RESEARCH ON COMPENSATION OF HYDROLOGICAL PROJECT REGULATION FOR ECO-ENVIRONMENTAL FLOW GUARANTEE IN THE WEIHE RIVER BASIN, CHINA

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Abstract This study aims to guarantee the ecological flow of the river in the Weihe River Basin, to construct a sustainable water quantity regulation mechanism, the ecological regulation compensation is analyzed from the view of demand side and supply side. Based on the policy, legal, economic, social, ecological and environmental perspective, and puts forward some effective measures to protect water ecological compensation ecological scheduling, including many aspects of system, management and technology. Some advice is given from the supply side, and the demand side. The study is believed to be of a referential value for policy-making in the water management in the WEIHE River basin under the changing environment.

1. INTRODUCTION

Weihe is the largest tributary of the Yellow River, the water problems of the Yellow River are also existed in the Weihe River. The WEIHE River is known as “the little Yellow River”. In recent years, Weihe comprehensive improvement project basically completed, the Weihe river basin water ecological environment has improved, Weihe River Basin Ecological scheduling has played a positive role. Shaanxi Province, ecological protection and construction target of Weihe basin based on the water situation, determine the different target of different ecological restoration, ecological environment of dry tributary of the main control section of the water requirement (suitable, minimum and lower limit) control index, put forward measures of water dispatching of short and long term, but is to ensure sustained and concerted development of ecological environment and social economy that must be based on the status quo, respect history, guarantee on the downstream water fair, water ecological compensation for the implementation of regional ecological regulation measures and the main maintenance of Weihe basin ecological environment.

The location of the Weihe River Basin in China is shown in Figure 1. The Weihe River is the biggest tributary of the Yellow River, flowing through Shaanxi Province, Gansu Province, and Ningxia Hui Autonomous Region. It originates from the Niaoshu Mountain of Weiyuan County, Gansu Province, and inflows into the Yellow River in

Tongguan County of Shaanxi Province. The total catchment area of the Weihe River is 134800 km^2 with 67100 km^2 inside Shaanxi Province. Cities of Shaanxi Province inside the Weihe River include Baoji, Yangling, Xianyang, Xi'an, Tongchuan, Weinan, and part of Yan'an and Yulin. The Guanzhong plain is in the downstream area of the Weihe River. The Weihe river has many tributaries, most of them in the south bank but big ones in the north bank. The river system presents fan-shaped distribution. Jinghe and Beiluohe are the two big tributaries of the Weihe River with the catchment area of 45400 km^2 and 26900 km^2 respectively. The Weihe River is in a typical continental monsoon climate zone. The average annual precipitation is 601.1mm with great annual and inter-annual variations. With the rainfall concentrating in July to September, the basin is dry in winter and spring seasons. The precipitation in mountain areas is higher than that in plain areas, decreasing from the south to the north. Average annual runoff is 5.62 billion m^3, and its distribution is consistent to precipitation.

The Weihe River has an intense water conservancy development. Up to the end of 2010, there are 441 constructed reservoirs in the basin, with the total storage capacity of 2.18 billion cubic metres and the water supply capacity of 1.42 billion cubic metres. There are 2073 diversion projects and 4293 water-lifting projects. However, the average water resources per person and per mu (1/15 ha) are 307m^3 and 318m^3 respectively, which are only 17% and 24% of the national averages. Water resources scarcity aggravates the competition among all water use sectors.

With the rapid development of economy and society in Weihe River, total water use has been increasing continually. On the other hand, water resources show a declining trend due to climate variation and human activities. The above two factors leads to the reduction of ecological water use, causing eco-environmental issues and restricting the regional sustainable development. Solving the problem of eco-environmental water requirement in the Weihe River is imminent. In 2011, Shaanxi Province carried out a comprehensive treatment project along the Weihe River. The total investment of the project is more than 60 billion RMB. Under the condition of water resources insufficiency, to preserve river health and coordinate man-water harmonization, there are 3 questions to be answered: 1) How much eco-environmental flow is required? 2) Where is the source of eco-environmental water? 3) What kinds of regulation measures can be adopted to guarantee the environmental flow? To answer the first question, based on the eco-environmental function zone in the Weihe River, we present target values of eco-environmental flows at key sections concerning the aspects of ecology, environment, and landscape. For the second question, given the current situation of water utilization and project regulation ability, we analyze the regulation approaches of ecological water demand from seven aspects. For the third question, the paper explores the water transfer measures and guarantee mechanism suitable for Shaanxi province in the Weihe River.

