Study on the optimal operation of urban combined drainage channel box

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Abstract. This paper optimizes the operation mode of the combined drainage channel box sluice in H river basin of a city in south China to solve the problem of frequent sluice opening. Based on the InfoWorks ICM software, the hydraulic model of drainage system of the river basin was established, the measured rainfall and liquid level were screened, the model parameters were determined by using the rainfall data of medium and heavy rain, and the model was verified by using the rainfall data of heavy rain. The optimal liquid level is obtained by analyzing and comparing the simulation results. The simulation results are basically consistent with the actual precipitation. After optimization, the optimal liquid level of the combined drainage channel box sluice gate increased by 0.8m compared with the manually operated maximum liquid level. After the operation mode of sluice is optimized, the annual sluice opening times are reduced by 78%. After the experience, the InfoWorks ICM hydraulic model has high reliability, and the optimal sluice opening liquid level can be obtained through simulation analysis, which can more effectively prevent waterlogging and reduce river pollution.

1. Introduction
InfoWorks ICM hydraulic model accurately simulates the interaction between urban drainage system and receiving water surface. The GIS spatial analysis system is seamlessly connected with the one-dimensional model of the drainage system, and the construction of the two-dimensional model of the study area is completed [1-2]. Based on the InfoWorks ICM model, the author uses the measured rainfall and online monitoring of the liquid level to simulate the hydraulic condition of the confluent drain box, optimize the opening level of the sluice gate, and prevent waterlogging and reduce pollution.

2. Model establishment

2.1 Introduction to drainage system
There is a confluent drainage system in the river basin H of a city in south China. Sewage and rainwater flow into the confluent drainage channel box through the main drainage pipe, and the outlet gate is set at the end of the channel box. When the liquid level in the channel box reaches a certain height, the outlet gate shall be opened to discharge the confluent sewage into the river. The drainage system in this basin is shown in figure 1.

2.2 Establish InfoWorks ICM hydraulic model
A one-dimensional model of drainage system was established based on the relevant data of drainage pipe network, gate station, pumping station and river-stream drainage in the basin, etc. The GIS spatial analysis tool was used to input the surface elevation and contour lines to generate the basin geographical model, which was coupled with the one-dimensional model of drainage system to build the two-dimensional InfoWorks ICM hydraulic model of drainage system[3-4].

3. Model verification
Online monitoring and data collection of rainfall and liquid level at each liquid level monitoring point were conducted in the drainage network of the basin in real time, and a hydraulic model of the drainage network was established[5]. Then the simulated data and the corresponding measured data were compared and analyzed to determine the model parameters and verify them.

3.1 Dynamic data monitoring

3.1.1 Selection of monitoring points. Query the historical flooding points in the confluence drainage canal area, select liquid level monitoring point 2, liquid level monitoring point 3 and liquid level monitoring point 4 as waterlogging monitoring points, and the well depths are 2.3m, 2.5m and 2.8m, respectively. Liquid level monitoring point 1 is the liquid level monitoring point in front of the sluice. There is a rainfall monitoring point in the central area of the catchment area of the confluent drain box. The installation location of each monitoring point is shown in figure 1.

3.1.2 Data collection and collection equipment. The collected data includes rainfall and liquid level. The rain gauge uses a triggered dump bucket rain gauge produced by Beijing Huayun for measuring rainfall in a certain period of the river basin. The liquid level gauge uses the pressure type liquid level gauge provided by Ambrella manufacturer to measure the height of the free water surface in the
inspection well or pipeline.

3.2 Rainfall data screening
It is not necessary to open the sluice when the rainfall grade is light rain. When the rainfall level is above heavy rainstorm, the combined drainage canal sewage and landscape water will be discharged in advance. At this time, the optimization space of sluice level is limited, so the optimization of light rain, large rainstorm and extraordinary rainstorm will not be considered. In the spring and summer rainfall period from March to July, 2 groups of measured moderate rain, heavy rain and rainstorm rainfall data were selected[6]. Among them, the model parameters were determined with the rainfall data of medium rain and rainstorm, and the reliability of the model was verified with the rainfall data of heavy rain. The selected measured rainfall and the liquid level data of each monitoring point under different rainfall are shown in Table 1.

| Rainfall number | Rainfall level  | Rainfall/mm | Liquid level/m |
|-----------------|----------------|-------------|----------------|
| 1               | Moderate rain  | 10.1        | 1.04           |
| 2               | Heavy rain     | 22          | 1.81           |
| 3               | Rainstorm      | 40          | 2.32           |
| 4               | Moderate rain  | 14.5        | 1.38           |
| 5               | Heavy rain     | 18          | 1.62           |
| 6               | Rainstorm      | 65          | 1.94           |

3.3 Model parameter adjustment and checking
Peak level and peak time were used as the comparative index. The middle and heavy rain rainfall data were input into the model for operation simulation, compared with the simulation results and the measured data, checked the pipe network information and the records of gate opening, and locally adjusted the distribution of runoff coefficient and water collecting area. Then the heavy rain data was input into the model for operation simulation to further test the accuracy of the model simulation output results. The comparison between the simulation results and the measured data is shown in Table 2.

