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Study on Risk Assessment and Prevention Strategy of Zhengzhou City Flood

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Abstract: With the acceleration of global climate change and urbanization, urban flooding has become a major challenge hindering sustainable urban development. Taking Zhengzhou, a national central city, as a case study, this paper systematically analyzes the causes, mechanisms, and risk characteristics of urban flooding, while evaluating the effectiveness and shortcomings of existing prevention systems. The research reveals that Zhengzhou's flood risks primarily stem from multiple factors: increased extreme rainfall due to climate change, altered hydrological effects from urban expansion, and delayed drainage system development. To address these issues, the study proposes a comprehensive prevention framework integrating engineering and non-engineering measures, along with governance strategies based on the principles of "source reduction, pipeline drainage, combined storage and drainage, and emergency response for exceedance." The findings provide theoretical foundations and practical references for enhancing flood prevention capabilities in Zhengzhou, while also offering valuable insights for similar cities in flood management.

Keywords: Urban Waterlogging; Risk Assessment; Prevention and Control Strategies; Sponge City; Resilient City.

1. Introduction

Urban flooding refers to the phenomenon where heavy rainfall or prolonged precipitation exceeds the capacity of urban stormwater systems, resulting in water accumulation on city streets. In recent years, accelerated urbanization and global climate change have intensified urban flooding, posing a major challenge to sustainable urban development. Statistics show that between 2015 and 2020, over 200 cities nationwide experienced flooding annually, causing economic losses exceeding 100 billion yuan. The 2021 Zhengzhou "7.20" mega-flood incident particularly exposed the fragility of China's urban flood control and drainage systems, with direct economic losses surpassing 100 billion yuan and causing significant casualties and property damage. [1-2]

As a national central city and core city of the Central Plains Urban Agglomeration, Zhengzhou faces typical and representative urban flooding challenges. Rapid urbanization has significantly altered the city's surface topography, with a dramatic increase in impermeable surfaces that disrupts natural hydrological cycles. Concurrently, rainfall patterns in Zhengzhou have become increasingly extreme, marked by heightened intensity and frequency of heavy downpours. The combined pressures of urban expansion and climate change have led to a continuous escalation of flood risks in the city.

This study systematically investigates flood risk assessment and prevention strategies in Zhengzhou, carrying significant theoretical and practical value. Theoretically, it enhances understanding of urban rainwater formation mechanisms and refines the theoretical framework for flood simulation and early warning systems. Practically, it provides scientific evidence for flood control and drainage in Zhengzhou, strengthens the city's emergency response capacity, and offers valuable references for flood management in similar cities.

2. A Review of Domestic and International Research

2.1. Progress in Foreign Research

Developed countries pioneered research on urban flooding, establishing comprehensive theoretical frameworks and technical systems. The U.S. Environmental Protection Agency's SWMM (Storm Water Management Model) stands as a seminal urban stormwater model, having evolved through over five decades to its current version 5.2 and now widely adopted for drainage system simulations. Denmark's DHI developed the MIKE series models, utilizing one-dimensional pipe networks coupled with two-dimensional surface simulation techniques to achieve higher accuracy in urban waterlogging processes. Meanwhile, the InfoWorks ICM model by Wallingford, integrating hydrological, hydrodynamic, and water quality modules, has become a cornerstone of European urban stormwater management.

In terms of prevention and control strategies, international practices have evolved from traditional "rapid discharge" to "sustainable drainage". Concepts like Low Impact Development (LID) and green infrastructure have gained widespread acceptance and application. The United States promotes Best Management Practices (BMPs), Japan implements "rainwater retention and infiltration" technology, while Germany enforces regulations requiring rainwater infiltration measures in new construction areas. These measures have all achieved remarkable results.

2.2. Status Quo of Domestic Research

Research on urban flooding in China started relatively late, but has developed rapidly in recent years. In terms of urban rainwater models, domestic scholars mainly adopt two approaches: introduction and digestion, and independent development. The introduced models are mainly SWMM, MIKE URBAN, and InfoWorks ICM. The independently developed models include the DigitalWater model developed by Tsinghua University and the IFMS/Urban system

developed by the China Institute of Water Resources and Hydropower Research.