This study aims to guarantee the ecological flow of the river in the Weihe River Basin, to construct a sustainable water quantity regulation mechanism, the ecological regulation compensation is analyzed from the view of demand side and supply side.

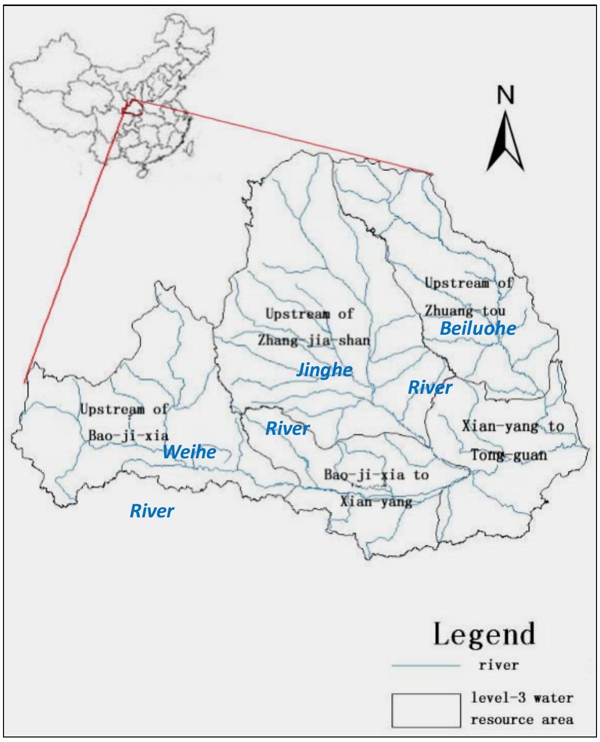

Figure 1. Location of the Weihe River Basin in China

2.ECO-ENVIRONMENTAL TARGETS AND FLOW INDICES IN THE MAINSTREAM OF WEIHE RIVER

The fish as the top living beings of water ecosystem can reflect the characteristics of ecosystem. Thus Grade 1 and 2 partitions of fish are used as the first and second partitions of water ecosystem zones. Soil properties have a significant effect on river morphology and the nutritive salt of runoff, therefore the regional soil property is used as the third partition of water ecosystem zones. Water environmental pollution is also a factor for ecological damage in the mainstream of the Weihe River, and water function zoning was promulgated and implemented for the water environment protection in the river, so it is adopted as the fourth partition of water ecosystem zones. The river is divided into 14 water function zones, but in this study some modifications are made to the original division, i.e., part of water resource protection zones is changed into water ecological protection zones, and the fishery function of some agricultural water use districts is defined. Comprehensively considering the initial result of each partition, and the estuary of tributary and hydrological stations, the mainstream of Weihe River is divided into 24 eco-environmental function zones (see Figure 2). The goals of eco-environmental protection at 5 key sections (5 hydrological stations) are analyzed with a focus in this study and shown in Table 1.

Table1. Key sections and goals of eco-environmental protection

Section number	Section name	Requirement of eco-environmental water	Ecological treatment water demand

2#	Lin Jiacun	Ecological basic flow		Maintaining channel stability in flood period	Landscape water demand
7#	Wei Jiabao	Ecological basic flow		Maintaining channel stability in flood period	Landscape water demand
12#	Xianyang	Ecological basic flow		Maintaining channel stability in flood period	Landscape water demand
18#	Lintong	Ecological basic flow	Flow rate pulse in spawning season	Maintaining channel stability in flood period	Landscape water demand
22#	Huaxian	Ecological basic flow		Maintaining channel stability in flood period	Landscape water demand

