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Application of Three-dimensional Modeling in a Hydrologic Test Reach

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Abstract To address the problem that the display effect of hydrologic test data was not intuitive, the three-dimensional modeling technology of a hydrologic test reach based on GIS technology was proposed. The reach of of the Yellow River around Lanzhou hydrological station was selected to study three-dimensional modeling. The elevation data of river was processed through three-dimensional model constructing, water surface modeling and three-dimensional animation demonstration by using ArcGIS Pro software. Based on the historical highest flood level data of the test reach on September 15, 1981, the real scene restoration was carried out based on the three-dimensional model, and the hydrological factors such as water depth and channel storage were analyzed. The three-dimensional modeling based on GIS technology can directly and realistically reflect the changes of topography and water surface of the test reach, and improve the application of hydrologic test results in flood control.

Key words Three-dimensional modeling; Hydrologic test; ArcGIS; Lanzhou hydrological station

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With the advancement of society and economy, coupled with scientific and technological progress, there is an increasing demand for enhancements in hydrological monitoring capabilities and service levels. Currently, scholars are investigating ways to enhance hydrological monitoring capabilities through information technology. For instance, Chen Chen *et al.*[1] used a UAV test system to study applications of hydrological monitoring. Based on the hydrologic test system developed in Java, Luo Yi *et al.*[2] implemented new data processing techniques, such as hydrological data compilation, flow calculation and analysis of water-level discharge relationship curves, achieving significant progress. Previous studies have mainly focused on using information technology to improve hydrological testing methods and the efficiency of hydrological data compilation, with test data predominantly displayed in two dimensions. There are few studies on the three-dimensional modeling and visualization technologies for hydrological test data. This paper utilizes GIS technology to conduct three-dimensional modeling of a hydrological test reach, enhancing the visualization and analytical capabilities of hydrological test outcomes, thereby further elevating the application level of these results.

1 Research data

This study focuses on the river segment from Zhongshan Bridge to Yuantong Bridge at the Lanzhou hydrological station on the Yellow River. The test reach features a straight channel, approximately 800 meters in length, with a rectangular cross-section. The water flow travels from west to east through the city, with the river surface width varying generally between 190 and 229 meters. The average longitudinal slope of the river segment is approximately 0.8‰. The riverbed consists of sand and pebbles, with relatively stable cross-sections. Both banks are protected by masonry revetments, and the flood protection standard for the embankment design is set for a 100-year flood event. This paper gathered measurement data from the study reach for the year 2022, encompassing both above-water and underwater topography. The above-water topography was measured using a Hi – Target RTK survey instrument, while the underwater topography was surveyed using a multibeam echosounder and sounding rod. The map scale used was 1 : 2 000, with the plane coordinate system based on the CGCS 2000 National Geodetic Coordinate System, and the vertical datum referenced to the 1985 National Height Datum.

The raw hydrologic test data are in .dwg format. These original line layer data are converted into .shp format files. A topological check is performed on the test data to identify errors such as line overlaps, dangling lines, and missing elevations. These topological errors are then corrected to prepare the data for three-dimensional modeling (Fig. 1).

Fig. 1 Digital line data of the reach of the Yellow River from Zhongshan Bridge to Yuantong Bridge

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2 Methods

ArcGIS is a popular mainstream geographic information system platform software, and is mainly used for creating, editing and managing geographic data, as well as spatial operation, analysis, modeling and mapping of geographic data. In this paper, ArcGIS Pro 2.5 was used to study the application of three-dimensional modeling for a hydrologically tested reach, mainly including the generation of three-dimensional models of the river channel, the production of water surface simulation maps, and three-dimensional animation demonstrations.

2.1 Generation of three-dimensional model of the river channel Convert the processed elevation line data of the test river segment into a polygon layer, which includes river channel elevation attribute information. In the 3D scene view of ArcGIS software, load the river channel elevation polygon layer data and use the elevation information to render the three-dimensional terrain of the river channel. Given the relatively minor topographic variations in the test segment, to enhance the 3D visualization effect, the elevation values are vertically exaggerated; in this study, the vertical exaggeration factor is set at 7.5 times. The layer is then displayed with graduated colors and overlaid with annotations for major landmarks. The three-dimensional model of the river channel for the Lanzhou hydrological station test reach is shown in Fig. 2.

