C103

Modeling Flow and Pollutant Transport of Urban Areas under Flood Disaster

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Although research on the transport of pollutants in natural rivers has been extensively conducted, there are still few studies on the transport of pollutants in urban inundation areas. In this research, the development and implementation of a two-dimensional, numerical pollutant transport model is delineated. Unstructured grids are employed to facilitate grid generation and localized refinement, providing clear boundaries for different land uses such as buildings, roads, and others. This allows for a more accurate assignment of the Manning coefficient, exchange coefficient, diffusion coefficient, and other attribute information to grids. It is then applied to model the distribution and transport of pollutants in Uji Campus, Kyoto University when urban inundation happened. The results from the numerical simulations illustrate that the pollutants will have an impact on residential and agricultural areas in the south and west.

1. Introduction

Urban inundation disasters caused by heavy rain, tsunamis, and floods have become increasingly frequent in recent years. The Global Assessment Report 2019 released by the United Nations Office for Disaster Risk Reduction pointed out that secondary disasters caused by the impact of flood hazards occur frequently but are often overlooked, such as the pollutants leakage incidents that occurred during the 2002 European floods, and 2005 Atlantic hurricane season[1]. Therefore, it is necessary to study the transport of pollutants in urban areas under flood disasters.

This research employs unstructured grids to facilitate grid generation in the research area, and discretizes the transport equation on the unstructured grid, proposing a two-dimensional numerical model for pollutant transport. Using the proposed model to simulate pollutant transport on Uji Campus, Kyoto University and its surrounding areas under flood disaster.

2. Research Contents

This research is divided into two parts: urban inundation simulation and pollutant transport simulation. The urban inundation simulation utilizes the unstructured grid model proposed by Kawaike[2], with the transport equation being discretized on the same unstructured grid. An example of unstructured grids is illustrated in Figure 1. Delineating boundaries between different land uses through unstructured girds allows for accurate assignment of attributes and information.

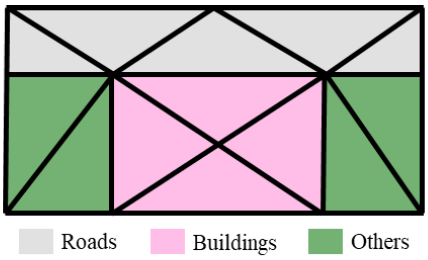

Figure 1 Example of unstructured grids

(1) Urban Inundation Simulation

This research simulates the urban inundation caused by the breach of the Uji River. The study area is the hazardous material storage room at the Uji Campus, Kyoto University, enclosed by two waterways leading to the Uji River and the Keihan Uji Line. There are no water flux exchanges along the boundaries, except at the breach point. The length of the breach point is 20m, and a total of Q = 4.5*10^6 m^3 of water flows into the study area within 5 hours. The study area and breach point are illustrated in Figure 2.

(2) Pollutant Transport Simulation

The two-dimensional pollutant transport equation used in this research is given by:

$$\frac{\partial(Ch)}{\partial t}+\frac{\partial(CM)}{\partial x}+\frac{\partial(CN)}{\partial y}=\frac{\partial}{\partial x}\left(Dh\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(Dh\frac{\partial C}{\partial y}\right)$$

