Study on the Method of Determining the Early Warning Level of Supply and Demand of Water Resources in Middle and Short Terms

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Abstract. Taking the situation of water resources supply and demand at the regional short-term scale as the object of early warning, this paper puts forward the early warning index system of regional water resources supply and demand, clearly divides the early warning level of regional water resources supply and demand into three levels, and puts forward the determination methods of different early warning level standards, which provides support for the realization of early warning of regional water resources supply and demand. Yueqing City of the Wenzhou City was selected as a typical area for application research, and different levels of early warning standards were defined.

1. Introduction
With the deepening of the research and application of water resources and the increasing complexity of water resources issues, experts and scholars are constantly exploring new and more scientific and rational research methods and management means [1]. At present, according to the different objects of early warning research, regional water resources early warning research mainly includes two aspects. The first is to regard water resources as a system and take the sustainable utilization of water resources, water resources security or water security as the research object of early warning, mainly including the early warning of sustainable utilization of water resources and the early warning of water resources security [2]-[6]. The second is to deal with the early warning of unilateral problems such as flood, drought and water pollution faced by regional water resources, mainly including flood early warning, drought early warning, water pollution early warning and groundwater early warning [7]-[10]. But at present, most of the early warnings about water resources are in the sense of level year or specific emergencies, the balance of water resources supply and demand in the sense of level year can not represent the balance of water resources supply and demand in specific years and different periods of the year, and the early warning index system can not adapt to short-term (ten days-three months) water demand for early warning of supply and demand of resources, because it contains more statistical and planning indicators.

The early warning of water supply and demand in the short and medium term is also very important in the evolution of water supply and demand situation. It is of great significance to guide the regional adjustment of water supply strategy and mode, and to strengthen the implementation of specific work of water intake management. Current situation of water resources supply and demand early warning related research is less, and the relevant theory is not perfect. Therefore, it is necessary to monitor,
forecast and warn the supply and demand situation of water resources in the short and medium term by selecting relevant indicators that can reflect the supply and demand situation of water resources in the short and medium term. Referring to the results of early warning research in related fields, the concept, influencing factors and early warning process of water resources supply and demand are defined.

2. Early warning boundary of regional water resources supply and demand

2.1. Definition of early warning scope
The early warning of regional water resources supply and demand is based on the early warning theory. With the help of modern monitoring means and forecasting methods, the mathematical model is established by monitoring the information of water resources quantity and water supply and demand related to the supply and demand of water resources in a certain space-time scale, and whether the relevant indicators deviate from the expected state of the supply and demand of water resources is evaluated and analyzed, and the relationship between water resources supply and demand is grasped dynamically. In order to avoid the contradiction between supply and demand of water resources without knowing it or insufficient preparation, and to minimize or avoid the impact and loss caused by insufficient water supply, it is necessary to warn about the possible contradiction between supply and demand of water resources.

The regional water resources supply and demand early warning at short-term scale is different from that at horizontal annual scale. Considering that the longer the forecast period of early warning is, the longer the preparation time is, the better the balance between supply and demand of water resources will be guaranteed. However, with the increase of the forecast period, the prediction accuracy will decrease and the reliability of early warning will decrease. Based on the current situation of forecasting research on water resources supply and demand indicators, the forecast period is defined as 10 days.

2.2. Early warning objects
The early warning of water resources supply and demand emphasizes the timeliness, sensitivity and accuracy of early warning. Considering the complexity of the supply and demand system of water resources and the gradual change of the contradiction between supply and demand of water resources and the development process, in order to measure the supply and demand situation and development trend of water resources timely and accurately, this study selected the supply and demand situation of water resources as the early warning object.

By reflecting the coordination degree between regional water resources supply and water users demand in the foreseeable period, the contradiction degree and evolution trend of regional water resources supply and demand can be judged in turn, so that managers can accurately grasp the situation of regional water resources supply and demand, issue early warning information and take necessary measures to deal with possible water shortage.