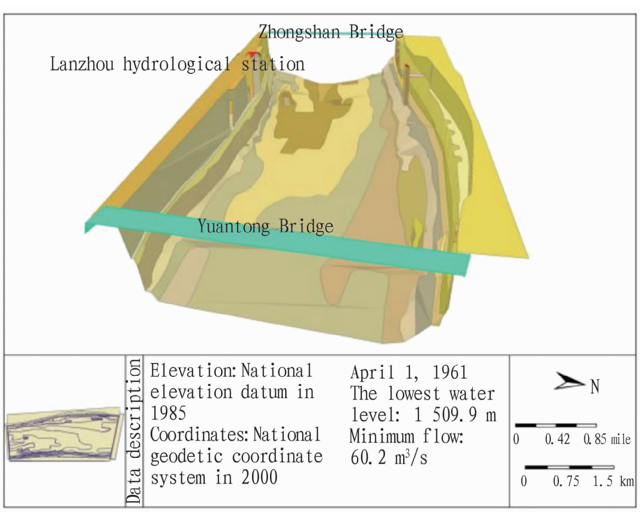


Fig. 2 Three-dimensional channel model of the test reach of Lanzhou hydrological station

2.2 Production of water surface simulation diagrams The river channel elevation surface layer is converted into a DEM raster dataset, where a color gradient is applied to represent varying water depths, thereby visualizing spatial variations in water depth. A water surface simulation map is constructed using the Model Builder[3], which iteratively generates water surface simulation maps for different water levels (Fig. 3). The specific steps are as follows:

(1) Create a model with the river channel DEM raster data as input and water surface simulation maps as output. The model incorporates a "For loop" iterator and "Raster Calculator".

(2) Parameter settings of "For loop" iterator: Based on the actual elevation distribution, the elevation of DEM raster data for this river reach has 94 grayscale levels. Set the start value of the "For loop" to 1, the end value to 94, and the increment to 1.

(3) In "raster calculator", Python statement Con ("%b63%" < %value%, "%b63%") was input, in which "b63" is DEM raster data; The statement means that within the river channel, if the DEM elevation is less than the current value in the "For Loop", return the elevation itself.

(4) Multiple water surface simulation maps were obtained by running the "For loop" (Fig. 4).

