Discussion on the Function and Scale of Dasha Regulating and Storing Reservoir in Zhoushan Continental Diversion Project

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Abstract: The construction of Zhoushan Archipelago New Area in Zhejiang Province is strategically important, however, an insufficient supply of water resources in Zhoushan has become one of the main factors affecting its economic and socially sustainable development. Zhoushan Continental Diversion Project provides a reliable guarantee for the construction and development of the Zhoushan islands. Based on the project water diversion and local water resources conditions, this paper analyzes the necessity of setting up Regulating and Storing Reservoir and discusses the rationality of the reservoir scale in terms of water supply guarantee rate, emergency water sources, and development costs.

1 INTRODUCTION

Zhoushan City is located in the East of Zhejiang Province, on the East China Sea at the South side of the Yangtze River Estuary and the outer edge of Hangzhou Bay. It is the junction of China's North-South coastal routes and the Yangtze River waterway, and its strategic position is very important. On June 30th, 2011, Zhoushan became the first national level new district with the theme of marine economy in China. With the increasing demand for water resources in the construction of new islands and coastal defense, the shortage of freshwater resources has become a bottleneck that seriously restricts the sustainable development of Zhoushan Islands. The total water resources of Zhoushan Islands are 692 million m^3, and the per capita water resources are 618 m^3, which is less than 1/3 of the national per capita level (Wan et al., 2018; Dou et al., 2018; Wang et al., 2010).

Zhejiang Province put forward the strategic layout of water diversion from the mainland to Zhoushan Islands, which named Zhoushan Continental Diversion Project (ZCDP). The water intake is located in Yao River, with a planned water diversion flow of 5.0 m^3/s and an annual water diversion of 107 million m^3. The project was implemented in three phases. The first phase of the project was completed in 2003, with a water diversion scale of 1.0 m^3/s and an annual average water diversion volume of 21.6 million m^3. In 2015, the second phase of the project achieved trial water supply, with a water diversion scale of 2.8 m^3/s and an annual average water diversion capacity of 60 million m^3, and the Huangjinwan Regulating and Storing Reservoir (HRSR) was built. The water diversion scale of the third phase water diversion project in Zhoushan City under construction is 1.2 m^3/s, with an average annual water diversion volume of 25.9 million m^3. At the same time, it is planned to build Dasha Regulating and Storing Reservoir (DRSR) in 2017 (Gu et al., 2019; Zhang et al., 2020).

To give full play to the benefits of the project, cope with the unevenness of water sources for water transfer across river basins, and increase the guaranteed rate of water supply, long distance water transfer projects need to build Regulating and Storing Reservoir (RSR) (Han et al., 2013; Liu et al., 2011). At the same time, RSR also serves as an emergency water source and improves the utilization of local water resources. Therefore, as an important part of the ZCDP Project, RSR is a key guarantee for the scientific deployment of water diversion from the mainland and local water intake. This paper takes the 2030 level year as the future working condition, considers the scheduling principles and compensation mechanism of water diversion from the mainland and local water intake, and

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demonstrates the necessity and rationality of constructing DRSR.

2 METHODOLOGY

2.1 Reservoir Operation Principle

Continental Water Diversion (CWD) directly enters HRSR and DRSR, meanwhile, carries out joint water supply dispatching with Local Networked Reservoir (LNR). The dispatching principles are as follows.

(1) Water diversion conditions: According to the comprehensive consideration of the actual water level of the Yao River, the surrounding water intake requirements and navigation requirements, Zhoushan City and Ningbo City have signed a water intake agreement. The minimum water intake level determined by the agreement is 0.73 m, that is, the water level of the Yao River. When it is lower than 0.73 m, water of the Yao River must be stopped from withdrawing.

(2) Peak shaving compensation: In the dry season (October to May of the following year), when the storage capacity of LNR is less than 90% of the RSR, CWD is used priority, otherwise LNR is used priority; in the wet season (June to September), when the LNR storage capacity is lower than 40% of the RSR, the CWD is used priority, otherwise the LNR is used priority.

(3) System maintenance: Considering that the ZCDP has a longer distance and a longer cross-sea section of pipelines, in order to ensure the safety of water supply, consider a one-month maintenance period for each water pipe every year. According to the habits of water work and the water level of the Yao River, try to choose months with less impact from water cuts.

2.2 Basic Parameters of Joint Operation

(1) Calculation sequence: A total of 49 years from 1961 to 2009 was selected as the calculation sequence, and the calculation step was daily.

(2) Urban Monthly Unevenness Coefficient (UMUC): According to the change trend of urban water supply in Zhoushan over the years, the UMUC is statistically analyzed and shown in Table 1.

(3) Intake water level process: The 49-year daily water level process at the Yao River water intake is used as the statistical sequence. The frequency of water levels at all levels and Water Supply Guarantee Rate (WSGR) is shown in Table 2.

