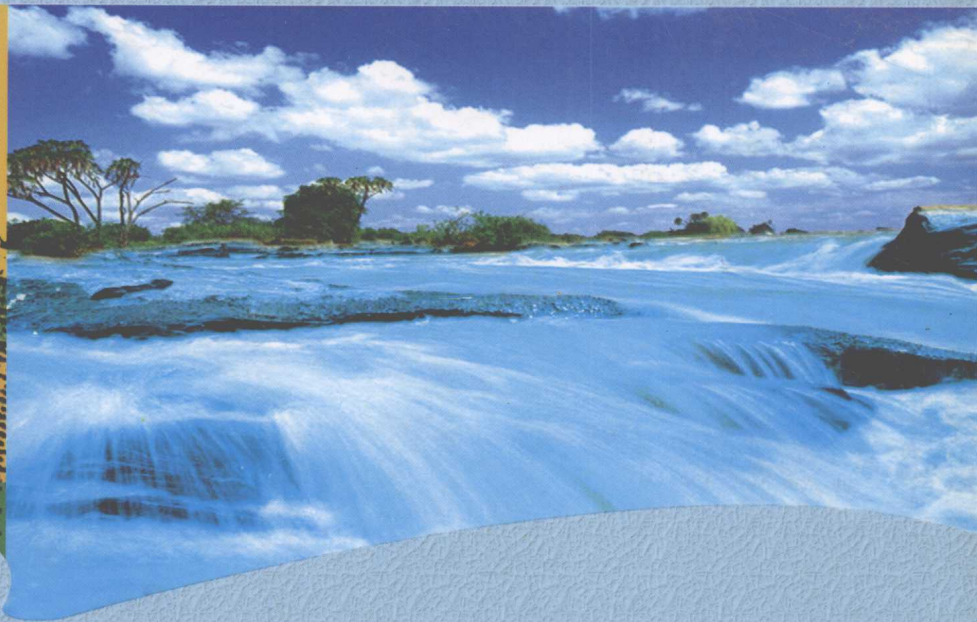


CALIBRATION AND RELIABILITY IN GROUNDWATER MODELING “MANAGING GROUNDWATER AND THE ENVIRONMENT”



Editor: Yanxin Wang

Associate Editors: Yu Zhou & Yiqun Gan



CHINA UNIVERSITY OF GEOSCIENCES PRESS

PROCEEDINGS OF THE 7TH INTERNATIONAL CONFERENCE ON CALIBRATION AND
RELIABILITY IN GROUNDWATER MODELING
ModelCARE2009, WUHAN, CHINA, SEPTEMBER 20-23 2009

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图书在版编目 (CIP) 数据

地下水模型校正与可靠性: “地下水和环境管理”

= **Calibration and Reliability in Groundwater Modeling: “Managing Groundwater and the Environment”**: 英文/王焰新主编. —武汉: 中国地质大学出版社, 2009.9

ISBN 978-7-5625-2417-5

I. 地…

II. 王…

III. ①地下水-模型-校正-英文

②地下水-模型-可靠性-研究-英文

IV. P641.13

中国版本图书馆 CIP 数据核字 (2009) 第 170217 号

Calibration and Reliability in Groundwater Modeling “Managing Groundwater and the Environment”

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Responsible Editors: *Guitao Liu, Hua Zhou, Qi Chen*

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Published by China University of Geosciences Press

388 Lumo Road

Wuhan, Hubei 430074

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Preface

The 7th International Conference on Calibration and Reliability in Groundwater Modeling (ModelCARE2009) was held in Wuhan, China from September 20-23, 2009. The conference addressed the applicability of various approaches to real-world problems through case studies and identified future needs and paths toward progress for research and development. The conference theme was “Managing Groundwater and the Environment”. Within the context of model calibration and reliability, issues of groundwater quantity and quality were also addressed.

The conference was organized by the International Commission for Groundwater (ICGW) of the International Association of Hydrological Sciences (IAHS) and China University of Geosciences. I would like to thank our sponsors: China University of Geosciences (Wuhan), China Geological Survey (CGS); Xi'an Center of Geological Survey, CGS; National Natural Science Foundation of China; and International Research Center on Karst (Guilin, China).

