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Research Article

Construction and Application of Groundwater Impact Analysis Model Based on Random Matrix Model

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Traditional groundwater models do not consider the influence of random factors, so their results of simulation and prediction cannot reflect the actual dynamics of ongoing groundwater changes. By comparing the statistical properties of random multidimensional time series, the random matrix theory can reflect the degree of deviation from randomness in actual data and reveal the behavioral characteristics of the overall correlation in actual data. On the basis of summarizing and analyzing the previous literature, this study expounded the research status and significance of groundwater impact analysis models, elaborated on the development background, current status, and future challenges of the random matrix model, introduced the methods and principles of the finite isometric properties and observation feature dimension, conducted the spectral analysis of the random matrix of groundwater impact analysis data, analyzed the eigenvalue and the eigenvector distribution of the random matrix of the groundwater impact analysis data, constructed a groundwater impact analysis model based on the random matrix model, designed the hydrodynamic model for the groundwater impact analysis, discussed the parameter variation mechanism of the groundwater impact analysis, and finally carried out a case application and its result analysis. The study results show that in the membership calculation formula of the random matrix model, it is found that there is an inverse relationship between the expected value of the target index and its membership value. According to the initial fuzzy membership function value, the random matrix model uses the normalization formula and evaluation criteria of the catastrophe model to carry out a comprehensive quantitative recursive operation and finally determines the concept, characteristics, influencing factors, evaluation content, purpose, and scope of the groundwater impact analysis model. The random matrix model can not only reflect the spatial and temporal differences of groundwater-influencing factors but also reflect the dynamic mechanism of aquifer or groundwater system or the inherent law of groundwater movement, so it is more applicable and convenient to evaluate groundwater resources.

1. Introduction

For groundwater impact analysis, due to different modeling mechanisms and starting points, usually a problem can have different evaluation methods. Each traditional method has its own characteristics but generally can be divided into two categories, namely, the subjective weighting method and the objective weighting method [1]. The subjective weighting method reflects the intention of the decision-makers, but the evaluation results are highly subjective and arbitrary; the evaluation results of the objective weighting method have a certain theoretical basis, which avoids the deviation caused by human factors. But its weight coefficient sometimes is different than the actual importance of each index, and the evaluation results are easily affected by the random errors of the index samples; therefore, these two methods have certain limitations [2]. The entropy value and superentropy reduce the degree of influence of the maximum value and the ambiguity in the evaluation process, and the error of the results is eliminated under the repeated calculation, and the evaluation results of the groundwater impact analysis model are comprehensively made more accurate, which are often averaged in the simulation, so the simulation prediction results cannot reflect the actual future groundwater changes

[3]. In fact, the groundwater model contains many random factors, and is restricted and influenced by them, so it has a certain degree of uncertainty. When applying the model to forecasting and management, a very important issue is how to quantify the uncertainty of the model to ensure the reliability of the model [4].

Different stochastic models obtain different groundwater impact analysis results, and the main reason for the analysis is whether the influence of uncertain factors is considered in the mathematical model. The traditional hydrogeological calculation uses a deterministic model, which does not consider the influence of parameter uncertainty; it simply takes the mean value of each parameter without considering the discrete degree of parameter values [5]. In fact, according to the theory of probability, the mean value of the parameters in the random matrix model should have a fluctuation range, and the corresponding calculation result should also have a range [6]. The random matrix model does not require specific hydrogeological parameters, and it only uses the data of the groundwater level sequence itself for modeling and prediction. The random matrix model has been improved on the basis of the deterministic model, considering the influence of the uncertainty factors of the parameters, and the corresponding probability can be obtained when the evaluation result is calculated [7]. This not only improves the reliability of the evaluation results to a certain extent and makes the calculation results more reasonable, but also provides more reference information for analysts. The stochastic matrix model belongs to the category of stochastic mathematics, and its theoretical basis is the stochastic process theory. For this reason, it is necessary to first examine the stochastic characteristics and stability of the groundwater system [8].

On the basis of summarizing and analyzing the previous literature, this study expounded the research status and significance of groundwater impact analysis models, elaborated on the development background, current status, and future challenges of the random matrix model, introduced the methods and principles of the finite isometric properties and observation feature dimension, conducted the spectral analysis of the random matrix of groundwater impact analysis data, analyzed the eigenvalue and the eigenvector distribution of the random matrix of the groundwater impact analysis data, constructed a groundwater impact analysis model based on the random matrix model, designed the hydrodynamic model for the groundwater impact analysis, discussed the parameter variation mechanism of the groundwater impact analysis, and finally carried out a case application and its result analysis. The study results of this study are expected to provide a reference for the subsequent research on the construction and application of the groundwater impact analysis models based on the random matrix model. The detailed chapters are arranged as follows: Section 2 introduces the methods and principles of the finite isometric properties and observation feature dimension; Section 3 conducts the spectral analysis of the random matrix of groundwater impact analysis data; Section 4 constructs a groundwater impact analysis model based on the random matrix model; Section 5 carries out a case application and its result analysis; and Section 6 is the conclusion.

2. Methods and Principles

2.1. Finite Isometric Properties of the Random Matrix Model. If the stochastic matrix model is applied to the construction of the groundwater impact analysis model, a_i represents the groundwater detection index, b_i represents the groundwater category, c_i represents the groundwater category, d_i represents the detection index, and thus, the random matrix model for groundwater evaluation can be obtained as follows:

$$A_i = \frac{(e_i - a_i)(g_i - b_i)}{(f_i - c_i)(h_i - d_i)} - \frac{(k_i - a_i)}{(l_i - a_i)}, \tag{1}$$

where e_i is the posterior probability; f_i is the prior probability; g_i is the likelihood probability; h_i is the average standard value of the i-th evaluation index; k_i is the ratio of the measured to average value of the i-th evaluation index; and l_i is the weight of the i-th evaluation index.

