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Study on Ecological Water Demand Evaluation of Typical Mountainous Rivers in Zhejiang Province—Taking Kaihua River as an Example

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Abstract. In view of the ecological environmental problems and protection needs of mountainous rivers in Zhejiang province, a suitable ecological water demand evaluation system was established based on investigation and monitoring. Taking the Kaihua river as an example, the research on ecological water demand and the current situation evaluation were carried out. The main types of ecological water demand in Majin River are ecological basic flow and lake wetland outside the river, and instream flow and water demands for water quality in Zhongcun river. In the wet season each ecological water demand is 18.05m³/s and 2.56m³/s, and in the dry season is 3.00m³/s and 0.61m³/s. Three indexes of flow, duration and occurrence time are used to evaluate the ecological water demand. The degree of ecological water demand in the past three years is low level of satisfaction. Meanwhile the existing problems are analyzed, put forward reasonable measure and suggestions.

1. Introduction

The water resources demonstration guidelines issued by the Ministry of Water Resources in 2005 put forward clear requirements for the ecological discharge of damming rivers. However, a large number of small hydropower development projects have not considered the demand of ecological flow basically. In the process of construction and operation, the maximization of power generation benefit is often pursued and ignored. The ecological environment of rivers is protected. Therefore, it is necessary to consider the water requirement of river ecosystem while meeting the water demand of human beings[1]. In view of the ecological environment problem and protection demand of mountain rivers in Zhejiang Province, how to reasonably determine the appropriate ecological water demand and maintain and guarantee it, It is an important aspect of hydropower ecological construction and transformation and upgrading, and is also the key problem to be solved urgently in the construction of ecological civilization and beautiful Zhejiang.

2. Present situation of Water Environment and selection of typical Rivers in mountainous areas of Zhejiang Province

2.1. A Summary of Water Environment in typical mountainous areas of Zhejiang Province

The typical mountain rivers in Zhejiang Province are basically located in the upper and middle reaches of the river system, with excellent ecological environment, abundant biological resources and good



water quality, which are generally superior to the water quality standards of class II -III throughout the year. Due to the steep slope of the source river, the flood rises and falls sharply, the water storage capacity of the river is poor, and the amount of water in most natural rivers decreases obviously during the dry season. Due to the agglomeration of industries and the density of population, the pollution into the rivers increases. The water quality is inferior to the source.

The small hydropower is mainly distributed on the tributaries of mountain streams with large drop, and the zero flow section is mainly concentrated in the section below the Weir dam to the section of the power plant, under the double stresses of the decrease of water quantity and the decline of water quality. Mountain rivers with better natural ecological environment are being destroyed to varying degrees.

2.2. selection of river in typical mountainous areas of Zhejiang Province

2.2.1. Selection of typical mountain river. According to the selection principle of selecting artificial intervention, ecological protection target, water requirement, abundant hydrology and water environment data, the important ecological barrier in Zhejiang Province, which requires higher ecological protection is selected. In the pilot list of national main function area construction, open river is chosen as typical mountain river.

Kaihua County is located at the source of Qiantang River, an important river basin in Zhejiang Province, with an area of 2231km², with an average rainfall of 1762mm for many years. With the new ecological industry and become the dominant economic development of the county, the "quality and quantity" of water resources become the key factors of development.

Majin River is the most important mainstream river in Kaihua County, passing through the city, with more manual intervention, and is the only source of drinking water in the county at present. In 1957, there was a Kaihua (Misai) hydrologic station; the Zhongcun stream was a tributary of the Mahin Creek. There are reservoirs and cascade power stations in the upper reaches, villages along the river in the middle and lower reaches, and farmland. According to the preliminary investigation, it is found that the contradiction of water resources demand is more prominent, and the water quality has been deteriorating in recent years. Therefore, we select Chengguan Town and Zhongcuxi as examples to investigate and evaluate the typical mountain channel, and the basic situation of the typical river is shown in the table1.