3. Early warning method of regional water resources supply and demand

3.1. Construction of early warning index system
The forecasting and early warning indicators of regional water resources supply and demand can directly and clearly reflect the severity and development trend of the imbalance between supply and demand in different industries in the process of regional water resources development and utilization. Considering that the regional water use industry mainly consists of high-quality water users of centralized water supply in urban and rural areas, industrial water users of self-provided water supply and agricultural irrigation water users, the index of supply and demand of high-quality water in urban and rural areas, the index of supply and demand of self-provided industrial water, and the index of supply and demand of agricultural water are selected as the forecasting and warning indicators of regional water supply and demand. The early warning indicators have the following meanings.
3.2. Determination of early warning level standard

3.2.1 Classification of early warning level standards. Referring to the results of water resources early warning classification in related fields, the regional water resources supply and demand forecast and early warning is divided into three levels: grade III, grade II and grade I, which are characterized by green, blue and yellow signals respectively, and grade I is the highest level. The characteristics of regional water resources supply and demand forecasting and early warning status under different levels of standards are detailed in the table below.

Table 1. Standard classification table for early warning level of regional water resources supply and demand.

| Warning Level | Grade Characteristics | Warning Degree | Signal |
|---------------|-----------------------|----------------|--------|
| Grade III     | The regional supply and demand situation is basically balanced. | Mild early warning | Blue light |
| Grade II      | The balance of regional supply and demand is expected to be broken, and water supply tension will be shown in various industries. | Moderate early warning | Yellow light |
| Grade I       | The situation of regional supply and demand will be more severe, and various industries will show a more obvious situation of water shortage. | Severe early warning | Red light |

3.2.2 Determination of threshold of early warning grade standard. Multi-scenario comparative judgment method is used to analyze the threshold of early warning indicators, that is, to set up multiple scenarios at different levels of water demand satisfaction for regional industries at truncation level. Through comparative analysis of industry water demand and water supply for corresponding water sources under different scenarios, the critical value of indicators with different water demand satisfaction degree is analyzed as the threshold of early warning indicators. The thresholds of different levels of early warning indicators are determined as follows:

- **Class III early warning**: According to the target that the water supply from water source can meet the water consumption of various industries for many periods, the threshold lower limits of high-quality water supply and demand index, industrial water supply and demand index and agricultural water supply and demand index in the foreseeable period of this grade are expressed by $\beta^{2c}$, $\beta^{2h}$ and $\beta^{2a}$ respectively, and the upper limits of the threshold are expressed by $\beta^{3c}$, $\beta^{3h}$ and $\beta^{3a}$ respectively.

$$b_{2c} < EX_i(i) \leq b_{2h} \text{ or } b_{2c} < EX_i(i) < b_{2h} \text{ or } b_{2a} < EX_i(i) < b_{2a}$$

(1)

- **Class II early warning**: The lower threshold limits of urban and rural high-quality water supply and demand index, self-provided industrial water supply and demand index, and agricultural irrigation water supply and demand index are expressed by $\beta^{2c}$, $\beta^{2h}$ and $\beta^{2a}$ respectively, and the upper threshold limits are expressed by $\beta^{3c}$, $\beta^{3h}$ and $\beta^{3a}$ respectively.

$$b_{3c} < EX_i(i) \leq b_{3h} \text{ or } b_{3c} < EX_i(i) < b_{3h} \text{ or } b_{3a} < EX_i(i) < b_{3a}$$

(2)

- **Class I early warning**: The index of supply and demand of urban and rural high-quality water, the index of supply and demand of self-provided industrial water and the threshold upper limit of supply and demand index of agricultural irrigation water in the foreseeable period of this grade are determined by analogy with the expressions of $\beta^{3c}$, $\beta^{3h}$ and $\beta^{3a}$ respectively.

$$EX_i(i) \leq b_{3c} \text{ or } EX_i(i) < b_{3h} \text{ or } EX_i(i) < b_{3a}$$

(3)

$EX_i(i)$ in the formula represents the index of supply and demand of high-quality water for the i foreseeable period. $EX_i(i)$ in the formula represents the index of supply and demand of industrial
water for the i foreseeable period. $EX_{c}(i)$ in the formula represents the index of supply and demand of agricultural water for the i foreseeable period.

