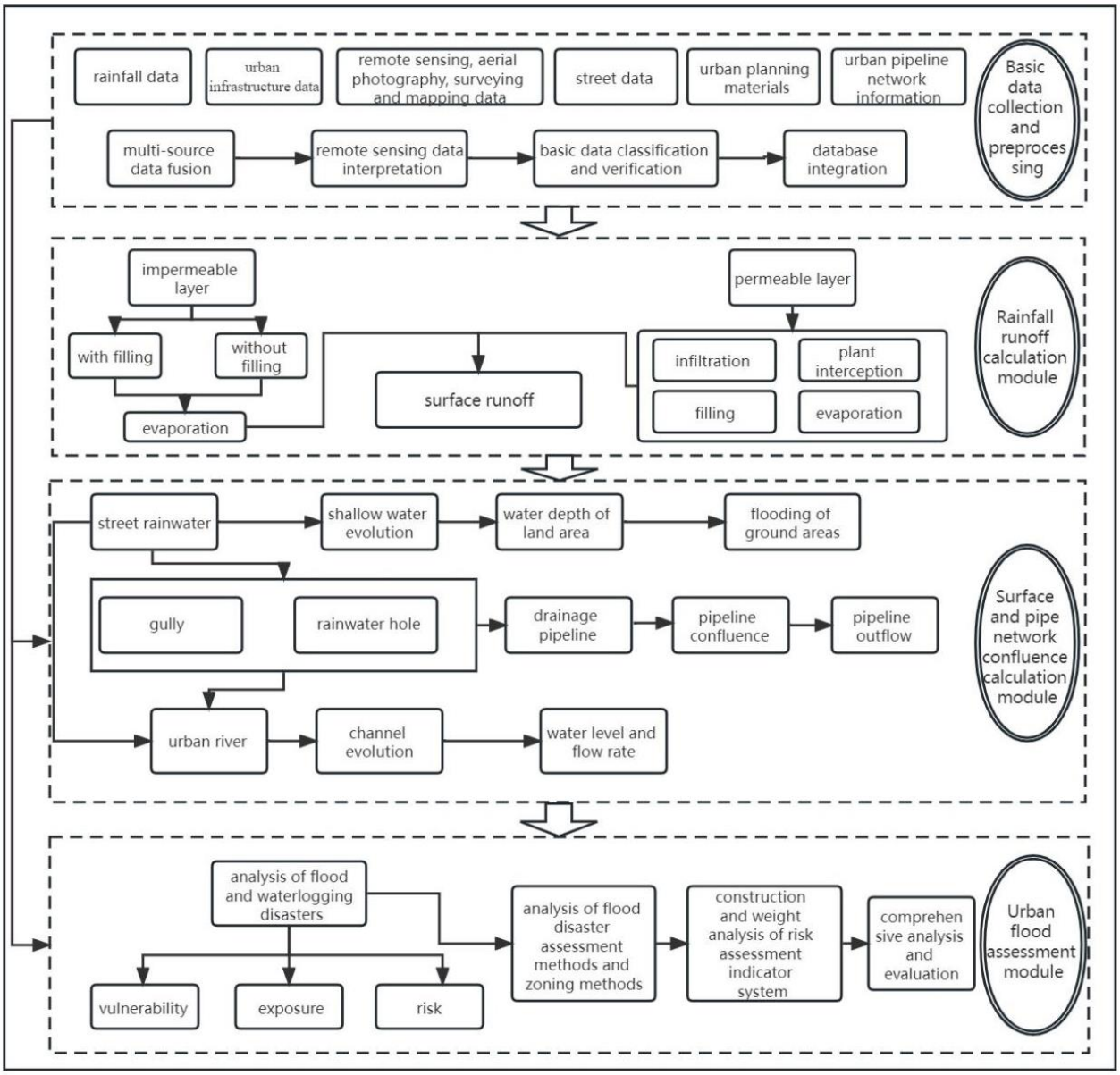

Figure 1. Urban flood simulation and evaluation process

Flood risk assessment can be divided into four methods based on data types, processing techniques, and evaluation ideas [5], as shown in Table 2.

