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SciVerse ScienceDirect
Procedia Earth and Planetary Science 7 (2013) 709 – 712
Procedia
Earth and Planetary Science

Water Rock Interaction [WRI 14]

Solving for dispersivity in field dispersion test of unsteady flow in mixing flow field: mass transport modeling

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Abstract

A combined groundwater flow and mass transport model was constructed to simulate the migration of contaminants and to obtain dispersion parameters from a field dispersion test in unsteady flow in mixing flow field in groundwater. Aquifer parameters were obtained by a pumping test. Tracer tests were carried out in order to characterize the characteristics of groundwater flow and to determine the velocity of the pollutant diffusion process from the source to the pumping well. Groundwater head and velocity were analyzed in the groundwater flow model and the total dissolved solids (TDS) concentration was computed in the mass transport model. The observed drawdown and the observed TDS concentration were found to respectively match closely with the computed drawdown and TDS concentration.

Selection and/or peer-review under responsibility of the Organizing and Scientific Committee of WRI 14 – 2013

Keywords: dispersion parameters; field dispersion test; tracer test; mass transport model (MT3DMS); TDS

1. Introduction

Accurate dispersion parameters are the foundation of groundwater pollution evaluation and prediction [1]. It is generally accepted that spatial variations in the hydraulic conductivity of porous materials and unsteady hydraulic conductivity gradients contributes significantly to the spreading of solutes dissolved in groundwater [2].

The data derived from dispersion tests make it possible to determine dispersive parameters such as the coefficient dispersion and dispersivity. Laboratory simulation and field dispersion experiments are the

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Selection and/or peer-review under responsibility of the Organizing and Scientific Committee of WRI 14 – 2013
doi:10.1016/j.proeps.2013.03.155

two kinds of dispersion tests. The flow field of dispersion test can be divided into three types: natural, man-controlled and mixing flow field (both of the two above-mentioned). The analysis is often made by using analytical solutions such as a statistical approach, or a probabilistic approach [3, 4]. Numerical simulations are being used extensively for analyzing transport in complex geologic media [5, 6].

In this paper, Modular three-dimensional groundwater flow model (MODFLOW) [7] and the mass transport model MT3DMS [8] are used to solve the advection-dispersion equation of transient flow in mixing flow field and to obtain the hydrological parameters.

2. Location and hydrogeology

Jiangnan Park is situated about 440m in south of Songhua River in Jilin City, China. The water supply for the entertainment equipment in the park is pumped from one well in the centre of the park. The well pumps water at a rate of 526 m^3/day. The lithology of the drilled bore holes reveals that aquifer is made of sands and gravels. The aquifer is an unconfined aquifer with 13-14m thickness. Lithology of overlying strata consists in silty-fine sand and silty clay. The overlying strata layer extends to a depth of about 8 m. Based on the data the hydraulic conductivity of the aquifer is estimated as 50-80m/d.

3. Tracer test

A Tracer test is carried out in order to make sure the characteristics of groundwater flow and to find out the velocity of pollutants diffusion process from the source to pumping well. Salt (NaCl) as tracer is selected based on easy detectability and easy availability [9]. Three other wells are drilled in the upstream of the pumping test in Jiangnan Park (Fig. 1). Well 1 and well 2 are selected to be observation wells, well 3 is selected as tracer injection well. The connection of well 1and the injection well is in the same direction with groundwater flow. During the tracer test, the pump stops for three times to make a mixing field. During the test, the water samples are collected from wells to measure total dissolved solid (TDS) of injected tracer about every 30 minutes.

4. Groundwater flow and mass transport models

4.1. Generalization, identification and validation

The model area covers 40 m × 40 m. In order to prepare groundwater flow and mass transport models, a finite difference grid was used. No flow boundary has been assumed to the east and west. To the south and north the boundary has been assumed to be head boundary. The groundwater flow field is modeled is conjunction with the mass transport model using MODFLOW and MT3DMS. A mass-loading rate of 147g/min is considered as an input that lasted for one minute.

Observation data of drawdown and TDS of the four wells are used to identify and validate the simulation results. The drawdown computed is found to match closely with the observed drawdown (Fig 3 (a), (b)) as well as the computed TDS concentration and the observed ones (Fig. 4 (a), (b)).

Table1. The optimal parameters given by the model

Model layers	Hydraulic conductivity (m/d)	Specific yield	Effective porosity	Longitudinal dispersion degree (m)	Transverse dispersion degree (m)
first (silty-fine sand)	0.5	0.10	0.10	30	9
second (silty clay)	0.45	0.05	0.05	25	5
third (gravel)	70	0.20	0.20	55	22

