Fuzzy Systems and Data Mining VIII
A.J. Tallón-Ballesteros (Ed.)

doi:10.3233/FAIA220407

Operation Dispatching Feature Analysis Based on TELEMAC-2D

Guoyi LI[a], Jiahong LIU[a,b,c1] and Weiwei SHAO[a]

[a]*China Institute of Water Resource and Hydropower Research, State Key Laboratory of Simulation and Regulation of Water Cycle in River Basin, China, Beijing 100038, China*

[b]*Water Resources and Water Ecological Engineering Technology Research Center of Ministry of Water Resources, Beijing 100044, China*

[c]*Key Laboratory of Ministry of Water Resources digital twin River basin, Beijing 100038, China*

Abstract. China is in the stage of rapid urbanization, resulting in more and more serious urban waterlogging problems. Based on the TELEMAC-2D hydrodynamic model, this paper conducted mathematical modeling of Swan Lake flood storage and detention area in Dongying City, and simulated the inflow and inundation process of Swan Lake flood storage and detention area under three rainfall scenarios of typhoon "Rumbia","Lekima" and 50-year return period. The simulation results show that when three water intakes are opened at the same time (Plan A), the total amount of water inflow under typhoon "Rumbia", "Lekima" and 50-year return period rainfall scenario is not exceeding the storage capacity, respectively. When only one water intake was opened (Plan B), the total incoming flow is not exceeding the storage capacity of Swan Lake flood storage and detention area. In all setting plans and rainfall scenarios, the maximum water level before sluice is 3.42m. By operating and dispatching the intake sluice in the flood storage and detention area of Swan Lake, the water level of Guangli River can be effectively controlled below 3.5m, ensure that the urban drainage system is not supported by the top and maintain the normal drainage function. In all setting plans and rainfall scenarios, the maximum flow of 1#, 2# and 3# water intake is not exceeding the design flow of corresponding water intake, respectively. The simulation results can provide a scientific basis for the operation regulation and flood control operation of Swan Lake flood storage and detention area.

Keywords. Urbanization, TELEMAC-2D model, DongYing city, flood storage and detention

1. Introduction

Under the background of global climate change and rapid urbanization, urban waterlogging disaster in China has become a major natural disaster affecting economic

[1]Corresponding Author, Jiahong Liu, China Institute of Water Resource and Hydropower Research, State Key Laboratory of Simulation and Regulation of Water Cycle in River Basin, China, Beijing 100038, China; E-mail: liujh@iwhr.com.

This study was supported by the Chinese National Natural Science Foundation (No. 51739011 and 51979285), the Research Fund of the State Key Laboratory of Simulation and Regulation of Water Cycle in River Basin (SKL2022TS11).

and social development with increasing frequency and increasing disaster losses [1, 2]. By 2020, China's urbanization rate has exceeded 60% [3]. With the rapid advancement of urbanization in China, the problem of urban waterlogging has attracted much attention. In 2013, China put forward the sponge city strategy, aiming to carry out systematic governance through six measures of "seepage, stagnation, storage, purification, utilization and drainage", and implement comprehensive measures to realize "natural accumulation, natural infiltration and natural purification" in the city, and comprehensively solve the urban water problems [4]. Under the background of new urbanization, China's urbanization process will be further accelerated in the future, and the research on urban waterlogging disaster analysis is becoming more and more important [5]. Urban flood simulation is an important method to analyze the characteristics of waterlogging disaster. Through the numerical simulation of urban waterlogging under different rainstorm scenarios, the analysis of the characteristics of urban waterlogging is of great practical significance for the evaluation of the characteristics of urban waterlogging, the study of its evolution mechanism and the prevention countermeasures [6-9]. Flood storage and detention area is an important part of river flood control system, which is an effective measure to guarantee flood control safety in key areas and reduce disasters. In order to ensure the safety of flood control in key areas, favorable conditions should be developed into flood storage and detention areas with planned flood storage and detention. Dongying city is approved by the State Council to determine the central city of the Yellow River Delta, important oil base in China. The city has jurisdiction over 3 districts and 2 counties, covering a total area of 8243 km^2, with a permanent population of 2.18 million and an urban population of 1.51 million, with an urbanization rate of 69.24%. Once Dongying City suffers from urban waterlogging disaster, it will bring huge economic losses. For example, Typhoon "Rumbia" in 2018 and Super Typhoon "Lekima" in 2019 both caused serious economic losses to Dongying City. Swan Lake Flood Storage and Detention Area was built in Dongying City in order to hold back flood water and alleviate urban waterlogging. It has become a key scientific problem to utilize the flood storage and detention area scientifically and efficiently and to reduce the water level of Guangli River to the maximum extent during the flood period. In order to solve the problem of urban waterlogging, domestic scholars have carried out a lot of research using different flood models and achieved fruitful results [10-15]. In this paper, a two-dimensional hydrodynamic model of Swan Lake flood storage and detention area was established based on Telemac-2D to simulate the inflow and inundation process under different water sluice combination schemes,