Table 2. Summary of Evaluation Methods

Evaluation method	Basic Principles	main features
Historical disaster statistics method	Probability method of mathematical statistics	Simple calculation, high dependence on historical data
Remote sensing technology and GIS coupling method	RS: Threshold method, spectral analysis method, or multi band operation method GIS: Hydrodynamic Method	Reflecting the spatial distribution characteristics of regional flood disasters and risks, it can analyze real-time monitoring data and has high accuracy requirements for ground elevation data
Indicator system method	Analytic Hierarchy Process; Entropy weight method; Principal component analysis, etc	It can reflect the causal relationship between various indicators and flood disasters, with high requirements for data and information
Scenario simulation method	Hydrology method Hydrodynamic method	Qualitative or quantitative risk analysis of the region, intuitively reflecting the spatial distribution characteristics such as the impact range of flood disasters

In application, Wang Zhongmei et al. [6] used long-term historical flood disaster inundation data to quantitatively analyze the flood risk in the lower reaches of the Yellow River; Zhu Jing [7] used GIS to conduct inundation analysis in Wenshan County, Yunnan Province, and combined remote sensing technology to obtain the types of disaster bearing bodies for regional risk analysis; Huang Yixuan et al.[8] used the indicator system method to conduct a flood risk analysis on the north side of the Shenzhen River Basin. Seyoum et al.[9] simulated urban flood processes using a one-dimensional hydrodynamic model and a self-developed two-dimensional surface model.

Great progress has been made in theory and application of urban flood risk assessment, but there is still limited research on coupling dynamic analysis of dynamic disaster processes and underlying environment. It is still necessary to improve urban flood simulation models, obtain key evaluation data, and improve the accuracy and reliability of the data.

4. Conclusion

With the rapid development and prosperity of cities, the harm caused by urban floods has become increasingly evident. The trend of urban rainwater and flood research will focus on improving the data foundation, physical mechanisms of urban rainwater and flood models, combining computer technology to achieve real-time dynamic evolution of floods, and evaluating the coupling of RS and GIS technologies. Improving the monitoring and reporting system and simulation evaluation model can also achieve the goal of flood prevention and disaster reduction, which will play a guiding role in the construction of smart cities.

References

[1] ZOU Q, ZHOU J Z, ZHOU C.et al. Comprehensive flood risk assessment based on set pair analysis-variable fuzzy sets model and fuzzy AHP[J]. Stochastic Environmental Research & Risk Assessment, 2013, 27 (2): 525 - 546.

[2] SONG Xiaomeng, ZHANG Jianyun, WANG Guoqing, et al. Development and Challenges of Urban Hydrology in ChangingEnvironments—II. Urban Stormwater Simulation and Management [J]. Advances in Water Science, 2014, 25 (05): 752 - 764.

[3] XU Zongxue, CHEN Hao, REN Meifang, et al. Research progress on disaster mechanism and risk assessment of urban floods in China [J]. Advances in Water Science, 2020, 31 (05): 713 - 724.

[4] LIU Yong, ZHANG Shaoyue, LIU Lin, et al. A review of urban flood simulation research from the perspective of smart cities [J]. Advances in Geographical Sciences, 2015, 34 (04): 494 - 504.

[5] LUO Haiwan. Research on urban flood disaster risk assessment method and its application [D]. South China University of Technology, 2020.

[6] WANG Zhongmei, TONG Yifeng, JING Xinai. Quantitative analysis and calculation of flood risk in the lower reaches of the Yellow River [J]. People's Yellow River, 2013, 35 (01): 14 - 16.

[7] ZHU Jing. Risk assessment of urban flash floods: Taking Wenshan County, Yunnan Province as an example [J]. Geographical Research, 2010, 29 (04): 655 - 664.

[8] HUANG Yixuan, XU Zongxue, CHEN Hao, et al. Flood risk analysis on the inland side of the Shenzhen River Basin [J/OL]. Water Resources Protection: 1 - 16.

[9] SEYOUM S.D., VOJINOVIC Z., PRICE R.K., et al. Coupled 1D and noninertia 2D flood inundation model for simulation of urban flooding [J]. Journal of hydraulic engineering. 2011, 138 (01): 23 - 34.