

# Risk analysis of construction diversion scheme

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**Abstract.** The determination of diversion risk in the construction of water conservancy and hydropower projects is a key problem related to the guarantee of project safety, saving project investment, giving full play to benefits in advance and facilitating construction. According to the design data, considering the influence of the uncertain factors such as hydrology and hydraulics, this paper analyses the relationship between the elevation of the upstream cofferdam and the upstream design water level, uses the Monte Carlo method to simulate the construction flood process and the discharge capacity of the diversion buildings, makes statistical analysis and determines the risk corresponding to the upstream water level distribution of the cofferdam and the water retaining height of the cofferdam, and establishes the calculation model of the construction diversion risk.

## 1 Preamble

There are many uncertain factors in construction diversion, and there are many ways to study the risk rate of construction diversion. However, the application time of risk analysis in water conservancy and hydropower construction is relatively short, and the results have certain limitations. In the construction diversion planning of water conservancy and hydropower, people usually only regard the peak discharge as the uncertain factor, then select the construction diversion standard, diversion discharge and finally determine the diversion scheme according to the type and scale of the building. Obviously, only considering hydrological uncertainty is not comprehensive enough. In the construction diversion, in addition to the objective uncertainty of peak discharge, there are also uncertainties of hydraulic, structural and storage capacity, which will bring diversion risk<sup>[1]</sup>. In this paper, Monte Carlo method is used to simulate the process of construction flood and the discharge condition of diversion buildings. The flood routing of construction flood is carried out through system simulation. The water level distribution in front of upstream cofferdam and the dynamic risk of cofferdam operation under different diversion standards are determined by statistical analysis model.

## 2 Example calculation and analysis

### 2.1 Calculation model of diversion risk rate

The total installed capacity of a hydropower project is 40MW, its normal water storage level is 458.00m, the elevation of the dam top is 460.00m, and the total storage capacity is 934.63m<sup>3</sup>. According to "Standard for rank classification and flood protection criteria of water and hydropower projects (SL252-2017)", It belongs to small (I) type projects such as IV. According to "Specifications for construction planning of water resources and hydropower projects (SL303-2017) [2]", its diversion buildings are Class V, and the corresponding diversion standards for earth-rock cofferdam design can adopt a flood return period of 5-10 years.

According to the division of the hydrological data for the time period, combined with the topographical geology, the layout of the hydraulic structure and the requirements of the diversion, a diversion scheme using cofferdams to block water during the dry season and flooding of the foundation pit during the flood season was preliminarily drawn up. The flood characteristics of each construction period are shown in Table 1, and the diversion flow of each diversion period is shown in Table 2.

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**Table 1.** Design Flood Information.

Period (month)	Average flow rate (m <sup>3</sup> /s)	Cv <sup>a</sup>	Cs/Cv <sup>b</sup>	Frequency design flow rate(m <sup>3</sup> /s)	
				P=10.0%	P=20.0%
1	41.8	0.26	4	56.4	50.4
2	65.3	0.62	4	112.0	84.4
3	113.0	0.65	4	203.0	149.0
4	263.0	0.65	4	491.0	375.0
5	457.0	0.56	4	795.0	630.0
6~9	1910.0	0.54	4	3230.0	2510.0
10	307.0	0.65	4	577.0	430.0
11	172.0	0.70	4	324.0	241.0
12	62.3	0.28	4	85.1	75.6

<sup>a</sup> Cv—The ionization coefficient of *P - III* distribution.

<sup>b</sup> Cs—The dispersion coefficient of *P - III* distribution.

**Table 2.** Diversion flow in each period.

Diversion period	Period(month)	Q <sub>20%</sub> (m <sup>3</sup> /s)	Q <sub>10%</sub> (m <sup>3</sup> /s)
<b>Initial diversion</b>	11~4	375	491
<b>flood season</b>	6~9	2510	3230
<b>Late stage</b>	10~5	630	795

## 2.2 Diversion and discharge capacity

In the initial period, the river bed is narrow for discharge. In the flood season, the river bed on the left bank and the bottom hole of the open scouring bar section are used to discharge the flood, and the 2 holes with the bottom holes of 6m×10m are

arranged at the later scouring bottom hole section for discharge.

Hydraulic parameters of discharge, The flow rate coefficient factor is subject to the triangular distribution, and the values of the three parameters in each period are shown in Table 3.

