Single Factor Risk Analysis of Reservoir Operation

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Abstract. The reservoir operation method is used for the storage routing, due to the existence of forecast information errors and other uncertain factors, it may bring risks to the reservoir and its upstream and downstream flood prevention safety. Therefore, the risk analysis is to design and implement the reservoir flood prevention and dispatch the key to the way. This paper introduces a single factor risk analysis method for reservoir operation. Taking Qingshan Reservoir as an example, the risk of reservoir operation using forecast is analysed. The results displayed that taking into account the flood forecast error, when the reservoir adopts the forecast operation method, the risk rate of the reservoir dam body safety.

1. Introduction

In the implementation of flood prevention, due to the existence of forecast information errors and other uncertain factors, it may bring risks to the reservoir and its upstream and downstream flood control safety. There are risks in real-time scheduling. In order to evaluate the feasibility of reservoir flood control operation and its impact on the safety of reservoir, it is necessary to analyze the risks of reservoir operation [1]. Similarly, it is of great significance to study the risk analysis of reservoir operation, and also provide certain information for the real-time dispatching of reservoirs [2]. The risk analysis of reservoir flood control [3] is to maximize the profitability of the reservoir by increasing the amount of water stored in the reservoir while taking into consideration the risks under the existing engineering equipment and the amount of incoming water.

The flood forecasting method uses the predicted cumulative net rainfall as a discriminant indicator in the process of formulating the rules, so this is an increased risk source compared with the conventional method, that is, the forecast error of runoff [4]. Therefore, does the implementation of the flood prevention and dispatch method of the reservoir have any impact on the risk rate of the reservoir and it’s upstream and downstream? If it does, you need to analyze and calculate the magnitude of the risk, and analyze whether it is within an acceptable level. This is the reservoir decision-makers most concern the problem is also the key to whether the flood forecasting can be implemented safely [5].

Compared with the risk analysis results of the original design of the operation method, only the risks caused by flood forecasting errors are considered in the narrow risk analysis of the flood forecasting. Therefore, this paper mainly uses an actual reservoir as the research background to study the changes in the flood prevention risk of the reservoir after implementing the flood prevention compared to the conventional case. According to the definitions of the selected flood prevention method risk rate and dam safety maximum risk rate, analyze and calculate the flood forecasting and dispatching method selected by the actual reservoir for implementing flood forecasting methods. The risk rate under the method and the maximum risk rate for dam safety are analyzed.
2. Analytical method

2.1 Risk rate of reservoir operation based on the information of flood forecasting

Reservoir operation based on flood forecasting increase runoff forecasting errors compared to the conventional operation method.

If the original design check standard flood encounters the expected error of runoff forecast, the frequency with which the highest water level calculated based on the forecast dispatch method and the given flood limit water level flood regulation can resist flood is called the risk rate of the forecasting reservoir operation, that is,

\[ \psi_c = P_{zc}\left[R(R_{m0} + R_i), Z_{mc}\right] \leq P_z(Z_{L0}, Z_{m0}) \]

Where:
- \( \psi_c \) is the risk rate of the forecasting reservoir operation;
- \( R_{m0} \) means the runoff depth of dam check standard;
- \( R_i \) indicates the expectation error of runoff;
- \( R() \) -Corrected runoff depth of the calibrated standard frequency;
- \( Z_{mc} \) shows Adjust the maximum water level of the revised standard flood according to the operation;
- \( P_{zc} \) is the frequency of flood resistance with \( Z_{mc} \);
- \( P_z(Z_{L0}, Z_{m0}) \) means the standard frequency of the original designed flood limit water level and check flood level.

2.2 The maximum risk rate of forecasting reservoir operation

Equ.1 defines risk from the perspective of expected error. From the most unfavorable point of view, the risk of checking standard floods to the most rare frequency runoff forecast errors should be considered.

If the original check standard flood encounters a rare frequency runoff forecast error, based on the forecast dispatch method and the frequency with which the highest water level calculated for a given flood limit water level can resist floods, it is called the maximum risk rate of the forecasting reservoir operation.

\[ \psi_{max} = P_{zi}\left[R(R_{m0} + \Delta R_{mi}), Z'_{mi}\right] \leq P_z(Z_{L0}, Z_{m0}) \]

Where:
- \( \psi_{max} \) means the maximum risk rate of the forecasting reservoir operation;
- \( R_{m0} \) is the runoff depth of dam check standard;
- \( \Delta R_{mi} \) shows the prediction error of the runoff depth corresponding to the rare frequency i.
- The value of frequency i can be equal to the standard frequency of the original check of the reservoir; \( R() \) indicates the corrected runoff depth of the calibrated standard frequency;
- \( Z'_{mi} \) reveals the highest water level of the revised after the correction of the standard flood process with the rare frequency i runoff depth error;
- \( P_{zi} \) - \( P_{zc} \) is the frequency of flood resistance with \( Z'_{mi} \);
- \( P_z(Z_{L0}, Z_{m0}) \) means the standard frequency of the original designed flood limit water level and check flood level.

2.3 Risk analysis methods and steps of reservoir operation

Step 1: The maximum water level results for different design frequencies based on forecasting methods, including original designing limited water levels are calculated.

Step 2: The highest water level-frequency relationship between \( Z_{mj} \) and \( P_j \) are drawn on the Hessen frequency grid paper.

