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Numerical Simulation Analysis of Water Resource Supply and Demand Balance

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Abstract: With the growth of global population and economic development, the contradiction between supply and demand of water resources is becoming increasingly prominent, and the shortage of water resources has become an important factor restricting social and economic development. Therefore, scientific and reasonable analysis of water resource supply and demand balance is of great significance to ensure the sustainable utilization of water resources. As an advanced water resources management tool, numerical simulation analysis can accurately evaluate the supply and demand of water resources through the simulation and prediction of water resources system, and provide scientific basis for rational allocation and effective management of water resources. Based on this, this paper discusses the connotation and characteristics of water resources supply and demand balance, analyzes the influencing factors of water resources supply and demand balance, and studies the numerical simulation analysis method of water resources supply and demand balance. Through numerical simulation analysis, the future water resource supply and demand situation can be predicted more accurately, and the changing law and trend of water resource supply and demand balance can be revealed. It is expected that the research in this paper can promote the development and application of numerical simulation analysis technology of water resource supply and demand balance and improve the level of water resource management.

1. Introduction

Water is an important basic resource for human survival and development. However, with population growth, economic development and urbanization, the shortage of water resources is becoming more and more serious. In order to ensure the sustainable utilization of water resources, it

is necessary to conduct in-depth research and analysis on the balance of water supply and demand. As an advanced water resources management tool, numerical simulation analysis can accurately assess the supply and demand of water resources through the simulation and prediction of water resources system, and provide a scientific basis for the rational allocation and effective management of water resources[1]. This paper aims to discuss the numerical simulation analysis method of water resource supply and demand balance, in order to provide new ideas and methods for water resource management.

2. Connotation and characteristics of water resource supply and demand balance

2.1 Definition of water supply and demand balance

Water resources supply and demand balance refers to the relative balance between the supply and demand of water resources in a specific time and space. Supply usually includes natural runoff, groundwater, reclaimed water and other available water resources, while demand includes agriculture, industry, life and other aspects of water demand. The balance between supply and demand of water resources is the basis of sustainable utilization of water resources and an important goal of water resources management.

2.2 Characteristics of water resource supply and demand balance

The characteristics of water supply and demand balance are manifested in many aspects. First, it is dynamic and a constantly changing process, which is not only restricted by natural factors such as climate, topography, geomorphology and hydrology, but also affected by human factors such as social economy, population growth and water use habits. Changes in any factor may cause changes in the balance of supply and demand of water resources[2]. The second is regional characteristics. There are significant differences in the supply and demand of water resources in different regions. Some regions are rich in water resources and the supply is greater than the demand, while others are faced with water shortage and the demand is greater than the supply. The third is seasonality. Affected by seasonal rainfall, snowmelt and other natural factors, water supply increases in the rainy season, and water shortage may occur in the dry season, which requires the development of seasonal water management plans to cope with the changes in supply and demand in different seasons. The fourth is complexity. It involves the interaction and influence of meteorology, hydrology, geography, sociology and other fields and disciplines, making the problems complicated and diverse[3].

3. Influencing factors of water resource supply and demand balance

3.1 Natural Factors

Among the natural factors, rainfall and evaporation are the two most intuitive variables. When rainfall is abundant, water resources supply is naturally sufficient. The increase of evaporation directly leads to a large loss of water resources[4]. In addition, climate characteristics such as temperature and humidity also affect the distribution pattern and utilization efficiency of water resources invisibly, affecting the availability and utilization conditions of water resources. Topography also plays an important role in the balance of water supply and demand. Mountainous and hilly areas can collect and store water resources more effectively by virtue of their terrain advantages. In contrast, plain areas may face the dual challenges of water loss and pollution due to their flat terrain[5]. The flow and water quality of rivers directly determine the availability and

sustainability of water resources, while lakes and reservoirs, as important water resources storage and regulation facilities, play an irreplaceable role in water resources management and allocation[6].

3.2 Socio-economic factors

Continuous population growth directly leads to a sharp rise in domestic water consumption, which intensifies the demand for water resources, especially in areas that are already water-scarce, and the contradiction between supply and demand is becoming more acute. Economic development also promotes the rising demand for water in agriculture, industry and other fields. Agricultural irrigation and industrial production are inseparable from the massive support of water resources, and with the acceleration of urbanization brought by economic development, urban water consumption continues to increase[7]. In addition, there are significant differences in water use habits among different regions and groups. Some regions or groups have water resources waste, such as over-irrigation of farmland and random discharge of sewage. These bad habits undoubtedly further aggravate the tension between supply and demand of water resources. Policies and management also play an important role. Scientific and reasonable water resources management systems and policies can effectively promote the sustainable utilization and optimal allocation of water resources, while the lack of effective management systems and policy guidance may lead to serious waste of water resources and frequent pollution[8].

4. Numerical simulation analysis method of water resource supply and demand balance

Numerical simulation analysis is a water resource management tool based on mathematical model and computer technology. Through the simulation and prediction of water resources system, the supply and demand of water resources can be evaluated more accurately, and scientific basis can be provided for rational allocation and effective management of water resources.