2. Methodology

2.1. Study Area

Dongying City is located in the northeast of Shandong Province, China (118°40′—118°47′E, 37°22′—37°25′N). The city has a warm temperate continental monsoon climate with four distinct seasons. The average annual rainfall is about 555.9mm, approximately 65% of which falls from July to September. And the precipitation varies greatly from year to year, making it easy to form drought and flood disasters.

In this paper, study area is located in the southeast of Dongying City with total area of about 2300ha. Swan Lake Flood Storage and Detention Project has a storage capacity of 40 million m^3, which is divided into north and south parts, with the new Guangpu River as the boundary. In the north of the flood storage and detention area, the storage capacity is 28 million m^3, the water storage level is 3.0m, and the bottom elevation is 0.0m. Through Xuzhou Road, Dongqi Road, Dongsi Road and Naner Road drainage system, the total inflow of flood water is 170m^3/s (612,000 m^3/h, 14.69 million m^3/d). The drainage is discharged into the new Guangpu River and Guangli River by Xuzhou Road Water System Control Sluice and Naner Road Outlet Sluice, with the designed drainage rate of 63m^3/s. Considering the completion time sequence and the availability of detailed topographic data, this paper only conducts modeling analysis for the northern part of the flood storage and detention area. The upstream boundary of the river is the Guangli River Dengzhou Road section, and the downstream is the Guanglu Hedong Badu Bridge section. The location of the study area is shown in Figure.1.