This volume contains nearly 140 manuscripts (and abstracts) submitted by colleagues from over 17 countries. The manuscripts include theoretical, laboratory, and field-based studies. The volume begins with the plenary keynote lectures, followed by contributions to four sessions of the symposium as follows:

- Advances and innovations in model calibration, prediction, and uncertainty analysis
- Using models to evaluate sustainability of and manage groundwater resources
- Well hydraulics and numerical modeling for system characterization and prediction
- Modeling, calibration, and uncertainty of reactive transport, groundwater contamination and remediation
- CO₂ sequestration modeling and uncertainty assessment
- Geologic and engineering applications for improving groundwater models

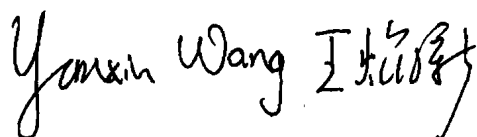
We especially recognized the efforts of our 16 keynote speakers to update the theory and methodology of groundwater modeling.

Abstracts of all the manuscripts have been peer-reviewed by our SAC (Scientific Advisory Committee) members:

- Corinna Abesser, British Geological Survey, UK; Vice-President of ICGW
- Mary Anderson, University of Wisconsin-Madison, USA
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- Yuesuo Yang, Jilin University, China
- William Yeh, University of California-Los Angeles, USA
- Xun Zhou, China University of Geosciences-Beijing, China

Special thanks must go to the tremendous help of my assistants: Dr. Yiqun Gan, Dr. Yu Zhou and Ms. Xinxin Guo. And I wish to thank Mary Hill and Chunmiao Zheng for their constant and firm support throughout the organization process of this conference.



Yanxin Wang
Editor & Chairman, ModelCARE2009

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CONTENTS

Preface XI

Section 1

Advances and innovations in model calibration, prediction, and uncertainty analysis

Automatic calibration of seawater intrusion modeling using genetic algorithm <i>M. Bastani, M. Kholghi & G. R. Rakhshandehroo</i>	3
Development of an operational drought forecasting system using coupled models for groundwater, surface water and unsaturated zone <i>W. L. Berendrecht, A. H. Weerts, A. A. Veldhuizen & T. Kroon</i>	7
Feasibility research on numerical simulation of karst spring dynamics using a single continuum model <i>X. Q. Du, X. Y. Ye, C. Rehr & S. Birk</i>	11
Karst spring discharge modeling based on grey system theory: A case study at Shentou, Northern China <i>Q. H. Guo, Y. X. Wang & T. Ma</i>	15
Parameter calibration of multi-tank model and its application to rainfall infiltration <i>X. L. Huang & J. Xiong</i>	19
The effects of trend and outliers on geostatistical analysis of hydraulic conductivity <i>X. W. Jiang, L. Wan & X. S. Wang</i>	23
Full-bayesian, pest inversion and transmissivity assessment of the Edwards aquifer, Texas, USA <i>Y. Jiang & A. D. Woodbury</i>	27
A new optimization method for groundwater flow and transport inverse modeling <i>M. Kholghi & L. Parviz</i>	31
Identification of aquifer parameters using improved decimal-coded genetic algorithm <i>H. W. Lei, Z. H. Tang & Y. L. Yang</i>	35
Uncertainty analysis of an integrated hydrological model using posterior covariance matrix from automatic calibration <i>H. T. Li, W. Kinzelbach, H. J. Hendricks Franssen, P. Brunner & A. von Boetticher</i>	39
Bayesian method for groundwater uncertainty analysis using pumping test data <i>L. Lu & J. C. Wu</i>	43
Risk analysis using stochastic reliability methods applied to Jinan district groundwater quality model <i>X. Y. Ma & K. Wu</i>	47
Groundwater parameter estimation via ensemble kalman filter with covariance localization <i>T. C. Nan & J. C. Wu</i>	51

