Research on the Effect of Natural Cisterns on Flooding in Villages in The Plain Area-Take A Village in Shandong Province as An Example

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Abstract. In recent years, flood have become more frequent and serious. The important measure to prevent villages flood disaster is to construct the drainage system. This paper takes the typical villages in the plain area as the research object, based on SWMM to establish the rain-floods model. In consideration of backwater of river, pipeline and channel siltation, we made the simulation of rain-flood with different frequency of rainstorms. We evaluate the rural drainage system scientifically and analyze the role of rural natural cisterns in it. The result shows that the rain-flood model in this study can simulate the actual disaster process well, and the results are reliable. Natural cisterns can reduce the pipeline overload and water accumulation, and improve the capacity of flood prevention of the village.

Keywords: SWMM; rain-flood model; flood; rural area

1 Introduction

Floods are one of the most important natural disasters in China. They have threatened the safety of people's lives and property since ancient times. In recent years, flood have become more frequent and harmful in Asia. [1] The development of China's rural economic is backward. Some villages are located along low-lying and flood-prone rivers. Many villages were constructed without considering the drainage system, and the drainage pipes and channels in the villages were not perfect. Most of the existing drainage systems are composed of open channels (drainage ditches), and pipes are set at the intersections of channels. At the same time, the original village's natural cisterns were occupied. In summary, flood disasters are difficult to prevent and the causes are complex. Guangming He et al. have proposed to investigate flooding from the aspect of drainage system [2].

At the same time, in the plain area of Shandong Province, the water level of rivers and riverbeds is high, and the phenomenon of "overground rivers" is very common. In many rural areas,

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although the village will not be flooded, it will receive backwater from the river and the flood water in the village will not be discharged in time, creating standing water. In addition, the villagers' awareness of flood control is relatively weak. Because the level of rural infrastructure construction, disaster early warning facilities, and disaster response speed is lower than that of urban areas, rural areas are more susceptible to flood disasters than urban areas, and their ability to resist floods is weaker. Therefore, in rural areas, once a flood occurs, casualties and economic losses are more likely to occur.

In 2017, JDMA et al. [3] conducted a study on urban flood disasters on different urban-rural gradients, and the results showed that the degree of urbanization can explain the difference in hydrological response between rural and urban areas. In 2019, H Halim et al. [4] studied the risk of flood disasters and their coping strategies. The study found that the response strategies of local residents to flood disasters will greatly affect the risk of flood disasters. Khadka et al. [5] used the SWMM model to analyze the capacity of stormwater storage facilities in southwestern Finland, and to study how to use stormwater storage facilities to improve flood resistance in cities. In 2020, PSOMIADIS E et al. [6] applied the SCS-CN model to analyze the hydrological changes caused by land changes.

This paper takes typical villages in the plain area as the research object, and investigates the drainage system in the village. On this basis, SWMM is used to establish a rainfall model for the simulation of village rainfall under different frequency storms. Scientific assessment of the drainage capacity of village drainage systems, with emphasis on the role of rural natural cisterns in the drainage system. The results show that drainage and water storage capacity of village can be enhanced by natural cisterns. It can provide a basis and reference for the prevention and control of rural flood disasters in my country.

2 Materials and Methods

The research area of this paper is selected in a village in a plain area of Shandong Province. It is high in the west and low in the east and has a monsoon climate, with rain and heat in the same period, and four distinct seasons. In this study, design rainstorms with different frequencies were obtained according to the local hydrological manual.

The SWMM model is often used to simulate floods. The main application fields and directions are: urban drainage system planning, low-impact development research (LID) and water quality simulation, etc. SWMM contains a pipeline network convergence module, so it is often used for simulation drainage system, which is widely used in storm and flood simulation research [7-9]. The groundwater module was added to the SWMM model in 1988, making it applicable to rural areas.

Terrain data is an important basis for dividing catchment areas. Due to the inhomogeneity of topographic data, further sub-catchment divisions for the entire village can improve the accuracy of model parameters and the final simulation results. In this study, the entire village was divided into 8 sub-catchments based on the DEM topographic data with an accuracy of 12.5m in the study area. And according to DEM data and remote sensing images, parameters such as slope and impervious area of each sub-catchment are determined. The respective sub-catchment data are shown in Table 1.

Table 1. Sub-catchment Parameters

ID	Area(ha)	Slope (%)	Feature width (m)	Impermeability percentage (%)
S1	78825	0.47%	321	45%
S2	38718	0.40%	132	47%
S3	16531	0.57%	123	48%
S4	20429	0.66%	136	46%
S5	38045	1.54%	285	47%
S6	34780	0.71%	270	47%
S7	33212	1.40%	229	48%
S8	75422	0.37%	310	46%

According to the field investigation and referring to the SWMM model parameter table, it is determined that the n value of the pervious area is 0.3, the n value of the impervious area is 0.014, the n value of the drainage channel is 0.016, and the depression storage of the pervious and impervious ground are 5.62 mm and 1.05 mm respectively. The pipeline water flow evolution model adopts the dynamic wave method, and the infiltration model adopts the Horton model. According to the local climate and terrain, the maximum and minimum infiltration rates are set as 73 and 10.7 mm/h, respectively, and the attenuation coefficient is 4.