| Rainfall serial number | Monitoring stations serial number | Liquid level/m |
|------------------------|----------------------------------|----------------|
|                        |                                  | The measured   | Simulation    |
| 1                      | 1                                | 1.81           | 1.84          |
| 2                      | 2                                | 1.39           | 1.42          |
| 3                      | 3                                | 1.33           | 1.32          |
| 4                      | 4                                | 0.96           | 0.97          |
| 1                      | 1                                | 1.62           | 1.62          |
| 2                      | 2                                | 1.2            | 1.09          |
| 5                      | 3                                | 0.91           | 0.92          |
| 4                      | 4                                | 0.75           | 0.76          |

The relative error between the measured value and the simulated value of the liquid level of the monitoring point is less than 10%. The model can simulate the actual situation well, so it is considered that the verification is completed.

4. Evaluation of current operation status of sluice
According to the opening record of the sluice gate, the opening level and the level of corresponding monitoring point 1 are shown in Table 3.
Table 3. Opening and closing status of drain gate

| Rainfall number | State of the gate | Open brake level /m | Monitoring point 1 liquid level /m |
|-----------------|-------------------|---------------------|-----------------------------------|
| 1               | closed            | Not opened          | 1.04                              |
| 2               | open              | 1.70                | 1.81                              |
| 3               | open              | 2.30                | 2.32                              |
| 4               | closed            | Not opened          | 1.38                              |
| 5               | closed            | Not opened          | 1.62                              |
| 6               | open              | 1.94                | 1.94                              |

It can be seen from table 3 that under the rainfall conditions of No. 1, No. 4 and No. 5, the gate was not opened, the liquid level of each monitoring point was lower than the ground. Under the rainfall conditions of No. 2, No. 3 and No. 6, the gate was opened, and the water flooding risk of each waterlogging monitoring was shown in table 4.

Table 4. Risk analysis data of water immersion at waterlogging monitoring points

| Rainfall number | Monitoring point number | Water level at highest level distance from the ground /m |
|-----------------|-------------------------|--------------------------------------------------------|
| 2               | 2                       | 0.91                                                   |
|                 | 3                       | 1.17                                                   |
|                 | 4                       | 1.84                                                   |
|                 | 2                       | 0.41                                                   |
| 3               | 3                       | 1.31                                                   |
|                 | 4                       | 1.88                                                   |
|                 | 2                       | 0.74                                                   |
| 6               | 3                       | 1.77                                                   |
|                 | 4                       | 2.19                                                   |

According to table 1, table 3 and table 4: Under different rainfall conditions, the height of water surface from the ground in well 2 is the lowest, which is the most unfavorable point. Under the No. 2 rainfall condition, when the liquid level of sluice is 1.7m, the distance between the water surface and the ground at the highest liquid level of each waterlogging monitoring point is 0.91m. Under the No. 3 rainfall condition, when the liquid level of sluice opening is 2.3m, the minimum distance between the water surface and the ground at the highest liquid level of each waterlogging monitoring point is 0.41m, and there is no flooding risk. Under the No. 6 rainfall condition, when the sluicing level is 1.94m, the water level below the highest level of the waterlogging monitoring point is at least 0.74m away from the ground. It can be seen that the manual operation of the sluicing gate is slightly conservative, and there is still room for optimization of the sluicing level.

5. Optimization and simulation of sluice opening liquid level

The principle of optimizing sluicing level is: on the premise of avoiding waterlogging, raise sluicing level as much as possible, reduce sluicing times, so as to reduce pollution.

5.1 Selection of rainfall and determination of flood risk limit

By comparison, 4 groups of real-time monitoring rainfall data with high rainfall and high liquid level of monitoring points were selected from February to July during the spring and summer rainfall period in this city, and 5 groups of rainfall data in the rain recurrence period were P=0.25, P=0.5, P=1, P=2 and P=5, and the rainfall lasted for 120min were optimized and simulated. The selected rainfall data used to optimize the simulation is shown in table 5.
Table 5. Rainfall data for optimization simulation

| Rainfall number | Rain return period | 12h rainfall /mm | The rain type    |
|-----------------|--------------------|------------------|-----------------|
| 7               |                    | 32.0             | Rainstorm       |
| 8               |                    | 41.8             | Rainstorm       |
| 9               |                    | 80.2             | large rainstorm |
| 10              | P = 0.25           | 41.8             | Rainstorm       |
|                 | P = 0.5            | 53.4             | Rainstorm       |
|                 | P = 1              | 65.9             | Rainstorm       |
|                 | P = 2              | 78.3             | large rainstorm |
|                 | P = 5              | 95.5             | large rainstorm |

According to the "Outdoor Drainage Design Code" (gb50014-2006), in the process of fluid level optimization and simulation of sluice opening, the control standard of water flood prevention limit is: the fluid level of waterlogging point should be at least 0.2m lower than the corresponding ground.