New model of groundwater simulation and prediction based on wavelet de-noising <i>Y. F. Sang, J. C. Wu, D. Wang & C. P. Ling</i>	55
Risk assessment of karst collapse based on groundwater flow modeling in Linyi city <i>J. L. Shao, X. D. Lei, C. M. Yao & Y. L. Cui</i>	59
An objective-oriented pilot point method for identifying spatially variable hydraulic parameters <i>N.-Z. Sun</i>	63
Grey box modeling of a groundwater well field <i>F. Ö. Thordarson, H. Madsen & H. Madsen</i>	67
Uncertainty of mass discharge estimates from contaminated sites using a fully bayesian framework <i>M. Trolborg, W. Nowak, P. J. Binning, P. L. Bjerg & R. Helmig</i>	71
A combined representer – preconditioned conjugate gradient method for inverse groundwater flow modeling <i>J. R. Valstar & J. Verkaik</i>	75
Ground water model calibration using geology information along with sensitivity analysis and estimation methods (UCODE-2005), the Acque Albule model, Rome (Italy) <i>F. La Vigna, R. Rossetto & R. Mazza</i>	79
Application of level set method to groundwater parameter estimation problem <i>C. Wang</i>	83
Comparison of three average methods to finite difference scheme of 1-D boussinesq equation <i>Q. R. Wang, Z. H. Tang, Q. H. Wang, L. J. Zhai & W.O. Balogun</i>	85
Uncertainty analysis and visualization of thermo-hydro-mechanical coupled processes in a hot-dry-rock geothermal reservoir using high-performance-computing <i>N. Watanabe, C. I. McDermott, W. Wang, T. Taniguchi, B. Zehner & O. Kolditz</i>	89
Uncertainty analysis of a regional groundwater model <i>X. Wei, V. Guvanasean & M-S. Tsou</i>	93
Advances in basinal-scale groundwater modeling in China <i>D. G. Wen, E. Y. Zhang, Z. H. Tang, L. J. Lin, L. Wan, C. X. Chen, J. L. Shao, Y. S. Zhao, W. K. Wang, H. Qian & W. P. Li</i>	97
Application of the niched pareto tabu search to multiobjective optimal design of groundwater remediation systems <i>Y. Yang & J. F. Wu</i>	103
Optimization of a complex and highly parameterized groundwater system <i>B. Zhang, D. G. Abbey, P. J. Martin, S. C. James, W. W. Wossener, R. G. Andrachek, C. Gabriel & B. W. Arnold</i>	107
Fuzzy optimization assessment of DRASTIC groundwater vulnerability based on entropy weight and GIS <i>B. X. Zhang, C. Yu, F. H. Meng & L. Wan</i>	111

Section 2

Using models to evaluate sustainability and manage groundwater resources

A numerical groundwater flow model of Linfen Basin aquifer, Shanxi Province, China <i>W. O. Balogun, Z. H. Tang, Q. J. Tian & X. L. Gong</i>	117
---	-----

Simulating regional groundwater transport to surface waters combining stream tube and hydrogeochemical approaches. <i>H. P. Broers, R. Heerdink & A. Visser</i>	121
Three-dimensional numerical simulation of impacts of urbanization on groundwater flow and salt transport in a coastal aquifer system, Busan, Korea <i>H. J. Cho & J. M. Kim</i>	125
The impact of thermal water exploitation on groundwater in Quaternary aquifers: a case study at Duncun, Xinzhou Basin, Northern China <i>Y. Q. Gan, X. X. Guo & Y. X. Wang</i>	129
Calibration of hydrogeochemical model of Xinzhou Basin using strontium isotopes <i>X. X. Guo, Y. Q. Gan, J. Liu, F. J. Shi & Y. X. Wang</i>	133
How can large scale integrated surface – subsurface hydrological model be used to evaluate long term climate change impact on groundwater reserves <i>P. Goderniaux, S. Brouyère, H. J. Fowler, S. Blenkinsop, R. Therrien, Ph. Orban & A. Dassargues</i>	137
Handling and linking data and hydrological models – experiences from the Danish national water resources model (DK-model) <i>A. L. Højberg, L. Trolborg, P. Nyegaard, M. Ondracek & S. Stisen</i>	141
Challenges of regional-scale groundwater model in the water resources management of the Shiyang River Basin <i>L. T. Hu & Y. Xu</i>	145
Numerical modeling of groundwater flow in Datong Basin <i>L. Y. Huang, S. G. Dong, Z. H. Tang, B. W. Liu & D. O. Addo</i>	149
Modeling of groundwater flow using GMS in Zhengzhou Plain, China <i>M. G. Jin, W. Y. Luo, Y. F. Liu & R. L. Sun</i>	153
Regional groundwater flow modeling in Chaiwopu Basin and River Valley <i>N. Li, Y. X. Zhou & W. P. Li</i>	157
The response of Prairie lakes in the Great Plains of North America to extreme variability in climate: An integrated observational and model-based analysis <i>G. Liu, F. W. Schwartz, B. Zhang & Z. Yu</i>	161
Numerical simulation of groundwater flow in Yanqi Basin, Xinjiang Province, China <i>Y. F. Liu, M. G. Jin & G. R. Jiang,</i>	167
Numerical modeling of physical clogging during groundwater artificial recharge: a novel multi-phase approach <i>Y. Lu, X. Q. Du, B. M. Chi & Y. S. Yang</i>	171
Response matrix method in determining the volume of groundwater exploitation in Zhongmu Country <i>C. M. Ma, D. F. Mao & X. Y. Zhang</i>	175
Regional groundwater flow modeling in Western Nile Delta, Egypt <i>R. F. Mohamed & C. Z. Hua</i>	179
A management model to control contaminant loading mass and pumping rates for sustainable groundwater use in Agricultural Region <i>D-K. Park, G-O. Bae & K-K. Lee</i>	183
Research of regulation and storage capacity of groundwater reservoir on Manasi River Watershed <i>X. Y. Qiao, W. K. Wang & J. Wang</i>	187