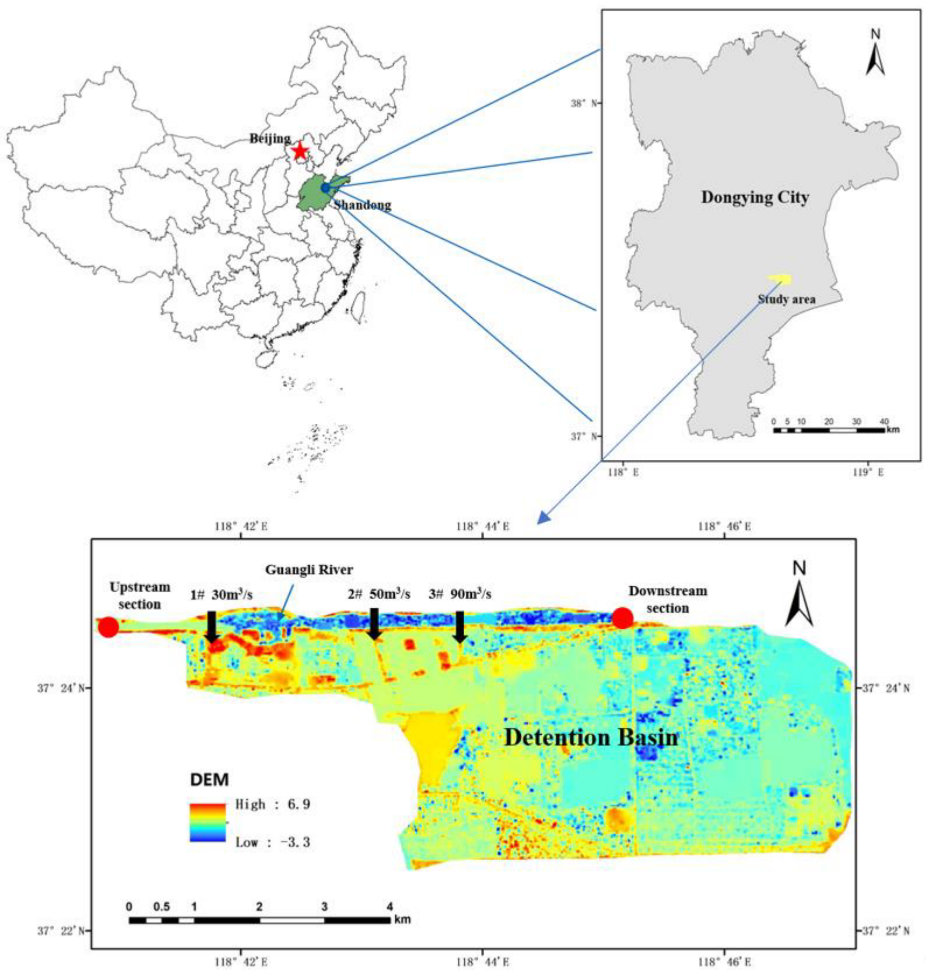


Fig. 1. Location and terrain of the study area.

2.2. Data Preprocessing

The DEM data adopted by the model can be obtained from the geospatial data cloud(http://www.gscloud.cn/) with a resolution of 30m*30m, which basically meets the accuracy requirements. In this paper, ArcGIS10.4 is used to preprocess the acquired DEM elevation data. The internal topographic data of the flood storage and detention area are obtained from on-site surveying and mapping data, which can reflect the topography, slope and other characteristics of the whole study area in a relatively fine manner. Intake Sluice and other hydraulic engineering parameters are obtained through the design drawings, and the actual value after the implementation of the project is consistent.

Based on the model of urban waterlogging in Dongying city center, this paper simulates the process of stage-discharge in section of Dengzhou section of Guangli River. In the Swan Lake Flood Storage and Detention Area, the water level and discharge process of Dengzhou Road section of Guangli River were used as the inflow for scheduling simulation.

2.3. Model Setup

In this paper, TELEMAC-2D hydrodynamic model is used to simulate the inundation of Swan Lake flood storage and detention area in Dongying City. Telemac-Mascaret model is an open source one, two and three-dimensional hydraulic modeling system of rivers, estuaries and coasts developed by the National Laboratory of Hydraulics and the Environment in France. The Navier-Stokes equations are solved using finite element numerical methods. TELEMAC-2D is a two-dimensional module in Telemac-Mascaret, which can be used to solve two-dimensional Saint-Venant's equation and simulate two-dimensional free surface flow [16, 17]. TELEMAC-2D uses finite element method to solve two-dimensional shallow water equations, and its basic equations are as follows [18, 19]:

$$\frac{\partial \mathrm{h}}{\partial t}+\frac{\partial (hu)}{\partial x}+\frac{\partial (hv)}{\partial y}=0 \tag{1}$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-g\frac{\partial Z}{\partial x}+F_x+\frac{1}{h}div(hv_e\nabla u) \tag{2}$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-g\frac{\partial Z}{\partial y}+F_y+\frac{1}{h}div(hv_e\nabla v) \tag{3}$$

The influence of Coriolis force and wind resistance is not considered in the calculation of source term, and the bottom friction term is calculated by Manning formula:

$$F_x = -\frac{1}{\cos(\alpha)}\frac{gm^2}{h^{\frac{4}{3}}}u\sqrt{u^2+v^2} \tag{4}$$

$$F_y = -\frac{1}{\cos(\alpha)}\frac{gm^2}{h^{\frac{4}{3}}}v\sqrt{u^2+v^2} \tag{5}$$

In the formula, u and v represent velocity in x and y directions respectively; t is time; h is water depth; Z is water level; v_e is effective viscosity coefficient; g is gravitational acceleration; F_x and F_y are resistance components in x and y directions respectively; m is Manning coefficient; α is slope Angle; div is the symbol of divergence ; ∇ is the symbol of gradient operation.

