Research of great type reservoir storage calculation method based on the spatial information technology

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Abstract: It is very difficult to calculate the large-scale reservoir storage rapidly and accurately by the traditional calculating method of reservoir storage, and can't meet the request of the reservoir regulation. Based on the spatial information technology, this paper presents a new method of calculation of reservoir storage by gathering the precise terrain data of reservoir bottom and establishing reservoir watercourse DEM. Based on the method, the software system of reservoir storage calculation had been developed and used to calculate the static reservoir storage and dynamic reservoir storage of the Three Gorge Reservoir. The calculation results are quite accurate, which indicates that the method is feasible and can be promoted in the other large-scale reservoirs that have the terrain DEM data.

Key words: spatial information technology, static reservoir storage, dynamic reservoir storage, DEM, reservoir regulation

1. Introduction

Large-scale reservoir storage curve, including static reservoir storage and dynamic reservoir storage, is the basal data of the reservoir regulation and management. It relates with long-term benefits of reservoir. For the lake reservoir, reservoir regulation can be satisfied by carry on the flood control computation using the static storage curve. However, For the large-scale river type reservoir, because its water surface isn't the level, its reservoir storage is composed of the static reservoir storage below the horizontal and the wedge-shaped reservoir storage between its real water surface and the horizontal, and they are both concerned with all the processes in the reservoir flood control. Therefore, it's inaccurate and unfeasible by only utilizing the static reservoir storage curve and reservoirs regulation must make use of dynamic reservoir storage method. It is very difficult to calculate the large-scale reservoir storage rapidly and accurately by the traditional calculating method of reservoir storage, and can't meet the request of the reservoir regulation, mainly as a result of the calculating method of reservoir storage and technology's limits.

Based on the spatial information technology, rapidly calculating the static reservoir storage can be achieved by gathering the precise terrain data of reservoir bottom and establishing reservoir watercourse DEM and accurately simulating reservoir current terrain. For the large-scale river type reservoir, based on the reservoir watercourse terrain DEM, real-time calculating the dynamic reservoir storage can be realized by establishing 1-D unsteady river flow model and using the GIS component secondary development technology so that the real reservoir storage value can be got and instruct the reservoir regulation. It will have important significance because of its increasing the reservoir's economy and society benefits.

2. Reservoir terrain data's gathering and integration

The reservoir storage computational method is based on the high accuracy reservoir terrain DEM data. So firstly, it's essential for gathering the high accuracy reservoir terrain data and constructing the reservoir terrain digital elevation model (DEM). In order to guarantee the reservoir storage computational accuracy, the precision of DEM data usually must be quite high and should achieve the scale above 1:5000 as well.

2.1 Reservoir terrain data's gathering

The accurate reservoir aquatic terrain data can be got by digital photographic survey method and the reservoir underwater terrain data can be obtained by GPS and "water sonar" technology. Reservoir terrain data gathering scope: For the lake reservoir, only the terrain data below reservoir check flood stage need be gathered; for the river type reservoir, it's necessary for the watercourse terrain data of the corresponding frequency flood submergence scope, according to the actual reservoir flood control standard.

2.2 Reservoir terrain data's pretreatment and integration

Because the aquatic and underwater terrain data is obtained by the different technology, data format, sampling interval, coordinates system etc. are different and need carry on the unification and standardized processing. Firstly, the underwater DEM data need be reorganized by eliminating noise, unifying data format including the coordinates system, the height system, dividing belt standard and so on. And then the DEM data are integrated by splicing. Because the joint edges of the different frame's DEM data can have overlaps or cracks, the DEM data must be disposed as one by one frame in order to guarantee the data splicing seamless and smooth characteristic.

3. Static reservoir storage computational method

The static reservoir storage refers to storage volume below some water level. This paper uses the grid method based on the reservoir terrain DEM data to carry on the static reservoir storage computation. Its principle is as follows: The static reservoir storage below some reservoir water level can be obtained by taking the central point's elevation of DEM data's each grid as the grid's elevation and then summing cubage of these prisms composed of each grid and appointed the reservoir water level. The formula is as follows:

$$V(H)=\sum_{i=1}^{n} P_S \times (H-h_i) \quad ①$$

where, $V(H)$ denotes the static reservoir storage that water level equal H , m^3;

n is the number of DEM grid which elevation value is smaller than H;

H is elevation value of appointed reservoir water level, m;

h_i is the elevation value of grid which elevation value is smaller than H, m;

p_s is area of single grid, m^2. When the scale of DEM equal 1:5000, $p_s = 2.5 \times 2.5$.

The Specifically realizing process to be as follows:

(1) The data quantity of large-scale reservoir high accuracy's reservoir terrain DEM is very big, so they must be stored piecemeal. For the river type reservoir，only those data within watercourse are valid data and each DEM data possibly exists a lot of redundant data. Therefore, it's necessary to carry on the DEM data compression by using the lossless data compressing technique.

(2) The module of static reservoir storage computation had been developed by Visual C++6.0 and ArcEngine9.2, combining with the GIS component secondary development technology. The interface is shown in Figure 1.