The random matrix structure is defined as a matrix subgraph whose number of connections between internal nodes is larger than the number of connections between nodes and external edges. It is the structure of a matrix and an important feature for studying matrix topology and matrix composition. As an important measure to measure the quality of the random matrix structure division, the modularity measure B_i is defined as follows:

$$B_i = \sum_{i=1}^{n} \left[\frac{(m_i - a_i)}{(o_i - c_i)} - \frac{(p_i - b_i)}{(o_i - d_i)} \right], \tag{2}$$

where m_i is the ratio of the edges of the nodes connecting two different communities in the matrix to all the edges; n is the sum of the elements on the diagonal of the matrix; o_i is the sum of the elements in each row or column; and p_i is the sum of all elements in the matrix. In the actual matrix, different numbers of communities are divided into corresponding standard values; the positions of these peaks are closely related to the expected division positions.

When the number of index sets is large, the relative membership weight coefficient is relatively small, which causes the multiplication of the weight vector and the membership fuzzy matrix to increase the error, and the phenomenon of rank ambiguity occurs. The groundwater impact analysis model based on the random matrix model can better avoid the above errors, and the weight value appears to be close to the actual regional groundwater environment under the dual weighting of subjective and objective. The calculation of the membership degree is based on the matrix characteristic parameters and the measured data alone, and the parameters under the unilateral constraint condition are directly calculated by taking the value of the groundwater sample. The traditional groundwater model does not consider the influence of random factors, that is, it does not treat the real random variables as deterministic variables, such as precipitation and river water level. In the process of using the random matrix model to evaluate the groundwater impact in a certain area, a comprehensive evaluation can be made in combination with other evaluation methods for a single index exceeding the standard [9]. In the research on the calculation formula of membership degree of the random matrix model, it is found that there is an inverse relationship between the expected value of the target index and its membership degree value. Groundwater quality is determined by the combined action of multiple factors; selecting appropriate evaluation indicators is the key to accurately reflect the relationship between regional groundwater quality and the environment in which the local groundwater is located.

2.2. Observation Feature Dimension for the Random Matrix Model. The purpose of solving the evaluation problem is to classify and rank the elements of the system under study as a whole, and at the same time, it is hoped that the combined evaluation function value of the sample is the best representative as close to its weighted average as possible. To this end, the objective function q_i can take the sum of the scores of various evaluation methods of each sample and the absolute value of the deviation of the combined evaluation function value to the power of r as follows:

$$C_i = \sum_{i=1}^{n}\left[\frac{(q_i - a_i)^r}{(s_i - b_i)^r} - \frac{(t_i - c_i)^r}{(u_i - d_i)^r}\right], \tag{3}$$

where s_i is the combined evaluation index function value of the i-th sample; t_i is the weight of the evaluation method; and u_i is the value of the i-th evaluation index.

When synthesizing projected values, it is required that the scattering characteristics of projected values should be as dense as possible for the local projected points, preferably condensed into several point clusters. In order to eliminate the dimension of each evaluation index and unify the variation range of each evaluation index, the following formula can be used to normalize the extreme value of the evaluation index of the larger the better, and the projection indicator function can be constructed as follows:

$$D_i = \sqrt{\sum_{i=1}^{n}\left[\frac{(v_i - a_i)}{(w_i - b_i)} - \frac{(x_i - c_i)}{(y_i - d_i)}\right]}, \tag{4}$$

where v_i is the standard deviation of the projection value i; w_i is the local density of the projection value i; x_i is the mean value of the system; y_i is the window radius of the local density, which is selected so that the average number of projection points included in the window is the number that should not be too small; and it should not increase too high with the increase in the number of evaluation indicators.

To apply the random matrix model to the construction of the groundwater impact analysis model, it is necessary to mathematically demonstrate that the model has the mutation characteristics of the random matrix model and conforms to the primary mutation type. The catastrophe of geological environmental problems such as land subsidence and ground subsidence caused by groundwater overexploitation is the theoretical basis for demonstrating the catastrophe in the construction of the groundwater impact analysis models. For the regional groundwater system, the construction of the groundwater impact analysis model means that the pressure and disturbance to the groundwater system in the process of groundwater development and utilization have exceeded the system's own bearing capacity, resulting in system instability and adverse consequences [10]. The concept, characteristics, influencing factors, evaluation content, purpose, and scope of the groundwater impact analysis model are constructed, and the mutation demonstration is constructed according to the groundwater impact analysis model, and the stochastic matrix model is used to evaluate the construction status of the groundwater impact analysis model. According to the groundwater impact analysis model, the model constructs the evaluation concept and content, the internal role relationship of risk factors, and the principle and purpose of index selection, and decomposes the risk evaluation target at multiple levels. According to the initial fuzzy membership function value, the random matrix model uses the normalization formula of the catastrophe model and the evaluation criteria of the catastrophe model to carry out a comprehensive quantitative recursive operation, and finally normalized to a parameter, that is, the total catastrophe membership value is obtained.

3. Spectral Analysis of the Random Matrix of Groundwater Impact Analysis Data

3.1. Eigenvalue Distribution of the Random Matrix of Groundwater Impact Analysis Data. According to the characteristics of the groundwater flow system, the factors affecting the groundwater level dynamics and the stability of the spring flow sequence are mainly manifested in the artificial interference of the groundwater system, including changes in the groundwater extraction amount and the extraction method within the system, the allocation of surface water bodies across the system, and the construction of reservoirs or other large-scale construction projects with stable groundwater systems. If the artificial disturbance is relatively stable, then the dynamics of groundwater level and spring flow will show relative stability. The information that constitutes the groundwater system mainly includes precipitation infiltration, surface water distribution, artificial irrigation and drainage, groundwater level dynamics, and spring flow dynamics. The artificial mining, farmland irrigation with surface water, and interbasin water transfer are all random, and the dynamics of groundwater level and spring flow are closely related to the above factors, so they must be random. The study of groundwater level dynamics is generally based on the long-term observational data of observation holes, which is regarded as a time series for research. Therefore, the characteristics of groundwater level dynamics are essentially to the time series of its observational data, and the same is true for precipitation, well flow, spring flow, etc.