Table 1. Basic conditions of typical river courses

| River name | Area (km ²) | Length (km) | Slope descent(‰) | Annual average rainfall(mm) | Annual average temperature(°C) | Annual average flow(m ³ /s) |
|------------|-------------------------|-------------|------------------|-----------------------------|--------------------------------|--|
| Zhongcun | 139.4 | 32.8 | 19.1 | 1908 | 16.3 | 5.27 |
| Majin | 1011.3 | 102.2 | 7.1 | 1879 | 16.3 | 30.73 |

2.2.2. Current situation of Water Environment in typical mountainous Rivers. The water quality of Majin river is better. Between class II -III, the water quality reached the standard rate of 100% in 2015, the vegetation in the basin is rich and diverse, the forest coverage is more than 70%, the environment is beautiful, the waterfall stream is vertical and horizontal, the tourist resources are abundant, the annual discharge is large, and there is no large diversion power station in the main stream. There is no zero flow section, some monthly water quality monitoring indexes of Zhongcun river are not up to the standard, and there are more small hydropower stations. In some periods of dry season, the water quality monitoring index is not up to standard.

The normal water quality monitoring station of Zhongcun River showed TP exceeded the standard in June and July 2014, NH₃-N exceeded the standard in January 2015, TP exceeded the standard in February, and the remaining months reached the standard. The COD_{Mn} is kept at a low level of 100% per month for two years. Zhongcun River passes through Chengfan Village, the area under its jurisdiction is nearly 15km², mainly rice and facilities vegetable planting, the estimated results of annual river pollution are detailed in Table 2, the main causes of water quality problems are related to local living and agricultural non-point source pollution.

Table 2. Amount of pollution entering the river in Chenfan village (Unit : t / a)

| Classify | COD _{Mn} | NH ₃ -N | TP |
|------------------------|-------------------|--------------------|------|
| Domestic pollution | 5.13 | 1.07 | 0.14 |
| Agricultural pollution | 1.12 | 0.31 | 0.11 |

The water reduction section of Zhongcun River is concentrated in the lower reaches of the diversion dam of Yinkeng Hydropower Station, which mainly affects the villages such as Wangcundian, Shangcheng, Longwukeng and Chengfan. The most serious area of water reduction is concentrated in Cheng fan Village, which is about 3 km in length. The power station draws water from the section of Wangcun dian in the upper stream of Zhongcun River. As a result, the water quantity in the downstream Chengfan village section is insufficient, which is in contradiction with the river landscape and irrigation water for agriculture along the river, and the water quality of some low water periods becomes worse obviously.

3. Comparison and Analysis of Ecological Water demand calculation methods for typical Section of River in Mountain area

The typical sections of Zhongcun river in Chengfan Village and MaJin river in Longtan Dam are selected for ecological water demand calculation. The main types of ecological water demand in Longtan dam section of MaJin river are ecological basic flow and wetland ecological water demand outside river, and ecological basic flow and water quality in Chengfan Village section of Zhongcun river. The results of ecological water demand calculation for typical sections are detailed in Table 3.

In order to make up for the seasonal variation in hydrology and hydraulics, the natural discharge of the mountainous river in Zhejiang Province has a large seasonal variation and is abundant and withered significantly, and the natural discharge of the dry month is small in order to make up for the seasonal variation in the year. Therefore, the annual ecological water demand is divided into high water month and dry month. The outsourced value of each calculation method is used in the month of abundant water, and the minimum value is adopted on the basis of satisfying the water quality requirement of the whole year, that is, the minimum value of ecological basic flow (landscape recreation water demand) and the value of water quality outsourced water demand.