Fig. 1 The interface of static reservoir storage computation's module

(3) According to the lowest water level, the highest water level and water level interval value that users input, the elevation of DEM each grid is input into the procedure in turn by using scan line seed filling algorithm. The corresponding static reservoir storage's values can be rapidly calculated by using the formula ①.

4. Dynamic reservoir storage computational method

The regulation of large-scale reservoir must use the dynamic reservoir storage curves to carry on the flood control computation. However, the dynamic reservoir storage hasn't only relation with the reservoir watercourse terrain, but also with inflow flood's composition, reservoir regulation's method, watercourse hydraulic characteristic and so on. So it's very difficult to calculate it. It has been realized in this paper that rapidly and exactly calculating the dynamic reservoir storage of large-scale river type reservoir, based on the spatial information technology and combining with the reservoir watercourse 1-D unsteady river flow model.

4.1 The computational principle of river type reservoir's dynamic reservoir storage

The computation includes two steps. Firstly, establish the reservoir watercourse 1-D unsteady river flow model in order to calculate the water surface profile in different flow condition; Secondly, using the GIS component secondary development technology and combining with the water surface profile data, the water surface DEM of reservoir watercourse can be established by spatial interpolation method. Finally, the dynamic reservoir storage value can be attained by summing cubage of these prisms composed of water surface DEM and bottom of reservoir watercourse.

4.2 watercourse 1-D unsteady river flow model

The hydrodynamic model can be established by using Saint Venant Equation. The equations may carry on discrete computation by Preismann difference format. The model and method are validated by the historical flood process's computation. The boundary conditions are upstream reservoir inflow, local inflow and the water level of downstream control cross section. The computational result includes the water level and flux of each cross section. The measured water level and flux of the important section are used to compare with the computational ones. Thus the model parameters are modified and optimized to improve the computing precision of the hydrodynamic model. The module of the hydrodynamic model computation had been developed by using Compaq Fortran6.6. The interface is shown in Figure 2.

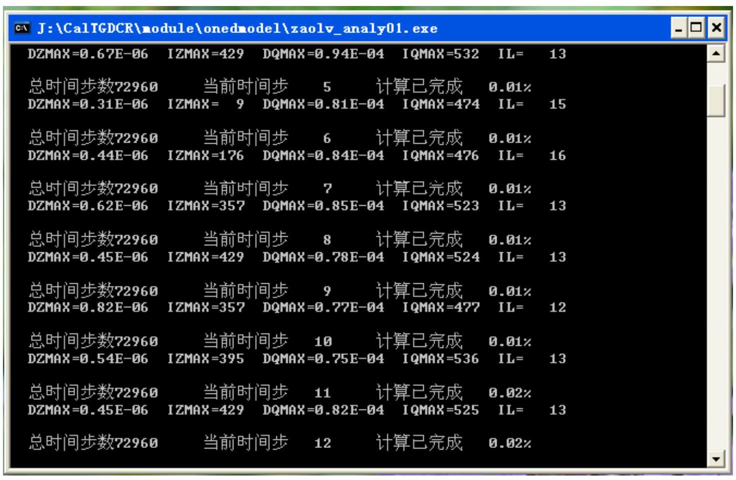

Fig. 2 The interface of the hydrodynamic model computation.

4.3 Dynamic reservoir storage computation based on DEM and hydrodynamic model

The water surface profile that is obtained by the hydrodynamic model, can't directly participate in the dynamic reservoir storage's computation. Two key problems must be solved.

Firstly, the hydrodynamic model computational result is each transect line's water level and isn't each grid's water level of watercourse water surface's DEM data. This problem can be solved by spatial interposition. Water level of grids between two adjacent transect lines is in direct proportion to distance of the upriver transect line and in inverse proportion to distance of the downriver transect line, besides the watercourse terrain between two adjacent transect lines is comparatively straight when transect line is sliced in order to establish the hydrodynamic model. So each grid's water level can be got by linear interposition in relation to distances between grid and two adjacent transect lines. Compared with the grid's underwater data, the reservoir's water surface scope can be identified. Based on the underwater DEM and water surface's DEM, dynamic reservoir storage can be calculated by the grid method.

Secondly, the water surface profile obtained by the hydrodynamic model's calculating only includes river's trunk stream and some big branches. For those slim branches that can't calculate the water surface profile, it's feasible to take water level of the center point at confluence of the river's trunk stream and branch as the branch's water level. Their reservoir storage can be got by using static reservoir storage computational method.

The reservoir's dynamic reservoir storage can be obtained by summing them.

The module of dynamic reservoir storage computation had been developed by Visual C++6.0 and ArcEngine9.2, combining with the GIS component secondary development technology. The interface is shown in Figure 3.

5. Application in reservoir storage computation of the Three Gorges reservoir

In order to confirm the feasibility of the above computational method, based on the method, the software system of reservoir storage calculation had been developed and used to calculate the static reservoir storage and dynamic reservoir storage of the Three Gorge Reservoir.