The sub-catchment close to the river (runoff directly into the river) was excluded, and the study area was divided into the 8 sub-catchment areas. At the same time, 16 drainage pipes and channels are generalized. Through on-the-spot investigation and measurement, the parameters are shown in Table.2 and the schematic diagram is shown in Figure 1.

Table 2. Drainage pipe parameter

ID	Shape	Length(m)	Height(m)	Width(m)	Material
G1	Trapezoidal	269	0.4	0.55 & 0.35	cement
G2&G3	Rectangular	45&55	0.5	0.9	cement
G4	Trapezoidal	83	0.4	0.55&0.35	cement
G5&G6&G7	Trapezoidal	212&150&70	0.4	0.55 & 0.35	cement
G8	Trapezoidal	140	0.5	0.60 & 0.30	cement
G9	Trapezoidal	210	0.4	0.55 & 0.35	cement
G10	Trapezoidal	139	0.5	0.6 & 0.3	cement
G11	Circular	10	0.4	\	cement
G12&G13	Trapezoidal	92&241	0.4	0.55 & 0.35	cement
G14	Circular	10	0.4	\	cement
G15	Irregular	400	\	\	soil
G16&G17	Circular	20	0.4	\	cement

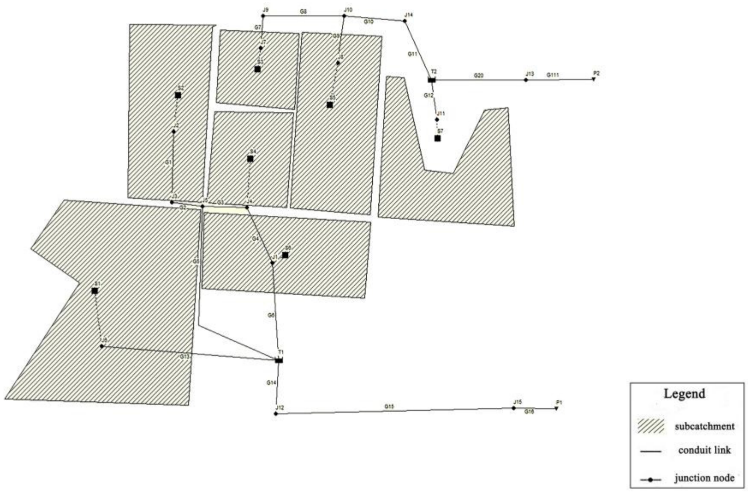

Figure 1. Schematic diagram of drains and sub-catchments

Among them, pipelines G11, G14 and G16 in the drainage system are seriously silted up and are set as siltation pipes. G15 is a relatively wide drainage ditch with an irregular cross-sectional shape, but there is also a problem of siltation, and the overcurrent capacity is reduced as appropriate. According to the above model and design rainfall, the storm flood process with and without natural cisterns is simulated.

3 Results & Discussion

After using the above data to establish a model, the rainstorm simulation calculation with or without natural cisterns is carried out by adopting the design rainstorm once in twenty years. The calculation results are shown in Table 3 and Table 4.

Table 3. Simulation results without natural cisterns

Pipes and Channels	Full Flow Times/h	Nodes	Node Sur-changed times/h	Total Flood Volume/m^3
G14	12.77	J20	12.77	2.683
G13	1.72	J6	1.72	0.327
G6	1.23	J14	0.55	0.039
G5	1.22	J8	0.33	0.021
G9	0.33	J2	0.06	0.001
G11	0.01			
G1	0.01			

Table 4. Simulation results without the reservoir

Pipes and Channels	Full Flow Times/h	Node	Node Sur-changed times/h	Total Flood Volume/m3
G1	0.14	J6	0.61	0.452
G7	0.14	J8	0.32	0.206
G6	0.01	J2	0.32	0.19
G5	0.01	J1	0.24	0.181
G9	0.01	J5	0.22	0.062
		J7	0.15	0.022

The above simulation data shows that in the case with natural cisterns, the total amount of rural flood water and the overload time of pipes and channels are significantly reduced. At the same time, it can be seen that the serious overload pipes are G14, G13, G9, G7, G5, G6 and G1. And the overloaded pipelines are mostly main pipelines or pipelines in larger sub-catchments.

4 Conclusions

As can be seen from the above, overloading of pipes and nodes was alleviated with the installation of small reservoirs. Node water is reduced, the village's flood control capacity is significantly enhanced. The main conclusions and recommendations are as follows.

(1) Small reservoirs with a certain volume have a positive effect on rural flood control. In the case of river support, the waterlogging water exceeding the rural flood discharge capacity can be temporarily stored in the small reservoirs to relieve the pressure of village drainage. In the practice of rural flood control, the existing small reservoirs can be maintained according to specific conditions. The small reservoirs that are not included in the drainage system can be reconstructed to give full play to the positive role of the existing small reservoirs in rural flood control.

(2) Some rural drainage pipes and channels have serious siltation problems, especially the siltation of main pipes and channels into rivers, which seriously affects the ability of flood and waterlogging drainage. Through dredging and other measures, the ability of flood control and waterlogging prevention in rural areas can be greatly improved.

(3) The size and shape of rural drainage pipes are basically the same in the whole village, and the main pipes and branch pipes are not divided. However, since the main channels bears greater flood control pressure, it should be differentiated in design. The simulation results show that properly deepening the drainage capacity of the main channels has a greater effect on rural flood control.

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