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Study on the Application of HEC-RAS in the Regulation of Small and Medium-Sized Rivers in Cities

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Abstract. Problems such as waterlogging and poor flood discharge capacity in urban rivers make the reinforcement of urban river embankments gradually put on the schedule of water conservancy work. Therefore, this paper mainly introduces the foreign free software HEC-RAS and its calculation principle. Taking the county section of Mangpian River's Comprehensive Treatment Project in Lincang, Yunnan Province as an example, we carry out the simulation research and application of the river water surface line, and compare the simulation calculation results with the design calculation values. The two results agree well, which indicates that HEC-RAS has strong operation ability. It is expected that HEC-RAS will be further studied in the future. The research results can better serve the engineering practice.

Keywords. Urban Rivers, HEC-RAS, water surface line, research, engineering practice

1. Introduction

Urban river channel is the lifeblood of a city, and its primary task is flood control. With the development of economy and urbanization, urban waterlogging, poor flood discharge capacity of rivers and serious water pollution make it an urgent task for water conservancy workers to harness urban rivers. In the management of small and medium-sized rivers in cities, the determination of engineering scale is an important part of design. The method to determine the height of the dike is: firstly, determine the design flood standard according to the protected object and the grade of the dike; secondly, determine the flood flow and flood level according to the design standard; finally, consider a certain safety superelevation of the dike to draw up the height of the dike [1]. The calculation of natural river water surface line plays an important role in the flood control of urban rivers. The manual calculation method of hydraulics is common in river engineering treatment, and the workload is heavy and tedious. We simulate the actual project through HEC-RAS, a foreign free software, to provide ideas for workers and guide river engineering better.

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2. Introduction and Calculation Principle of HEC-RAS Software

2.1. Introduction of HEC-RAS Software

HEC is a hydrological and hydraulic software developed by the famous Hydrologic Engineering Center in the United States. It includes HEC-1, HEC-2, HEC-3, HEC-4, HEC-5, HEC-6, HEC-FFA, HEC-RAS, C-ResSim, etc. HEC-RAS (River Analysis System, River Hydraulic Analysis Model) [2-4] is a complete hydraulic simulation model, which is famous for its powerful simulation ability and has been widely praised and applied abroad. HEC-RAS model includes: graphical interface (GUI, graphical user interface), independent hydraulic analysis module, data storage and management module, image and reporting tools, etc [5].

2.2. Calculation Principle of HEC-RAS Software

HEC-RAS model can be used for one-dimensional hydraulic simulation calculation of natural or artificial river networks, and one-dimensional steady flow and unsteady flow hydraulic analysis models. One-dimensional flow movement is mainly expressed by Saint-Venant equations, which are partial differential equations describing the movement law of unsteady gradual flow in open channels [6]. They are composed of continuous equations and momentum equations:

Continuity equation

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial s}=0 \tag{1}$$

Momentum equation

$$\frac{1}{\mathrm{g}}\left(\frac{\partial v}{\partial t}+v\frac{\partial v}{\partial \mathrm{s}}\right)+\frac{\partial \mathrm{h}}{\partial s}-i+J_f=0 \tag{2}$$

Where, *A* is the cross-sectional area (m); *T* is time (s); *Q* is the flow rate (m^3/s); *S* is the process (m); *H* is the average water depth of the section (m); *V* is the average cross-section velocity (m/s); *I* is the river gradient; J_f is the gradient of the head loss along the way, also known as the friction ratio gradient; *G* is the acceleration of gravity.

3. Engineering Example Application

3.1. Project Overview

Mangpian River is located in the southwest of lincang, Yunnan Province, and belongs to the first-class tributary of Xiaohei River and Lancang River system. The regulation section is located in Gengma County, the middle reaches of Mangpian River, the first tributary of Xiaohei River. The river channel is responsible for flood control in Gengma County. The comprehensive regulation length is 2.84 km, the average gradient of the riverbed is 5.391‰, and the bending coefficient is 1.55. The flood control standard for flood control reaches is once every 20 years (P = 5%), the flood standard during the construction period is once every five years (P = 20%). During the river control, the designed river section is a compound section, and M7.5 mortar masonry gravity retaining wall is adopted at the normal water level (P=20% in design). The retaining wall rises to the bottom of the river by 1.0 m~1.5 m, which meets the requirements of river scour resistance. Ecological concrete bricks are used for slope protection above the normal water level, and the top of the dike is determined by the flood level once every 20 years and the safety superelevation. The following focuses on the application of HEC-RAS model to simulate the water surface line of the river channel.