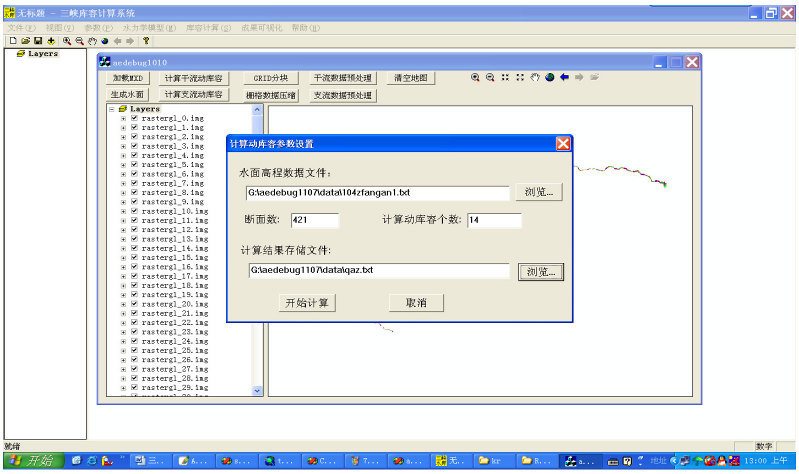

Fig. 3 The interface of dynamic reservoir storage computational module

5.1 Static reservoir storage computation of the Three Gorges reservoir

The normal water level of the Three Gorges reservoir is 175m. Its flood limit water level is 145m. Based on DEM data, the static reservoir storage of the Three Gorges reservoir has been calculated by applying static reservoir storage computational module. When water level is 175m, its value equal 388.95 hundred million m^3. When water level is 145m, its value equal 168.55 hundred million m^3. Its flood control capacity between 145m and 175m is 220.4 hundred million m^3. Compared with the flood control capacity of preliminary design report, it reduces 1.1 hundred million m^3. The two results are basically consistent.

5.2 Dynamic reservoir storage computation of the Three Gorges reservoir

Combining with the actual measured hydrologic data of the Three Gorges reservoir 156m storage process, one dimension flow field has been obtained by using hydrodynamic model computational module. And then based on DEM data, the dynamic reservoir storage's process value which interval is 8 hours has been calculated by using dynamic reservoir storage computational module. According to the computed result, the dynamic reservoir storage's variety curve along with time has been drawn, as is shown in figure 4.

According to the computed result, the dynamic reservoir storage's value of the Three Gorges reservoir is 170.93 hundred million m^3 at 9-20-2006 16:03, when the Three Gorges reservoir 156m storage process started. The dynamic reservoir storage's value of the Three Gorges reservoir is 277.08 hundred million m^3 at 10-27-2006 8:03, when the Three Gorges reservoir 156m storage's process ended. The difference between the two results is the accumulated water-holding capacity and equal 106.15 hundred million m^3. The accumulated water-holding capacity that the Three Gorges Corporation issued is 105 hundred million m^3. The two results are basically consistent.

5.3 Conclusions

Based on the spatial information technology and the reservoir terrain DEM data， the software system of reservoir storage calculation can been developed by using the above method, combining with the GIS component secondary development technology. The software can realize rapid computation of the large-scale reservoir's static reservoir storage and dynamic reservoir. The high accuracy's reservoir terrain DEM data has guaranteed high accuracy of the reservoir storage computation. The static reservoir storage and dynamic reservoir storage of the Three Gorge Reservoir has been calculated and is quite accurate, which indicates that the method is feasible and can be promoted in the other large-scale reservoirs that have the terrain DEM data.

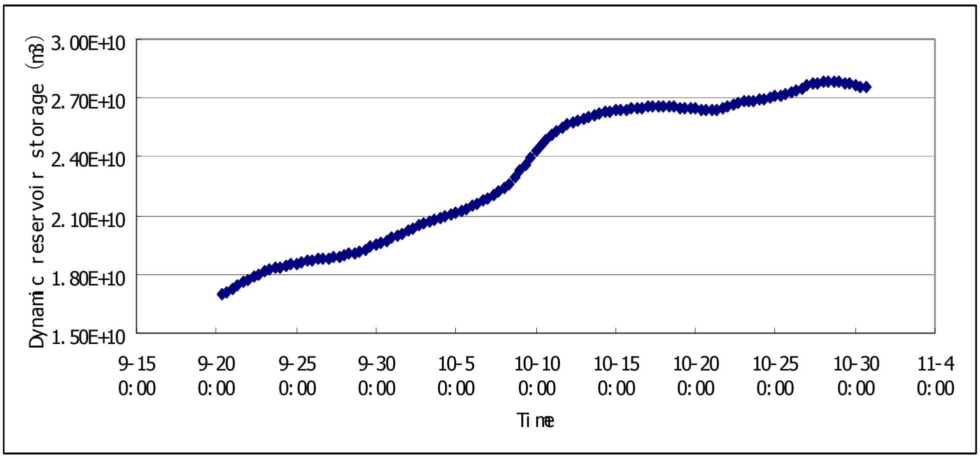

Fig. 4 The dynamic reservoir storage's variety curve along with time in the Three Gorges reservoir 156m storage process.

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