JOHN DOHERTY

Associated Expert/Senior Reviewer

AREAS OF EXPERTISE

- Groundwater Flow and Contaminant Transport Simulation
- Model Calibration and Uncertainty Analysis
- Application of Inverse Methods for Calibration and Uncertainty Analysis of Numerical Models
- On Behalf of Gas Company and Regulatory Agencies, Development and Construction of Regional Groundwater Models for Coal-Seam Gas-Impact Assessments
- Development, Documentation and Training on Utilities Linking Multiple Numerical Simulators with the PEST Program

SUMMARY OF QUALIFICATIONS

Dr. Doherty is the author of PEST and its supporting utility software. He is a self-employed consultant who also holds an honorary position as a professor with the National Centre for Groundwater Research and Training, Australia. He is an associated expert with SSP&A and has collaborated closely with SSP&A staff since 2001. Dr. Doherty started his career as an exploration geophysicist, but then moved to environmental modelling. He has since worked in the government, private, and tertiary sectors. His research interests include the continued development of software and methodologies for solution of inverse problems using environmental models, quantification of model predictive uncertainty, and appropriate use of models in the decision-making. Much of his recent consulting work has involved assessment of water-use sustainability, and the assessment of the impact on regional groundwater systems from coal seam gas extraction. SSP&A staff have collaborated with Dr. Doherty on model development, training and publication on advanced modeling techniques. Two SSP&A staff undertook their graduate studies under his tutelage.

YEARS OF EXPERIENCE: 40

EDUCATION

PhD, Physics, University of Queensland, 1987
BSc, Geophysics, University of Queensland, 1975

PROFESSIONAL HISTORY

S.S. Papadopulos & Associates, Inc., Associated Expert, 2001 to present
Watermark Numerical Computing Pty. Ltd. Director, 1995 to present
Flinders University, National Centre for Groundwater Research and Training, Professor, 2010 to present
University of Idaho, Idaho Falls, Visiting Professor, 2001
University of Queensland, Dept. of Natural Resources, Senior Groundwater Hydrologist, 1991–1995
James Cook University of North Queensland, Research Fellow, 1987–1991
University of Queensland – Dept. of Physics, Student Researcher, 1985–1987
Northern Territory Power and Water Authority, Geophysicist, 1979–1985
Geological Survey of Queensland, Geophysicist, 1976–1979.

REPRESENTATIVE EXPERIENCE

S.S. Papadopulos & Associates, Inc., Bethesda, MD

- **PEST++** Development — Collaborated in the development of the "next generation" of PEST (i.e., PEST++), including development of parallelization utilities, web-based software for model interaction and calibration, and updated documentation.
- **Fate-and-Transport Model Development,** Los Angeles, CA — Worked with SSP&A staff in the development and calibration of a contaminant fate-and-transport model in the Port of Los Angeles area to assess the movement of fuel-related impacts to groundwater.
- **Hanford Site Groundwater Remediation Strategy,** Washington State —Worked with SSP&A staff in the implementation of a null-space monte-carlo uncertainty analysis for the likely performance of a river-protection groundwater remediation strategy at the DOE Hanford Site.

Watermark Numerical Computing Pty. Ltd., Brisbane, Australia

- **PEST Software** — Provided maintenance, support and development of upgrades for PEST, a state-of-the-art model-independent nonlinear parameter estimator used throughout the world for

the calibration of environmental models of all kinds. Developed utility software to expedite the use of PEST with specific models. *[See www.pesthomepage.org]*