3.2. Numerical Simulation of HEC-RAS

3.2.1. Generalization of Geometric Characteristics of River Channel

Run HEC-GeoRAS in ArcView GIS environment, pre-process the river channel, generalize the river channel data, create river channel centerline, riverbank, river path centerline, land use types and other layers, establish river channel GIS data, and connect these data to HEC-RAS. At the same time, you can see the basic geometric attributes of the constructed river network, including: river direction, river network shape, river section, Manning coefficient of different land use types. Figure 1 is a generalized map of geometric characteristics of Mangpian River. The river section is divided into 13 sections, and the water surface line of the river is calculated from the downstream to the upstream. The distance of the river section is mainly determined by topography and water flow pattern, etc. The value of manning coefficient (roughness) n in the section data mainly refers to the HEC-RAS user manual for describing the maximum, normal and minimum roughness of different types of rivers to draw up the roughness of different river sections.

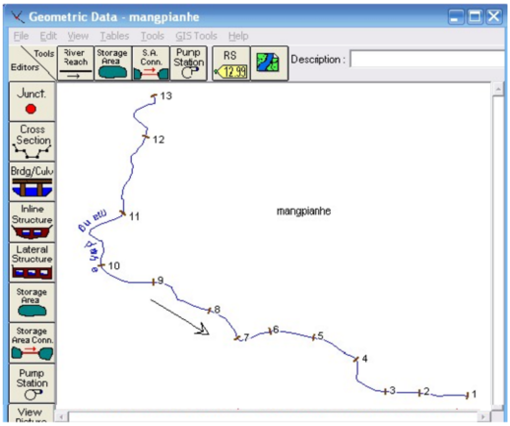

Figure 1. Generalization diagram of geometric characteristics of Mangpian River.

3.2.2. Determination of the Initial Conditions of the Model

After saving the river channel data, we input the unsteady flow data in "Unsteady Flow Data", set two groups of flow, design flow and flood flow in dry season, and set the downstream boundary condition as the average slope of the river channel under normal water depth. The flow state of the river is mixed flow state. Finally, we run the program and check the results.

4. Results Analysis

Through the simulation calculation by HEC-RAS software, we can get the water depth along the flood channel of No.1 ~ No.13 River section once every 5 years and the water depth along the flood channel once every 20 years. The comparison results between the rechecked water depth of HEC-RAS and the original design water depth are shown in table 1 and table 2, in which the absolute error is the difference between the original design calculation value and the HEC-RAS numerical calculation value, and the relative error is the percentage of the absolute error and the original design calculation value.

Table 1. Recheck of water depth along the river course (flood with a frequency of 5 years).

Calculation section	Mileage (km+m)	Depth of water		Error	
		Original design calculation value /m	Numerical calculation value of HEC-RAS /m	Absolute error /m	Relative error /%
13	0+000.00	0.75	0.72	0.03	4.00
12	0+260.00	0.88	0.90	-0.02	-2.27
11	0+720.00	0.98	0.94	0.04	4.08
10	1+060.00	0.56	0.54	0.02	3.57
9	1+300.00	1.74	1.76	-0.02	-1.15
8	1+580.00	0.30	0.30	0.00	0.00
7	1+750.00	3.40	3.24	0.16	4.71
6	1+900.00	1.26	1.23	0.03	2.38
5	2+080.00	0.94	0.90	0.04	4.26
4	2+280.00	1.19	1.15	0.04	3.36
3	2+500.00	0.65	0.66	-0.01	-1.54
2	2+640.00	1.24	1.23	0.01	0.81
1	2+840.00	1.33	1.32	0.01	0.75

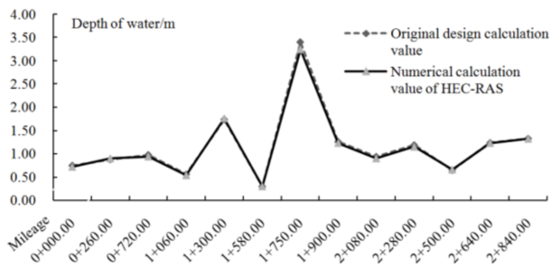

Figure 2. Comparison chart of recheck of water depth along the river course (flood once every 5 years).