Figure 1 shows the eigenvalue distribution of the random matrix of groundwater impact analysis data. The stochastic simulation of the groundwater flow model can more realistically approach the objective hydrogeological conditions,

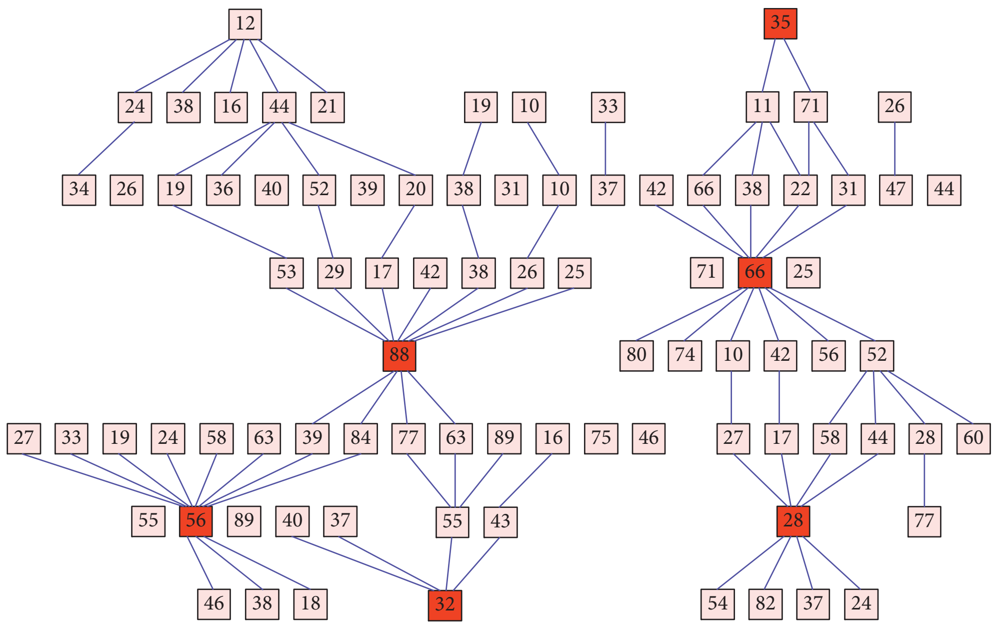

Figure 1: Eigenvalue distribution of the random matrix of groundwater impact analysis data.

which is an important progress in hydrogeological research. Each prediction model has its applicable basis and application conditions. It should be flexibly used according to the applicable conditions of the model, but it should not rely too much on the results of the prediction model, and it should be judged according to the actual situation in order to achieve the expected effect. The increase in ammonia nitrogen content can indicate the pollution of domestic sewage, and the modeling of geological bodies is a very complicated process. In addition, the pollution may come from the runoff and infiltration of farmland after fertilization. The locally optimized model is obtained for energy level transition, and the global optimization inversion is performed. Finally, the globally optimized model can be regarded as the ground state of the atom. The random matrix model uses the singular value decomposition based on the least squares to obtain the local minimum value of the objective function, and obtains the excited state of the atom [11]. The target energy level corresponding to each excited state transitions according to the energy level transition probability until it reaches the ground state of the atom. Since the error when using the random matrix model algorithm to solve includes the noise error of the field measurement data and the error after the regularization term is introduced, a selection of the regularization parameter is the key to balancing the error during the regularization solution.

When the length of the signal increases, the number of columns of the observation matrix needs to be increased accordingly, and a random matrix with fixed column weights can be selected as the observation matrix. In this case, it is only necessary to add several columns with the same structural characteristics to the original matrix. If the length of the signal remains unchanged, but the number of observations needs to be increased to meet the recovery requirements, a random matrix with fixed row weights can be selected as the observation matrix. In this case, it is only necessary to add several rows with the same structural characteristics to the original matrix. The more the number of nonzero elements in the random matrix, the better the recovery performance, but as long as it exceeds a certain number, it can meet the requirements, continues to increase the number of nonzero elements, and the performance change is not obvious, so the number of elements takes the smaller value that meets the requirements. Both the measurement and reconstruction time significantly increase with the increase in the sparse rate of the measurement matrix. This is because in the measurement and reconstruction process, the multiplication of the matrix and the vector is required, and the random matrix contains a large number of zero elements. There is a trade-off between the sparseness of the measurement matrix and the number of measurements required to accurately reconstruct the sparse signal. As the sparse rate of the measurement matrix decreases, the number of measurements required to accurately reconstruct the sparse signal slightly increases [12].

3.2. Eigenvector Distribution of the Random Matrix of Groundwater Impact Analysis Data. With the increase in the error uncertainty of the observational data, the deviation between the mean value of the groundwater level simulation results and the real groundwater level value increases, and the standard deviation of the groundwater level also shows an increasing trend. The existence of the error of the model structure generalization and groundwater level observational data brings uncertainty to the model parameters and model output results, but the influence degree is different, and the model structure generalization plays the main control role. When the generalization of the model structure is reasonable, the uncertainty of the model parameters and model output results is relatively small, showing a trend of increasing with the increase in the uncertainty of the observational data error. When the generalization of the model structure is unreasonable, the model parameters and the uncertainty of the model output results significantly increase and are mainly controlled by the influence of the generalization of the model structure, and the influence of the error of the observational data can be basically ignored [13]. When the error of the observational data is the same, the more reasonable the generalization of the model structure is, the closer it is to the real hydrogeological conditions, and the smaller the uncertainty of model parameters and model output results. In practice, it is necessary to strengthen the grasp of the hydrogeological conditions of the study area. On the premise of ensuring the rationalization of the model structure, the error of the observational data should be minimized, thereby effectively reducing the uncertainty of groundwater numerical simulation. At the same time, on the other hand, it is also possible to verify whether the generalization of the model structure is reasonable by appropriately increasing the error of the observational data and analyzing whether the uncertainty of the parameters and model output results increases in a trend (Figure 2).