- Developed stochastic and upscaling techniques and software for use in assessing the impact of coal-seam gas on regional groundwater systems.
- On behalf of gas company and regulatory agencies, developed regional groundwater models for coal-seam gas-impact assessment.
- Developed and constructed groundwater models for environmental, agricultural, water-supply, remediation and mining applications.
- Applied inverse methods for calibration and uncertainty analysis of geothermal models.
- Provided instruction on environmental modelling through direct advisory consultancies, and leadership of modelling courses and workshops in Australia, Europe, the US, and elsewhere. These courses are mainly focused on the use of nonlinear parameter estimation methods in the calibration of environmental models, and the exploration of the uncertainty pertaining to predictions made by these models.
- Provided services for the calibration of models used in the hydrological and environmental sciences. Contracts to-date have included work with stormwater and sewage system models; forest production models; watershed models (including both quantity and quality aspects of surface-water movement); groundwater flow-and-transport (including salt-water-intrusion) models; and multi-phase, multi-component fluid flow models.
- In conjunction with the U.S. Geological Survey, U.S. Environmental Protection Agency, U.S. Department of Energy, U.S. Department of Agriculture, and U.S. Army Corps of Engineers, developed methodologies and software for application of nonlinear parameter estimation and predictive uncertainty analysis techniques in the surface-water, vadose zone, and groundwater modelling contexts.

Flinders University, National Centre for Groundwater Research and Training, Adelaide, Australia

- Supervised post-graduate students working on projects involving the development and application of state-of-the-art environmental model calibration and predictive uncertainty analysis software and methodologies.
- Developed public domain software to implement linear and nonlinear uncertainty analyses.

University of Idaho – Idaho Falls, Idaho Falls, Idaho

- Developed software to facilitate the use of nonlinear parameter estimation methods in groundwater and surface-water modelling. Applied and tested these methods in conjunction with personal from the U.S. Geological Survey and the U.S. Environmental Protection Agency.
- Provided formal education in the use of nonlinear parameter estimation methods for calibration and predictive analysis of environmental models.

University of Queensland, Department of Natural Resources, Queensland, Australia

- Constructed and calibrated large, complex models simulating groundwater and surface-water movement within irrigation areas.
- Developed groundwater modelling-based procedures to assess salinity risks in dryland and irrigated agricultural areas.
- Developed translation software for transfer of data between models, Geographical Information Systems, databases, and visualization/display packages.
- ThEnhanced Geographical Information Systems for use in the groundwater context.

James Cook University, North Queensland, Australia

- Constructed and calibrated large, complex models simulating groundwater and surface-water movement within irrigation areas.
- Developed groundwater-modelling-based procedures to assess salinity risks in dryland and irrigated agricultural areas.
- Developed translation software for transfer of data between models, Geographical Information Systems, databases, and visualisation/display packages.
- Enhanced Geographical Information Systems for use in the groundwater context.

University of Queensland, Department of Physics, Queensland Australia

Conducted research into the numerical simulation of the electromagnetic response of subsurface bodies to external magnetic and electrical excitation. This work culminated in a thesis exploring the use of the boundary element method in the "two-and-a-half dimensional" modelling context.

Geological Survey of Queensland, Queensland, Australia

- Conducted geophysical surveys for groundwater supply and environmental investigations. Methods used included seismic refraction, resistivity, IP, EM and magnetics. Interpreted and reported data gathered on these surveys.
- Developed computer programs for forward and inverse modelling of earth response to different geophysical techniques.
- Designed and constructed surface and downhole instrumentation.
- Operated a borehole logging system.
- Conducted geological mapping and logging of drilling returns.

Water Division, Northern Territory Power and Water Authority, Australia

- Performed geophysical surveys for groundwater supply and environmental investigations, Methods used included seismic refraction, resistivity, IP, EM and magnetics. Interpreted and reported data gathered on these surveys.
- Developed computer programs for forward and inverse modelling of earth response to different geophysical techniques.
- Designed and constructed surface and downhole instrumentation.
- Operated a borehole logging system.
- Performed geological mapping and logging of drilling returns.