In this study, V7P2 version in TELEMAC-2D was used for flood simulation. BlueKenue software is used to divide the study area into unstructured triangular grids. The intake sluice and river channel are finely divided. The intake sluice grid is 1m, the river grid is 10m, and the other submerged areas are 50m. A total of 58,792 grids, 29,666 nodes, with a resolution of 30m.The inlet conditions were set at the entrance, the rest were set as solid boundary conditions, the initial water depth was set as 1m, the simulation duration was 48h, and the time step was 0.5s. On the basis of scientific generalization of the study area to a certain extent, a two-dimensional hydrodynamic model of Swan Lake flood storage and detonation area was established to simulate the inundation of Swan Lake area. In the simulation process, Dongsi Road, Xuzhou Road and Dongqi Road were named as 1#, 2#and 3# water intakes respectively for convenience of recording, and the inflow process was set.

3. Results and Discussion

Under three different rainfall scenarios: 1) Typhoon "Lekima", 2) Typhoon "Rumbia", 3)50-year return period rainfall event. Open three intake sluice at the same time and open only one intake sluice respectively under the combined scheme. The simulated stage-discharge process is shown in Figs. 2, 3 and 4. The following conclusions can be drawn from the analysis of the process diagram.

The change range of water level before the Intake Sluice is small (the maximum increase is about 0.6m), which makes the water level of Guangli River controlled within the safe range. The reason is that when the water level of the river in front of the sluice rises, it is necessary to discharge water through the sluice gate to ensure that the water level of the river is below the safe water level. The flood storage and detention area behind the sluice is mainly used to divide and detain the flood water, so the water level varies greatly. At the same time, the inflow of the water intake changes with the whole rainfall process. When the rainfall is large, the inflow of the water intake increases; while when the rainfall is small, the inflow of the water intake decreases. Therefore, the variation of the water level behind the intake sluice is similar to the rainfall process.

The total amount of inflow under plan A is shown in Table 1. The total inflow of typhoon "Rumbia", "Lekima" and the 50-year return period rainfall scenario were respectively 4.51, 4.70 and 4.01 million m^3. The total amount of inflow under plan B is shown in Table 2. Under the typhoon "Rumbia", the total water intake of 1#, 2# and 3# was 1.22, 2.44 and 5.28 million $m^{3,}$ respectively. Under Typhoon "Lekima", the total water intakes of 1#, 2# and 3# are 1.17, 2.68 and 5.68 million m^3, respectively. Under the 50-year return period rainfall scenario, the total water intakes of 1#, 2# and 3# are 1.33, 2.62 and 5.74 million m^3, respectively. It can be seen that, in the whole simulation stage, the total inflow of each combination scenario does not exceed the water storage capacity of the flood storage and detention area (28 million m^3). By comparing the total inflow of the corresponding sluice under plan A and B, it can be seen that the total inflow of 1#, 2# and 3# under plan B is greater than that under plan A. In Plan B, the total amount of each inlet is 3#> 2#> 1#, indicating that the 3# intake sluice has strong flood control ability. In Plan A, the total amount of inlet water at 1#, 2# and 3# is not significantly different, indicating that the three intake sluices can well adjust and work together to separate flood water and reduce their respective inlet pressure during flood season.

Table 1. Total inflow volume in 48 hours under the condition of simultaneously opening three water intakes (10^4m^3).

	Rumbia	**Lekima**	**50-year-return**
123_1#	136	126	146
123_2#	127	126	115
123_3#	189	217	141
Total volume	451	470	401

Table 2. Total inflow volume in 48 hours under the condition of opening only one water intake (10^4m^3).