Table 1: UMUC of Zhoushan City (1961-2009).

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
UMUC	0.94	0.91	0.96	0.95	0.94	1.01	1.03	1.21	1.20	1.06	0.95	0.84

Table 2: The frequency of water levels in Yao River (1961-2009).

Water Level (m)	The number of days above the water level (days)	WSGR (%)
1.33	95	26.03
0.93	194	53.15
0.73	248	67.95
0.43	284	77.81
0.13	300	82.19
-0.37	352	96.44
-0.87	361	98.90

3 RESULTS AND DISCUSSIONS

According to the forecast of water demand, the total water demand of Zhoushan in 2030 will be 21.14 million m3, and the different compensation calculation schemes are shown in Table 3. Firstly, without the establishment of DRSR, it could be found that there are 6 hydrological years (April to March of the following year) of water shortage, namely 1967-1968, 1968-1969, 1969-1970, 1978-1979, 1979-1980, 2003-2004. Correspondingly, the Annual Water Supply Guarantee Rate (AWSGR) and Monthly Water Supply Guarantee Rate (MWSGR) are 84% and 93% respectively, which cannot meet the 95% requirement of MWSGR in the specification. Secondly, the LNR and CWD joint dispatch calculations were performed to balance the supply and demand, and the DRSR calculation results of 4 sets of different storage capacity schemes were further obtained, the water shortage as well as the guarantee rate in each water shortage period were analyzed.

It is clear that the MWSGRs of Scheme B and C are 93% and 94% respectively, and less than 95%

cannot meet the requirements. Compared with the absence of DRSR, Scheme D has a certain degree of relief for each water shortage period. If the storage capacity is further increased, the WSGR cannot be increased accordingly, so Scheme E is also not recommended.

DRSR is located in the North Line District of Zhoushan City, which is also the area with the fastest economic and industrial development. According to the water demand forecast, the annual water storage capacity of the North Line District in 2030 is about 90 million m3. DRSR can meet the water demand for about one month. From the perspective of emergency and standby water sources, the storage capacity of Scheme D is appropriate.

The rainfall collection area of the downstream river network of DRSR is about 15.18 km2. Excluding the 2.64 km2 rain collection area of reservoirs and ponds, there is still 12.54 km2 that can be used to further tap the potential. This is extremely precious to Zhoushan City, which is seriously lacking of water resources. Under the premise of Scheme D, the design water flow rate can be 1.6 m3/s, and the annual water supply can reach 4.75 million m3. The unilateral adjustment of storage capacity investment is about 80 yuan, and the development cost is acceptable for island areas with poor water resources.

Table 3: WSGR of different compensation calculation schemes in ZCDP.

Calculation schemes	Water shortage years (Hydrological years)	Number of water shortage months	Water shortage in 2030 (10000 m^3)	AWSGR (%)	MWSGR (%)
Scheme A (Without DRSR)	1967—1968	8	6 719	84	93
	1968—1969	6	4 421		
	1969—1970	4	1 921		
	1978—1979	5	2 230		
	1979—1980	6	2 437		
	2003—2004	6	2 215		
Scheme B (DRSR with 4 million m^3 storage capacity)	1967—1968	7	5 941	86	94
	1968—1969	6	4 375		
	1969—1970	4	1 754		
	1978—1979	4	1 852		
	1979—1980	6	2 356		
	2003—2004	5	1 825		
Scheme C (DRSR with 6 million m^3 storage capacity)	1967—1968	7	5 748	86	94
	1968—1969	6	4 379		
	1969—1970	4	1 760		
	1978—1979	3	1 626		
	1979—1980	6	2 364		
	2003—2004	5	1 627		
Scheme D (DRSR with 8 million m^3 storage capacity)	1967—1968	7	5 563	88	95
	1968—1969	5	4 383		
	1969—1970	4	1 766		
	1978—1979	2	1 442		
	1979—1980	5	2 371		
	2003—2004	5	1 433		
Scheme E (DRSR with 10 million m^3 storage capacity)	1967—1968	7	5 379	88	95
	1968—1969	5	4 386		
	1969—1970	4	1 772		
	1978—1979	2	1 259		
	1979—1980	5	2 379		
	2003—2004	5	1 245		

4 CONCLUSIONS

After the implementation of ZCDP, the scientific deployment of water diversion from the mainland and local water is the key to Zhoushan's future water resources protection. Water diversion from the mainland is affected by the environment of the submarine pipeline and the changes in the Yao River, and there are many uncertain factors. Therefore, the construction of RSR is a prerequisite for the rational dispatch of water resources. This paper conducts qualitative and quantitative analysis on the impact of the storage capacity on the guarantee rate of water supply, the role of emergency reserve, and the rational use of local water resources. It is considered appropriate that the storage capacity of the DRSR is 8 million m3. It also has certain reference significance for other water transfer projects to reasonably determine the scale of storage projects.

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