COMMERCIAL AND PUBLIC DOMAIN SOFTWARE

- **2013–2014: PEST** — Continued development of PEST and associated utility support software, with focus on the use of complex models in conjunction with simple models or proxy models to assist in calibration and uncertainty analyses based on the former where model run times are large.
- **2012: PLPROC** ("parameter list processor") — This model is a pre-processor that uses a Python-like command-line syntax to manipulate model parameters, and to undertake spatial interpolation of model parameters. Functionality includes use of 2D and 3D radial basis functions for pilot point interpolation, as well as embedded functions in generalized model input template files.
- **2010: BEOPEST** — In conjunction with Willem Shreuder of Principia Mathematic, a version of PEST named "BEOPEST" was developed to replace Parallel PEST. This software uses TCP/IP as a means of communication between master and model-running slaves. Hence model runs can be parallelized using cores on a user's computer, on an office network, or around the world.

- **2009: Pareto Mode** — A new mode of operation based on the exploration of the Pareto front was added to PEST. This software was designed for use in highly parameterized contexts where expert-based subjective judgments must be used in determining optimality of imposition of regularization constrains during calibration, and optimality of imposition of calibration constraints during predictive uncertainty analysis.
- **2007: Null Space Monte Carlo** — This software required modifications to PEST and the development of a number of utility support software to allow rapid generation of multiple parameter realizations that, on the one hand, respect a user-specified stochastic distribution, while on the other hand provide a fit between model outputs and field data that are as good as that of the "calibrated model".
- **2006: Improvements to PEST** — These included improvements to its regularisation of capabilities, new algorithms for accommodation of poor model performance with respect to derivatives calculation, improved recording of history of the calibration process, incorporation of the LSQR solver for highly parameterized systems, and parallelised versions of the CMA and SCE global inversion engines as calibration alternatives to PEST.
- **2005: Advanced Model Predictive Error Analysis** — Based on theory published in a number of scientific journals (*see below*), utility software was developed to carry out fast and efficient model predictive error analysis as an adjunct to regularized inversion. This software allows rapid analysis of the uncertainty range of model parameters; and source terms and predictions that are compatible with a given suite of historical measurements of system state and with the known or inferred level of geological heterogeneity prevailing in a study area. This technology is unique to PEST.
- **2004: Advanced Regularisation** — In 2004, a unique hybrid regularisation methodology known as "SVD-Assist" was added to PEST. This was supported by the addition of a number of new programs to the PEST utility suite. Use of SVD-Assist realizes great gains in the numerical stability of a regularised inverse problem, at the same time as it results in large efficiency gains.
- **2003: MICA** — This model-independent Markov Chain Monte Carlo program was developed under contract with the U.S. Environmental Protection Agency for calculation of model predictive uncertainty in a Bayesian framework.
- **2002–2003: Improvements to PEST** — These improvements include functionality for adaptive regularisation, compressed data storage, and other devices to improve the use of PEST in highly parameterised contexts. They also include drivers that allow PEST to avoid entrapment in local minima during surface-water model calibration.
- **2001:**

  TSPROC — TSPROC is a comprehensive time-series processor developed for use as an adjunct to PEST in the calibration of surface-water models on the basis of many different kinds of measured and/or processed data.

  Pilot Point Utilities — A number of programs were added to the Groundwater Data Utility Suite that facilitate the use of PEST in MODFLOW and MT3D spatial parameterisation. Sophisticated, geostatistically-based, regularisation conditions are introduced to the parameterisation process, making use of PEST-ASP's advanced regularisation capabilities.
- **2000:**

  MF2PEST — MF2PEST is a MODFLOW2000-to-PEST dataset translator, allowing use of PEST as an enhancement to MODFLOW. This is complemented by MODFLOW-ASP, an enhanced version of MODFLOW-2000 that includes a PEST interface, the ability to parameterise a model domain using pilot points, and better handling of drying/re-wetting conditions.

  PEST-ASP ("Advanced Spatial Parameterisation") — In late 2000, PEST was upgraded to include sophisticated regularisation capabilities to enhance its use in the calibration of

complex distributed-parameter models in heterogenous settings .

PEST Interface to GMS Version 3.1 — This version was developed jointly with personnel from Brigham Young University.

- **1999:**

  Composite IQQM/MODFLOW Model — MODFLOW96 was linked to IQQM, a basin-scale hydrologic and water- management model developed by the New South Wales Department of Land and Water Conservation.