5.2 Optimization simulation of sluicing level
The liquid level of sluice opening under the condition of No. 9 heavyrainstorm was optimized and simulated. Set the opening liquid levels to 2.0m, 2.5m and 3.0m respectively, and input rainfall data for hydraulic simulation. Use the longitudinal section view function of the pipeline and the node fluid in the ICM hydraulic model software Position change curve graph function, analyze the highest water level in the well of themost unfavorable monitoring point 2. When the opening level is 2.5m, the highest water level in the monitoring point 2 well is 0.51m away from the ground; when the opening level is 3.0m, the highest water level in the monitoring point 2 well 0.03m from the ground. Therefore, when the gate opening level is between 2.5 ~ 3.0m, the highest water surface in the well of monitoring point 2 is 0.20m away from the ground. After detailed analysis in the interval of 2.5~3.0m, it can be obtained by the same method that the critical level corresponding to this critical state is 2.8m. Under this rainfall condition, when the optimal opening liquid level is 2.8m, the water level in well 2 of the monitoring point is 2.1m, 0.2m from the ground, the water level in the well 3 of the monitoring point is 1.1m, 1.7m from the ground, and the monitoring point 4 The water level in the well is 0.7m and 1.8m above the ground. At this time, the most unfavorable hydraulic profile of the pipeline is shown in figure 2 and figure 3.

![Hydraulic longitudinal profile of the optimal sluice level pipeline at monitoring points 1 and 2](image-url)
5.3 Simulation results of sluicing level optimization

Through the optimized simulation, the optimal sluice level corresponding to each rainfall can be obtained (see Table 6).

| Rainfall number | Rain return period | The actual flood liquid level/m | The optimal flood liquid level/m |
|-----------------|--------------------|-------------------------------|---------------------------------|
| 7               |                    | 1.80                          | Without breaking                 |
| 8               |                    | 1.30                          | Without breaking                 |
| 9               |                    | 1.40                          | 2.80                            |
| 10              |                    | 1.90                          | 2.87                            |
| P = 0.25        |                    | 2.00                          | 2.90                            |
| P = 0.5         |                    | 2.00                          | 2.85                            |
| P = 1           |                    | 2.00                          | 2.80                            |
| P = 2           |                    | 2.00                          | Open the sluice ahead of time    |
| P = 5           |                    | 2.00                          | Open the sluice ahead of time    |

As can be seen from Table 6, under the rain conditions of No. 7 and No. 8, the sluice gate is always closed, and the simulation result is that no waterlogging occurs, further illustrating that there is a lot of room for optimization of the opening and closing control of the sluice gate.

| Open brake level /m | Highest liquid level /m Monitor point 2 | Monitor point 3 | Monitor point 4 |
|---------------------|----------------------------------------|-----------------|-----------------|
| 2.0                 | 2.23                                   | 2.37            | 1.25            |
| 2.5                 | 2.25                                   | 2.38            | 1.25            |
| 3.0                 | 2.27                                   | 2.45            | 1.25            |

| Open brake level /m | Highest liquid level /m Monitor point 2 | Monitor point 3 | Monitor point 4 |
|---------------------|----------------------------------------|-----------------|-----------------|
| 2.0                 | 2.45                                   | 2.9             | 1.34            |
| 2.5                 | 2.45                                   | 2.9             | 1.34            |
| 3.0                 | 2.46                                   | 3               | 1.34            |

It can be seen from Table 7 and Table 8 that under heavy rain conditions with recurrence periods of P = 2 and P = 5, if the water level before the gate reaches 2.0m and above, the sluice gate opens, and the three waterlogging monitoring points The maximum liquid level is basically the same. Because the level of the river surge has been greatly increased, the discharge effect of the sluice gate is greatly reduced. Therefore, according to the weather forecast, it is necessary to conduct pre-discharge scheduling for the opening of the confluence drainage canal according to the upcoming heavy rain or
extra heavy rain. The remaining 5 types of rainfall, That is, the optimal opening liquid level corresponding to heavy rain and the following rains is higher than 2.8m, so the opening liquid level is finally optimized to 2.8m.

6. Analysis of optimization results
In the spring and summer rainfall period from March to July, 9 rainfall events opened the sluice. Based on the simulation of InfoWorks ICM model, the sluice level was 2.8m after optimization, which was 0.8m higher than the manually operated maximum sluice level 2m. After optimization, the number of rain fields opened by the sluice gate is 2, and the number of sluice opening is reduced by 7. The equivalent ratio is converted to the annual sluice opening reduction ratio of 78%.

7. The conclusion
Through the establishment of a two-dimensional hydraulic model of InfoWorks ICM for a drainage system in the H watershed of a city in south China, it is concluded that the optimal opening water level of the combined drainage channel box sluice is 2.8m and the maximum liquid level error is 0.2m. On the premise of preventing waterlogging, the opening times of the sluice can be reduced and the sewage discharge can be reduced.

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