4.1 Construction of numerical model

Building numerical model is the basis of numerical simulation analysis. Numerical models need to be able to reflect the physical, chemical and biological processes of water resources systems and the impact of human activities on water resources. Common numerical models include hydrological model, hydrodynamic model, water quality model and so on. These models can be selected and combined according to different research objectives and needs. When constructing a numerical model, it is necessary to consider the applicability, accuracy and reliability of the model. Applicability refers to the characteristics that the model can be applied to the research area and the research object. Accuracy means that the model can accurately reflect the actual situation of water resources system. Reliability refers to the stable performance of the model during long-term operation and multiple simulations[9].

4.2 Parameter Setting and Verification

Parameter setting is an important step in the process of numerical model construction. The selection and setting of parameters need to be based on actual data and empirical knowledge to ensure the accuracy and reliability of the model. Common parameters include rainfall intensity, evaporation, soil permeability coefficient, river flow, etc.[10] (Table 1). Parameter verification is an important means to ensure the accuracy and reliability of the model. By checking and adjusting the parameters of the model, the performance of the model can be optimized and the accuracy and reliability of the simulation results can be improved. Common calibration methods include

comparison of experimental data, sensitivity analysis and so on.

Table 1 Parameter setting and verification table of numerical model

Parameter name	Description/Definition	Setting basis
Rainfall intensity	Rainfall per unit of time	Based on historical meteorological data and regional climatic characteristics
Evaporation capacity	The amount of water lost per unit time on the surface of water body	Depends on the temperature, humidity, wind speed and other meteorological conditions
Soil permeability coefficient	The speed and ability of water to move through the soil layer	Depends on soil type, structure, moisture and other factors
River discharge	The flow of water per unit of time in a river	Affected by rainfall, topography, and human activities

4.3 Simulation process and result analysis

After the numerical model is built and the parameters are set, the simulation process can proceed. The simulation process includes three steps: input data, running model and output result. Input data include meteorological data, hydrological data, social and economic data, etc. The operational model is solved by computer program. The output results are the data and charts of the simulation results (Table 2). The analysis of simulation results is a key step to evaluate the effectiveness of numerical simulation analysis, which can help us deeply understand the changing law and trend of water resource supply and demand balance, so as to provide scientific basis for water resource management.

Table 2 Detailed steps of the simulation process

Step description	Involve elements/content
Input data preparation	Meteorological data (such as rainfall, temperature, etc.), hydrological data (such as river flow, water table, etc.), socio-economic data (such as population, GDP, water consumption, etc.)
Operation model	The numerical model is solved by computer program, including model initialization, iterative calculation and result storage
Sorting and analyzing the output results	Data of simulation results (such as water supply and demand, water level changes, water quality conditions, etc.) and charts (such as time series charts, spatial distribution charts, etc.)

4.4 Analysis of simulation results

The analysis of the simulation results is a multi-dimensional and in-depth process aimed at fully revealing the dynamic characteristics and potential risks of the water supply and demand balance. First of all, trend analysis is the cornerstone of this process. It aims to reveal the evolution law of water supply and demand balance over time by carefully examining the change trend of water supply and demand in different time scales (such as year, season and month) of the simulation results. This step not only focuses on the absolute changes in supply and demand, but also explores the internal relationship between these changes and external factors such as climate and social

economy, providing important clues for understanding the dynamic mechanism of water supply and demand balance.

Spatial distribution analysis is the key to reveal the regional difference of water resources supply and demand. Through careful interpretation of the simulation results, we can clearly see the differences in water supply and demand in different regions, and identify which regions face severe challenges of water shortage and which regions have relatively abundant water resources. This spatial differentiation analysis provides a solid basis for the formulation of more targeted water resources management strategies, and helps to realize the optimal allocation and efficient use of water resources.

Sensitivity analysis goes further into the model, observing the changes in the simulation results by adjusting the key parameters in the model (such as rainfall, evaporation, water use efficiency, etc.), so as to assess the extent of the impact of these parameter changes on the balance of water supply and demand. This process helps to identify the factors that have the greatest impact on the balance of water supply and demand, provide a scientific basis for decision makers to prioritize the direction of improvement, and promote the continuous optimization and improvement of water resources management strategies.

Scenario analysis is an important tool to predict future water supply and demand. By setting different socio-economic and climate change scenarios, such as population growth, economic development, policy adjustment, etc., we can predict the change trend of the supply and demand balance of sewage resources in these scenarios. This forward-looking analysis helps us to gain insight into the potential challenges and opportunities of future water supply and demand, providing a scientific basis for the formulation of long-term water management plans to ensure the sustainable use of water resources and the sustainable development of society.

Finally, the uncertainty analysis is carried out. Due to the factors such as model parameters, input data and system complexity, the simulation results are often uncertain. By quantifying sources of uncertainty and their impact on simulation results, we can provide decision-makers with more comprehensive and accurate information to help them make more informed decisions in the face of complex and volatile water management issues.

5. Conclusion

The numerical simulation analysis of water resource supply and demand balance is an advanced water resource management tool, which has broad application prospect and important practical significance. By constructing numerical model, setting parameters, simulation and analysis, the supply and demand of water resources can be evaluated more accurately, and scientific basis can be provided for rational allocation and effective management of water resources. In the future, with the continuous progress of technology and the increasing demand, numerical simulation analysis will play a more important role in water resources management. At the same time, it is also necessary to strengthen interdisciplinary cooperation and exchanges, optimize model structure and parameter Settings, improve data accuracy and processing capacity, etc., in order to promote the continuous development and improvement of numerical simulation analysis technology of water resource supply and demand balance.

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