  PEST2000 — A major PEST upgrade including the addition of nonlinear predictive uncertainty analysis functionality.

  PEST Surface-Water Utilities — A suite of software tools developed to enhance the use of PEST in the calibration of surface-water models.

- **1998:**

  Utilities for use of PEST with HSPF — Written on behalf of the U.S. Environmental Protection Agency.

  PEST98 — A major upgrade for PEST, including the addition of user-intervention functionality.

- **1997:**

  PEST GMS Utilities — A set of programs that facilitates the use of PEST with the popular "Groundwater Modelling System" developed by Brigham Young University.

  Parallel PEST — A version of PEST that dramatically reduces optimization time by undertaking simultaneous model runs across a PC network.

- **1996: SENSAN: A Model-Independent Sensitivity Analyzer** — Uses the PEST model interface protocol for the construction of a model-independent sensitivity analyzer.

- **1995: Groundwater Data Utilities** — A suite of programs to undertake certain aspects of groundwater model pre- and post-processing, and to facilitate data transfer between MODFLOW, MT3D, MICROFEM, PEST, SURFER, GIS and various visualization/display packages.

- **1994:**

  PEST Utilities for MODFLOW/MT3D Parameter Estimation — A set of utilities to facilitate the use of PEST with MODFLOW and MT3D.

  PEST —A model-independent nonlinear parameter estimator that is presently used worldwide for the calibration of hydrological and other engineering/scientific models, and for interpretation of field data based on mathematical inversion. PEST is supported by a number of commercial modelling graphical-user interfaces including FEFLOW, Visual MODFLOW, Groundwater Vistas, GMS, PMWIN and BASINS.

- **1991: MODINV** — A MODFLOW-specific parameter estimator, MODINV was used at over 250 sites worldwide.

PUBLICATIONS & PRESENTATIONS

PUBLICATIONS

Burrows, W. and J. Doherty, 2016. Gradient-Based Model Calibration with Proxy-Model Assistance. *Journal of Hydrology*, 533, pp. 114-127.

White, J.T., M.N. Fienen, and J.E. Doherty, 2016. pyEMU: A Python Framework for Environmental Model Uncertainty Analysis. *Environ Modell Software*, v. 85, pp. 217-228.

Doherty, J., 2015. Calibration and Uncertainty Analysis for Complex Environmental Models. Published by Watermark Numerical Computing, Brisbane, Australia. 227 pp. ISBN: 978-0-9943786-0-6. www.pesthomepage.org.

Doherty, J. and R. Vogwill, 2015. Models, Decision-Making and Science. in *Solving the Groundwater Challenges of the 21st Century*. Vogwill, R. ed. CRC Press.

Herckenrath, D., J. Doherty, and W. Panday, 2015. A Methodology for Assessing the Impact of Coal Bed Methane Extraction on Regional Groundwater Systems. *Journal of Hydrology*, 523 (2015), pp, 587-601.

Moore, C.R., J.E. Doherty, S. Howell, and L. Erriah, 2015. Some Challenges Posed by Coal Bed Methane Regional Assessment Modelling. *Ground Water,* v. 53, no.5, pp. 737-747.

Welter, D.E., J.T. White, J.E. Doherty, and R.J. Hunt, 2015. PEST++ Version 3. A Parameter ESTimation and Uncertainty Analysis Software Suite Optimized for Large Environmental Models. *U.S. Geological Survey Techniques and Methods Report.* Book 7, Section C, Chapter 12.

Burrows, W. and J. Doherty, 2014. Efficient Calibration/Uncertainty Analysis Using Paired Complex/Surrogate Models. *Groundwater*, v. 53, no. 4, pp. 531-541.

Nolan, B.T., R.W. Malone, R.W., J. Doherty, J.E. Barbash, L. Ma, D.L. Shner, 2014. Data Worth and Prediction Uncertainty for Pesticide Transport Fate in Nebraska and Maryland, USA. *Pest Management Science*. DOI 10.1002/ps.3875.