Table 3. Comparison and selection of ecological water demand results of typical sections

| Ecological elements | computational method | water demand results (m ³ /s) | |
|---------------------|---|--|----------------------------|
| | | Zhongcun river | Majin river |
| Basic flow | Tennant(10%) | 0.42 | 3.01 |
| | mean monthly minimum flow | 0.52 | 3.12 |
| | 7Q10 | 0.61 | 4.18 |
| | Low water channel analysis | 0.41 | — |
| | Tennant(60%) | 2.50 | 18.05 |
| | Wetted perimeter method | 2.56 | — |
| | Comprehensive Value | Rich:2.56 Low:0.41 | Rich:18.0 5 Low:3.01 |
| environmental flow | 90 % guaranteed maximum monthly flow rate | 0.092 | — |
| | The most dry monthly average flow in the last ten years | 0.61 | — |
| | Water quality objective restriction method | 0.19 | — |
| | Comprehensive Value | 0.61 | — |
| | ecological water demand in the river | Rich:2.56 | Rich:18.0 |

| | | |
|---|-----------------------|----------------------------|
| | Low:0.61 | 5 |
| ecological water demand outside river(Lake diversion) | — | Low:3.01 0.25 |
| River ecological water demand(Comprehensive results) | Rich:2.56 Low:0.61 | Rich:18.3 0 Low:3.26 |

Note: the month of RICH water is from April to September, that is, the period of spawning and young (reproduction) of fish, and the month of LOW water is from October to March of the following year, that is, the period of general water.

For sections with special water requirements, such as landscape recreation in the river, diversion of wetlands and lakes outside the river, water use for urban environment, etc., the calculation is based on the water demand or the specific calculation formula corresponding to the actual required water level. Finally, the outsourced method is used to estimate the overall ecological water demand of the river with the calculation value of ecological base flow and water quality, and the ecological water demand outside the channel, such as diversion of wetland lakes, urban environmental water, etc., is calculated by superposition method. The results showed that the growth cycle of Cyanobacteria was generally 30 days, and the growth period, peak period and aging period were 10 days respectively[2]. In order to effectively control the algae outbreak in lakes, the water exchange period of the lake can be increased, and the water exchange period will be increased. The control was about 10 days.

4. Evaluation on ecological water demand of rivers in typical mountainous areas

Three hydrological indexes, discharge, duration and occurrence time, were used to evaluate the degree of ecological water demand, and to evaluate the whole situation of abundant, dry season and 2015 respectively.

The flow rate is characterized by the monthly average flow and the ecological water demand rate which do not meet the ecological water demand status; the duration is represented by the number of months that do not meet the ecological water demand[3]; the occurrence time is listed out as the month when the ecological water demand is not satisfied, It is pointed out that the month of not meeting ecological water demand is more concentrated in different periods in 2015. The corresponding evaluation criteria are shown in Table4. The results of the evaluation are shown in Table5.

Table 4. Assessment criteria for ecological water demand satisfaction

| Period | Evaluation standard of flow satisfaction degree (%) | | | | |
|--|---|--------|--------|------------|------|
| | ample | good | medium | difference | bad |
| Annual | 100 | 80~100 | 60~79 | 50~59 | 0~49 |
| Diachronic satisfaction evaluation criteria (not meeting the number of months) | | | | | |
| April-September(Fish breeding period) | 0 | 0 | 1 | 2 | ≥3 |
| October-next March(low water period) | 0 | 1 | 2 | 3 | ≥4 |

Table5. Evaluation results of ecological water demand satisfaction degree (2015)

| River name | Flow satisfaction degree | | | Diachronic satisfaction evaluation | | Occurrence time | |
|------------|--------------------------|-------|--------|------------------------------------|-------|-----------------|-------|
| | O.-N.M | A.-S. | A | O.-N.M | A.-S. | O.-N.M | A.-S. |
| Zhongcun | ample | good | good | medium | good | Jan. | Sep. |
| Majin | medium | ample | medium | good | ample | Jan. | - |

Note: O.-N.M means October-next March; A.-S. means April-September; A means Annual

5. Problem analysis and suggestions

5.1. Problem analysis

5.1.1. Current problems. Changing the temporal and spatial distribution of water resources in power stations. The contradiction of water use is more and more obvious. The self-purification capacity of the river is greatly reduced.

Changing the temporal and spatial distribution of water resources in power stations means that over exploitation of small hydropower projects, construction of dams and diversion of water have changed the spatial and temporal distribution of river runoff. We'll find a dewatering section obviously like a "White Beach".