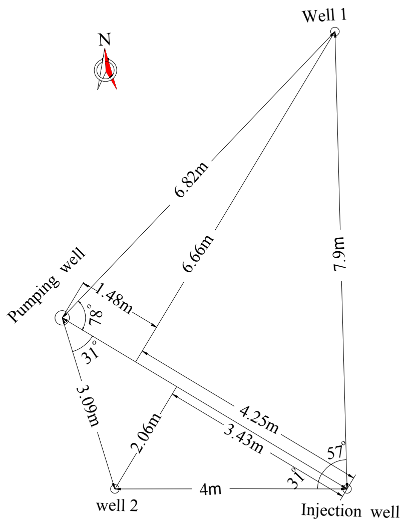


Fig.1. Relative position of wells

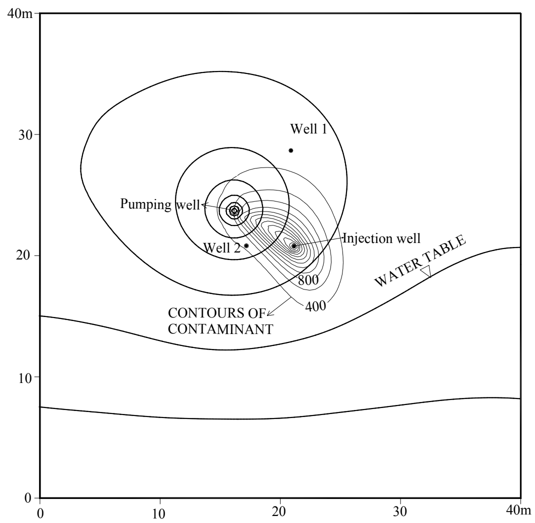
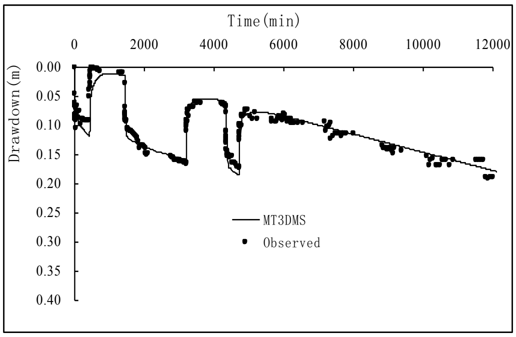


Fig.2. Computed contamination migration from injection well to pumping well in mixing flow field



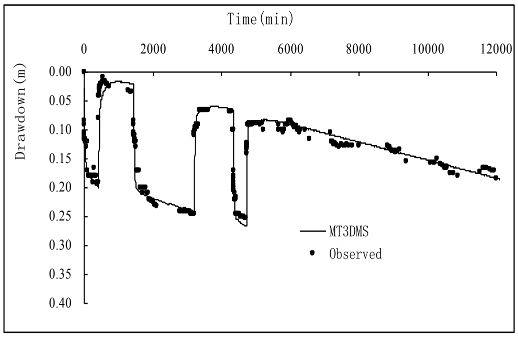
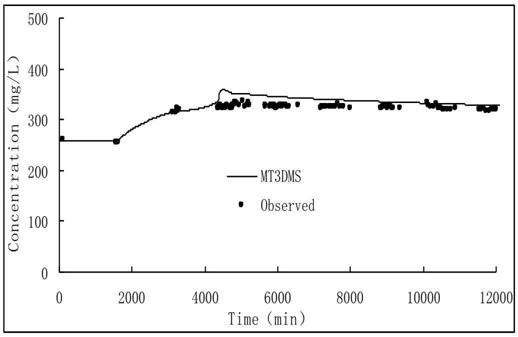


Fig. 3. Comparison of MT3DMS drawdown and observed drawdown. (a) well 1, (b) well 2.



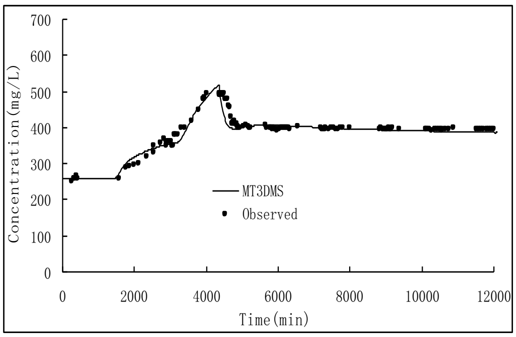


Fig. 4. Comparison of MT3DMS concentration of TDS and observed concentration of TDS. (a) well 1, (b) well 2.

4.2. Results

The contour of TDS concentration shows the migration path from the injection well to the pumping well (Fig. 2) The hydraulic conductivity is finally computed as the value of 0.5m/d, 0.45m/d and 70.5m/d for the three layers (Table 1). The drawdown around the pumping well is computed. In nature flow field, the flow direction is from south to north, but in man- controlled flow field, the groundwater flows to the pumping well rapidly. The direction of migration of the contaminant from the injection well to the pumping well is composed of two directions. When the pump opened, contaminant moves from the injection well to the pumping well, otherwise it moves from the injection well to the well 1 as the flow direction changes.

5. Conclusion

In mixed flow field conditions, the flow direction is superimposed by man-controlled and natural flow directions; the analytic method is inapplicable to solve the parameter because the velocity changed. The MT3DMS presented herein has given dispersion results which makes it possible to consider its use in transient flow of mixing flow field. The adaptability of MT3DMS is better than traditional analytic method in the process of solving dispersion parameters.

Acknowledgements

The authors would like to acknowledge the support of the Jilin province scientific and technological project (20080543; 20100452) and the Ministry of Education Potential oil and gas resources project (OSR01-7) and the Ministry of Water Resources Public Welfare Project (200901037). They also thank the reviewers for helpful comments.

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