Compartment approach for regional hydrological analysis: Application to the Meijiang Catchment <i>F. Sun, C. Chen, W. Q. Wang, Y. J. Wu, G. Y. Lai & O. Kolditz</i>	191
Characteristics of groundwater recharge under deep vadose zone at Luancheng, China <i>B. G. Wang, M. G. Jin & G. L. Wang</i>	195
Simulation of groundwater management in the Inner Mongolia Energy Base of Ordos Basin <i>L. F. Wang & F. S. Hu</i>	199
Study on safe yield of groundwater resources bases on ecological replacement water in Yanqi Basin, China <i>S. X. Wang, X. G. Dong, B. Wu & P. N. Yang</i>	203
The prediction and evaluation of emergency exploitation of groundwater in Zhengzhou City, China <i>W. L. Wang, Y. L. Cui & J. L. Shao</i>	207
The application of risk assessment for artificial recharge <i>Z. J. Wang, B. M. Chi, X. Q. Du & Y. S. Yang</i>	211
The application of risk assessment for artificial recharge <i>Z. J. Wang, B. M. Chi, X. Q. Du & Y. S. Yang</i>	215
Application of groundwater runoff model to compute stratified runoff yield <i>P. L. Wu & J. Z. Ma</i>	219
Application of the multiscale finite element method to the numerical modeling of regional ground water systems <i>S. J. Ye, Y. Q. Xue, J. C. Wu, Z. X. Wei & Q. F. Li</i>	223
Conjunctive use planning of surface water and groundwater in Southern California, USA <i>William W-G. Yeh</i>	227
Numerical simulation and sustainable utilization of groundwater in the Blown-sand region of the Northern Shanxi Province <i>H. Zhang, S. B. Han, W. K. Wang, X. F. Li & H. M. Liu</i>	229
An annual water balance model for the middle reaches area in Heihe River Basin <i>J. Zhao, X. S. Wang & L. Wan</i>	233
Environmental impact assessment of pile foundation on groundwater by GMS-A case study in Shenzhen City, China <i>J. W. Zhou, C. Aida & A. G. Zhou</i>	237
FEFLOW modeling of groundwater-surface water system of Maozui area of Jiangnan Plain, Central China <i>Y. Zhou, Y. X. Wang, F. Zwahlen & J. Bolliat</i>	241

Section 3

Well hydraulics and numerical modeling for system characterization and prediction

A new well-aquifer coupling model for characterizing well hydrodynamics in abstraction well <i>J. M. Cheng, D. H. Huang, X. Wu & M. Chang</i>	247
Analysis of pumping tests for the characterization of heterogeneous transmissivity fields <i>N. K. Copty, P. Trincherro & X. Sanchez-Vila</i>	251

Airflow induced by pumping tests <i>J. J. Jiao & H. P. Guo</i>	255
Estimation of hydrogeologic parameters by tracer and slug tests at petroleum contaminated site in Chuncheon, Korea <i>J. W. Kim, H. M. Choi & J. Y. Lee</i>	259
Development of numerical model for radial collector well hydraulics and its application to riverbank filtration <i>E. Lee, J. Shin, Y. Hyun & K-K. Lee</i>	263
An Analytical Interflow Scheme for Distributed Hydrological Models I: Numerical Tests in a Homogenous Soil <i>G. Liu, E. D. Soulis & J. R. Craig</i>	267
Modeling field-scale uranium mass transfer at the Hanford IFRC site <i>R. Ma, C. Zheng, H. Prommer, J. Greskowiak, C. Liu, J. Zachara & M. Rockhold</i>	271
Modeling canal seepage and the induced groundwater response <i>X. M. Mao, Y. Y. Wang & X. Zhang</i>	275
Heterogeneity and sequential indicator simulation of hydraulic conductivity of the basalt in the dam area of Guandi Hydroelectric Station, China <i>R. L. Sun, X. Liang & M.G. Jin</i>	279
Numerical modeling of flowing artesian wells using well index method <i>X. S. Wang</i>	283
Analysis of boundary condition's accuracy to groundwater modeling <i>W. Q. Wu, G. M. Li & Q. W. Chen</i>	287
Hydrodynamic dispersion in radial flow using J.Dupuit steady well flow model <i>Q. Yu & J. W. Wan</i>	291
Simulation of moisture movement in the unsaturated zone based on in-situ testing <i>G. Z. Zhao, W. K. Wang, J. T. Huang, Y. He & Y. L. Li</i>	295