### Calculation of early warning indicators

According to the calculation results of high-quality water in urban and rural areas, self-provided industrial water, agricultural water demand and water supply projects for different industries, the supply and demand index of various water use industries and the comprehensive index of regional water supply and demand are analyzed and calculated.

\[
EX_{c}(i) = \frac{Q_{c}(i)}{W_{c}(i)} \quad (4)
\]

\[
EX_{i}(i) = \frac{Q_{i}(i)}{W_{i}(i)} \quad (5)
\]

\[
EX_{a}(i) = \frac{Q_{a}(i)}{W_{a}(i)} \quad (6)
\]

$Q_{c}(i)$ in the formula represents water supply for regional high-quality water users for the i foreseeable period. $Q_{i}(i)$ in the formula represents water supply for regional industrial water users for the i foreseeable period. $Q_{a}(i)$ in the formula represents water supply for regional agricultural water users for the i foreseeable period. $W_{c}(i)$ in the formula represents the water demand of high quality water users in the i forecasting period. $W_{i}(i)$ in the formula represents the water demand of industrial water users in the i forecasting period. $W_{a}(i)$ in the formula represents the water demand of agricultural water users in the i forecasting period.

On this basis, according to the forecasting value of regional water resources supply and demand forecasting and early warning indicators, combined with the determination of early warning level threshold, the early warning level of regional water resources supply and demand is determined according to the principles of choice the high not the low.

### 4. Case study

#### 4.1. Survey of the research area

This study chooses Yueqing County of Wenzhou City as the research area to carry out the application research of regional water resources supply and demand early warning. Yueqing City is located in the southeast of Zhejiang Province. Its land area is 1174 km² and its economy is developed. The average annual precipitation in Yueqing City is 1765 mm. The annual precipitation is uneven, concentrated in the Meiyu period in April-June and the typhoon period in July-September. From south to north, Bai Shi-xi, Tan-xi, Qing-Jiang and Da Jing-xi flow into the river system, with an average runoff depth of 1093.6 mm for many years. At present, 21 reservoirs have been built, with a total reservoir capacity of 107.29 million m³, including four medium-sized reservoirs, with a total reservoir capacity of 96.82 million m³. Overseas water diversion project is mainly Nan-xi River diversion project, with a diversion scale of 200,000 m³/d.

#### 4.2. Determination of early warning level

**4.2.1 Basic data.** According to the determination method of early warning grade standard, this study takes the minimum middle-aged runoff series of the long series of runoff series in Yueqing City from 1956 to 2016 as the typical runoff series, and forecasts the water demand of water users from 2014 to 2016. Based on this, the water supply capacity of water source project is analyzed.

**4.2.2 Analysis of early warning level criteria.** Based on the water demand of different industries and the water supply under typical runoff system in Yueqing City, the water supply quantity of water source is used to meet the water demand of water industry for many periods of time. The supply and
demand index of high-quality water in urban and rural areas, the supply and demand index of self-contained industrial water, the threshold coefficient of agricultural water supply and demand index $\beta_1c$, $\beta_1a$, $\beta_2c$, $\beta_2a$ and $\beta_2a$ are determined.