Step 3: Analyzes the frequency distribution of the forecast error of the flood forecasting scheme on which the forecasting is based, finally, the frequency distribution table and graph of total runoff forecast error are obtained.

3. Study case and results

Qingshan Reservoir has more rainfall stations with even distribution. The automatic monitoring and forecasting system for rainfall in the river basin is stable. Meteorological information collection systems
such as satellite cloud images and river basin flood forecasting have high accuracy. The study considered the basic conditions of flood forecasting to modify the original flood control method.

Predicted cumulative net rainfall was selected as the judgment index, and the gradual adjustment method was used to calculate the flood prevention rules for multiple schemes and multiple frequencies.

### 3.1 Analysis of Qingshan reservoir operation results

| Water level /m | Conventional operation rule | Forecasting operation rule | Risk rate /% |
|---------------|----------------------------|----------------------------|--------------|
| Zm            | P /% 0.01 0.05 0.1 1 2 5 10 20 |                            |              |
| 26            | 36.87* 0.01 33.39* 32.37 31.89 31.05 30.26 29.59 29.13 28.19 0.001* |

Seen from Table 1, the data with "**"reveals that, adjusted from 26m, assuming that the forecast is accurate, on the 0.001%-99.999% Heisen frequency grid paper, from the 33.39m point (0.01%), the upper left extension straight line intersects with the 36.87m leftward horizontal line. This point is resistant to floods frequency (0.001% < 0.01%, 0.006% < 0.01%).

### 3.2 Risk Rate Analysis of Qingshan Reservoir operation based on forecasting

The forecasting reservoir operation method is mainly based on the total rainfall and runoff forecast, that is, the cumulative net rainfall is used to control the discharge index to make rules for scheduling. Therefore, the accuracy mainly depends on the accuracy of the runoff depth. The probability of the absolute error of the runoff depth is subject to P-III after simulation prediction distributed. Its probability density function is:

$$f(x) = \frac{\beta^\alpha}{\Gamma(\alpha)}(x - \alpha_0)^{\alpha-1}e^{-\beta(x-\alpha_0)}$$  \hspace{1cm} (3)

where $\Gamma(\alpha)$ is the gamma function of; $\alpha, \beta, \alpha_0$ means the parameters.

The absolute error of the runoff depth is statistically obtained as follows: $\bar{x} = 6.18$; $C_r = 0.74$; $C_5 = 2C_r = 1.48$

The value of the random variable $x_p$ corresponding to a certain frequency P and the probability can be obtained by the following formula:

$$F(x) = P(x \geq x_p) = \int_{x_p}^{\infty} f(x)dx$$  \hspace{1cm} (4)

Set

$$x = \bar{x}(1 + C_r \Phi)$$  \hspace{1cm} (5)

Check the deviation coefficient $\Phi$ of the P-III frequency curve, the $x_p$ can be obtained through the above formula, which can draw the absolute error frequency distribution curve of runoff depth (Figure1).
Figure 1: The absolute error frequency distribution curve of runoff depth

The results about risk rate analysis of Qingshan reservoir operation based on forecasting is showed in Table 2.

Table 2: The results about risk rate analysis of Qingshan reservoir operation based on forecasting (26.0m)

| Criterion                        | Order | \( \Delta R_{\text{mai}} \) | \( R_{c} \) |
|----------------------------------|-------|-----------------------------|-------------|
| Absolute error /mm               | 1     | 38.41                       | 6.18        |
| Updated calibration standard runoff | 2     | 723.81                      | 691.58      |
| High water level /m              | 3     | 33.71                       | 33.44       |
| Rick rate /%                     | 4     | 0.0018*                     | 0.0011*     |

Runoff depth error corresponding to various frequencies (line 1 in Table 2) was used to modify the original designed runoff depth in the event of a flood of 685.4 mm, and the runoff depth in each year considering the error of runoff depth at different frequencies was obtained (line 2 in Table 2) and its process line (that is, using the ratio of amplification to enlarge the original verification flood process).

Using the forecasting and dispatching rules, there are 26.0m of the above-mentioned various error-corrected once-in-a-year flood process lines to find different maximum flood water levels (line 3 in Table 2). The risk rate (line 4 in Table 2) can be obtained by interpolation from the original designed check flood level of 36.87 m (corresponding frequency 0.01%) and 33.39 m (risk rate 0.001% when the forecast is accurate).

The results indicate that the risk rate with the limit water level control value (26.0 m) is 0.0011%, and the maximum risk rate with the \( P = 0.01 \) is 0.0018%.

4. Conclusion

Reservoir implementation of flood control operation method has reduced the maximum level of flood regulation and obtained significant benefits. However, the information is based on flood forecasting and the impact of forecasting errors on the reservoir and upstream and downstream must be analyzed. In this chapter, Qingshan Reservoir is taken as examples, and the runoff forecast error distribution law is used as the basis of calculation. According to Professor Wang Bender's definition of the risk rate of flood forecasting and operation methods, the maximum risk rate of dam safety, and the risk rate of downstream flood control points, the risk rate of flood forecasting and dispatching methods, the maximum risk rate
of dam safety, and the risk rate of downstream flood control points were analyzed and calculated. The analysis and calculation results show that, as long as the reservoir is dispatched in accordance with the flood regulation principles determined by the analysis of the flood prevention and dispatching mode, compared with the original design, the flood prevention risk rate of the reservoir and its downstream flood control points has not increased.

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