The stochastic matrix model is mainly based on groundwater dynamics to establish partial differential equations. In addition, the stochastic matrix model can establish the conservation equation of groundwater movement according to the law of mass conservation. The equation contains parameters representing the water conductivity of the aquifer, which can better describe the equilibrium characteristics of groundwater [14]. However, this model has high requirements for aquifer parameter information, so when there are not many regional hydrogeological exploration and test work, few hydrogeological parameters are obtained, or the parameter accuracy is not high, and the application of this method is bound to be limited. As shown in Figure 3(a), if the models want to obtain more accurate hydrogeological parameters, the required funds and fieldwork are often very large, and the actual conditions are often not allowed. The stochastic model uses the statistical theory to analyze, mainly including the spatial distribution of pollutants, temporal and spatial changes, and risk analysis. Because in the establishment of a stochastic model, it is not required to have specific hydrogeological parameters, and only the data of the groundwater level sequence itself are used for modeling and prediction (Figure 3(b)). Therefore, for areas lacking hydrogeological parameters, when systematic groundwater dynamic observational data are available, it is more applicable and convenient to use the stochastic model to evaluate groundwater resources.

The function of groundwater resources refers to the recharge security role or effect of groundwater resources with certain recharge, storage, and renewal conditions. Taking the possession, regeneration, regulation, and availability of resources into consideration, comprehensively, the evaluation results of groundwater resources are divided into strong, strong, general, weak, and weak. To facilitate connection with the concept of aquifers, the stochastic matrix model integrates major good intervals to form a conceptual

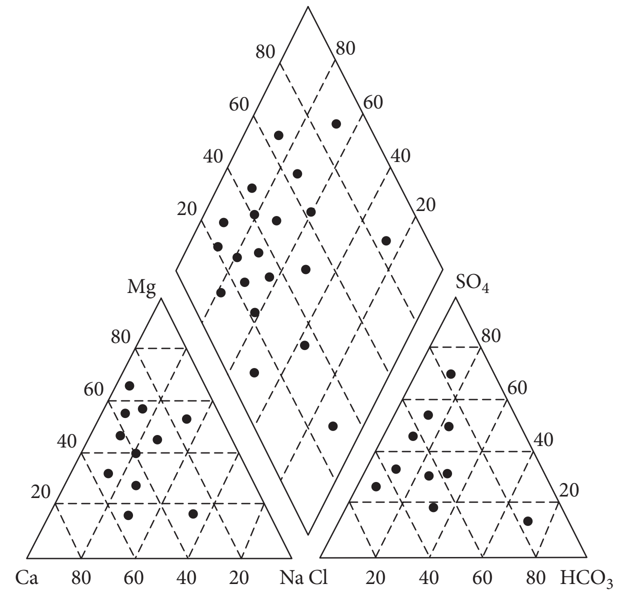

Figure 2: Eigenvector distribution of the random matrix of groundwater impact analysis data.

production horizon that constitutes the finite element simulation plane. Different from general aquifers, its main mining layers are deeply conceptualized and have many uncertain characteristics. The degree of pollution source load refers to the distribution of pollution sources in the study area, which is divided into industry, agriculture, sewage irrigation, livestock and poultry breeding, oil extraction, garbage dump, and other types. According to the distribution type and density of pollution sources, the degree of pollution source load in the study area is divided into basically no pollution source area, slight pollution source load degree area, general area, and serious area. According to the survey data of pollution sources, the random matrix model is determined by comprehensive analysis using quantitative or qualitative methods. By comprehensively considering the classification, stacking form, total amount of pollutants, and existence period of characteristic pollutants, a matrix evaluation method of groundwater pollution source load is obtained.

4. Construction of the Groundwater Impact Analysis Model Based on the Random Matrix Model

4.1. Hydrodynamic Model for Groundwater Impact Analysis. The deterministic model requires more basic data, and the factors affecting groundwater dynamics have spatial and temporal differences, which limit the application of the deterministic model in practice. However, the deterministic model can reflect the characteristics of groundwater movement and can be used within a certain accuracy requirement that meets the requirements, so a deterministic model is recommended for small study areas with sufficient observational and measured data. Although the stochastic model can reflect the temporal and spatial differences of

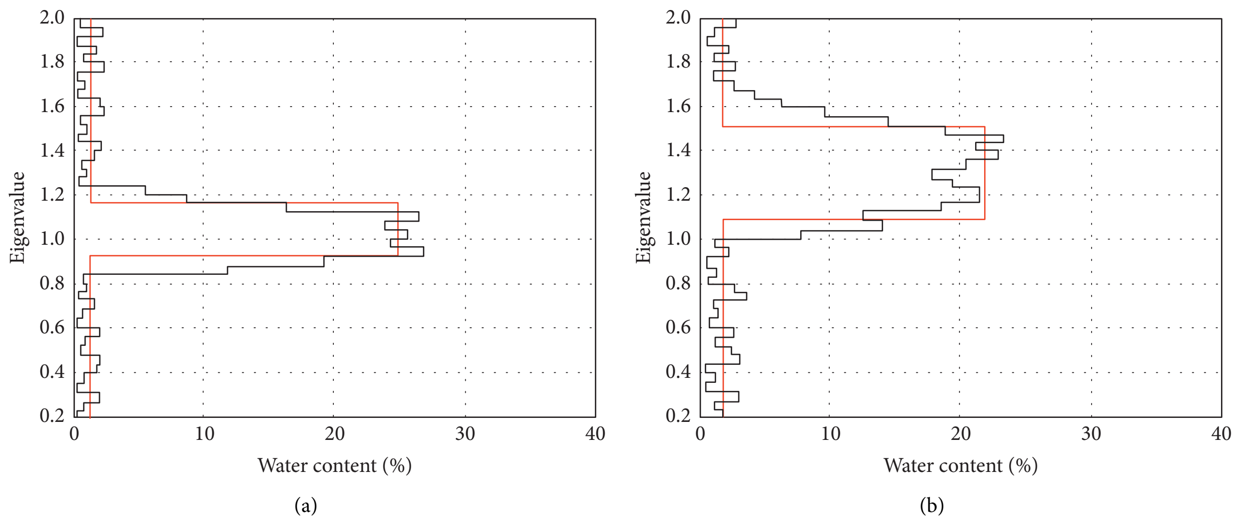

Figure 3: Relationship between water content and eigenvalue of the random matrix model with finite isometric properties (a) and observation feature dimension (b).