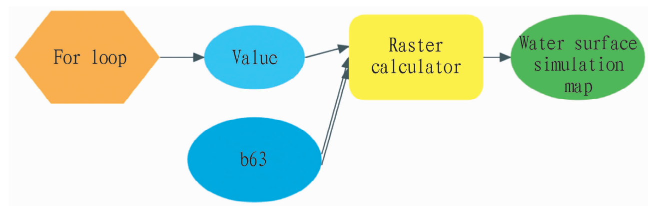


Fig. 3 Model construction of water surface simulation maps

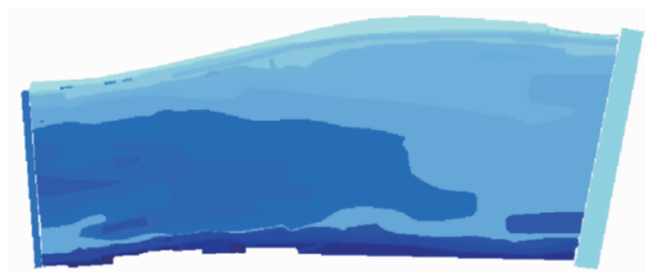


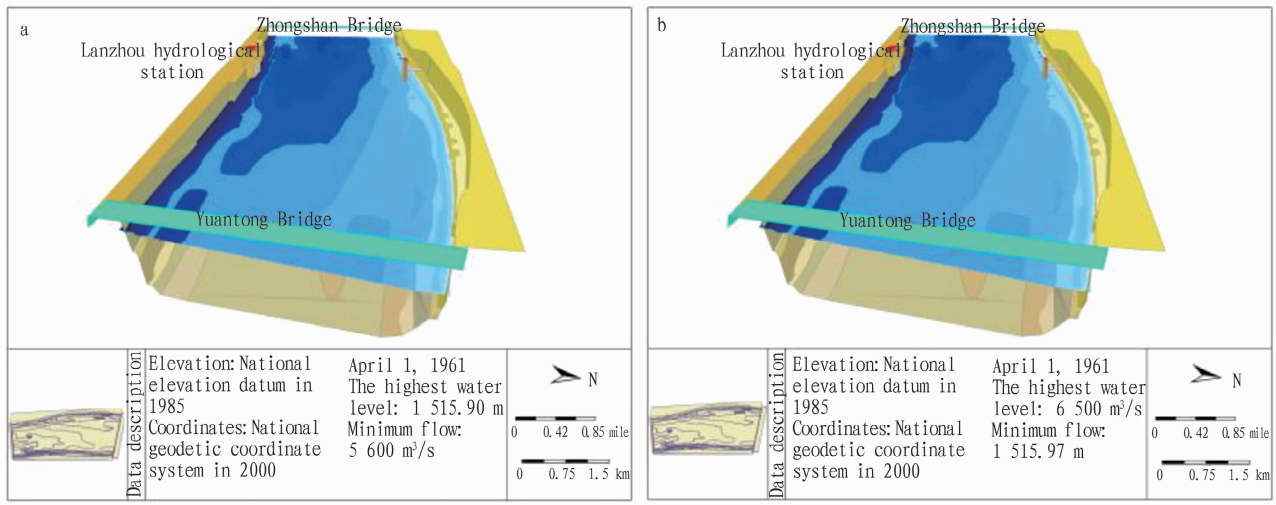
Fig. 4 Water surface simulation map

2.3 Three-dimensional animation demonstration The fundamental principle of demonstrating a three-dimensional water surface animation is to overlay various water surface simulation maps at different water levels onto a 3D river channel model, thereby illustrating the dynamic changes in water surface at different levels. Using ArcGIS software, load the 3D river channel model and water surface simulation maps for different water levels, then create a new layer group to contain all the water surface simulation maps. Create a group animation, select the layer group for water surface simulations, configure keyframe time intervals, layer visibility, and other playback parameters. Play the animation through the animation controller to demonstrate the changes in water surface at various levels.

3 Real scene restoration and simulation analysis

Using historical peak flood level data from the Lanzhou hydrological station, a real-scene simulation was conducted to depict the water surface conditions within the test reach, and these were compared with the flood protection water level standards for Lanzhou Municipal Government. According to historical records, the highest recorded flood level occurred on September 15, 1981, at 1 515.90 m with a corresponding flow rate of 5 600 m^3/s[4]. The flood protection standard flow rate for Lanzhou city is 6 500 m^3/s, corresponding to a water level of 1 515.97 m. The water level simulation map is shown in Fig. 5.

The three-dimensional river model established in this paper intuitively displays the condition of river channel in the case of the highest flood level measured in history, and the measurement of water depth and water surface width and the calculation of hydrological factors such as section area, river channel storage can be realized. The difference between the highest water level measured in the test reach and the corresponding water level of flood control standard in Lanzhou was 0.07 m. The maximum water depth of the section was 10.6 m, and the average water depth was 7.00 m. The river surface was 233 m wide, and the section area was 1 630 m^2, while the storage capacity of the channel was 1.2 million m^3.



Note: a. Highest water level on records; b. Flood control standard of Lanzhou Municipal Government.

Fig.5 Three-dimensional situation maps of the test reach of Lanzhou hydrological station

4 Conclusion

Using GIS three-dimensional modeling technology, three-dimensional modeling of the test reach around Lanzhou hydrological station was performed, and three-dimensional animations demonstrating changes in water surface at different levels were created. Through realistic restoration and simulation analysis of the historical peak flood level, the water surface conditions of the historical flood in the current river channel were depicted intuitively and realistically, and the process of flood changes was previewed. This provides robust support for decision-making and consultation related to flood and other emergency disaster events. Future studies should focus on integrating real-time hydrological observation data with results of oblique photogrammetry of the river channel, implementing online digital hydrological functions, and continuously enhancing the "four prevention" functions of hydrological stations.

References

[1] CHEN C, RONG JW, QIAO BC. Application of UNMANNED aerial vehicle test system in hydrological monitoring[J]. Water Resources & Hydropower of Northeast China, 2021(11): 69-70.
[2] LUO Y, ZHAO YD, WANG YS. Development and application on software for hydrological test system based on Java language[J]. Jilin Water Resources, 2020(11): 33-38.
[3] YAN L, ZHANG HL. ArcGIS: From foundation to actual combat[M]. Beijing: China Water Resources and Hydropower Press, 2007.
[4] Hydrological data of the Yellow River basin[G]//Hydrological Yearbook of the People's Republic of China: volume 4, 1981. Zhengzhou: Yellow River Water Conservancy Commission, 1982: 8, 200.