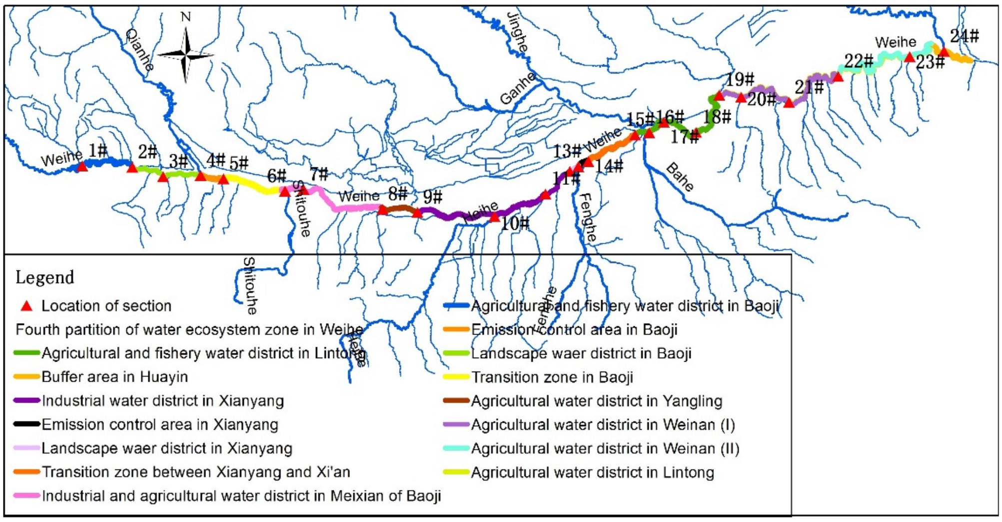

Figure 2. Eco-environmental function zones and sections

The holistic method, which combines fish habitat analysis, water environmental design flow method, hydrological method and stakeholder workshops etc (Tharme et al, 2003; Rogers et al, 2010; Tamai, 2013), is adopted to calculate the eco-environmental flow at 5 key sections. The daily river flow series at the 3 sections of Lin Jiacun, Xiangyang and Huaxian except are from the observation, whereas those at the 2 sections of Wei Jiabao and Lintong and the outlets of tributaries are based on the simulation results of WEP-L (Jia et al, 2006) because of lacking the observation.

The water and energy transfer processes (WEP) model (Jia et al., 2001) was developed by combing the merits of PBSD models and SVAT models. The model has been successfully applied in several watersheds in Japan, Korean and China with different climate and geographic conditions. The WEP model has the following main characteristics: (1) combined modeling of hydrological processes and energy transfer processes, (2) consideration of the land use heterogeneity inside a computation unit by adopting the mosaic method, and (3) incorporation of the runoff generation theory of various source areas into the model through a numerical simulation in groundwater/subsurface water flows to directly reflect topography's effects in runoff generation, thus cable of modeling infiltration excess, saturation excess and mixed runoff generation mechanism.

The improved WEP model can be adopted to accomplish water cycle simulation and general water resources assessment for preset conditions with and without consideration of water use. For the case with consideration of water use, surface runoff and subsurface runoff are obtained by evaluating the effects of water use on hydrological process of natural water cycle. In addition, hydrological simulation and water resources assessment results under different conditions of meteorology and land covers can be obtained by changing input data of meteorology and land covers.

After calculating the ecological basic flow in drought period, flow rate pulse in spawning season, design flow of water function zone, wetland and landscape water demand, and water for sediment transport in flood season, the target values of eco-environmental flows at key sections can be calculated based on tributary inflow, intake of the mainstream, and water balance principle. Considering the drastic variation of inflows in the Weihe River, the weak storage capacity of water conservancy project, the drastic competition between economic water use and eco-environment water use, and the time requirement of registration construction, the indices includes 3 levels: extremely low eco-flow, low limit eco-flow and appropriate eco-flow.

A stakeholders' workshop has been organized by the local water administration authority to discuss on these indices and give modification comments. Finally, control indices at 5 key sections are decided and shown in Table 2. The eco-environmental flow indices have been adopted by local water administration authority as ecological regulation goals in mainstream of the Weihe River.