influencing factors and requires less basic data, it does not reflect the dynamic mechanism of the aquifer or groundwater system, nor does it reflect the inherent laws of groundwater movement, and the prediction accuracy is not high [15]. A stochastic model is, therefore, recommended for large study areas. In the past, numerical simulation generally took a set of random variables and then ran the numerical model to obtain a set of results; this set of results was different from the mean value obtained by random finite element, and the deterministic simulation was only a special case of stochastic simulation. The eigenvalue distribution of groundwater flow, level, and salinity in the groundwater impact analysis model based on the random matrix model is shown in Figure 4. The structure of a random matrix with fixed row weight is that each nonzero element takes a positive real value, and each row contains an equal number of nonzero elements. The structural feature of a random matrix with fixed column weight is that each nonzero element takes a positive real value, and each column contains the same number of nonzero elements.

Due to the difficulty of studying this transformation, there is no mature model form available so far. One of the main approaches in this type of conversion study is to use the soil hydrodynamic methods. This method considers that the movement of soil water occurs under the action of soil water potential, so the equation of soil water movement can be written. However, there are indications that the structure of the vadose-zone soil and the state of the gas within the vadose zone has a considerable influence on the water transition. Off-the-shelf kinetic model forms cannot be considered reliable until these effects are comprehensively considered. Although the low-pressure zone can be laterally extended in the aquifer with better water permeability, it is generally distributed around the main production well sections in the area, so it is often oblique to each aquifer (Figure 5). The value of groundwater is high, and as an effect relationship, it has less contamination; once polluted, it will cause huge losses in production and life in the affected area. On the contrary, if the use value of groundwater is low, although the probability of being polluted is relatively high, the loss of production and life after being polluted is not very large. The main mining layer not only plays a leading role in the groundwater system, and because this layer can be connected to the social water system through mining wells, it is also the interface between the groundwater system and the social system in the construction and application of the groundwater impact analysis model based on the random matrix model.

The accuracy of water chemical type partitioning by the spatial analysis model for water chemical type partitioning is mainly affected by the quality of spatial interpolation data. Because the spatial correlation of different water chemical components in groundwater is quite different, when setting up sampling points, the geostatistical analysis should be carried out through historical data to obtain the range value of the different water chemical components, and the minimum range value should be taken as the minimum range value. The sampling interval tries to increase the density of sampling points within the scope of economic cost control. When performing spatial interpolation, the formation and distribution characteristics of groundwater chemical components in the study area should be fully considered. When the density of sampling points is large, the chemical formation mechanism of groundwater is simple, the spatial variation of groundwater chemical components is limited, and the results of different interpolation methods have little difference [16]. When the groundwater chemical composition has large spatial variation characteristics, the global spatial autocorrelation is poor, and it is necessary to explore and analyze its trend characteristics when establishing a model, and select an appropriate model for interpolation. The spatial analysis model of groundwater chemical types can better determine and automatically partition groundwater chemical types. Compared with the traditional analysis methods, it can better reflect the spatial evolution characteristics of water chemical types, and the map visualization effect is better.

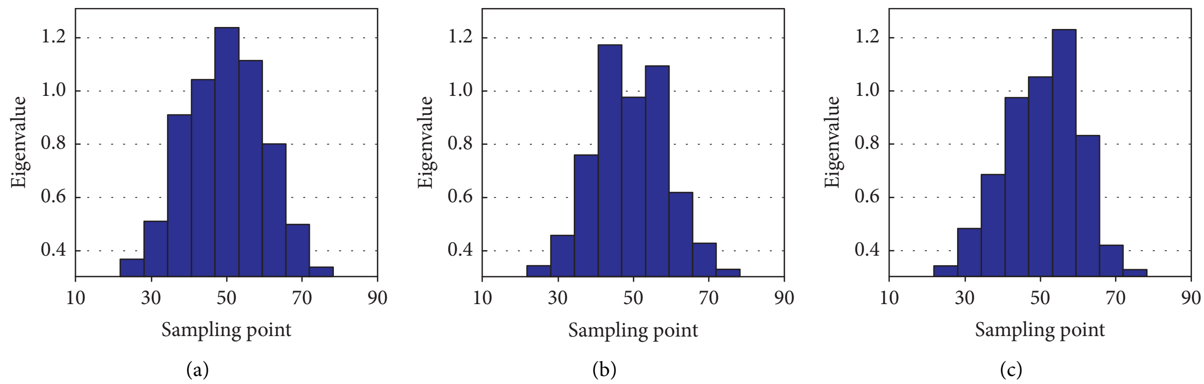

Figure 4: Eigenvalue distribution of groundwater flow (a), level (b), and salinity (c) in the groundwater impact analysis model based on the random matrix model.

4.2. Parameter Variation Mechanism of Groundwater Impact Analysis. In the process of groundwater numerical simulation, studying the response law of the simulation results of the numerical model to the changes of important parameters in the model is helpful to improve the reliability of the model and the accuracy of the simulation prediction results. Due to the complexity of hydrogeological conditions and the limited data, the determination of parameter values is both crucial and difficult for the model. At the same time, in addition to hydrogeological parameters, the influence of other factors on the simulation results should be considered in the model, and the model should be optimized based on the actual situation and previous experience to obtain more accurate simulation results. As shown in Figure 6(a), if the parameters of a linear system change with time, it is called a linear time-varying system, and it is usually described by a linear differential equation or difference equation with time-varying coefficients. As shown in Figure 6(b), if the parameters of a linear system do not change with time, it is called a linear time-invariant system and the system is often described by linear differential equations or difference equations with constant coefficients. Therefore, the method of using the linear algebraic equation system is composed of the algebraic technical functions with water level or water level requirements in the groundwater flow field as the constraint conditions of the linear programming, and establishing the groundwater system management model together with other water volume or water level constraints is called the response matrix method.