Rossi, P.K., P. Ala-aho, J. Doherty, and B. Klove, 2014. Impact of Peatland Draining and Restoration on Esker Groundwater Resources—Modelling Future Scenarios for Management. *Hydrogeology Journal*. DOI: 10.1007/s10040-014-1127-z.

Schilling, O., P. Brunner, J. Doherty, Y. Pengnian, W., Haijing, and W. Kinzelbach, 2014. The Worth of Tree Ring Data in Modelling the Interaction Between Surface Water, Groundwater and Vegetation on the lower Tarim River. *Journal or Hydrology*. *Accepted for publication: in press.*

Sepulveda, N., and J. Doherty, 2014. Uncertainty Analysis of a Groundwater Flow model in East-Central Florida. *Groundwater,* v. 53, no. 3, pp. 464-474.

White, J.T., J.E. Doherty, and J.D. Hughes, 2014. Quantifying the Predictive Consequences of Model Error with Linear Subspace Analysis. *Water Resources Research*, v. 50, no. 2, pp. 1152-1173. DOI: 10.1002/2013WR014767.

Doherty, J. and C.T. Simmons, 2013. Groundwater Modelling in Decision Support: Reflections on a Unified Conceptual Framework. *Hydrogeology Journal,* 21: pp. 1531–1537.

Fienen, M.M., M. D'Oria, J. Doherty, and R. Hunt, 2013. Approaches to Highly Parameterized Inversion: bgaPEST, a Bayesian Geostatistical Approach Implemented with PEST — Documentation and Instructions. USGS Techniques and Methods Report 7-C9. Groundwater Resources Program.

Watson, T.A., J.E. Doherty, and S. Christensen, 2013. Parameter and Predictive Outcomes of Model Simplification. *Water Resources. Research,* v. 49, no. 7, pp. 3952-3977. DOI: 10.1002/wrcr.20145.

Brunner, P., J. Doherty, and C.T. Simmons, 2012. Uncertainty Assessment and Implications for Data Acquisition in Support of Integrated Hydrologic Models. *Water Resources Research.* doi:10.1029/2011WR011342.

Muffels, C.T., W.A. Schreüder, J.E. Doherty, M. Karanovic, M.J. Tonkin, R.J. Hunt, and D.E. Welter, 2012. Approaches in Highly Parameterized Inversion — GENIE, a General Model-Independent TCP/IP-run Manager. U.S. Geological Survey Techniques and Methods, Book 7, Section C6, 26 p.

Welter, D.E., J.E. Doherty, R.J. Hunt, C.T. Muffels, M.J. Tonkin, and W.A. Schreüder, 2012. Approaches in Highly Parameterized Inversion: PEST++, a Parameter ESTimation Code Optimized for Large Environmental Models. U.S. Geological Survey Techniques and Methods, Book 7, Section C5, 47 p.

Wilsnack, M.M., J.E. Doherty, and D.E. Welter, 2012. A Pareto-based Methodology for Calibration and Uncertainty Analysis of Gated Culvert Flows. *Journal of Irrigation and Drainage Engineering (ASCE),* v. 138, no. 7, pp. 675-684. DOI.10.1061/(ASCE)IR.1943-4774.0000431.

Doherty, J., 2011. Modeling: Picture Perfect or Abstract Art? *Ground Water*, v.49, no. 4, pp. 455-456.

Doherty, J. and S. Christensen, 2011. Use of Paired Simple and Complex Models in Reducing Predictive Bias and Quantifying Uncertainty. *Water Resources Research (*featured article). doi:10.1029/2011WR010763. WRR.

Herckenrath, D., C.D. Langevin, and J. Doherty, 2011. Predictive Uncertainty Analysis of a Saltwater Intrusion Model Using Null-space Monte Carlo. *Water Resources Research*, v. 47. W05504. doi:10.1029/2010WR009342.

Hunt, R.J. and J. Doherty, 2011. Interesting or Important? Resetting the Balance of Theory and Application. Guest editorial in *Ground Water,* v. 49, no. 3, p. 301.