Table2. Target values of eco-environmental flows at key sections Unit：m^3/s

Section number	Section name	Extremely low eco-flow	Low limit eco-flow	Appropriate eco-flow
2#	Lin Jiacun	5.4	8.6	12.8
7#	Wei Jiabao	8.4	11.6	23.5
12#	Xianyang	10	15.1	31.7
18#	Lintong	12	20.1	34.3
22#	Huaxian	12	12	34.1

In view of the economic and social development and current water supply and consumption in the Weihe River, the paper systematically analyses the potentiality of water transfer for ecological water demand outside and inside the River, and puts forward seven regulation approaches to meet the eco-environment flow indices: water-saving, utilization of recycled water, reservoirs joint regulation, regulation and storage of groundwater, controlling intake of hydropower, local water source project construction, the inter-basin water transfer project. Besides, principles of ecological regulation are presented, such as the priority of different water sources and users, increasing exploitation of groundwater in dry period and so on.

3. WATER ECOLOGICAL COMPENSATION AND GUARANTEE MECHANISM

3.1 Regulation measures

Limiting water intake for hydropower generation: except irrigation water demand, the water intake merely for hydropower should not be considered, i.e., the water diversion from LinJiacun canal head and WeiJiabao canal head merely needs to meet downstream irrigation water requirements. The scheduling plan for ecological basic flow should be carried out.

Reducing irrigation water in irrigation districts: Reducing irrigation water diversion from LinJiacun canal head and WeiJiabao canal head in drought period and the peak period of agricultural irrigation to increase the water of downstream channel; reducing irrigation water from Jinghuiqu canal head and Jiaokou water diversion to increase the eco-flows at Lintong section and Huaxian section.

Strengthening reservoirs joint operation: reservoir in the upstream of key section can adopt conjunctive operation to ensure the ecological basic flow. For example, the conjunctive operation of Fengjiashan and Shitouhe reservoirs can effectively increase the eco-flow at Wei Jiabao section. The optimized operation of Jinpen Reservoir can add the eco-flow at Huaxian section.

Inter-basin water transfer project: In 2020, after the completion of the Hanjiang to Weihe River Water Transfer Project, the diversion water amount can be allocated to different users, which can replace the local surface water and groundwater. The return water can replenish surface water, and increase water in the river.

Establishing irrigation management and reform measures: development and reform system in irrigation district should be continuously perfected. The investment of water conservancy infrastructure should be strengthened by the government. The upstream area should put great efforts to perform water-saving measures and increase the recycling dosage of reclaimed water.

3.2 Water ecological compensation standard

To ensure the sustainable coordinated development of ecological environment and social economy, must be based on the status quo, respect history, guarantee on the downstream water fair, water ecological compensation for the implementation of regional ecological regulation measures and the main maintenance of Weihe basin ecological environment. On the basis of domestic and international research on the basis of ecological regulation, the establishment of a reasonable economic compensation system to solve the contradictions between the parties to eliminate the adverse effects of ecological regulation. Follow the "if he uses, he must compensation; who benefit who pays" principle, the establishment of compensation between the subject and the object of interest mechanism, negotiation mechanism, and compensation funds calculation and allocation mechanism and compensation standard system framework.

According to the implementation of the Weihe River Basin Ecological regulation scheme, and regulation of income groups, it can be defined all the tributaries confluence area of area of ecological compensation is determined for the main stream of Linjiacun ~ Huaxian Weihe into the yellow section of Shaanxi Province, Weihe river basin 67 thousand square kilometers. It includes parts of Baoji, Yangling, Guanzhong area of Xianyang Xi'an, Tongchuan, Weinan City, Yanan, Yulin city in Northern Shaanxi. There are 9 districts and it involves 61 counties.

According to the implementation of Weihe River Basin Ecological regulation plan, regulation object mainly is the implementation of the main ecological regulation including hydropower station management unit, management unit, irrigation reservoir management unit and along the water unit. According to the different stages of ecological regulation of the implementation of the main contribution of the size of the object to determine the priority order, while taking into account the 2020 and 2030 to meet the regulation objectives, the compensation object can be added.

The recent management unit of hydropower station can be included in the compensation object, can be considered to be middle management unit, irrigation reservoir management unit into the compensation object. The long term visual Hanjiang to Weihe River water diversion project with water source area into the compensation object.