Combining with the analysis results of water demand and water supply, for urban and rural high-quality water, the initial water supply in each period of water source can meet the water demand in the next six decades. According to this, the initial water supply in each period of water source can take 6.0 for $\beta_1c$, 3.0 for $\beta_2c$ and 1.0 for $\beta_3c$. For self-provided industrial water, the initial water supply in each period of water source can meet the water demand in the next three decades, and according to this, take 3.0 for $\beta_1i$, 1.0 for $\beta_2i$ and 0.8 for $\beta_3i$. For agricultural water, the initial water supply in each period of water source can meet the water demand in the next three decades. According to this, 2.0 for $\beta_1c$, 1.0 for $\beta_2c$ and 0.6 for $\beta_3c$.

Table 2. Regional water demand and availability analysis results table.

| Time (month) | Water demand of water users (10,000m$^3$) | Minimum water supply for water users (10,000m$^3$) |
|-------------|------------------------------------------|------------------------------------------|
|             | High quality water | Self-provided industrial water | Agricultural water | High quality water | Self-provided industrial water | Agricultural water |
| 1           | 881.7 | 12.8 | 5.0 | 5343.0 | 944.0 | 9.0 |
| 2           | 746.1 | 10.5 | 4.5 | 5178.0 | 1005.0 | 9.0 |
| 3           | 726.2 | 13.5 | 5.0 | 5175.0 | 1221.0 | 9.0 |
| 4           | 769.9 | 14.6 | 4.8 | 5238.0 | 1291.0 | 9.0 |
| 5           | 887.7 | 17.4 | 685.8 | 5401.0 | 1362.0 | 2739.0 |
| 6           | 851.9 | 17.4 | 2671.8 | 5659.0 | 1590.0 | 5119.0 |
| 7           | 1019.3 | 25.0 | 2057.8 | 5689.0 | 1749.0 | 3889.0 |
| 8           | 1015.7 | 16.7 | 2378.0 | 5671.0 | 1613.0 | 3913.0 |
| 9           | 912.7 | 15.8 | 2418.2 | 5494.0 | 1490.0 | 5984.0 |
| 10          | 951.2 | 15.6 | 2652.3 | 5244.0 | 1355.0 | 4084.0 |
| 11          | 797.3 | 15.2 | 4.8 | 5364.0 | 1217.0 | 9.0 |
| 12          | 990.3 | 15.2 | 5.0 | 5475.0 | 992.0 | 9.0 |

Table 3. Outcome table of early warning level standards for research areas.

| Warning Level | Early warning grade standard | Warning Degree |
|---------------|-----------------------------|----------------|
| Grade III     | Indicators of arbitrary water users meet the requirements and choice $3.0 < EX_i < 6.0$, or $1.0 < EX_i < 3.0$, or $1.0 < EX_i < 2.0$ | Mild early warning |
| Grade II      | Indicators of arbitrary water users meet the requirements and choice $1.0 < EX_i < 3.0$, or $0.8 < EX_i < 1.0$, or $0.6 < EX_i < 1.0$ | Moderate early warning |
| Grade I       | Indicators of arbitrary water users meet the requirements and choice $EX_i < 1.0$ or $EX_i < 0.8$ or $EX_i < 0.6$ | Severe early warning |

5. Conclusion
In view of the insufficiency of early warning research on water resources supply and demand at short and medium scales in the current region, this paper defines the time scale of early warning on water resources supply and demand in the region as follows: the forecast period is 10 days, and chooses the regional water resources supply and demand situation as the early warning object, and puts forward the establishment of regional water resources supply and demand forecast composed of three indicators: urban and rural high-quality water supply and demand index, self-owned industrial water supply and demand index. The warning index system defines three levels of regional water resources supply and demand early warning, and puts forward different methods to determine the warning level
standards based on the foreseeable water demand and the minimum water supply. It is applied to the early warning of water resources supply and demand in typical regions, and puts forward the early warning level standards of water resources supply and demand in short-term and medium-scale regions in typical regions. Limited to the limitations of this study, further research is needed on the calculation factors of early warning indicators, such as the forecast of water resources, water demand and water supply in the foreseeable period, in order to provide more reliable data support for the early warning of regional water resources supply and demand.

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