Doherty, J., M.N. Fienen, and R.J. Hunt, 2010. Approaches to Highly Parameterized Inversion: Pilot-Point Theory, Guidelines and Research Directions. *USGS Scientific Investigations Report 2010-5169.* http://pubs.usgs.gov/sir/2010/5168/.

Doherty, J. and D. Welter, 2010. A Short Exploration of Structural Noise. *Water Resources. Research* (featured article), v. 46, W05525. doi:10.1029/2009WR008377.

Doherty, J., and R.J. Hunt, 2010. Response to Comment on "Two Statistics for Evaluating Parameter Identifiability and Error Reduction." *Journal of Hydrology*, v. 380, pp. 489-496.

Doherty, J., and R.J. Hunt, 2010. Approaches to Highly Parameterized Inversion: A Guide to Using PEST for Groundwater-Model Calibration. USGS Scientific Investigations Report 2010-5169. http://pubs.usgs.gov/sir/2010/5169/.

Doherty, J., R.J. Hunt, and M.J. Tonkin, 2010. Approaches to Highly Parameterized Inversion: A Guide to using PEST for Model Parameter and Predictive Uncertainty Analysis. *USGS Scientific Investigations Report 2010-5211.* http://pubs.usgs.gov/sir/2010/5211/.

Dausman, A.M., J. Doherty, C.D. Langevin, and M.C. Sukop, 2010. Quantifying Data Worth toward Reducing Predictive Uncertainty. *Groundwater, v.*48, no. 5, pp. 729-740.

Fienen, M.N., J.E. Doherty, R.J.., Hunt, and H.W. Reeves, 2010. Using Prediction Uncertainty Analysis to Design Hydrologic Monitoring Networks: Example Applications from the Great Lakes Water Authority Availability Pilot Project. USGS Scientific Investigations Report 2010-5159*,* 44 p.

Hunt, R.J., J. Luchette, W.A. Shreuder, J. Rumbaugh, J. Doherty, M.J. Tonkin, and D. Rumbaugh, 2010. Using the Cloud to Replenish Parched Groundwater Modeling Efforts. Rapid Communication for *Ground Water*. doi: 10.1111/j.1745-6584.2010.00699.

Keating, E., J. Doherty, J.A. Vrugt, and Q. Kang, 2010. Optimization and Uncertainty Assessment of Strongly Nonlinear Groundwater Models with High Parameterization Dimensionality. *Water Resources Research*, v. 46, W10517, 18 p. doi:10.1029/2009WR008584. (*Winner of the Water Resources Research Editor's Choice Award for 2010).*

Moore, C., T. Wöhling, and J. Doherty, 2010. Efficient regularization and uncertainty analysis using a global optimization methodology. *Water Resources Research,* v. 46, W08527, doi:10.1029/2009WR008627.

Doherty, J. and R.J. Hunt, 2009. Two Statistics for Evaluating Parameter Identifiability and Error Reduction. *Journal of Hydrology*, v. 366, pp. 119-127.

Dausman, A.M, J. Doherty, C.D. Langevin, J. and Dixon, 2009. Hypothesis Testing of Buoyant Plume Migration Using a Highly Parameterized Variable-Density Groundwater Model. *Hydrogeology Journal.* DOI 10.1007/s10040-009-0511-6.

Ellis, R.J., J. Doherty, R.D. Searle, and K. Moodie, 2009. Applying PEST (parameter ESTimation) to Improve Parameter Estimation and Uncertainty Analysis in WaterCAST Models. *in* RS Anderssen, R.S., R.D. Braddock and L.T. Newham, eds., *18th World IMACS Congress and MODSIM09 International Congress on Modelling and Simulation*, Modelling and Simulation Society of Australia and New Zealand and International Association for Mathematics and Computers in Simulation, Cairns, Australia, pp. 3158-3164.

James, S.C., J. Doherty, J. and A.-A. Eddebarh, 2009. Post-calibration Uncertainty Analysis: Yucca Mountain, Nevada, USA. *Ground Water,* v. 47, no. 6, pp. 851-869.