It should be noted that due to the heterogeneity of the aquifer and the influence of model generalization, the optimal drawdown of some observation holes is lower than the observed drawdown, and some are higher than the observed drawdown. During the drawdown forecast, it is necessary to analyze the specific relationship between the observational data of the actual observation hole and the simulated optimal fitting value. On the premise of collecting as much observational data as possible, a more accurate division and generalization of heterogeneous partitions should be carried out, in order to reduce the error in practical application. With the continuous generalization of the heterogeneity of the simulated area, the range of drawdown continues to expand. Compared with the drawdown mode of the reference aquifer, the relative probability of obtaining this value is getting smaller and smaller, and the posterior uncertainty is growing (Figure 7). According to the obtained descending samples, the random matrix model can not only calculate the confidence intervals corresponding to various confidence levels but also carry out a certain degree of risk analysis on the water supply problem [17]. The stochastic matrix model can not only ensure the feasibility of hydrogeological parameter identification and drawdown prediction, but also can specifically analyze the uncertainty caused by various factors, and quantify the uncertainty, which can be used in practical applications. While intuitively recognizing the uncertainty, it can also scientifically manage and utilize groundwater resources according to the size of the uncertainty, which is conducive to making correct and economical decisions.

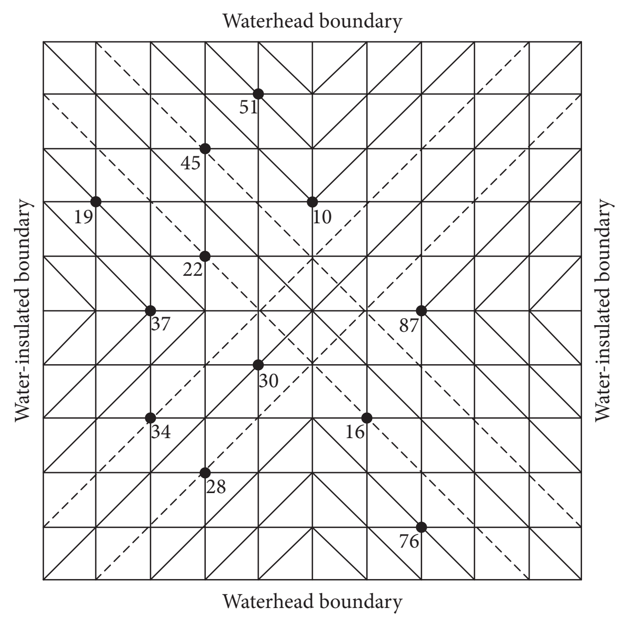

Figure 5: Hydrodynamic model for groundwater impact analysis based on a random matrix.

The groundwater system is an open system, it exchanges material, energy, and information with the external environment, and it includes two major subsystems,

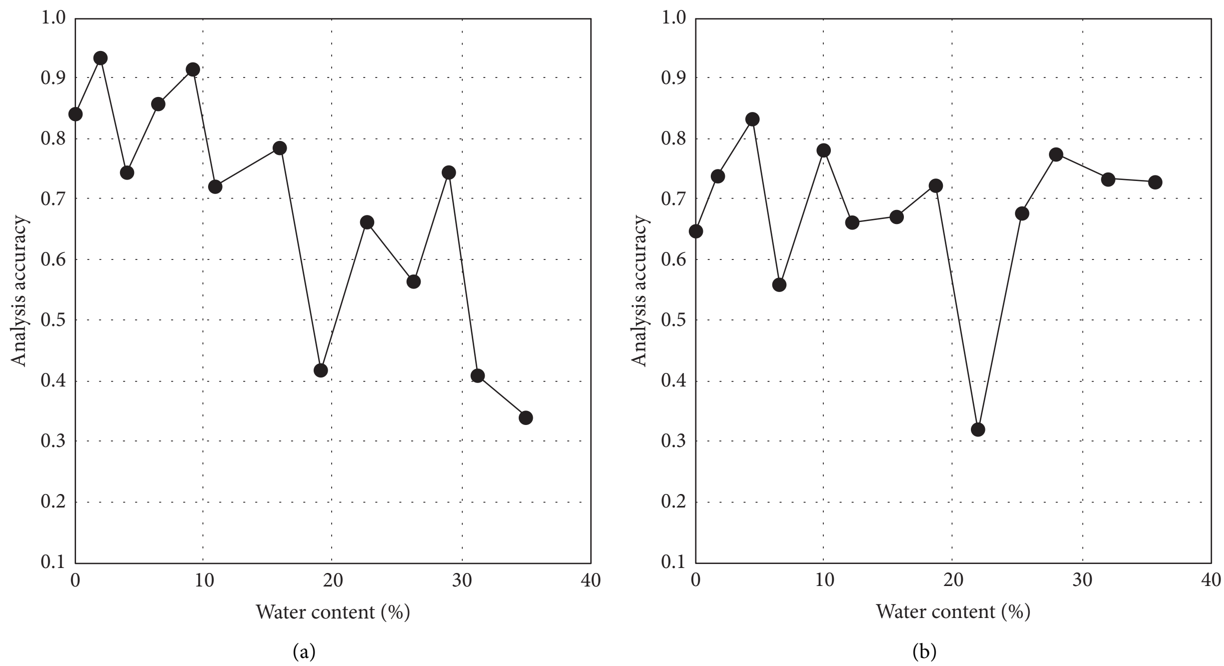

Figure 6: Relationship between analysis accuracy and water content based on the random matrix model with finite isometric properties (a) and observation feature dimension (b).