Section 4

Modeling, calibration, and uncertainty of reactive transport, groundwater contamination and remediation

Contaminant mass flux changes with induced oxide mineral precipitation at the up-gradient DNAPL source zones <i>H. L. Chen, S. H. Kim, J. H. Kang, K. J. Kim, Y. Roh, Y. K. Kim & E.G. Park</i>	301
Modeling remediation of PCE pollution in shallow groundwater by air sparging <i>H. Q. Chen & Y. L. Li</i>	305
Flow field analysis based on hydrogen and oxygen stable isotopes and total dissolved solids in deep groundwater <i>L. W. Chen, H. R. Gui, J. Z. Qian, X. X. Yin & Z. Chen</i>	309
Mobile-immobile model in solute transport through porous and fracture media <i>Z. Chen, J. Z. Qian, H. B. Zhan, L. W. Chen & S. H. Luo</i>	313
MTBE attenuation in a dual porosity chalk aquifer: Field observations and modeling results <i>L. Cheng, D. N. Lerner, S. Thornton & K. U. Mayer</i>	317

Groundwater containing high levels of iron in Jeongsun, Korea: hydrogeological implications <i>H. M. Choi & J. Y. Lee</i>	321
An Euler-Lagrange approach to transport modeling in coupled hydrosystems <i>J. O. Delfs, C.-H. Park & O. Kolditz</i>	325
Study on the movement pattern of groundwater microelements pollution caused by coal gangue leaching <i>E. Dong, X. L. Huang, Q. Xue & P. Liu</i>	329
Simulation of contaminant transport with risk contamination estimate <i>I. V. Galitskaya, I. A. Pozdniakova & L. S. Toms</i>	333
Hydrogeochemical characteristics of fluoride in groundwater: a case study in Yuncheng Basin, Northern China <i>X. B. Gao, Y. X. Wang & Y. L. Li</i>	337
Remediation design and water quality assessment at a coastline E&P gas plant site by means of finite element groundwater flow numerical modeling. <i>A. Gigliuto, C. Righetti, A. Chini & R. Rossetto</i>	341
Scale effects on parameter sensitivities in a dual-domain, multi-rate reactive transport system <i>J. Greskowiak, H. Prommer, C. Liu, V. E. A. Post, R. Ma, C. Zheng & J. M. Zachara</i>	345
Mine water streams of the self-fill aquifer in the North Bohemian Brown Coal Basin in the Czech Republic <i>J. Halíř & L. Žižka</i>	349
Numerical simulation and fluorine distribution of high fluorine groundwater in Ganzhou District, Zhangye City <i>S. B. Han, Y. H. An, J. He, H. Zhang & X. F. Jia</i>	353
Hydrogeochemical characteristics of high fluoride bearing groundwater in the Hetao Plain, Northern China <i>X. He, Y. X. Wang, T. Ma, X. B. Gao, & Y. M. Deng</i>	357
Characterization of organic pollutants in landfill leachate and groundwater around MSW using GC-MS with SPE <i>C. Z. Jia, C. X. Zhang, M. D. Li, J. Gong & Y. X. Wang</i>	361
Natural attenuation of TCE contaminated groundwater <i>Y. J. Jo, M. J. Choi & J. Y. Lee</i>	365
In situ controlled-release schemes for controlling the spread of organic contaminants in groundwater <i>Y. Kim, E. S. Lee, G. Liu, F. W. Schwartz & Z. Yu</i>	369
Surface wettability-dependent DNAPL migration in a rough-walled fracture <i>H. -B. Lee, I. W. Yeo, S. -H. Ji & K. -K. Lee</i>	373
Colloid transport-deposition in costal water-bearing media <i>H. M. Li, J. Ma, X. M. Gu, X. Y. Jia & Y. Li</i>	377
Numerical simulation research on groundwater pollution from landfill leachate <i>X. L. Li, L. G. Wang, L. Liu & J. Z. Di</i>	381
Numerical simulation Influence analysis of underground oil storage in rock caverns on ground water <i>Q. Y. Liu, L. Wan, B. X. Zhang, G. L. Cao & X. Zhang</i>	385
A biogeochemical transport model to simulate the attenuation of chlorinated hydrocarbon contaminant fluxes across the groundwater-surface water interface <i>F. Malaguerra, P. J. Binning & H. J. Albrechtsen</i>	389