In the field of model application research, domestic scholars have conducted extensive explorations by combining the characteristics of China's cities. Huang Guoru and others carried out secondary development of SWMM based on GIS, improving the efficiency of model parameter extraction. Zhang Jie integrated SWMM with GIS technology to construct a Zhengzhou urban stormwater and flood model, representing an early application of SWMM in China. As research progressed, domestic scholars also began developing independent models, such as the Urban Stormwater Pipeline Calculation Model (SSCM) proposed by Cen Guoping, which is China's first independently developed stormwater and flood model. [3-4]

In terms of prevention and control strategies, China has introduced the sponge city concept, addressing urban water issues through integrated measures such as infiltration, retention, storage, purification, utilization, and drainage. The General Office of the State Council issued the "Implementation Opinions on Strengthening Urban Flood Control," proposing that by 2025, all cities will establish a comprehensive urban drainage and flood prevention system featuring source reduction, pipeline discharge, combined storage and drainage, and emergency response for exceeding standards. The Ministry of Housing and Urban-Rural Development also released the "Technical Specifications for Urban Flood Prevention and Control" (GB51222-2017), providing technical standards for urban flood prevention.

3. Empirical Analysis of Zhengzhou City Flood Risk Assessment

3.1. Analysis of the Causes of Zhengzhou City Flood

The urban flooding in Zhengzhou results from the combined effects of natural and human factors. The city's natural climate is characterized by a temperate continental monsoon system, with highly uneven precipitation distribution. Annual rainfall is predominantly concentrated between June and September. During flood seasons, frequent rainfall and localized torrential downpours occur, often exhibiting sudden onset, rapid intensity, and concentrated duration, with short forecast lead times. The 2021 "July 20" extreme rainfall event further highlighted the significant threat posed by extreme weather phenomena. Human-induced factors, particularly urban surface changes caused by rapid urbanization, are the primary cause of worsening urban flooding. As city construction accelerates, the water surface ratio declines while surface runoff increases. Urban expansion has led to the artificial filling or repurposing of natural water storage and flood regulation features like depressions, ponds, and ditches, reducing their capacity for rainwater retention and diversion. Meanwhile, the significant increase in impermeable surfaces shortens surface runoff time, causing earlier peak occurrence and larger peak values, which places immense pressure on urban drainage and flood prevention efforts.

3.2. Spatial Distribution Characteristics of Flood Risk

The spatial distribution of urban flooding risks in Zhengzhou exhibits significant regional disparities. A comprehensive survey has identified 62 severely waterlogged areas across the city. Analysis of recent drainage challenges in Erqi District, Jinshui District, and Guancheng Hui District reveals that the expansion of urban areas and changes in the underlying surface have rendered the originally designed drainage systems inadequate. The main urban area contains 79 flood risk points of varying severity, primarily categorized into 20 critical flooding zones and 59 moderate flooding zones. The high-risk areas are mainly distributed in underground space dense areas, including underground garage, shopping mall and civil air defense project, which are in "inherent weakness" in flood control, and once water enters, it will easily cause great losses. The underpass interchange and tunnel areas, such as Jingguang Road, Longhai Road and Heyi Road, have not been fully resolved due to factors like land acquisition and funding issues. The old city and the area with imperfect drainage pipe network: the pipe diameter of the old city is small, generally cannot meet the drainage requirements of heavy rainfall; the pipe corrosion, bad rotten, invaded by tree roots, garbage and mud blockage and other problems are serious. The riverbed of the lower reaches of Dongfeng Canal is high, the slope is gentle, and the flood discharge capacity is low, which is easy to cause the rainwater discharge is not smooth; the riverbed of Jinshui River and Xiong'er River is narrow in some parts, which leads to the low-lying area is easy to backflow and overflow, forming the waterlogging.

3.3. Evaluation of the Effectiveness of Existing Prevention and Control Measures

Zhengzhou has implemented a series of flood prevention measures with notable results. In terms of planning, the city has established a "31382" flood control framework, comprising three thematic studies, a digital rainwater model, three comprehensive plans, eight specialized plans, and two implementation schemes. For engineering solutions, the city has enhanced drainage capacity through waterlogging point management, pipeline upgrades, and pump station construction. Non-engineering measures include emergency response plans, a monitoring and early warning system, and improved emergency management capabilities.

