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Influence of Infiltration Facilities on Groundwater and Research Status of Groundwater Visualization

Chao Guo[1,2,3,*], Xie Xiao[2,3]

[1] Shaanxi Provincial Land Engineering Construction Group, Key Laboratory of Degraded and Unused Land Consolidation Engineering, Ministry of Natural Resources., Xi'an 710071, China

[2] Shaanxi Engineering Research Center of Land Consolidation, Shaanxi Provincial Land Consolidation Engineering Technology Research Center., Xi'an 710071, China

[3] Shaanxi Provincial Land Engineering Construction Group, Land Engineering Technology Innovation Center, Ministry of Natural Resources., Xi'an 710071, China

Abstract

The rise of "sponge city" construction in China has promoted the development of recharge facilities such as rainwater gardens and rainwater seepage wells, but there is a lack of research on the impact of practical projects on groundwater. Rainwater infiltration has the risk of polluting groundwater, so recharging groundwater in these ways may increase the risk of secondary pollution of groundwater. Visualization technology can reveal the occurrence conditions, dynamic characteristics and movement changes of groundwater, and reveal the hydrogeological conditions in the study area.

Keywords

Infiltration Facilities; Groundwater; Groundwater Visualization.

1. Introduction

At present, the ground situation in society is grim. In the process of urbanization, people will gradually turn the development and utilization of the city to the underground1. Today, the main problems are the water quality pollution and water depletion of groundwater2-3. In order to effectively manage and control the possible pollution of rainwater recharge facilities to groundwater, it is necessary to make an accurate forecast of the water quality of groundwater. At present, groundwater simulation software can simulate groundwater flow, groundwater pollutant migration and groundwater level4, thus effectively predicting and controlling groundwater pollution. In the aspect of groundwater management, it has developed from single water quantity management to optimal management of water quality and quantity at the same time. Through the research and development in recent decades, a number of very influential groundwater simulation softwares have been formed in the world, such as GMS, FEFLOW, VISUAL MODFLOW, Visual groundwater, MT3DMS, TOUGH2, etc. The commonly used numerical simulation methods in hydrogeology include finite difference method and finite element method, among which Visual MODFLOW based on finite difference method and FEFLOW based on finite element method are widely used and powerful. The numerical simulation of groundwater in China began in the early 1970s, with GWMS1.0 from Baoding Institute of Hydrogeology and Engineering Geology and Tsinghua Xingda Groundwater Geographic Information System software5.

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2. Study on Influence of Infiltration Measures on Groundwater

Rainwater runoff infiltrates from the surface of rainwater recharge facilities, and enters underground runoff after being filtered, intercepted, infiltrated and stored in soil unsaturated zone. Centralized infiltration may increase the amount of pollutants entering groundwater while increasing the recharge of rainwater to groundwater, thus having a certain negative impact on water quality. Therefore, it is an important scientific issue to study whether the rainwater garden will adversely affect the groundwater environment while regulating the urban rainfall runoff. This paper summarizes the main research results of groundwater with infiltration management facilities in recent years. As shown in Table 1.

Table 1. Effect of infiltration management measures on groundwater

Researchers	Site	Contents and results
Machusick et al[4]	Southeast pennsylvania, usa	When the rainfall is more than 18 mm, rainwater runoff infiltrates downward through infiltration storage facilities to replenish groundwater, and the partially replenished groundwater bulges to form hills, which causes the groundwater level to fluctuate greatly.
Massuel et al[5]	Southern india	Infiltration accounts for 57% ~ 63% of the total storage tanks, and groundwater within 100 m of fiona fang is affected.
Watson et al[6]	South africa	Importance of incorporating short-term replenishment event modeling into improving replenishment estimation.
Boisson et al[7]	India	The water storage effect of unsaturated soil zone delays the infiltration recharge process, and the final recharge of groundwater is limited by the storable water quantity in unsaturated soil zone.
Sharda et al[8]	India	The water in the unsaturated area of soil is eventually evaporated or delayed to infiltrate into groundwater.

3. Groundwater Resources Visualization Research Status

In 1960s, foreign developed countries began to explore the use of visualization technology to reveal the occurrence conditions, dynamic characteristics and movement changes of groundwater, and to reveal the hydrogeological conditions in the study area. The first time in China to study groundwater-related problems by using groundwater numerical simulation method began in the 1970s. The visualization of groundwater temporal and spatial changes is based on hydrogeological investigation data, groundwater dynamic monitoring data, numerical simulation results and expert analysis data, and realizes visual simulation display. There are three main types of research in this field:

(1) The groundwater numerical simulation software module is combined with 3S technical software (Arcmap, RS, etc.). Geographic information system (GIS) has been widely used in the research of hydrogeology since the 21st century, including groundwater dynamics, groundwater diffusion, groundwater resources exploitation and planning based on GIS, joint dispatching of groundwater and surface water, etc.6 To realize hydrogeology information management, isoline drawing, water level profile generation and spatial query, etc.

