Preliminary study on Applicability of mine water inflow forecasting method

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Abstract. The commonly used calculation and prediction methods of mine water inflow in China are divided into deterministic and non-deterministic. Affected by many influencing factors, the applicability of the calculation method has not been reflected, resulting in a large prediction error. By combing the main influencing factors of mine water inflow, The characteristics, advantages, and limitations of evaluation prediction methods, Clarify the selection of the three-stage prediction methods in the exploration phase, well development phase, and mining phase, Establishing a framework for the principles and prediction process framework of mine water inflow forecasting. Achieve precise forecasting and reduce the risk of approval of water resources demonstration by management departments, Helps to turn mine water into waste and improve the management of comprehensive utilization of mine water, Realize the integration of unconventional water resources into the unified allocation of water resources, alleviate the conflict between supply and demand of water resources, and improve the efficiency and utilization efficiency of regional water resources allocation.

1. Introduction

China is a big country of mineral resources and a big country of mining. 172 kinds of minerals have been found and 162 kinds of proven resource reserves. The National Development and Reform Commission and the National Energy Administration jointly issued the "Mine Water Utilization and Development Plan"(National Development and Reform Commission,2013).In 2015, mine water discharge was approximately 7.1 billion m³, accounting for more than 80% of total mine water discharge. Gu Dazhao(Gu er al,2016) pointed out that the annual mine water utilization rate in China's coal industry is only about 25%, and the annual mine water loss is about 6 billion m³. In China, the total annual industrial and civilian water shortage is about 10 billion m³. For areas without water scarcity, mine water is waste water, but for areas without water scarcity, mine water is a valuable resource.

In order to implement the concepts of "green water, green mountains are golden mountains and silver mountains," and "accelerate the progress of ecological civilization," a series of reform measures have been implemented successively to strengthen the diversified, cascaded, and safe use of unconventional water such as mine water in water scarce areas, Forcibly promote the unconventional water into the unified allocation of water resources, increase the proportion of unconventional water utilization year by year, and strictly evaluate the requirements of the Party Central Committee(State
department, 2012, 2015, Ministry of Water Resources, 2017, National Development and Reform Commission, 2019). The accuracy of "quantity" is the basis for resource utilization.

At this stage, our country adopts metered monitoring data for existing mines to measure mine water inflow and external drainage. The prediction method is used to predict the planned construction of coal mines. Due to the influential factors of the mine water gush, the prediction is relatively difficult, which leads to large calculation errors. According to statistics, compared with the actual mine gushing water volume after mining, the error is less than 30%, only 10%, 80% of the mining area error is more than 50%, some errors are more than 100%, in severe cases, the difference is more than 10 times (Miao Lintian, 2017, Zhang Caiyun, 2018). There are several reasons for the large difference between the predicted water gush and the actual water gush. The hydrogeological conditions of the mine have not been identified or insufficiently understood, and the spatial differences of the hydrogeological parameters have resulted in improper parameter selection and incorrect selection of prediction methods or mathematical models.

On the one hand, the error of the forecast amount brings greater difficulties to the approval of water resources demonstration, on the other hand, it directly affects the safety of production and economic benefits of the enterprise. In summary, clarifying the influencing factors of mine gushing water, sorting out the existing calculation methods and applicability of mine gushing water in China, which will help reduce the risk of approval of water resources demonstration by management departments. It is helpful for enterprises to turn mine water into waste, realize unconventional water resources in the unified allocation of water resources, alleviate the contradiction between water supply and demand, and improve the efficiency and utilization efficiency of regional water resources allocation.

2. Factors Affecting Mine Water Inflow

2.1. Hydrogeological conditions
Hydrogeological conditions of the mine are the key factors affecting the amount of water in the mine. The first is reflected in the thickness of the aquifer, the development of fissured karst, water abundance, and the source of recharge. The general rule is that the three are positively related to the amount of water flowing from the mine. The second is reflected in the relationship between the mining coal seam and the local erosion surface and regional groundwater level. When it is below it and the recharge relationship is close, the mine gushing water is large. The third is a positive correlation with the size of the infiltration coefficient.