Laboratory test about impact of large-scale chemical enterprise on groundwater <i>D. F. Mao, H. S. Shi, J. W. Wan, S. Z. Cai & Q. Yu</i>	393
Modeling transport of contamination at the megasite port of Rotterdam <i>A. Marsman, E. van Nieuwkerk & J. Valstar</i>	397
Three-dimensional numerical simulation of groundwater flow and salt and radionuclide transport at a radioactive waste disposal site in Gyeongju, Korea <i>C. S. Oh & J. M. Kim</i>	401
The correspondence analysis method for identification of hydrochemical characteristics of groundwater in coal mine <i>J. Z. Qian, L. Ma, C. L. Zhang, X. P. Zhou & R. G. Zhang</i>	405
Modeling combined effects of solid solution formation and cation-exchange on the retardation of aqueous radium <i>H. Shao, , G. Kosakowski, D. A. Kulik & O. Kolditz</i>	409
Numerical estimation on diffusion mechanism of groundwater contamination by organoarsenic compounds in Kamisu City, Japan <i>S. Watanabe, N. Egusa, X. Jiang, T. Hirata, N. Yokoyama, Y. Yamazato & M. Morita</i>	413
Transport upscaling in a clay-rich sedimentary formation using multi-porosity models <i>M. Willmann, W. Kinzelbach & F. Stauffer</i>	417
Contaminant transport modeling with scarce data in a LUST groundwater system <i>J. F. Wu, J. C. Wu & X. B. Zhu</i>	421
Numerical simulation of tracer transport in reservoir and its application to Hade Oilfield, Tarim Oilfield in Northwest China <i>Y. M. Wu., Z. H. Tang, W. Zhou & T. Wang</i>	425
Experimental study of electrokinetic remediation of Cd-contaminated soil <i>Y. H. Xi, G. H. Zhou & M. Y. Deng</i>	429
Numerical simulation of fractional advection-diffusion equation: A method to anomalous diffusion <i>Y. Xia & J. C. Wu</i>	433
Molecular phylogeny based on the 16S rRNA gene of one arsenic-resistant bacterial strain isolated from aquifer sediments of Datong Basin, Northern China <i>Z. M. Xie, Y. X. Wang, M. Y. Duan, X. J. Xie & C. L. Su</i>	437
Removal of As(III) and As(V) from groundwater using magnetic nanometer-size iron oxides <i>J. Y. Zhang, Q. Shuai, X. G. Wang, W. Y. Du & J. H. Cheng</i>	441

Section 5

CO₂ sequestration modeling and uncertainty assessment

Numerical simulation of potential effects of CO ₂ leakage on shallow potable aquifers <i>L. Jiang, Y. L. Li, T. F. Xu, W. Zhang & G. B. Qiu</i>	447
Numerical simulation of impacts of mineralogical compositions on trapping mechanisms and efficiency of injected carbon dioxide in deep saline formations <i>J. H. gHhhhhKihm & J. M. Kim</i>	451