	Rumbia	**Lekima**	**50-year-return**
1#	122	117	133
2#	244	268	262
3#	528	568	574

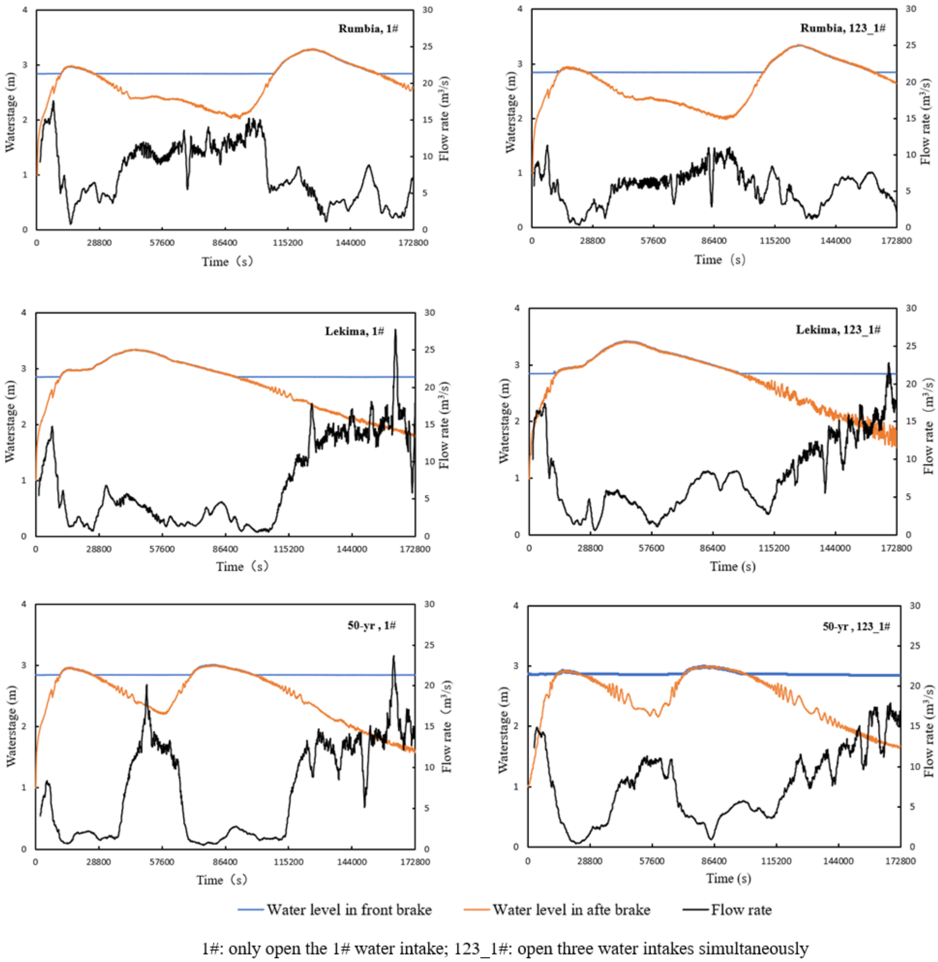
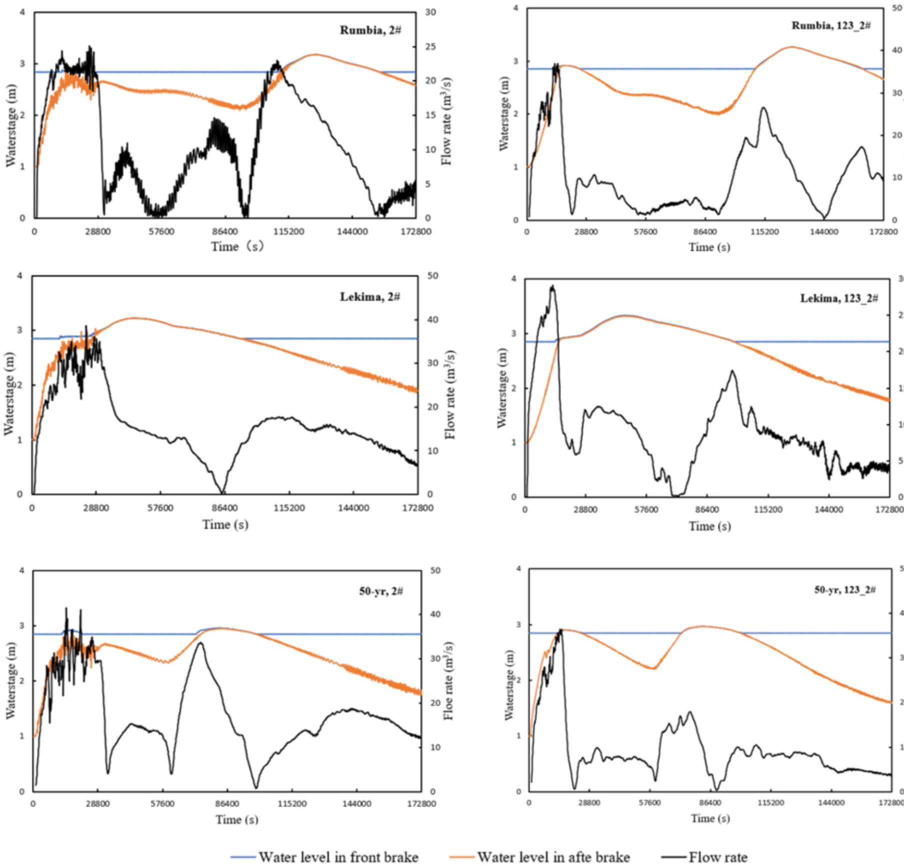