Tonkin M.J., and J. Doherty, 2009. Calibration-Constrained Monte Carlo Analysis of Highly Parameterized Models Using Subspace Techniques. *Water Resources Res*earch, v. 45, W00B10, doi:10.1029/2007WR006678.

Doherty, J., 2008. Model Predictive Error: How it Arises and How it can be Accommodated. in *Proceedings of MODELCARE 2007: Calibration and Reliability in Ground Water Modelling: Credibility of Modelling.* Copenhagen, Denmark. IAHS Publishers.

Banta, E.R., M.C. Hill, E. Poeter, J. Doherty, and J. Babendreier, 2008. Building Model Analysis Applications with the Joint Universal Parameter Identification and Evaluation of Reliability (JUPITER) API. *Computers & Geosciences,* v. 34 (2008), pp. 310–319.

Christensen S. and J. Doherty, 2008. Using Many Pilot Points and Singular Value Decomposition in Groundwater Model Calibration. in *Proceedings of MODELCARE 2007: Calibration and Reliability in Ground Water Modelling: Credibility of Modelling.* Copenhagen, Denmark. IAHS Publishers.

Christensen, S. and J. Doherty, 2008. Predictive Error Dependencies when using Pilot Points and Singular Value Decomposition in Groundwater Model Calibration. *Advances in Water Resources*, v. 31, Issue 4 (April), pp. 674-700.

Hunt, R.J., J. Doherty, and M.J. Tonkin, 2007. Are Models too Simple? Arguments for Increased Parameterisation. *Ground Water*, v. 45, no. 3, pp., 254–262.

Eddebarh, A.-A, S.C. James, J. Doherty, G.A. Zyvoloski, and B.W. Arnold, 2007. A New Saturated Zone Site-Scale Model for Yucca Mountain. *EOS Transactions,* American Geophysical Union, v. 88, no. 52, H21C-0706.

Gallagher, M. and J. Doherty, 2007. Predictive Error Analysis for a Water Resource Management Model. *Journal of Hydrology*, v/ 34, no. 3-4, pp. 513-533.

Gallagher, M.R., and J. Doherty, 2007. Parameter Interdependence and Uncertainty Induced by Lumping in a Hydrologic Model. *Water Resources Research*. v.43, W05421. doi:10.1029/2006WR005347.

Kim, S.M., B.L. Benham, K.M. Brannan, R.W. Zeckoski, and J. Doherty, 2007. Comparison of Hydrologic Calibration of HSPF Using Automatic and Manual Methods. *Water Resources Research*, v. 43, W01402. doi:10.1029/2006WR004883.

Tonkin, M., J. Doherty, and C. Moore, 2007. Efficient Nonlinear Predictive Error Variance for Highly Parameterized Models. *Water Resources Research*, v. 43, W07429. doi:10.1029/2006WR005348.

Doherty, J. and B. Skahill, 2006. An Advanced Regularization Methodology for use in Watershed Model Calibration. *Journal of Hydrology,* v. 327, no. 3-4, pp. 564-577.

Banta, E.R., E.P. Poeter, J. Doherty, and M.C. Hill, 2006. JUPITER: Joint Universal Parameter Identification and Evaluation of Reliability — An Application Programming Interface (API) for Model Analysis. Techniques and Methods 6-E1. U.S. Geological Survey, Denver, CO.

Gallagher, M.R. and J. Doherty, 2006. Parameter Estimation and Uncertainty Analysis for a Watershed Model. *Environmental Modelling and Software*, v. 22, 1000-1020.

Moore, C. and J. Doherty, 2006. The Cost of Uniqueness in Groundwater Model Calibration. *Advances in Water Resources*, v. 29, Issue 4 (April), pp. 605–623.

Skahill, B. and J. Doherty, 2006. Efficient Accommodation of Local Minima in Watershed Model Calibration. *Journal of Hydrology,* v. 329, no. 1-2, pp122-139.