Numerical simulation of two-phase flow in deformable porous media: Application to carbon dioxide storage in the subsurface	455
<i>O. Kolditz, N. Böttcher, U.-J. Görke, C.-H. Park & W. Wang</i>	
Reactive transport modeling and comparison of long-term CO ₂ geological storage in geological formations with different mineralogical assemblages	459
<i>Y. L. Li, T. F. Xu, W. Zhang, A. N. Omambia, G. B. Qiu & L. Jiang</i>	
Numerical simulation on geological storage of carbon dioxide constant pressure injection in QianJiang depression, JiangHan Basin, China	465
<i>G. B. Qiu, Y. L. Li, T. F. Xu, W. Zhang & L. Jiang</i>	
Validation of reactive transport models for CO ₂ geological sequestration	469
<i>T. Xu</i>	
A 2-D model of CO ₂ disposal into deep saline aquifers: case study of the Songliao Basin, China	473
<i>R. R. Zhao, J. M. Cheng, K. N. Zhang & M. Chang</i>	
Integrated modeling of basin-scale impacts on groundwater resources and plume-scale transport behavior of geologic carbon sequestration in the illinois sedimentary basin	477
<i>Q. Zhou, J. T. Birkholzer, H. Leetaru, E. Mehnert & Y. F. Lin</i>	
 Section 6	
 <i>Geologic and engineering applications for improving groundwater models</i>	
Simulation and management of land subsidence caused by groundwater exploitation in the Hangzhou-Jiaxing-Huzhou Plain, South China	483
<i>G. L. Cao, J. K. Zhao, M. J. Wu & C. M. Zheng</i>	
Analysis of bank slope stability with local seepage variation in Three Gorges Reservoir	487
<i>B. Chai, K. L. Yin & L. L. Xiao</i>	
The exploitation and utilization of Langkou hot spring geothermal resource in Hubei Province	491
<i>S. M. Fang, M. L. Tian, J. F. Li & R. S. Zhang</i>	
Venice uplift by seawater injection in a randomly heterogeneous aquifer	495
<i>M. Ferronato, G. Gambolati & P. Teatini</i>	
Simulation of regional-scale groundwater recharge and its change under transient climate condition	499
<i>S. O. Grinevskiy & S. P. Pozdniakov</i>	
Verification of optimum monitoring network of hydraulic tomography using numerical experiments based on SSLE	503
<i>C. Y. Guo, G. Chen, C. Hu & Z. H. Chen</i>	
Monitoring of aquifer pump tests with Magnetic Resonance Sounding (MRS)	507
<i>D. Herckenrath, E. Auken & P. Bauer-Gottwein</i>	
Slope Stability under transfusion of the upper reaches of the Xiaoba Reservoir in Sichuan	511
<i>L. L. Li, S. G. Cheng & Q. F. Xu</i>	
A new model for tortuous streamtubes in porous media	515
<i>W. C. Li & J. S. Wu</i>	

Numerical simulation of water and heat coupled model in unsaturated zone <i>Y. L. Li, G. Z. Zhao, W. K. Wang, J. T. Li & L. L. Hou</i>	519
Transient groundwater seepage field simulation of slope and its stability analysis influenced by reservoir water level fluctuation <i>Y. Y. Li, K. L. Yin & H. B. Miao</i>	523
The water-rock interaction modeling of Malan loess and Cr(III) <i>W. Luo, T. Ma, X. L. Yang & Q. Sun</i>	527
Calculation of air temperature and rainfall with noble gases in deep groundwater <i>X. M. Mao & F. L. Wang</i>	531
Chlorinated ethene plume migration in groundwater at Free-Phase Petroleum Sites <i>E. McBean</i>	535
Seepage field simulation and progressive failure analysis of debris landslide under the influence of reservoir water level fluctuation <i>H. B. Miao, K. L. Yin, L. L. Xiao & Y. X. Dai</i>	539
The thermo-hydro-mechanical behaviour of GMZ bentonite from China <i>W. J. Niu, W. M. Ye, B. Chen, J. Wang & Y.J. Cui</i>	543
Study on instable border in groundwater transient seepage field <i>Y. F. Peng & J. B. Zhou</i>	547
Evaluation of seepage problem under a concrete dam with finite volume method <i>A. Shamsai, E. Abdi Dezfuli, A. Zebardast & H. R. Vosoughifar</i>	551
The evaluation of the geothermal water in Henan Depression <i>M. C. Wang & C. M. Ma</i>	555
Application of numerical modeling to study the circulation pattern of groundwater flow systems in the Cretaceous Basin of the Ordos Basin <i>L. H. Yin, G. C. Hou, F. S. Hu & G. L. Cao</i>	559
Evaluation of the active region model for simulating heterogeneous soil water flow <i>W. X. Zhang, Z. Y. Zhang & K. Wang</i>	563
A study on calculation and distribution model of landslide thrust in Three Gorges Reservoir area <i>C. M. Zhou, X. F. Li, K. L. Yin & W. X. Jian</i>	567
Experimental of water transport in nonuniform soil & numerical simulation basing on water flow networks <i>L. Zhu, R. Therrien, J. Z. Yang & Q. Zhou</i>	571
Optimization of groundwater pumping considering land subsidence in Yangtze Delta, China <i>X. B. Zhu, J. C. Wu, J. F. Wu & S. J. Ye</i>	575
A quasi-3D numerical model for groundwater flow in irregular aquifer-aquitard system <i>Y. Zhu, J. Z. Yang, J. X. Tong & F. C. Zhou</i>	579
Geological model of the quaternary sediments <i>L. Žižka & J. Halíř</i>	583

Section 1

*Advances and innovations in model calibration, prediction, and
uncertainty analysis*