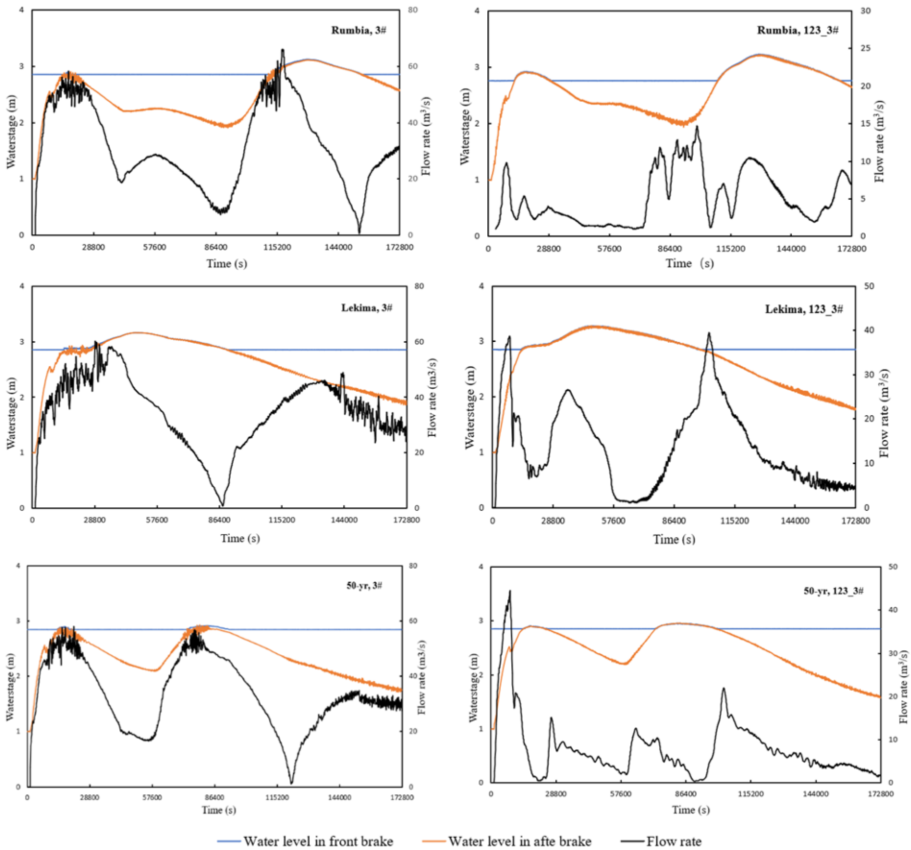


Fig. 2. Stage discharge curve of 1# intake sluice under different combination scenarios.