2.2 Geological structural features
The amount of mine gushing water is directly related to the geological structure, especially the folded fault. The geological structure plays a role in connecting and conducting water to the groundwater and surface water, and it also partially blocks the overflow. It is mainly determined by the richness of the source of the folding fault recharge. Abutment with aquifers and aquifers on the two discs of the fault.

2.3 Coal seam mining stage
At different stages of coal mining, there are differences in the amount of water flowing in the mine. After the mining of coal mines, the amount of water in the mine is generally divided into four stages. In the initial stage of the first stage of coal mining, that is, during the period from the infrastructure to the production period, a relatively large number of aquifers were exposed, and each aquifer was in a state of natural saturation. With the continuous expansion of the mining face, the coal seam was directly penetrated into the pit by various types of supplementary water sources. The amount of replenishment is large, and the amount of gushing water in the mine gradually increases; In the second stage, after a certain period of coal mining has been reached, new aquifers are generally not exposed in large areas. Due to the increase in mining time, the water level of the aquifer continues to decrease, and some aquifers have changed from pressure-bearing to non-pressure. Diameter, row balance. In the third stage, in the late stage of coal mining, the aquifer was partially dredged, and the water-carrying fissure zone
was gradually filled. In the fourth stage, when the coal mine is mined into the final stage (stop mining), the amount of water flowing in the mine becomes smaller. Due to the existence of a water barrier at the bottom of the coal seam, water gradually forms a "groundwater reservoir".

2.4 Atmospheric precipitation
Atmospheric precipitation and surface water are one of the sources of supply of mine water. In the first stage of mining, the precipitation and the mine gushing water have the same direction relationship; in the second stage of mining, the mine gushing water is in a state of balance, diameter and drainage, and the relationship between precipitation and mine gushing water is not obvious; the third and fourth stages of mining, the relationship between precipitation and mine gushing water is in the opposite direction.

2.5 Mining area
Affected by the mining plan, the mining area of coal mines has increased year by year. The relationship between the amount of water flowing from the mine and the mining area is the same as that of the mining stage. That is to say, in the first stage of mining, as the mining area increases, the mine gushing water volume increases. In the second, third, and fourth stages, the mine gushing water volume is in a state of complement, diameter, and drainage to a state of less than drainage, and the mining area and mine flooding There is no direct correspondence between water quantities.

2.6 Mining coal seam thickness
The thickness of the mining coal seam is closely related to the amount of water flowing from the mine. The greater the thickness of the mining coal seam, the greater the impact of the "upper three zones". The more the water-conducting fissure zone penetrates the overlying (isolated) water layer, the greater the overburden water supply and the mine The amount of gushing water increased.

2.7 Coal extraction
There is a good correlation between the amount of mining and the amount of water flowing in the mine, and coal and water coexist. Under certain hydrological, geological, and meteorological conditions, the amount of water flowing from a mine is positively related to the amount of coal mined. In the first stage of mining, the mine water influx is positively correlated with the amount of coal extracted; in the second stage of mining, as the aquifer is fully opened, the aquifer's water is continuously dredged, and the increase in the mining volume is gradually negatively correlated with the mine's water inflow; In the third and fourth stages, the mining volume has entered a stable period, and the mine water inflow is relatively stable.

According to the analysis of the factors affecting the mine water influx, it is found that the mine water influx is affected by many factors such as hydrogeology, meteorology and mining conditions in the mining area. Mine water inflow shows a clear trend of change.

