

Mr. Roberts has 31 years of experience in hydrogeologic characterization of low-permeability formations, design and development of advanced well-test analysis software, hydraulic testing, and hydrogeologic data analysis. He has worked extensively in the area of site characterization associated with nuclear waste repository programs in the United States, Canada, France, Japan, Sweden, Germany, Taiwan, and Korea, performing and interpreting hydraulic tests and providing training in advanced well-test analysis. Mr. Roberts has participated in both deep borehole testing and tests in underground facilities, designing and implementing the tests and analyzing the data. While working in Canada he was responsible for the design and analysis of over 250 pulse-injection/withdrawal and slug-injection/withdrawal hydraulic tests performed in six deep (depth > 800 m) and one shallow borehole. Mr. Roberts was the well-test analysis lead at the U.S. Department of Energy's Waste Isolation Pilot Plant (WIPP) for 17 years where he was involved in a variety of tests including pulse, slug, constant pressure, hydro-fracturing, and constant-rate tests. He was the technical lead for the design of Sandia National Laboratories' numerical well-test analysis code, nSIGHTS and is the world's leading authority on the application of nSIGHTS in low-permeability well-test analysis. In France, Mr. Roberts participated in the hydraulic testing and analysis of boreholes EST 210, EST 211, and EST 212, and in the re-interpretation of tests from boreholes MSE 101, and HTM 102. Mr. Roberts has taught advanced well-test analysis classes for personnel involved in nuclear repository characterization in Taiwan, Japan, Korea, France, Germany, and Canada.

Selected Hydraulic Testing Experience

Union Gas Ltd: Testing of Borehole UB.13, near Sarnia, Ontario, Canada. April-May 2013. *Numerical well-test analysis lead*, responsible for design and nSIGHTS analysis of pulse tests utilizing a straddle-packer test tool to characterize low-permeability ($K < 1E-11$ m/s) sedimentary strata in southern Ontario, Canada. Pulse tests were performed in 14 intervals at depths up to 493 m bgs.

Nuclear Waste Management Organization/Ontario Power Generation (Canadian Deep Geologic Nuclear Repository Program), Kincardine, Ontario, Canada. 2007 – 2011. *Well-Test Analysis Lead* responsible for design and analysis of all hydraulic tests performed in six 1000-m boreholes and one 200-m borehole utilizing a straddle-packer test tool in the low-permeability formations (down to $1E-14$ m/s) at the Bruce Power Site, southern Ontario, Canada. This effort was part of site characterization to assess suitability of low permeability formations for radioactive waste disposal. Responsibilities included the design, implementation, and analysis of over 250 hydraulic tests, including advanced uncertainty analysis of hydraulic parameter estimates, coordination of field activities with other contractors, data acquisition, and reporting. The analysis of the hydraulic testing data was performed using Sandia National Laboratories' numerical well-test simulator, nSIGHTS.

Waste Isolation Pilot Plant (WIPP), Carlsbad, New Mexico. 1989-2008 *Well-Test Analysis Lead* responsible for design, analysis, and reporting of packer tests performed both in the WIPP underground repository (2250 m bgs) and in deep boreholes drilled from the surface. Estimated K values of the tested formations ranged from $1E-5$ m/s to $1E-15$ m/s. *Team Lead* for developing advanced methodologies for quantifying uncertainty in hydraulic parameter estimates. These methodologies that included perturbation analysis, parameter-space mapping, Jacobian (sensitivity) analysis, residual analysis, and joint-confidence region calculations, were initially developed in GTFM (Graph Theoretic Field Model). GTFM was the DOS-based precursor to the Windows-based numerical well-test simulator, nSIGHTS. *Team lead* for the design and testing of Sandia National Laboratories' numerical well-test simulator, nSIGHTS. GTFM and nSIGHTS were the first

Years of Experience: 31

Education:

- M.S. Hydrology, 1990, New Mexico Institute of Mining and Technology
- B.S. Geology, 1986, North Dakota State University

Professional Registrations/Affiliations:

- National Groundwater Association
- ASTM International – Voting Member of Technical Committee D18

Professional History:

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| 2008– present | Principal & Managing Member - HydroResolutions |
| 1999 – 2008 | Senior Member Technical Staff – Sandia National Laboratories |
| 1989– 1999 | Hydrogeologist – INTERA, Inc./Duke engineering & Services |
| 1987 – 1989 | Research Assistant – New Mexico Institute of Mining and Technology |

Specialized Training:

- Well-test analysis: nSIGHTS expert
- MSHA 40 Hour Underground Experienced Miner Training
- Well Test Interpretation in Practice (Scientific Software-Intercomp)

Languages:

- English: written and spoken
- French: basic knowledge

groundwater well-test analysis codes to include these uncertainty-quantifying methodologies that were subsequently copied and adopted by other programs around the globe. *Team lead* for the inclusion, modification, and advancement of John Barker's Generalized Radial Flow model into nSIGHTS, making nSIGHTS the most advanced code available for the analysis of non-radial well-test responses.

Agence nationale pour la gestion des déchets radioactifs, France. 2004-2005 *Technical consultant and Well-test Analysis lead* responsible for planning packer tests, field operations supervision, well-test analysis and reporting as part of site characterization to assess suitability of low permeability ($K < 1E-11$ m/s) formations in France being considered for radioactive waste disposal. Hydraulic testing data were analyzed using nSIGHTS and analysis included quantification of the uncertainty in fitting-parameter estimates.

Selected Publications, Presentations, and Reports

Roberts, R., Chace, D., Beauheim, R., and Avis, J. 2011. Analysis of Straddle-Packer Hydraulic Tests in DGR Boreholes. TR-08-32. DGR Site Characterization Document, Intera Engineering, Ottawa, Ontario.

Avis, J.D., R.M. Roberts, D.A. Chace, N.J. Toll, and R.L. Beauheim. 2009. Hydraulic testing to characterize low-permeability sedimentary formations – proposed Deep Geologic Repository, Tiverton, Ontario. 62nd Canadian Geotechnical Conference & 10th Joint CGS/IAH-CNC Groundwater Conference.

Beauheim, R.L., J.D. Avis, D.A. Chace, R.M. Roberts, and N.J. Toll. 2009. Hydraulic Testing of Silurian and Ordovician Strata at the Bruce Site. AGU (poster presentation).

Roberts, R.M. 2006. Analysis of Culebra Pumping Tests Performed Between December 2003 and August 2005. Analysis report for AP-070, Sandia National Laboratories, Carlsbad NM. WIPP:1.4.2.3: TD: QA-L: DPRP1:PKG# 539221.

Roberts, R.M. and Domski, P.S. 2005. An nSIGHTS Analysis of Hydraulic Interference Test PT2 Conducted in Moderately Fractured Rock. Prepared by Sandia National Laboratories. Ontario Power Generation, Nuclear Waste Management Division Report No: 06819-REP-01300-10106-R00.

Roberts, R., and Enachescu, C. 2005. Re-interpretation of Hydraulic Packer Tests from Borehole MSE101: Callovian Tests 5, 6, 7, 8, and 9. Report D.RO.0BAK.04.021/A. Agence nationale pour la gestion des déchets radioactifs (ANDRA).

Roberts, R., Triganon, and A., Morchid, A. 2004. Test Hydrogéologiques Entre Obturateurs. Rapport Dopération – EST 210: Dogger. Report D.RO.0BAK.04.007/A. Agence nationale pour la gestion des déchets radioactifs (ANDRA).

Beauheim, R.L., R.M. Roberts. Well-Test Analysis Techniques Developed for the Waste Isolation Pilot Plant. Presentation for the 66th EAGE Conference, June 8, 2004, Paris, France.

Roberts, R.M. 2003. IN-SITU DIFFUSION EXPERIMENT: WELL-TEST ANALYSIS USING nSIGHTS. Report No: 06819-REP-01300-10073-R00. 51 pages. Ontario Power Generation

Roberts, R.M. 2002. Moderately Fractured Rock Experiment: Well Test Analysis Using nSIGHTS. Report No: 06819-REP-01300-10062-R00. 194 pages. Ontario Power Generation

Roberts R.M., R.L. Beauheim, P.S. Domski, 1999. Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Final Report, SAND98-2537, Sandia National Laboratories.