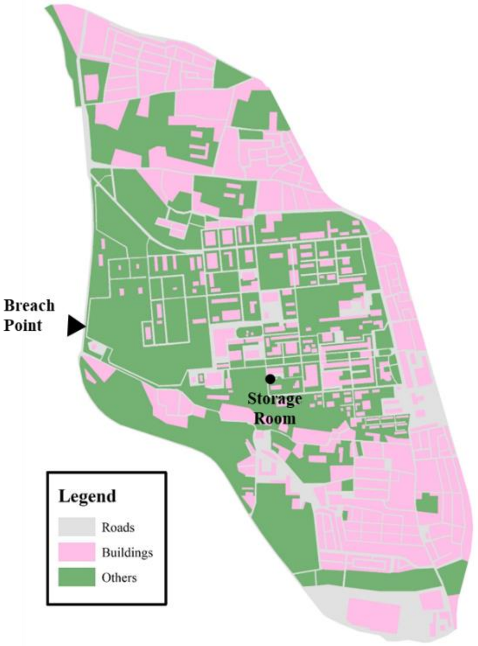

Figure 2 Location of the study area, storage room, and breach point

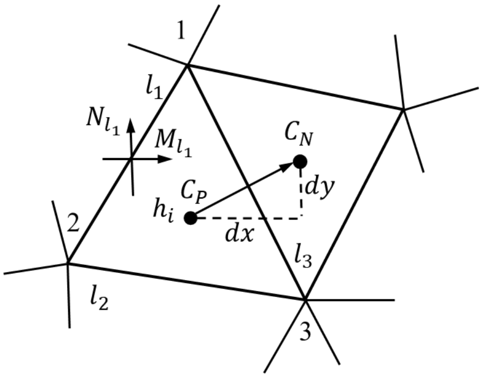

Figure 3 Discretization on unstructured grids

Where C is the mass concentration; h is the water depth; M, N are the flux of x,y direction; D is the diffusion coefficient. The transport equation is discretized on grids shown in Figure 3 and can be expressed as:

$$\frac{C_i^{n+3}h_i^{n+3} - C_i^{n+1}h_i^{n+1}}{2\Delta t} + \frac{1}{A_i}\sum_{l=1}^{m_i}\{\bar{C}_l^{n+1}M_l^{n+2}(\Delta y)_l - \bar{C}_l^{n+1}N_l^{n+2}(\Delta x)_l\} = \frac{1}{A_i}\sum_{l=1}^{m_i} hl_l^{n+1}D\left\{\frac{C_N^{n+1} - C_P^{n+1}}{\sqrt{dx^2+dy^2}}\frac{dx}{\sqrt{dx^2+dy^2}}(\Delta y)_l - \frac{C_N^{n+1} - C_P^{n+1}}{\sqrt{dx^2+dy^2}}\frac{dy}{\sqrt{dx^2+dy^2}}(\Delta x)_l\right\}$$

Based on the analysis of stored hazardous materials, this research assumes that a total of 220 kg of conservative substance, which can dissolve in water immediately, will be released into the water when the water depth in the storage room reaches 0.3m. This research utilizes rivers' longitudinal diffusion coefficient $D = 6.43hu^*$.

3. Results and Discussions

The water depth in the storage room reaches 0.3m approximately 23050 seconds after the breach, leading to the release of hazardous materials. Figure 4 illustrates the distribution of hazardous materials 30000 seconds after the breach. These materials generally move southeast with the flow, spreading simultaneously. Residential areas to the south and west of Uji Campus, Kyoto University, as well as agriculture lands, are affected. The Uji Municipal Nanbu Elementary School, designated as an emergency shelter, is also within the impact zone. Therefore, it is essential to recognize the secondary disaster of hazardous materials leakage during flood disasters.

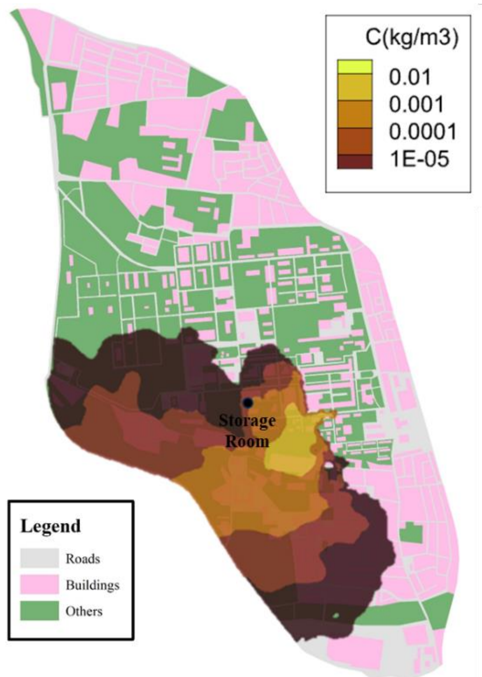

Figure 4 Pollutant distribution 30000s after breach

Reference

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[2] 川池健司, 井上和也, 林秀樹, 等. 都市域の氾濫解析モデルの開発[J]. 土木学会論文集, 2002 (698): 1-10