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Study on the Application Range of R in the Formulas of Mine Water Inflow

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Abstract Calculation of mine water inflow is an important content in hydrogeological work: It is one of the main work in deposit hydrogeological exploration. Based on the dynamics of groundwater, the large-well method (LWM) is simple and effective in the prediction of mine water inflow. However, how to reasonably select parameters in LWM has great influence on the results of water inflow prediction. This paper takes the water inflow prediction of panel 2101 in Chaokewula mine as an example, using analytical method and numerical method to explore the formula application range of reference influence radius R .The comparison results show that for confined water it is better to use $R=10S\sqrt{K}$; if the condition of the aquifer recharge is better or the thickness of confined aquifer is bigger, it is better to use $R=10S\sqrt{K}$ too. The research results provide scientific basis for the calculation of mine water inflow.
Keywords mine water inflow, large-well method, reference influence radius, confined water

Introduction

Calculation of mine water inflow is an important content in hydrogeological work, also it is one of the main work in deposit hydrogeological exploration. It runs through the whole mineral exploration, construction and production processes. At present, there are many methods to predict mine water inflow, such as water balance method, Q~S curve method, analogy method of hydrogeology, grey system method, artificial neural network method etc. While compare with other methods, the LWM is relatively simple and it is one of the most commonly used method. But LWM involves many empirical formulas for parameter calculation, the selection of different formulae can lead to different results, then it will have different effect on the results of water inflow prediction. The reference influence radius R is one of the most important parameters in LWM. There are generally two kinds of methods to calculate R, that is Buskin formula ($R=2S\sqrt{KH}$) and Juilliard formula ($R=10S\sqrt{K}$); the different calculation formulas of R, the calculation results vary greatly. This paper takes the water inflow prediction of panel 2101 on lower Cretaceous Bayanhua Group aquifer in Chaokewula mine as an example, and compares the calculation results of LWM with those of numerical simulation, exploring the formula application range of reference influence radius R.

Overview of the hydrogeological model

According to the regional hydrogeological data, the mining area can be generalized into 4 aquifers rock formations from the bottom to up, namely, 2# coal water-bearing formation of the lower Cretaceous middle(K_1b^2), sandy conglomerate water-bearing formation of the lower Cretaceous up(K_1b^3), pore confined water-bearing formation of Tertiary and pore phreatic water-bearing formation of Quaternary. There are stable aquicludes between the 2# coal roof and the K_1b^3 water-bearing formation, the first aquiclude and second aquiclude of 2# coal roof. Rainfall infiltration is the recharge water sources of Quaternary pore phreatic water-bearing formation. The aquifer and aquiclude of the lower Cretaceous Bayanhua group were described as follows.

Aquifers

The lower Cretaceous Bayanhua group aquifer distributes in entire mining area, the main lithology of the aquifer is coal, sandy conglomerate and sandstone. According to the litho logic association and coal-bearing characteristics, the aquifer is divided into 3 aquifers, the details are as follows.

The upper sandy conglomerate (K_1b^3) aquifer

The aquifer is dominated by metamorphic conglomerate which is overly on top of the coal strata; the main lithology of the aquifer is gray or light-gray sandy conglomerate, sandstone. Sand and gravel are poor sorting, sub-rounded, the particles' sizes are generally 2~45 mm, the gravel composition is dominated by metamorphic conglomerate, following by quartzite gravel, sub-rounded, argillaceous cement. The variation of aquifer thickness is large, generally 0.7~192.25 m with an average of 89.16 m. According to the pumping test data of NO.16 borehole in exploration report, the static water table is 2.26 m, the aquifer thickness is 149.52 m, the specific discharge q=1.9523 L/s·m, the hydraulic conductivity K=1.2078 m/d; according to the pumping test data of NO.1 and NO.2 hydrology borehole in hydrology supplement exploration, the static water table is 2.96～3.45m, aquifer thickness is 117.06～157.02 m, the specific discharge q=1.69～2.32L/s•m, the hydraulic conductivity K=1.51～1.60 m/d, it follows that this is a confined aquifer with strong water abundance.

The middle coal (K_1b^2) aquifer

This aquifer distributes in entire mining area, its distribution area is equivalent to that of coal seam. Lithology of the aquifer is dominated by coal seam, together with thin sand stone, sandy conglomerate, argillaceous cement, aquifer thickness is generally 1.35~161.90 m with an average 63.80 m. According to the pumping test data of NO.J4 borehole, the aquifer thickness is 53.25 m, the static water table is 1.73m, the height of water level is +912.128 m, the specific discharge q=0.00838 L/s•m, the hydraulic conductivity K=0.0137 m/d, it follows that this aquifer belongs to weak water abundance.