2#: only open the 2# water intake; 123_2#: open three water intakes simultaneously

Fig. 3. Stage-discharge curve of 2# intake sluice under different combination scenarios.



3#: only open the 3# water intake; 123_3#: open three water intakes simultaneously

Fig. 4. Stage-discharge curve of 3# intake sluice under different combination scenarios.

In plan A, typhon "Rumbia" scenario, the maximum flow rate of 1#, 2# and 3# water intakes are 11, 36 and 15m^3/s, and typhon "Lekima" scenario, The maximum flow rate of 1#, 2# and 3# water intakes are 23, 29 and 40m^3/s, respectively, and the maximum flow rate of 1#, 2# and 3# water intakes are 19, 37 and 47m^3/s under the 50-year return period rainfall scenario. In plan B, typhon "Rumbia" scenario, the maximum flow rate 1#, 2# and 3# water intakes are 17, 25 and 68m^3/s; Under the scenario of typhon "Lekima", the maximum flow rate of 1#, 2# and 3# water intakes are 28, 38 and 58m^3/s, and the maximum flow rate of 1#, 2# and 3# water intakes are 24, 42 and 58m^3/s under the scenario of 50-year return period rainfall scenario. The maximum flow rate at the intake sluice under the two plans is shown in Table 3.

As can be seen from the Table 4, the water level in front brake under the plan A and B is "Lekima" >"Rumbia"> 50-yr. In plan A, under the scenario of typhoon "Lekima", the water level in front brake of 2# is 3.42m, which is about 0.48m higher than that before the rainfall. In plan B, the minimum water level before sluice 3# is 2.92m under the 50-year return period rainfall scenario, and the water level rises by about 0.07m compared with that before the rainfall. By opening the water sluice in the flood storage and detention area of Swan Lake, the water level of Guangli River can be effectively controlled below 3.3m, so as to ensure that the urban drainage system is not supported by the roof and maintain the normal drainage function.

Table 3. Maximum discharge of each water intake under different combination scenarios (m^3/s).

	Rumbia	Lekima	50-year	Design flow rate
1#	17	28	24	30
123_1#	11	23	19	30
2#	25	38	42	50
123_2#	36	29	37	50
3#	68	59	58	90
123_3#	15	40	47	90

Table 4. Highest water level of river under different combination scenarios (m).

	Rumbia	waterhead	Lekima	waterhead	50-yr	waterhead
1#	3.29	0.44	3.34	0.49	3.01	0.16
123_1#	3.35	0.5	3.42	0.57	3	0.15
2#	3.18	0.33	3.22	0.37	2.96	0.11
123_2#	3.26	0.41	3.33	0.48	2.97	0.12
3#	3.12	0.27	3.16	0.31	2.92	0.07
123_3#	3.22	0.37	3.28	0.43	2.96	0.11

4. Conclusions

(1) The simulation results show that under the scenario of Plan A, typhoon "Rumbia", "Lekima" and 50-year return period rainfall, the total amount of water inflow was 4.51, 4.70 and 4.01 million m^3, respectively. In Plan B, under the scenario of typhoon "Rumbia", the total amount of water intake at 1#, 2# and 3# was 1.22, 2.44 and 5.28 million m^3;

(2) The simulation results show that the maximum flow rate of 1#, 2# and 3# water intakes was 28, 42 and 68m^3/s, respectively, under all the setting schemes and rainfall scenarios, all of which do not exceed the design flow rate of the corresponding water intakes, which can ensure the flood separation under the premise of safe operation of the sluice.