However, the current prevention and control measures still have the following shortcomings: Systemic issues: Insufficient coordination among various measures and lack of systematic integration. For instance, the Zhengzhou Natural Resources and Planning Bureau pointed out that it is necessary to strengthen systematic thinking, adhere to systematic governance, adopt comprehensive measures, and promote the coordinated advancement of urban flood control work. The issue of inadequate standards: Some drainage facilities have substandard specifications, making them ill-equipped to handle extreme rainfall events. In urban areas, certain river channels fail to meet the 5-year flood return period standard. The problem of decentralized management: Drainage management functions are dispersed in various departments and districts, which makes coordination difficult. Zhengzhou is exploring the integration of decentralized management functions of drainage pipe network, pumping station and other facilities in various departments and districts (development zones) to optimize the drainage management system and mechanism. The problem of capital investment: some projects are still not completely cured because of the capital factors. [5-6]

4. Construction of Flood Control Strategy System in Zhengzhou City

4.1. Engineering-based Prevention and Control Measures

Engineering measures form the foundation and hardware guarantee for flood prevention. To address Zhengzhou's urban flooding challenges, a multi-tiered engineering prevention system should be established. The source reduction project serves as the first line of defense. Guided by the principle of "prioritizing water storage and infiltration while enhancing existing capacity," the city should systematically advance sponge city construction across its entire territory, integrating sponge city concepts with comprehensive community development. The renovation of pipe network and pumping station is the key to improve the drainage capacity. The construction of drainage pipe network should be strengthened, the blank area of pipe network should be eliminated step by step, and the new drainage pipe network should meet the upper limit of the national construction standard as far as possible. The drainage channel project is an important means to ensure the smooth drainage of waterlogging. Rainwater storage and regulation facilities are effective measures to deal with excessive rainfall. [7-8]

4.2. Non-engineering Control Measures

Non-engineering measures are the software guarantee of flood prevention and control, which complement engineering measures and constitute a complete flood prevention and control system.

Planning is the basis of non-engineering measures. Zhengzhou should firmly establish the concept of planning first and make the urban municipal planning scientifically.

The development of monitoring and early warning systems is crucial for enhancing emergency response capabilities. Zhengzhou should strengthen digital empowerment by accelerating the construction of a city-wide integrated flood forecasting and early warning system, while enhancing the development of a smart flood control and prevention platform to achieve a breakthrough from "governance" to "intelligent governance".

The emergency management system is an important guarantee for reducing the loss of waterlogging. It is necessary to improve the emergency plan related to urban drainage and waterlogging prevention, clarify the connotation of the warning level, and implement the tasks, response procedures and disposal measures of relevant departments.

The innovation of management mechanism is the basis to ensure the effective implementation of all measures. Zhengzhou should integrate the management functions of drainage pipe network and pumping station which are scattered in various departments and districts (development zones) and optimize the drainage management system and mechanism.

References

[1] Z.W. Zhang, J.N. Wang: Crane Design Manual (China Railway Press, China 1998), p.683-685. (In Chinese)Zhang Jianyun, Wang Yintang, He Ruimin, et al. Analysis of urban flooding problems and their causes in China [J]. Progress in Water Science, 2016,27(4):485-491.

[2] Ren Hongchang, Zhang Hengde. Analysis of the Precise Characteristics and Main Causes of the Zhengzhou "7·20" Special Flood and Heavy Rain [J]. Journal of Hohai University (Natural Science Edition), 2022:1-14.

[3] Gironas J, Roesner L A, Rossman L A, et al. A new applications manual for the Storm Water Management Model (SWMM)[J]. Environmental Modelling & Software, 2010,25 (6): 813-814.J. Liu, E.L. Chen and Z.T. He: Journal of Shi Jia Zhuang Railway Institute (Natural Science), Vol. 22 (2009) No. 4, p.40-42.

[4] Huang Guoru, Huang Wei, Zhang Lingmin, et al. Urban stormwater flooding simulation based on GIS and SWMM model. Journal of Water Resources and Hydraulic Engineering, 2015(04):4-9.

[5] Zhang Jie. A Study on the Heavy Rain and Flood in Zhengzhou City Based on GIS and SWMM [D]. Zhengzhou University, 2012.

[6] General Office of the State Council. Implementation Opinions on Strengthening Urban Flood Control (State Council Document [2021] No.11) [Z]. 2021.

[7] Ministry of Housing and Urban-Rural Development. Technical Code for Prevention and Control of Urban Floods (GB51222-2017).2017.

[8] Zhengzhou Natural Resources and Planning Bureau. Reply to the suggestion on improving the urban waterlogging problem in flood season [Z].