3. Calculation Method and Review of Mine Water Inflow

3.1 Calculation method combing
The existing methods for calculating and predicting mine water inflow in China (Wang Youyu,2018, Zuo Wenzhe,2016, Fang Xiangqing,2018, Xu Gaoqiang,2008) are mainly classified into two categories: deterministic and non-deterministic. Limited by theory and data, different prediction methods have certain limitations and deficiencies. In actual calculation and prediction, it is necessary to select an appropriate calculation method according to the degree of investigation, such as survey, hydrogeology, meteorological conditions, and production stages. The characteristics and limitations of each prediction method are shown in Table 1.
Table 1. Summary of characteristics and advantages and disadvantages of different mine water gush calculation methods

| Category       | Method                  | Features                                                                 | Advantage                                  | Limitation                                                                                                                  |
|----------------|-------------------------|----------------------------------------------------------------------------|--------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| Deterministic  | Numerical simulation    | Computing with the help of a computer. Suitable for mines with complex hydrogeological conditions | Approximate segmentation principle, solve complex problems, fast operation speed | The approximate solution, the accuracy of the discretization method and the conceptual model, the boundary processing is difficult, the deep drop of deep aquifers is difficult to predict, and it lacks generality. |
|               | Analytical method       | Reasonable generalization and reconstruction of ideal analytical formula   | Strong adaptability and simplicity         | The simplification of the boundary and the accuracy of the calculation parameters affect the prediction accuracy. It is difficult to predict the large depth of deep aquifers, which is suitable for simple mines. Equilibrium factors are difficult to determine, suitable for macro-scale, and suitable for mines with simple groundwater formation conditions. |
|               | Water balance method    | Determining the value of the limit gushing amount of water in a mine        | Simple calculation process                  | The approximate estimation method, the similarity of similar conditions and the reliability of observation data, are suitable for mines with low mining levels, simple hydrogeological conditions, and low water inflow. |
|               | Analogy                 | Mines with similar conditions                                              | Simple calculation method                  | It is difficult to determine the trend, and it is obviously affected by each stage of mining.                      |
| Non-deterministic | Fuzzy mathematical model | Consider multiple factors                                                  | Comprehensive                              | The data fluctuates strongly and the simulation effect is not ideal. The length of the original data sequence is high, and the selection of correlation factors is difficult. The requirements for the length of the original data sequence are high, and it is obviously affected by each stage of mining. |
|               | Grey system theory      | Study the output sequence of the system                                   | Low requirements on raw data and strong generalization | It is obviously affected by each stage of mining. |
|               | related analysis        | Mathematical statistics                                                    | Avoids the problem of difficult to determine hydrogeological parameters |                                                                           |
|               | Time series analysis    | Study the output sequence of the system                                   | Simple calculation method                  |                                                                           |
|               | Neural Networks         | Nonlinear method                                                          | Persistent, timely and predictable         |                                                                           |

3.2 Calculation method combining
Overview of forecasting methods at different stages
(1) Exploration stage
Hydrogeological exploration is the initial understanding of the hydrogeological conditions of the mining area. The obtained hydrogeological conditions are less detailed and have fewer parameters. At
this stage, the mine belongs to the unbuilt stage, and the applicable methods are mainly analytical method, water balance method and comparison method.

The analytical method determines the boundary conditions based on the data of the mining area, and generalizes the hydrogeological model, which can generally achieve the accuracy of exploration forecasting requirements; the water balance method can only use the water balance data of the area where the mining area is located to calculate the water balance of the mining area, and the accuracy is generally not high; the analog method is applicable There are mines that have been put into production in the surrounding area, and the hydrogeological conditions are similar and the mining methods are basically the same.

(2) Development of wells and lanes
In the development phase of the well and the tunnel, the hydrogeological conditions around the well and the tunnel can be fully determined according to the amount of water inflow during the actual construction and the monitoring data of the surrounding observation holes (water level drop). The hydrogeological parameters obtained at this stage have good reliability. The analytical method is used to calculate and predict the mine water inflow with high accuracy.