The lower sand-mudstone (K_1b^1) aquifer

This aquifer is underlying in 4 coal group, its distribution area is slightly larger than the middle coal seam aquifer. The lithology of this aquifer is mainly composed with gray or gray-green sand stone, sandy conglomerate and conglomerate. In this exploration there are only 18 drillings that can be seen this layer. The thickness revealed by the drillings is generally 0.85~112.15 m with an average of 19.82 m.For this aquifer has no pumping test, so the water abundance is not clear.

This paper only takes the water inflow prediction of K_1b^3 aquifer as an example to explore the formula application range of reference influence radius R .

Aquicludes

There are mudstone aquiclude of 2#coal seam roof and aquiclude between coal measure strata in the lower Cretaceous Bayanhua group.

Mudstone aquiclude of coal seam roof

This layer formed in the 2# coal roof, the results of the exploration report shows that its thickness is between 0~92 m, and the average thickness is 30.93 m. The main lithology of it are gray,dark gray mudstone, sandy mudstone, siltstone. Dense core, joints and fracture did not develop lead to impermeability. According to statistics of mudstone impermeable layer formed in the second coal shows that the development of impermeable layer is instability in the mining area, partial missing.

The aquiclude in coal measure strata

Several layers of gray, dark gray mudstone,sandy mudstone and siltstone commonly formed in the middle coal measure strata of lower Cretaceous Bayan group. The lithology dense,well cemented,sedimentary stable lead to impermeability,widely distributed in or between the coal measure strata,but the development of impermeable layer is instability in the mining area, seen as unstable the impermeable layer.

Water inflow prediction of LWM

The formulas of water inflow prediction

Based on the analysis of the actual geological characteristic and the mining design, the water pressure will drop to below the roof of the aquiclude, the hydraulic properties will transform into confined-phreatic flow, so we can choose the following formula to predict water inflow.

$$Q = 1.366K\frac{(2H - M)M}{\lg R_0 - \lg r_0} \quad (1)$$

$$r_0 = \frac{L}{4} \quad (2)$$

$$r_0 = \eta\frac{a + b}{4} \quad (3)$$

$$R = 10S\sqrt{K} \quad (4)$$

$$R = 2S\sqrt{HK} \quad (5)$$

$$R_0 = R + r_0 \quad (6)$$

Where:

Q—mine water inflow , m^3/d :
K—hydraulic conductivity, m/d :
H—natural groundwater level, m:
M—thickness of aquifer, m;
S—drawdown, m;
R—reference influence radius, m;
r_0—reference radius, m;
L—length of roadway, m, here is refer to the length of 2101working face, its value is 1500 m;
a, b—the length and width of working face; *a*=1500 m, *b*=210 m;
η—coefficient of calculation; see table 1, η=1.08;
R_0—reference radius of groundwater table after mining,m.

Table 1 *The relation between b/a and* η

b/a	0	0.20	0.40	0.60	0.8	1.00
η	1.00	1.12	1.14	1.16	1.18	1.18

The main parameters of the aquifer

According to the pumping test data of NO.11-6 borehole, NO.1 and NO.2 hydro geological borehole, it can be determined the main parameters of this aquifer, seeing in table 2.

According to the pumping test data in table 2, the average of hydraulic conductivity is 1.446 m/d, the max value is 1.574 m/d, the min value is 1.208 m/d; the average of static water table is 911.15 m, the hydraulic head H=911.15-694.37=216.78 m; the thickness of aquifer using average thickness of the three pumping aquifer, namely M=141.2 m; the drawdown S=H-h, here, h=0, that is S=H=216.78 m.

Table 2 *Hydrogeological parameters of the lower Cretaceous Bayan group (K1b3) upper aquifer*

Hole number	Aquifer	Static water level H_0（m）	Drawdown S（m）	Discharge Q（L/s）	Specific discharge q（L/s·m）	Hydraulic conductivity K（m/d）	Thickness of aquifer M（m）
11-6	K_1b^3	911.42	10.06	19.642	1.9523	1.208	149.52
1# hydrology borehole		911.32	9.63	16.561	1.72	1.574	117.06
2# hydrology borehole		910.72	10.6	26.26	2.478	1.556	157.02

The calculation results

Based on the above parameters, using the above formulas, the calculation results of the water inflow are shown in table 3.