**Table 3.** Parameter value table of flow rate coefficient.

Diversion programme		Upper limit	Median	Lower limit
<b>Initial diversion</b>		0.385	0.367	0.356
<b>Flood season diversion</b>	<b>Downstream desilting(poor)</b>	0.270	0.172	0.074
	<b>Downstream desilting(fair)</b>	0.356	0.313	0.270
	<b>downstream dredging(good)</b>	0.385	0.367	0.356
<b>Later diversion</b>	<b>Downstream desilting(poor)</b>	0.378	0.360	0.349
	<b>Downstream desilting(fair)</b>	0.394	0.375	0.364
	<b>downstream dredging(good)</b>	0.410	0.390	0.378

## 2.3 Calculation results and analysis of diversion risk

According to the empirical formula of the traditional method, without considering the influence of random

factors, the corresponding diversion time of each flood is different. The water level and risk rate of the upstream cofferdam are shown in Table 4.

**Table 4.** Risk rate of water level in front of cofferdam.

Diversion period	flood frequency P	Maximum upstream water level (m)	Maximum discharge (m <sup>3</sup> /s)	Risk rate R
	10%	432.254	491	0.0513
<b>Initial diversion</b>	20%	431.340	375	0.1056
<b>Flood season diversion</b>	10%	438.282	3230	0.0513

	20%	436.613	2510	0.1056
	10%	438.999	795	0.0513
<b>later diversion</b>	20%	437.419	630	0.1056

Considering the random factors of hydrology and hydraulics, the calculation results of the diversion simulation of the power station at various periods are shown in the table. Table 5, table 6.

**Table 5.** Design water level risk of initial diversion.

flood frequency (%)	Design Water Level (m)	Expansion of excavation	Risk rate R	Guaranteed rate P
10%	432.254	Fully excavation	0.242	0.758
		50% excavation	0.279	0.721
		10%Expansion	0.421	0.579
20%	431.34	Fully excavation	0.520	0.480
		50% excavation	0.626	0.374
		10%Expansion	1.000	0.000

**Table 6.** Results of design water level risk in flood season and later stage.

Diversion period	Design flood frequency (%)	Design Water Level (m)	Downstream desilting status	Risk rate R	Guaranteed rate P
<b>flood season</b>	10%	438.282	Poor	0.598	0.402
			General	0.231	0.769
			Good	0.145	0.855
	20%	436.613	Poor	1.000	0.000
			General	0.507	0.493
			Good	0.285	0.715
<b>Late stage</b>	10%	438.999	Poor	0.349	0.651
			General	0.321	0.679
			Good	0.257	0.743
	20%	437.419	Poor	0.587	0.413
			General	0.527	0.473
			Good	0.480	0.520

Calculations proves that:

(1) As far as the same hydrological and hydraulic conditions are concerned, when the corresponding design frequencies are 10% and 20%, the risk of cofferdam water retaining during the initial, flood and later diversions considering random factors is 0.242 , 0.520 ,0.116, 0.257, 0.223 and 0.444 are greater than the risk calculated by traditional methods of 0.0513, 0.1056, so considering the influence of random factors can be more reasonable and clear to design the risk facing the cofferdam.

(2) According to the calculation of the initial diversion risk rate, when the completion rate of expansion is reduced from 100% to about 50%, the increase in the risk rate of cofferdam water retention is relatively small, from 0.242 to 0.279, and when the expansion is completed, When the rate is below 50%, the cofferdam risk rate increases significantly, from 0.279 to 0.421.

(3) Through the calculation of flood diversion and later diversion risk rates, it can be known that when the dredging rate is 100% to 85%, the cofferdam water retention risk rate increases relatively smoothly, and

when the dredging rate is less than 85% The risk rate of cofferdam water retention will increase sharply.

### 3 Summary

Based on the Monte-Carlo method, this paper simulates the construction flood inflow process and the analysis of the diversion of the diversion buildings, which shows that it is necessary to consider the influence of various uncertain factors in the calculation of the comprehensive risk of construction diversion. Computational analysis shows that after considering hydraulic uncertainties, the comprehensive risk of the system increases by about 20%. At the same time, this paper also analyzes the impact of changes in expansion and downstream dredging on the risk rate of cofferdam water retention. The risk has also increased by about 5% to 10%. Therefore, in establishing the calculation model of construction diversion risk, the uncertain factors to which the construction system is subjected should be fully considered.

## References

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