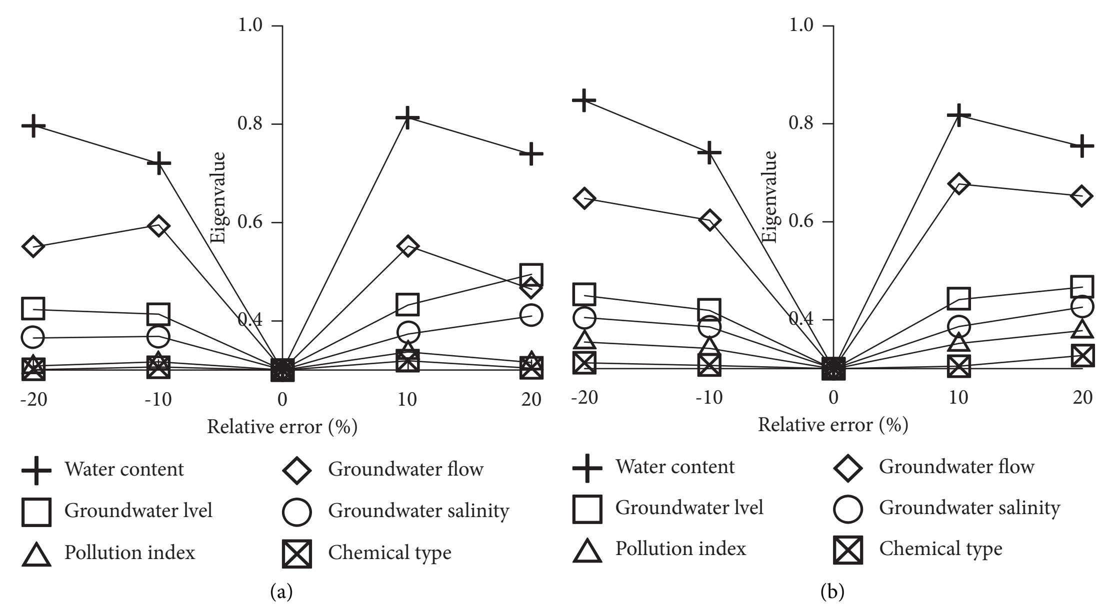

Figure 7: Parameter variation mechanism of groundwater impact analysis based on the random matrix model with finite isometric properties (a) and observation feature dimension (b).

that is, input and output. The input subsystem includes variables such as river inflow, irrigation area inflow, precipitation, and lateral recharge in front of mountains; the output subsystem includes variables such as groundwater extraction, spring water outflow, drainage, river outflow, and lateral discharge. Within the groundwater resource system, these variables are interrelated, mutually influenced, interdependent, and mutually restricted; with the changes in external input and output variables, they are also changing within the groundwater resource system, and these variables themselves are strictly subject to changes controlled by topography, geological landforms, soil, and vegetation [18]. Therefore, the evaluation of groundwater resources requires abandoning the single system or the scattered and isolated research methods of variables, and must identify the relationships and constraints between subsystems and variables in the groundwater system, and the control and feedback mechanisms between systems or variables. In order to achieve a quantitative description of groundwater resources in a region or basin, the change in groundwater resources is mainly affected by the external influence, that is, the interference of the two major subsystems of input and output.

5. Case Application and Its Result Analysis

5.1. Case Background and Research Design. In this study, an area of Guangzhou City, Guangdong Province, Southern China, is taken as an example to carry out research on groundwater impact analysis based on the random matrix model. The top boundary of the groundwater system in the study area is the ground surface, which is hydraulically connected with the return water of agricultural irrigation and the return seepage of urban and rural domestic water. The bottom of the study area is subclay with poor water permeability, which is used as a water barrier. The northern part of the study area is a piedmont plain area, the lithology of the stratum is mainly coarse sand and gravel, and the medium in most areas is permeable and water-rich; in the southern hilly area, the lithology of the stratum is mainly clastic rock and metamorphic rock and granite, the network-like fissures developed in it are partially filled, the connectivity is poor, and the water-rich groundwater is weak [19]. The mutual conversion between surface water and groundwater is an important feature in the water cycle process, and the coupled simulation of surface water and groundwater using mathematical models is a common method to study the interaction of surface water and groundwater. Due to the model structure, and observational data, there is often a certain deviation between the calculation results of the coupled model and the true value, which is the actual embodiment of the uncertainty in the coupled model.

5.2. Result Analysis. The random matrix model calculates the membership degrees of each evaluation index and takes the transition of groundwater boundary into consideration, which enhances the continuity of the data and makes the evaluation results more scientific and accurate. Combined with the actual situation, the fuzzy comprehensive evaluation based on the weighted average principle is more feasible than the maximum membership degree principle. However, the calculation process of the fuzzy comprehensive evaluation method is relatively complicated. When there are too many groundwater samples or evaluation indicators, the calculation difficulty will geometrically increase, which is suitable for high-precision evaluation work [20]. The evaluation results of the random matrix model are similar to the fuzzy comprehensive evaluation results, and the influence of each evaluation index on groundwater is also taken into consideration to reduce the influence of abnormal values on the evaluation results. The evaluation process of the stochastic matrix model is the simplest, and no calculation is required. The evaluation results can be obtained by comparing the water quality detection value with the water quality standard value, which can clearly show the excess status and distribution of pollution indicators (Figure 8). There are the principle of maximum membership degree and the principle of weighted average, which, respectively, use these two principles to determine the groundwater level. The evaluation results are relatively optimistic, and the calculation process is simpler, which is not affected by the size of groundwater samples and evaluation indicators, and has strong applicability.

After establishing the mathematical model to describe the groundwater flow, the random matrix model uses the difference quotient instead of the differential quotient. The finite element technology derived from structural mechanics also transforms the fixed solution problem describing groundwater flow into an algebraic equation through the regional division and interpolation methods. Therefore, when choosing the mathematical models of different dimensions for the same problem, the reasons and degrees of errors are obvious. In actual work, choosing appropriate mathematical models according to the characteristics of the problem and different accuracy requirements and field data is the foundation of groundwater numerical simulation technology [21]. The hydrogeological parameters in the model are mainly the permeability coefficient and water supply value. The random matrix model does not require specific hydrogeological parameters and only uses the data of the groundwater level sequence itself for modeling and prediction. On the one hand, the shallow groundwater may be polluted by domestic sewage; under aerobic conditions, ammonia nitrogen is the initial product of microbial decomposition of organic matter. On the basis of fully grasping the data of drilling holes and flat tunnels, a conceptual model of hydrogeology is established. With the conceptual model, the research area is generalized and abstracted, and a mathematical physical model that can simulate the research area is established. But even a finer model is always different from the actual stratigraphic and hydrogeological conditions.