(2) Visualization based on professional software of groundwater flow simulation. The internationally popular groundwater simulation softwares include GMS, FEFLOW, Visual MODEFLOW, Visual Groundwater, MIKE SHE, MT3DMS, TOUGH2, etc. Table 2 summarizes the numerical solution methods, data input methods, functions and shortcomings of the popular groundwater simulation software models.

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Table 2. Introduction of groundwater simulation software

Dynacomm	Developer	Numerical method	Data entry mode	Function	Insufficient
GMS[1]	Environmental model research laboratory of Brigham Young University and drainage engineering experimental station of Ministry of Military Industry, USA.	Finite difference method and finite element method	Module data, external GIS data, etc.	Carry out water flow migration simulation and water quality migration simulation	GIS module can only be applied to steady-state data.
FEFLOW[9]	WASY company of Germany	Finite element method	Geographic information system data interface	Specializing in complex groundwater simulation engineering	Adjusting parameters is more troublesome.
Visual MODEFLOW[2]	Developed by Waterloo Hydrogeology Company of Canada.	Finite difference method	Instrumental auxiliary module data	Water flow simulation, solute migration simulation and reaction migration simulation	Not suitable for some complicated geological conditions.
Visual Groundwater[3]	Environmental lsimulation,Inc.USA	Finite element method and finite difference method	ASCⅡ file	Simulation of saturated flow state	At present, the applied research is insufficient.
MIKE SHE[1]	Danish DHI International Consulting and Research Institute	Finite difference method	GIS	Groundwater flow and water quality transport	It is difficult to establish the model.
MT3DMS[2]	C. Zheng p. Wang	Finite difference method	Instrumental auxiliary module data	Groundwater solute transport	Only solute transport simulation can be performed.
TOUGH2[10]	Lawrence Berkeley laboratory, USA	Finite difference method	Subroutine input data	Groundwater flow and heat transfer	The model is not easy to correct

(3) Multi-technology combination visualization is mainly the joint use of the above technologies and software with other methods. Using the similarities between 3S grid data processing and grid division and discrete data processing of groundwater numerical simulation model, the effective combination between them is realized. The simulation software will further integrate RS, GIS, environmental isotopes and other technologies to preliminarily predict the isoline of groundwater flow field; For the areas lacking hydrogeological data, the system prediction theory and methods such as MATLAB software, artificial neural network technology, stochastic theory and regression model are used for preliminary exploration, so as to further use groundwater software to explore hydrogeology more accurately, thus making the prediction accuracy more accurate. Su Wanyi and others used Matlab to couple with the hydrogeologic finite element processing software (HFEM) to draw the three-dimensional isoline of

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groundwater. The Central Groundwater Commission (CGWB) of the Ministry of Water Resources has developed GEMS software by using MapInfoProfessional, MapInfoVerticalMapper, SPSS and R2V, which effectively completes the groundwater dynamic simulation and visualization method in the traditional software environment.

4. Conclusion

With the development of water resources visualization and groundwater numerical simulation technology, most domestic researches on groundwater visualization are still biased towards numerical simulation of various large-scale, large-scale basins and moderately and heavily polluted areas, and there is a great lack of research on artificial rainwater recharge measures, especially centralized infiltration facilities such as rainwater gardens and rainwater seepage wells.

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References

[1] Davis A P. Green engineering principles promote low-impact development [J]. Environmental Science & Technology, 2005, 39(16):338A-344A.

[2] Broder G. Low Impact Development [M]. Stormwater Management for Smart Growth. Springer US, 2005.

[3] Smith VH, Tilman GD, Nekola JC. Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems [J]. Environmental Pollution, 1999, 100(1-3):179-196.

[4] MACHUSICK M, WELLKER A, TRAVER R. Groundwater mounding at a storm-water infiltration BMP[J]. Journal of Irrigation and Drainage Engineering, 2011, 137:154-160.

[5] MASSUEL S, PERRIN J, MASCRE C, et al. Managed aquifer recharge in South India: what to expect from small percolation tanks in hard rock [J]. Journal of Hydrology, 2014, 512: 157-167.

[6] Watson A, Miller J, Fleischer M, et al. Estimation of groundwater recharge via percolation outputs from a rainfall/runoff model for the Verlorenvlei estuarine system, west coast, South Africa [J]. Journal of Hydrology, 2018, 558:238-254.

[7] BOISSON A, BAISSET M, ALAZARD M, et al. Comparison of surface and groundwater balance approaches in the evaluation of managed aquifer recharge structures: case of a percolation tank in a crystalline aquifer in India [J]. Journal of Hydrology, 2014, 519: 1620-1633.

[8] SHARDA VN, KUROTHE RS, SENA DR, et al. Estimation of groundwater recharge from water storage structures in a semi-arid climate of India [J]. Journal of Hydrology, 2006, 329(1): 224-243.

[9] MASSUEL S, PERRIN J, MASCRE C, et al. Managed aquifer recharge in South India: what to expect from small percolation tanks in hard rock [J]. Journal of Hydrology, 2014, 512: 157-167.

[10] Watson A, Miller J, Fleischer M, et al. Estimation of groundwater recharge via percolation outputs from a rainfall/runoff model for the Verlorenvlei estuarine system, west coast, South Africa [J]. Journal of Hydrology, 2018, 558:238-254.