From the comparative analysis of table 1 and figure 2, it can be seen that the relative error between the original design calculation value and HEC-RAS numerical calculation value is small under the condition of a five-year flood, the maximum value is only 4.71%, and most of the HEC-RAS calculation values are smaller than the original river channel calculation value. Only the HEC-RAS calculation values of section 12, section 9 and section 3 are larger than the original design calculation value, and the maximum difference among the three sections is -0.02. The relative error value is -2.27%, which indicates that the original design scheme of the river meets the basic requirements of the project. Figure 2 proves that the original design calculation value is in good agreement with the HEC-RAS numerical calculation value.

Table 2. Recheck of water depth along the river course (flood with a frequency of 20 years).

Calculation section	Mileage (km+m)	Depth of water: Original design calculation value /m	Depth of water: Numerical calculation value of HEC-RAS /m	Error: Absolute error /m	Error: Relative error /%
13	0+000.00	1.48	1.47	0.01	0.68
12	0+260.00	1.58	1.57	0.01	0.63
11	0+720.00	1.47	1.52	-0.05	-3.40
10	1+060.00	1.29	1.26	0.03	2.33
9	1+300.00	2.30	2.41	-0.11	-4.78
8	1+580.00	0.95	0.93	0.02	2.11
7	1+750.00	3.94	3.87	0.07	1.78
6	1+900.00	1.90	1.89	0.01	0.53
5	2+080.00	1.60	1.62	-0.02	-1.25
4	2+280.00	1.92	1.90	0.02	1.04
3	2+500.00	1.45	1.49	-0.04	-2.76
2	2+640.00	1.80	1.72	0.08	4.44
1	2+840.00	2.13	2.11	0.02	0.94

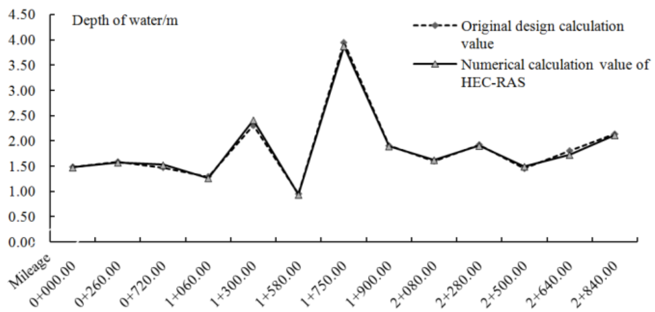

Figure 3. Comparison chart of recheck of water depth along the river course (flood once every 20 years).

From the comparative analysis of table 2 and figure 3, it can be seen that under the flood standard of 20-year return period, the relative error between the original design calculation value and HEC-RAS numerical calculation value is also small, with the maximum value being only -4.78%, and the HEC-RAS calculation value is larger than the original design calculation value only in four sections, namely, section 11, section 9, section 5 and section 3, and the numerical calculation values of other sections are all smaller than the original design calculation value. Similarly, it shows that the original design scheme of the river meets the engineering requirements. The design height of the 20-year flood plus the corresponding safety superelevation is the crest elevation. In the project, it can be considered whether to appropriately reduce the crest elevation to reduce the project cost according to the actual situation. Figure 3 also shows that the original design calculation value is in good agreement with HEC-RAS numerical calculation value.

5. Conclusions

In this paper, HEC-RAS commercial software is used by us, the water surface line of Mangpian River, an urban river channel, is calculated once every 5 years and once every 20 years, and the coincidence between the manual calculation value of the design scheme and HEC-RAS is analyzed. The research shows that the numerical simulation value of HEC-RAS meets the changing law, and the results are reasonable. Based on the characteristics of low investment, fast calculation and high use value of numerical simulation, it is expected that HEC-RAS will be further studied in the future, and its research results will serve engineering practice better.

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