

# **Report as of FY2006 for 2005IL62B: "The Flow Dimension of Groundwater Resources in Northeastern Illinois"**

## **Publications**

- Conference Proceedings:
  - Cello, P. A., D. D. Walker, A. J. Valocchi, and B. Loftis, 2005. Identifying Models for the Heterogeneity of Hydraulic Conductivity in Fractured Aquifers, 50th Annual Midwest Ground Water Conference, Urbana, IL, November, 2005.
  - Walker, D. D., P. A. Cello, A. J. Valocchi, and B. Loftis, 2005. Flow dimensions corresponding to stochastic models of heterogeneous aquifers, AGU Fall Meeting, San Francisco, Dec, 2005.
  - Cello, P. A., D. D. Walker, A. J. Valocchi, and B. Loftis, 2005. The behavior of tracer tests in aquifers with noninteger flow dimensions, AGU Fall Meeting, San Francisco, Dec, 2005.
- Other Publications:
  - Walker, D. D., P. A. Cello, A. J. Valocchi, and B. Loftis, 2006. High-Throughput Computing for the Analysis of Tracer Tests in Fractured Aquifers, Illinois State Water Survey Contract Report 2006-4, Champaign, IL.
- Articles in Refereed Scientific Journals:
  - Walker, D. D., and R. M. Roberts, 2007. Reply to Comment by Chia-Shyun Chen and I. Y. Liu on Flow dimensions corresponding to hydrogeologic conditions, *Water Resources Research*, vol. 43, no. 2, W02602, doi:10.1029/2006WR005781.
  - Walker, D. D., P. A. Cello, A. J. Valocchi, and B. Loftis, 2006. Flow dimensions corresponding to stochastic models of heterogeneous aquifers, *Geophys. Research Letters*. vol. 33(4), L07407, doi: 10.1029/2006GL025695.

## **Report Follows**

## **Illinois Water Resources Center Annual Report 2007**

### **Project Title/PIs:**

The flow dimension of groundwater resources in northeastern Illinois / Douglas D. Walker, Albert J. Valocchi

### **Research Category:**

Aquifer characterization and modeling

### **Problem and Research Objectives:**

Characterizing groundwater flow and contaminant transport in fractured rock aquifers is complicated by their highly heterogeneous nature, translating into uncertainties in managing groundwater resources. An alternative approach to interpreting aquifer tests is the Generalized Radial Flow (GRF) approach, which infers the geometry of groundwater flow via an additional parameter, the flow dimension, which describes the effective flow area and how it changes with the radius of investigation. This research will elucidate the relationship between aquifer heterogeneity and the flow dimension, with the specific focus on the characteristics of fractured dolomite aquifers that are part of the groundwater resources in northeastern Illinois.

### **Methodology:**

The principle tasks of this research are:

1. Reinterpret existing aquifer test data from ISWS archives to infer the range of flow dimensions observed for fractured dolomite aquifers in northeastern Illinois. This task will use nSIGHTS, an advanced software package created by Sandia National Laboratories for the analysis of hydraulic tests.
2. Enhance the Monte Carlo simulation to include additional statistical analyses and thus help define the relationships between the flow dimension and aquifer parameters. Determining the flow dimensions for complex models of aquifer heterogeneity requires a Monte Carlo analysis of numerical models. In collaboration with and funded in part by NCSA, the ISWS has adapted public domain programs for geostatistical simulation (GSLIB) and transient groundwater flow (MODFLOW2000) to estimate the expected value and variability of the flow dimension for an aquifer test in candidate models of heterogeneity. The computational burden of this analysis is managed through the use of the NCSA TeraGrid set of distributed computing resources.
3. Manually calibrate the parameters of candidate models until the results of the Monte Carlo simulation reproduce the observed flow dimensions.

Note: A six-month, no-cost extension of this project was approved on February 15, 2007. This changes the completion date to August 31, 2007.

### **Principle Findings and Significance:**

During the second year of this two-year project, we have used nSIGHTS to determine the flow dimensions for 10 aquifer tests from the ISWS archives (Task 1). We have

continued using the Monte Carlo simulator to determine the flow dimensions of candidate models of aquifer heterogeneity (Task 2). The results this year indicate the following:

1. Aquifer tests in fractured dolomites have apparent flow dimensions ranging from 1.44 to 2.05 with an average of 1.7.
2. Several commonly used models of aquifer heterogeneity do not produce the flow dimensions observed in aquifer tests of fractured dolomite aquifers, even over a wide range of parameters for those models.
3. Site percolation networks can produce the flow dimensions of fractured dolomites, at least temporarily.
4. Fracture networks (Boolean models) also appear to be able to produce the flow dimensions of fractured dolomites. Ongoing work is helping to establish how the parameters of this model are related to the flow dimension.

The finding that the flow dimension appears to be associated with network models is significant because these networks have fractal characteristics, and as such, would have dramatically different contaminant transport than is found in the more traditional models of aquifer heterogeneity.

**Related and seed projects:**

Dr. Walker's participation in this project is funded by the Illinois State Water Survey. The computations for this research were performed on the TeraGrid resources hosted by the National Center for Supercomputing Applications, the San Diego Supercomputing Center, Argonne National Laboratories, and Purdue University. Sandia National Laboratories has provided access to nSIGHTS, a proprietary software package for the interpretation of hydraulic tests.

Related research efforts include:

- NCSA Faculty Fellowship, 2003-2004 (\$16,000)
- Sandia National Laboratories research contract PO 24699 (\$18,504).
- NSF/NCSA Medium Resource Allocations Grant EAR050016, approved 9/22/05.
- NSF/NCSA Medium Resource Allocations Grant (submitted).