Moore, C. and J. Doherty, 2005. The Role of the Calibration Process in Reducing Model Predictive Error. *Water Resources Research*, v. 41, no 5, W05050.

Tonkin, M. and J. Doherty, 2005. A Hybrid Regularised Inversion Methodology for Highly Parameterised Models. *Water Resources Research*, v. 41, W10412. doi:10.1029/2005WR003995, 2005.

Doherty, J., 2003. Groundwater Model Calibration Using Pilot Points and Regularisation. *Ground Water*, v. 41, no. 2, pp. 170-177.

Doherty, J. and J.M. Johnston, 2003. Methodologies for Calibration and Predictive Analysis of a Watershed Model. *Journal of the American Water Resources Association*, v. 39, no. 2, pp. 251-265.

McKenna, S.A., J. Doherty, and D.B. Hart, 2003. Non-Uniqueness of Inverse Transmissivity Field Calibration and Predictive Transport Modeling. *Journal of Hydrology*, v. 281, no. 4, pp. 265-282.

Tonkin, M.J., M.C. Hill, and J. Doherty, 2003. MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model — Documentation of MOD-PREDICT for Predictions, Prediction Sensitivity Analysis, and Enhanced Analysis of Model Fit. U.S. Geological Survey Open-File Report 03-385, 69 p.

Doherty, J., 2001. A Methodology for Preventing the Occurrence of Dry Cells in a Three-Dimensional MODFLOW Model. *Ground Water,* v. 39.

Doherty, J., 1990. The Interpretation of Pump-Test Data from a Disused Underground Mine. *Journal of Hydrology,* v. 114, pp. 109-123.

Doherty, J., 1988. EM modelling Using Surface Integral Equations. *Geophysical Prospecting*, v. 36, no. 6.

Doherty, J., 1987. The Use of Surface Integral Equations in Modelling for Electrical Prospecting. PhD Thesis, University of Queensland, Australia.

Dixon, O. and J. Doherty, 1977. New Interpretation Methods for IP Soundings. *ASEG Bulletin,* v. 8, no. 3, pp. 65-74.

PRESENTATIONS

2015 "Using Models to Make Decisions and Deciding how to use Models." California Water and Environmental Forum Annual Meeting, Folsom, CA.

2013 "Model-Based Decision Making: Separating Fact from Fantasy." Plenary session address, International Association of Hydrogeologists annual conference, Perth, Australia.

2013 "New Modelling Methodologies for Coal Seam Gas Impact Assessment." Keynote address at the International Association of Hydrogeologists annual conference, Perth, Australia.

2011 "Environmental Modelling – Encapsulating what we Know and Quantifying what we Don't." NCGRT Distinguished Lecture Series (presented at most Australian capital cities through 2011).

2011 "Complexity and Simplicity — Combining the Strengths of Both". Invited presentation at the Geological Society of America Annual Meeting, Minneapolis, MN.

2011 "Model-based Decision Making: A New Perspective." J.E. Doherty, S.C. James, and P.W. Reimus. *13th International High-Level Radioactive Waste Management Conference*, 1049-1058, Albuquerque, NM.

2009 "Models and Decisions: A Better Way". PEST Conference, Bethesda, Maryland.

2007 "Model Predictive Error: How it Arises and How it can be Accommodated". ModelCare Conference, Copenhagen.

2006 "Highly Parameterised Inversion in Calibration and Uncertainty Analysis for Complex Models". AGU Fall Meeting, San Francisco.

2003 "Decreasing Expectations and Increasing Credibility in Groundwater Modeling." MODFLOW 2003 Conference, Golden Colorado.

2001 "Groundwater Model Parameterisation — Space Age Technology or Science Fiction." MODFLOW-2001 Conference, Golden Colorado.

1999 "Model Parameterisation and Predictive Uncertainty— Their Role in the Model Construction Process." Geological Society of America Annual Meeting, Denver.

1998 "Model Complexity: How Much is Too Much?" MODFLOW98 Conference, Golden, Colorado.