(3) The simulation results show that the water level of Guangli River can be effectively controlled below 3.5m by opening the intake sluice in the Swan Lake flood storage and detention area, ensure that the urban drainage system is not supported by the roof and maintain the normal drainage function.

References

[1] Wang H, Mei C, Liu JH. Systematic construction pattern of the sponge city. Journal of hydraulic engineering. 2017; 48 (09),1009-1014,1022.

[2] Zhang JY, Song XM, Wang GQ, He RM, Wang Xiaojun. Development and challenges of urban hydrology in a changing environment: I: Hydrological response to urbanization. Advances in water science. 2014; 25 (04), 594-605.

[3] Ab A, Akt B, Gm C, Sk A, Sks D, Bu E, Sa FJQSA. Climate vulnerability and economic determinants: Linkages and risk reduction in Sagar Island, India. A geospatial approach. 2021.
[4] Qiu BX. The connotation, approach and prospect of sponge city (LID). Town and Country Construction 2015.
[5] Liu JH, Li ZJ, Mei C, Wang KB, Zhou GN. Urban flood analysis for different design storm hyetographs in Xiamen Island based on TELEMAC-2D. Chin Sci Bull. 2019; 64 (19), 2055-2066.
[6] Bach PM, Rauch W, Mikkelsen PS, Mccarthy DT, Deletic AJEM. Software, A critical review of integrated urban water modelling – Urban drainage and beyond. 2014; 54 (apr.), 88.
[7] Chen X, Ji P, Wu YH, Zhao YJ, Li Z. Coupling simulation of overland flooding and underground network drainage in a coastal nuclear power plant. 2017;325.
[8] Huang GR, Wang X, Huang W. Simulation of rainstorm water logging in urban area based on InfoWorks ICM Model. Water Resources and Power. 2017; 35 (02), 66-70,60.
[9] Gao K, Yang ZY, Gao XC, et al. A review of the evaluation methods of urban flood loss. Water Resources and Hydropower Engineering. 2021, 52(4): 57-68.
[10] Choe YWJW. A study on urban inundation using SWMM in Busan, Korea, using existing dams and artificial underground waterways. Water. 2021; 13(12).
[11] Hosseinzadehtalaei P, Ishadi NK, Tabari H, Willems PJJOH. Climate change impact assessment on pluvial flooding using a distribution-based bias correction of regional climate model simulations. Journal of Hydrology. 2021; 598.
[12] Jiang W, Yu J. Impact of rainstorm patterns on the urban flood process superimposed by flash floods and urban waterlogging based on a coupled hydrologic–hydraulic model: A case study in a coastal mountainous river basin within southeastern China. Nature Hazards, 2022.
[13] Tabari H, Asr NM, Willems PJJOH. Developing a framework for attribution analysis of urban pluvial flooding to human-induced climate impacts. Journal of Hydrology. 2021; 598 (6926), 126352.
[14] Wu M, Wu Z, Ge W, Wang H, Jiang MJJOH. Identification of sensitivity indicators of urban rainstorm flood disasters: A case study in China. Journal of Hydrology. 2021, 599.
[15] Zhu CH, Xia JQ, Chen Q. SWMM-Based urban flood modelling and risk evaluation. Catastrophology. 2018(02);224-230.
[16] Briere C, Abadie S, Bretel P, Lang PJCE. Assessment of TELEMAC system performances, a hydrodynamic case study of Anglet, France. 2007; 54 (4), 345.
[17] Jean-Charles; Galland; Nicole; Goutal; and Jean-Michel; Resources, H. J. A. i. W., TELEMAC: A new numerical model for solving shallow water equations. 1991.
[18] Mei C. Development of a coupled urban hydrological-hydrodynamic model and its application. 2019.
[19] China, N. B. o. s. o. t. P. s. R. o., Statistical bulletin of the People's Republic of China on National Economic and Social Development in 2019. 2019, (3).