Table 3 *Water inflow statistic results with different formulas*

Serial number	formulas	Reference radius r_0(m)	Reference influence radius R(m)	Reference radius of groundwater table after mining R_0(m)	Discharge Q (m^3/d)
1	(1)(2)(4)(6)	375	2624.74	2999.74	3814.506
2	(1)(2)(5)(6)	375	7729.04	8104.04	2580.149
3	(1)(3)(4)(6)	461.7	2624.74	3086.44	3764.480
4	(1)(3)(5)(6)	461.7	7729.04	8190.74	2572.442

Analysis of the results

According to the calculation results, the difference of calculated water inflow between number 1 and number 2, number 3 and number 4 is large, the main reason is that the reference influence radius calculated by formula (4) and (5) vary large; the difference of calculated water inflow between number 1 and number 3, number 2 and number 4 is not large, that is because the difference of reference influence radius calculated by formula (2) and (3) is quite small. Form this we can conclude that the reference influence radius has more influence on water inflow than reference radius.

Water inflow prediction of numerical method

Model building

In the process of establishing numerical model, we take the interference of mine drainage process and the possible effective range in draining process into consideration thoughtfully, making a large range which is about 140 km^2 as simulation area. Based on the generalized result of hydro geological conditions to splitting the 3D mesh. The vertical section is divided into 8 layers; the plane cell is divided into 150 rows and 150 columns with a total number of 22500 cells. The subdivision result is shown in fig. 1, the white grids are effective cell, the rest are invalid cells.

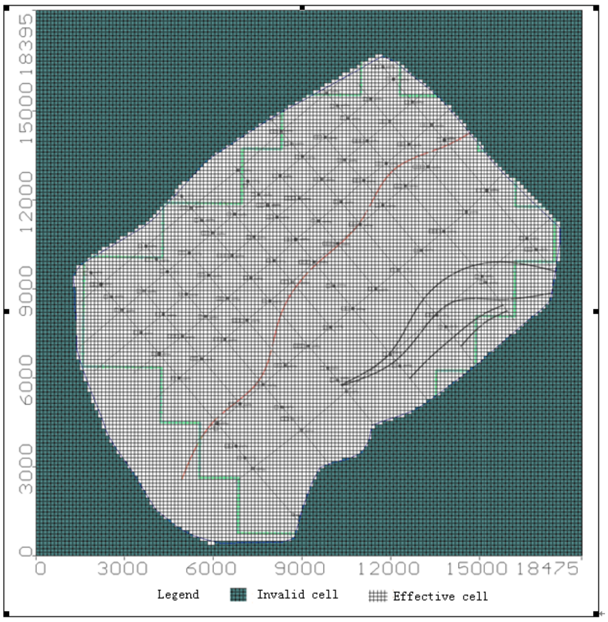

***Fig. 1** Simulation planar subdivision renderings of study area*

Water inflow process of numerical method

Initial conditions and simulation period

Due to lacking of sufficient observational data in this research area, what is more, the pumping test of existing pumping holes were carried out in different layers, so it is difficult to obtain accurately initial groundwater flow in each layer. Taking into account of the groundwater flow field is relatively stable and every aquifer has a uniform initial flow field before pumping test, this paper uses the static water level of the existing pumping holes, combining with surface elevation data to obtain the initial water level of each layer by interpolating (in fig.2). According to the collect data and the observation of groundwater table, select the processes of existing pumping tests to perform the numerical simulation of groundwater flow.

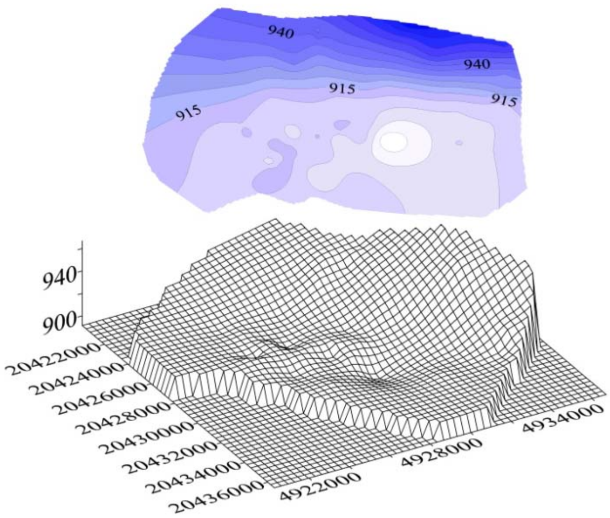

***Fig.2** The flow field of initial water table*

Model identification and verification

According to the established numerical model, conducting the model identification of groundwater system in simulation area. By trial and error method to adjusting the parameters, then getting an ideal model identification. The fitting results are shown in figure 3 and figure4. From the two figures, we can see that the change trend of water level is relatively consistent, and the relative error of the most fitting points is smaller. It is shown that the water level of pumping hole is fiting well, it has little influence on the whole groundwater flow field, the established numerical simulation model is correct.