On the Weihe River in the control section to meet the minimum ecological flow, low ecological flow and suitable ecological water requirements set different compensation standards respectively. On this basis, according to the scheduling scheme of ecological flow, approved ecological operation period, Weihe River tributaries along the different water departments of the control section of the minimum ecological flow, low flow and suitable ecological contribution degree of ecological water requirement, as a compensation basis.

3.3 Water ecological compensation pattern

With the development of Chinese market-oriented process, the market compensation mechanism should be the development trend of Chinese water ecological compensation mechanism. Water ecological compensation in the Weihe River basin can be divided into two types: compensation and compensation.

(1) Fund Compensation

Special funds should set up for ecological regulation of the Weihe River Basin, namely water ecological compensation fund. Funding channels can be charged water ecological compensation special fund at the provincial level, finance, to provide the necessary financial support for ecological regulation of Weihe River. In addition, it can be based on the existing implementation of the "urban water price ladder in Shaanxi province guidance" on the right to raise the price of water resources fee collection standards, according to the proportion of the funds under the water ecological compensation fund, stable water ecological compensation fund channel.

(2) Policy Compensation

Policy compensation is the superior government's power and opportunity compensation to the lower level government. The compensation in the authorized within the scope of the policy priority and preferential treatment, formulate a series of innovative policies in investment projects, industrial development and financial and other aspects of the tax increase in upstream support and benefits, promote the economic development of river basin. According to the Baoji gorge Linjiacun, Yangling hydropower station, offer certain preferential policies in investment projects, industrial development and public finance and taxation, are compensated by using the system resources and policy resources. The main measures include: appropriate relief hydropower station water resource fee collection standards or charges, appropriately increasing the electricity tariff and priority, appropriate relief tax of hydropower station, in a certain period of time, the hydropower industry transformation to offer economic support.

3.4 Guarantee mechanism

Improving relevant policies and regulations: a guideline for hydroelectric water use of the Weihe River should be prepared. It is necessary to define the government's subsidy system so as to control intake of hydropower. In order to realize the sustainable development in irrigation districts, irrigation district management reform measures should be implemented as soon as possible. In addition, the existed Water Regulation Methodology of Shaanxi Province in the Weihe River should be improved.

Strengthening water resources management: reservoirs joint regulation should be adopted so as to improve the social, economic and environmental benefits of water resources in the Weihe River. Making full use of water transfer project can effectively alleviate water resources insufficiency. Adequate consideration of the use of treated wastewater contributes to the construction of water-saving society. Excellent monitoring network is also required.

Researching on scientific and technical support: scientific design and operation of flood control level and rational use of the overlap of flood control capacity and water supply capacity have great influence on the utilization of flood resources and hydropower resources. The contradiction between eco-environmental water use and production water use can be relieved by regulating the exploitation of groundwater in different period and implementing joint operation of surface water and groundwater.

4.CONCLUSIONS

The study is believed to be of a referential value for policy-making in the water management in the WEIHE River basin under the changing environment.

The eco-environmental flow guarantee issue has become a main concern of local people in the Weihe River Basin after the implementations of the comprehensive treatment project of Shaanxi province and the strictest water resources management system. Based on the coordinated development of economic society and eco-environment, we try to answer the existing problems in the Weihe River, i.e., how much eco-environmental flow is required? Where is the source of eco-environmental water?

What kinds of regulation measures can be adopted to guarantee the environmental flow?

After analyzing the current situation of water resources in the Weihe River and its development and utilization, we put forward control indices of eco-environmental flows, Water ecological compensation, and guarantee mechanism, to provide technical support for the comprehensive treatment of the Weihe River. It is concluded that restoration of eco-environmental flows in the Wei River and balancing of economic and eco-environmental water uses can be gradually realized, though the target is very challenging.

Based on the policy, legal, economic, social, ecological and environmental perspective, and puts forward some effective measures to protect water ecological compensation ecological regulation in the Weihe River basin, including many aspects of system, management and technology. Some advice is given from the supply side (such as loss of ecological regulation, hydropower station, reservoir irrigation area), and the demand side (the water along the river government administrative departments, people and other ecological system of water ecological compensation spokesman). Although a further study is desired, the results are believed to be of an important referential value to a sustainable development in the basin.

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