(3) Extraction stage
This stage is the four mining stages of the coal seam described in section 1.3. A large amount of actual water gushing data can be obtained, which can be used for non-deterministic methods such as gray system theory, time series analysis, and neural network calculation and prediction methods. The degree of identification of hydrogeological conditions and boundary conditions at this stage have been clarified, which can provide sufficient water influx and corresponding water level changes for the numerical simulation method in the deterministic method.

4. Principles and Forecasting Process of Mine Water Inflow Forecasting

4.1 Principles to follow
(1) Foundation: Find out the water filling factors and hydrogeological conditions of the mining coal mine;
(2) Process: It runs through the entire process of hydrogeological exploration and production in the mining area;
(3) Degree: It is continuously revised and improved in the continuous deepening of hydrogeological and meteorological conditions.
(4) Accuracy: comprehensively grasp the data, analyze the filling conditions, and select the appropriate prediction method.

4.2 Prediction process
According to the principle of mine water gushing and principles of mine water prediction at different stages, comprehensive consideration of the influence factors of mine water, the process of forming mine water prediction is shown in Figure 1.
5. Conclusions and suggestions

5.1 Conclusions

1. Mine water influx mainly includes hydrogeological conditions, geological structural characteristics, coal seam mining stages, atmospheric precipitation, mining area, coal thickness, and mining influencing factors; the calculation and prediction methods of mine water influx are mainly deterministic (numerical simulation method, analytical method, Water balance method), non-deterministic (analog method, fuzzy mathematical method, gray system, time series method, correlation analysis method, neural network method) prediction methods.

2. The applicable methods in the exploration phase are mainly analytical method, water balance method and analogue method; the applicable methods in the well development phase are mainly analytical method; when the hydrological and geological conditions and boundary conditions are specified during the mining phase, the numerical simulation method is used. For mines with simple geological conditions, the applicable methods are mainly non-linear prediction methods such as gray system theory, time series analysis, and neural network.

3. Integrate the characteristics of multiple prediction methods to build a framework diagram of the mine water prediction process.

5.2 Suggestions

In the National Water Conservation Action Plan of 2019 (NDRC [2019] No. 695) [National Development and Reform Commission, 2019], it is clear to strengthen the diversified, cascade and safe use of unconventional water such as mine water in water scarce areas, and force the promotion of the inclusion of unconventional water. Unified allocation of water resources, increase the proportion of unconventional water use year by year, and strictly evaluate; under the general keynote of the current "water conservancy projects complementing shortfalls and strong supervision of the water conservancy industry" and the future development of water conservancy reform and development, unconventional water sources are included in water Unified configuration, the increase in the use of unconventional water resources in the current year compared to the previous year or the proportion of the total water
consumption in the current year is one of the implementation methods to strengthen water conservation supervision and management and water intensity control. The "Notice on Further Strengthening and Standardizing the Statistics of Unconventional Water Sources" in 2019 (Jie banyu [2019] No. 241) (Ministry of Water Resources,2019) emphasized the need to clarify the statistical caliber of unconventional water sources. Faced with these requirements, the technical department should choose a reasonable calculation method based on the actual situation of the mine, carry out staged forecast management and reduce forecast errors. On the one hand, it helps to reduce the risk of approving and approving water resources for management departments, and on the other hand, it helps to manage the comprehensive utilization of mine water.

Therefore, while sorting out the applicable conditions of the mine water prediction method in China, it is recommended that the water administrative department and other departments recommend in the relevant technical requirements amendments such as the Guidelines for the Demonstration of Water Resources for Construction Projects and the Guidelines for the Demonstration of Water Resources for Construction Projects in Mining Industry. Reasonable selection of forecasting methods in different mining stages to achieve accurate forecasting, realize the unallocation of unconventional water resources into the unified allocation of water resources, alleviate the contradiction between supply and demand of water resources, and improve the efficiency and utilization efficiency of regional water resources allocation.

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