The division principle of hydrogeological parameters mainly refers to the stratum and borehole pumping test data, and divides them according to the characteristics of the water-bearing medium and considering the seepage characteristics of the initial flow field. The hydrogeological parameters in the model are mainly the permeability coefficient and water supply value. Each hydrogeological parameter is given according to the results of the hydrogeological test carried out in the study area, and the initial value is given in combination with the lithological characteristics and empirical values, and is corrected by the model simulation. Finally, the hydrogeological parameters required for the simulation are obtained. This study selects a complete hydrogeological unit, which not only helps to clarify the conditions of groundwater recharge, runoff, and discharge in the evaluation area, but also makes the generalization of the boundary conditions of the evaluation area more convenient and accurate [22]. The random matrix model integrates the relationship between the longitudinal dispersion and the spatial scale used in multiple water quality models, determines the dispersion according to the scale of the

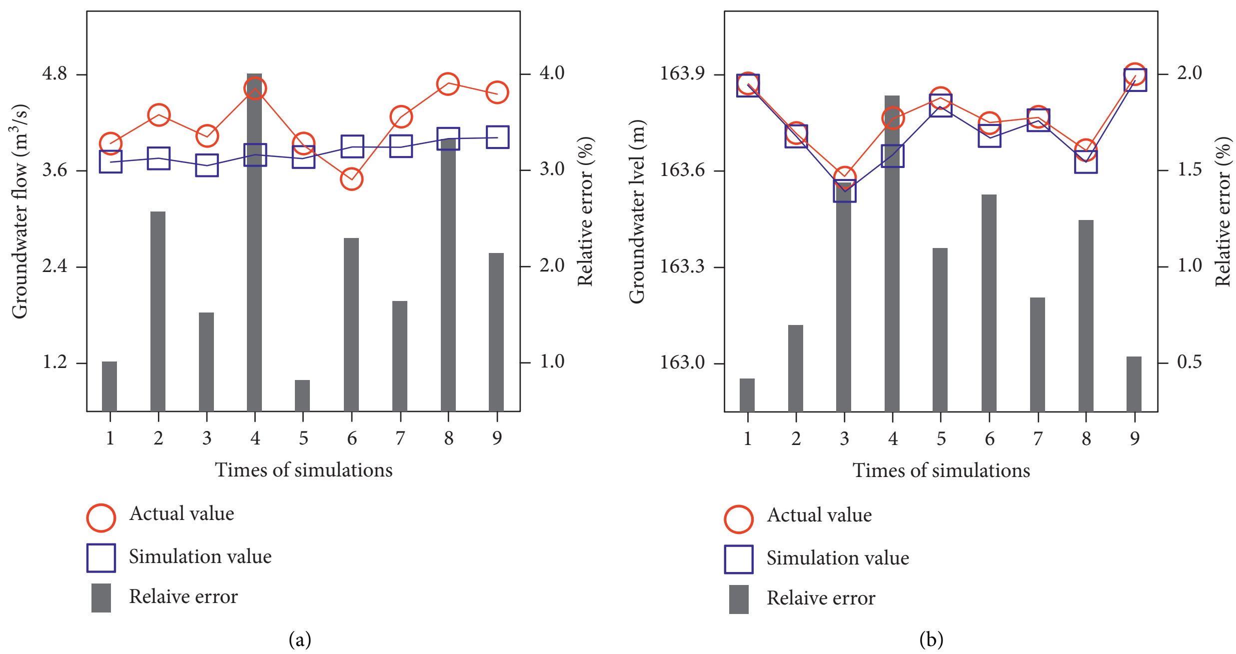

FIGURE 8: Actual values, simulation values, and relative errors of groundwater flow (a) and level (b) in the groundwater impact analysis model based on the random matrix model.

evaluation range, and then determines the dispersion coefficient according to the dispersion and flow velocity. Therefore, it should be recognized that the optimal mathematical model also has certain errors, and there is no geological model that is completely consistent with the actual situation. The groundwater numerical simulation model and the actual geological body are equivalent, but not equivalent. The method introduced above is that different models simulate the movement of the water level of the fracture network, resulting in different degrees of model errors.

6. Conclusions

This study conducted the spectral analysis of the random matrix of groundwater impact analysis data, analyzed the eigenvalue and the eigenvector distribution of the random matrix of the groundwater impact analysis data, constructed a groundwater impact analysis model based on the random matrix model, designed the hydrodynamic model for the groundwater impact analysis, discussed the parameter variation mechanism of the groundwater impact analysis, and finally carried out a case application and its result analysis in a certain area of Guangzhou City, Guangdong Province, Southern China, as an example. Each hydrogeological parameter is given according to the results of the hydrogeological test carried out in the study area, and the initial value is given in combination with the lithological characteristics and empirical values, and finally, the hydrogeological parameters required for the simulation are obtained. When the error of the observational data is the same, the more reasonable the generalization of the model structure is, the closer it is to the real hydrogeological conditions, and the smaller the uncertainty of model parameters and model output results. Therefore, for areas lacking hydrogeological parameters, the model can also perform a certain degree of risk analysis on water supply problems. The study results show that in the membership calculation formula of the random matrix model, it is found that there is an inverse relationship between the expected value of the target index and its membership value. According to the initial fuzzy membership function value, the random matrix model uses the normalization formula and evaluation criteria of the catastrophe model to carry out a comprehensive quantitative recursive operation, and finally determines the concept, characteristics, influencing factors, evaluation content, purpose, and scope of the groundwater impact analysis model. The random matrix model can not only reflect the spatial and temporal differences of groundwater-influencing factors, but also reflect the dynamic mechanism of aquifer or groundwater system or the inherent law of groundwater movement, so it is more applicable and convenient to evaluate groundwater resources.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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