Automatic calibration of seawater intrusion modeling using genetic algorithm

M. Bastani^①, M. Kholghi^② & G. R. Rakhshandehroo^①

① *Department of Civil Engineering, University of Shiraz, Shiraz, Iran*

② *Water Eng. Dept., Faculty of Soil & Water Engineering, University of Tehran, Karaj, Iran*

ABSTRACT: An attempt at inverse modeling of a seawater intrusion system is made by using genetic algorithm method as the optimization procedure. The auto-calibration objective function is defined with the root mean square errors (RMSE) between the observed and the simulated values. The observed data are consisted of both hydraulic heads and concentrations obtained from observation wells. Firstly, the SEAWAT code has been used for forward solution part of salt water intrusion phenomena and then a program is written in MATLAB for coupling the forward and inverse processes. This structure is applied in a real case aquifer near Tashk Salt Lake with an EC of 61420 $\mu\text{mhos/cm}$ in Northeast of Fars province in Iran. In last two decades, due to a sharp increase mostly in agricultural water demand, the overexploitation of groundwater has caused a major water level drawdown and consequently the saltwater intrusion. In the developed code, the flow and transport parameters are estimated simultaneously in steady and transient states. The comparison between observed and simulated water level and concentration show an acceptable value. It can be concluded that GA is a helpful tool for automatic calibration of variable density fluid systems such as seawater intrusion problem.

1 INTRODUCTION

Identifying groundwater parameters is based on seeking the values of aquifer parameters which minimize an objective function that computes the differences between the observed and the simulated values of state variables (i.e., hydraulic heads and solute concentrations). Apart from classical optimization methods that many scientific efforts were done to use them in the process of parameter estimation, a variety of approaches called “evolutionary algorithms” have been considered recently. Genetic algorithms are one of these global optimization techniques which have received a lot of attention during the past few decades. These are applied in many groundwater and surface water hydrology problems and played the role of appropriate tool in optimization procedures. Here, it is tried to use genetic algorithm in the frame of inverse modeling with the purpose of parameter estimation.

Reviewing the literature shows that inverse modeling of groundwater flow problems is a usual task among scientists. Moreover, the inverse problem of parameter identification in groundwater contaminant transport has been studied extensively during the last two decades (Yeh, 1986); but the use of inverse modeling for variable-density fluid flow and solute transport, such as occurs in seawater intrusion into aquifers, is even more uncommon (Iribar et al. considered only constant-density flow during intrusion and Shoemaker made an initial attempt at variable-density inverse modeling using sparse data) (Sanz & Voss, 2006). The intention of this work is to estimate some unknown variable-density groundwater flow parameters by using the inverse modeling concept and emphasizing on automatic calibration of a real coastal aquifer case located in Iran by means of coupling SEAWAT as forward code and GA as optimization inversion method.

2 MATERIALS AND METHODS

2.1 Forward Modeling

Forward modeling of variable-density groundwater system is accomplished by using SEAWAT code. The SEAWAT program was developed by the USGS to simulate three-dimensional, variable-density, transient groundwater flow in porous media. The source code for SEAWAT combines USGS MODFLOW and MT3DMS codes into a single program that solves the coupled flow and solute transport equations. The variable-density groundwater flow equation is solved using a finite-difference approximation based on MODFLOW-88. MODFLOW was modified to conserve fluid mass rather than fluid volume and uses equivalent freshwater head as the primary dependent variable. In the revised form of MODFLOW, the cell-by-cell flow is calculated from freshwater head gradients and relative density difference terms. The resulting flow field is passed to a solute transport module in MT3DMS; an updated density field is then calculated from the new solute concentrations and incorporated back into MODFLOW.

The general form of the partial differential equation for variable-density groundwater flow in porous media is formulated as:

$$-\nabla \cdot (\rho \bar{q}) + \bar{\rho} q_s = \rho S_p \frac{\partial P}{\partial t} + \theta \frac{\partial \rho}{\partial C} \frac{\partial C}{\partial t} \quad (1)$$

Where ∇ is the gradient operator, ρ is the fluid density, \bar{q} is the specific discharge vector, $\bar{\rho}$ is the density of water entering from a source or leaving through a sink, q_s is the volumetric flow rate per unit volume of aquifer representing sources and sinks, S_p is the specific storage in terms of pressure, P is fluid pore pressure, θ is porosity, C is solute concentration. In addition to the flow equation, a second partial differential equation is required to describe solute transport in the aquifer. The movement of groundwater and the transport of solutes in the aquifer are coupled processes, and the two equations must be solved jointly. Solute