The contradiction of water use is more and more obvious means that is difficult for river water resources to meet the requirements of comprehensive water demand. Before 2005 all power stations were not required to consider ecological flow, so the government can't reconcile the water conflict right now and have no enough money to buy water. The water resources demonstration guidelines issued by the Ministry of Water Resources in 2005 put forward clear requirements for the ecological discharge of damming rivers. However, owing to the lack of unified regulation and supervision, the facility did not release water as required.

The river's self-purification capacity has been greatly reduced, resulting in poor water quality. Although the hydropower of this river is a clean energy, it has no effect on the water quality, but the water diversion results in a substantial decrease in the downstream water volume, especially in the dry season, when the velocity of flow slows down, even the closed and non-flowing water body is formed, and the self-purification capacity of the channel is greatly reduced. The influence of a series of human activities, such as non-point source pollution, has resulted in the gap between the channel water quality and the higher target water quality in the mountainous river channel water function area.

5.1.2. The main reason. Historical reasons: Hydropower development became an important means of economic development in mountain counties in the 1990s, and most of the power stations in our province were also built in that period. Limited to the lack of understanding of protecting river ecological environment at that time, there is no corresponding requirement in the construction and operation of power stations, resulting in the investment and operation of hydropower stations blindly pursuing the maximization of water resources development, insufficient understanding of the importance of river ecological environment water use, but also caused the current serious river dehydration, ecological water needs to be met.

Newly increased water demand reason: With the development of economy and society, the demand for water is increasing and the types of water are becoming more and more abundant. The demands of comprehensive water demand, such as good water, living water, landscape recreation and environmental water, are increasing year by year.

5.2. Measure

According to the current situation and evaluation results of ecological water demand in typical river channels, combined with the analysis of problems, some suggestions on how to perfect the system and mechanism of water resources protection and comprehensive utilization are put forward for the rivers which have been satisfied with ecological water demand. Engineering and non-engineering measures are put forward to protect the healthy and sustainable development of river habitat on the basis of protecting ecological water demand.

The main measures include the construction of ecological discharge facilities, the effective control of the total amount of pollutants entering the river, the ecological restoration of rivers and lakes, the search for protection of water sources, the negotiation and adjustment of the operation rules of power stations, and the establishment of a small hydropower exit mechanism[4].

5.2.1. Construction of ecological discharge facilities. For diversion power stations with regulating capacity, using existing discharge facilities or new ecological units (discharge holes), according to the target value of ecological water demand, Ecological discharge, especially in dry season. It is suggested

that the management should install the flow monitoring facilities, release water around the clock for 24 hours and monitor whether the discharge can meet the target value of ecological water demand.

5.2.2. Implementing total amount control of pollutants into river. Aiming at major sources of pollution such as daily life and agricultural non-point sources, we should systematically treat the surrounding rural life pollution, including centralized or decentralized treatment of rural sewage, centralized collection and treatment of garbage, etc. In order to reduce the amount of sewage discharged into the river, the agricultural non-point source pollution should be comprehensively remedied from the source and industrial structure.

5.2.3. Ecological restoration of rivers and lakes. In view of the dewatering reach with landscape demand, under the premise of ensuring ecological water demand and meeting flood control safety, multi-stage ecological low Weir is built, hydrophilic ecological revetment is built, and water landscape is beautified. In view of the water diversion project of the lake outside the river, the water level of the lake is regulated by the intake gate and the height of the Weir dam, and the discharge of the water is controlled.

5.2.4. Looking for a secure Water Source. In view of the contradiction between the diversion of the power station and the drinking water of the residents, it is difficult to coordinate the water resources. In order to guarantee the water supply capacity of the water source in line with the increasing population speed.

5.3. suggestions

In view of the river basin with high level of water resources development and more construction of cascade power stations, the unified regulation and management of water resources in river basins should be strengthened.

In view of dam type or river bed type power station, the ecological operation mode of power station can be improved[5].

In addition, there is a need to increase hydrology-water-quality-biological monitoring capacity. Establishment of early warning, Supervision and Evaluation Management system for River Ecological discharge.

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