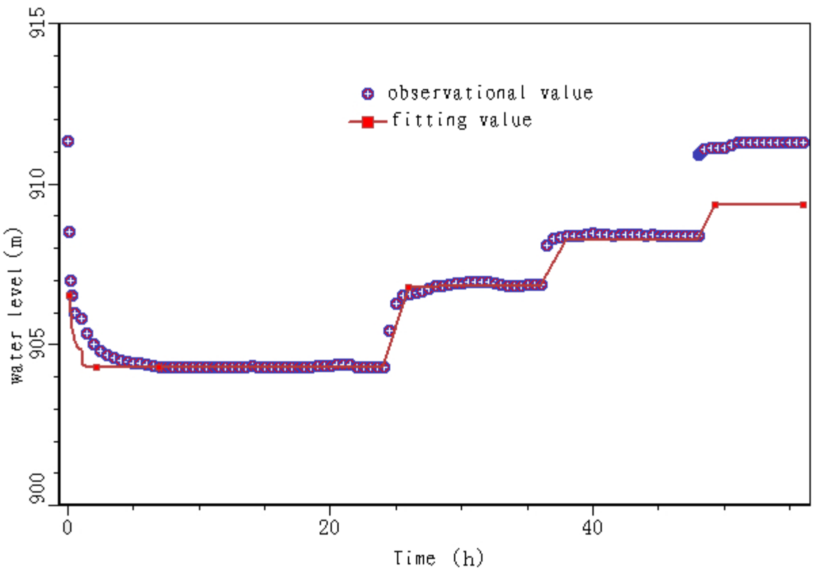

Fig.3 Pumping test water table fitting of 1# hydrology borehole

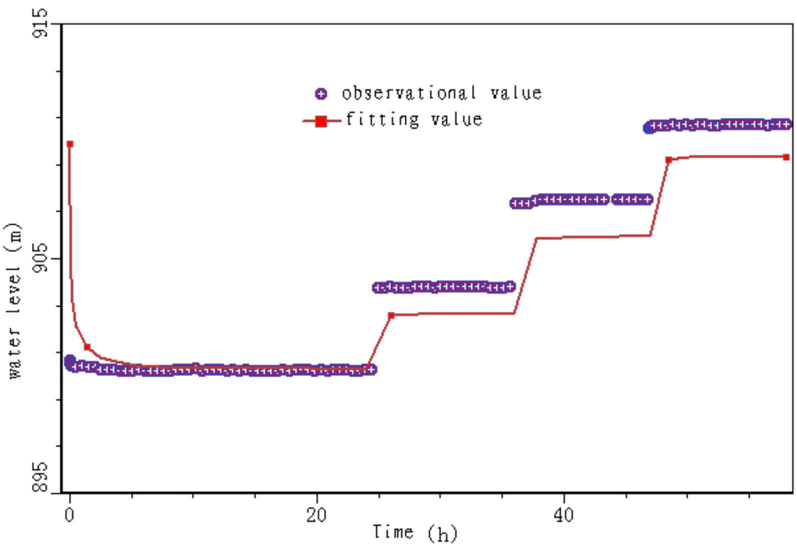

Fig.4 Pumping test water table fitting of 2# hydrology borehole

Water inflow prediction of numerical method

Considering two different cases to predict the water inflow of K1b3: (1) Under the condition of having pore water supply of the Tertiary but no boundary lateral recharge, the largest discharge is 3284.246 m^3/h; (2) Without pore water supply of the Tertiary and boundary lateral recharge, the largest discharge is 1297.945 m^3/h.

Conclusions

According to the above analysis, the aquifer of K1b3 is mainly confined water and its thickness is large. Taking the conversation of the prediction result by LWM is larger than those of others methods, the water result calculated by formula $R = 10S\sqrt{K}$ is close to the result of the first case of numerical simulation, however the water result calculated by formula $R = 2S\sqrt{HK}$ is close to the result of the second case of numerical simulation. The comparative results show that in the process of mine water inflow prediction by LWM, if the aquifer is confined or the condition of the aquifer recharge is better or the thickness of confined aquifer is bigger, the formula of calculating *R* is better to use $R = 10S\sqrt{K}$.

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