

# Estimating shallow recharge and discharge in northeastern Illinois using GIS and pattern recognition procedure

## Basic Information

<b>Title:</b>	Estimating shallow recharge and discharge in northeastern Illinois using GIS and pattern recognition procedure
<b>Project Number:</b>	2004IL49G
<b>Start Date:</b>	9/1/2004
<b>End Date:</b>	12/31/2007
<b>Funding Source:</b>	104G
<b>Congressional District:</b>	15
<b>Research Category:</b>	Ground-water Flow and Transport
<b>Focus Category:</b>	Groundwater, Methods, Models
<b>Descriptors:</b>	
<b>Principal Investigators:</b>	Yu-Feng Lin, Albert Joseph Valocchi

## Publication

1. Lin Y-F., J. Wang, and A. J. Valocchi, In-review (Submission Date: 3/2/2008), PRO-GRADE: A GIS plug-in package for ground water recharge and discharge estimation, Ground Water.
2. Lin Y-F., J. Wang, and A. J. Valocchi, Accepted (Submission Date: 2/1/2008), A New GIS Approach for Estimating Shallow Groundwater Recharge and Discharge, Transaction in GIS.
3. Lin Y-F., J. Wang, and A. J. Valocchi, 2008, Making Groundwater Recharge and Discharge Estimate Maps in One Day – An ArcGIS 9.2 application for water resources research, ArcUser, Winter 2008, Vol. 11, No. 1. p.32 – 35. <http://www.esri.com/news/arcuser/0408/groundwater.html>
4. Lin Y-F., A. J. Valocchi, P. Bajcsy, J. Wang, A. Yahja and C. Kim, Conference Abstract and Poster Presentation, How to Estimate Groundwater Recharge and Discharge Maps in One Day: A Framework for Evaluation of Alternative Conceptual Models Using Interdisciplinary Information, Illinois Water Conference 2008, Champaign, IL, October 8 – 9, 2008, <http://www.iisgcp.org/ilwater/index.htm>
5. Wang J., C. Kim, Y-F. Lin, A. J. Valocchi and P. Bajcsy, Conference Abstract and Poster Presentation, Development of Pattern Recognition and Learning Utilities for Groundwater Recharge and Discharge Estimation and General Model Conceptualization, National Ground Water Association – 2008 Ground Water Summit, Memphis, TN, March 30 – April 3, 2008, <http://ngwa.confex.com/ngwa/2008gws/techprogram/MEETING.HTM>
6. Lin Y-F., P. Bajcsy, A. J. Valocchi, C. Kim and J. Wang, Conference Abstract and Poster Presentation, Evaluation of Alternative Conceptual Models Using Interdisciplinary Information: An Application in Shallow Groundwater Recharge and Discharge, American Geophysical Union Fall Meeting, San Francisco, CA, December 10 – 14, 2007, <http://www.agu.org/meetings/fm07/>
7. Lin Y-F., R. J. Hunt, A. J. Valocchi, P. Bajcsy, J. Wang and C. Kim, Conference Abstract and Oral Presentation, A New Modeling Approach Evolving from Stoertz's Inspiration: Water Balance, Pattern Recognition and Initial Model Conceptualization, The Geological Society of America Annual Meeting 2007, Denver, CO, October 28 – 31, 2007, <http://www.geosociety.org/meetings/2007/>
8. Lin Y-F., C. Kim, P. Bajcsy, J. Wang and A. J. Valocchi, Conference Abstract and Poster Presentation, Development of Pattern Recognition and Learning Utilities for Shallow Groundwater

Recharge and Discharge Estimation in Semi-Humid Regions Using Multiple Data Sources, The Geological Society of America Annual Meeting 2007, Denver, CO, October 28 – 31, 2007, <http://www.geosociety.org/meetings/2007/>

9. Lin Y-F., C. Kim, P. Bajcsy, J. Wang and A. J. Valocchi, Conference Abstract and Poster Presentation, Development of Pattern Recognition and Learning Utilities for Groundwater Recharge and Discharge Estimation, the Sixth Annual UIUC Earth Research Review, Champaign, IL, April 27, 2007.
10. Lin Y-F., P. Bajcsy, J. Wang, A. J. Valocchi and R. J. Hunt, 2006, Conference Abstract and Oral Presentation, Development of Point-to-Zone Pattern Recognition and Learning Utilities for Groundwater Recharge and Discharge Estimation, Conference Abstract, The Geological Society of America Annual Meeting 2006, Philadelphia, PA.
11. J. Wang, Lin Y-F., C-H Huang, A. J. Valocchi, R. J. Hunt and X. Cai, 2006, Conference Abstract and the Best Student Poster by Jihua Wang, Development of an Image-Processing Tool for Groundwater Recharge and Discharge Estimation, Illinois Water 2006 Conference, Urbana, IL.
12. Lin Y-F., J. Wang, R. J. Hunt, A. J. Valocchi and X. Cai, 2005, Conference Abstract and Oral Presentation, Development of a GIS Tool for Groundwater Recharge and Discharge Estimation, The Geological Society of America Annual Meeting 2005, Salt Lake City, UT.
13. Lin Y-F., J. Wang, R. J. Hunt, A. J. Valocchi and X. Cai, 2005, Conference Abstract and Oral Presentation, Computer Aided Estimation of Groundwater Recharge and Discharge Using GIS and a Pattern Recognition Procedure, The 50th Midwest Ground Water Conference, Urbana, IL

# **IWRC Annual and Final Report to NIWR-USGS-104G Program**

## **April, 2008**

### **Problem and Research Objectives**

Evaluations of water availability and the management of water resources require quantifying the interaction between components of the hydrologic cycle, including the rates and variability of recharge and discharge to aquifers. These recharge and discharge rates define the relationships among groundwater, precipitation, and surface water, and thus can restrict management options for water supply. The management of water resources in northeastern Illinois is complicated by interstate agreements, hydraulically coupled aquifer systems, natural and anthropogenic contamination, groundwater / surface water interaction, and conjunctive use of multiple resources. This research has developed an automated computer software system implementing several methods of estimating and mapping recharge and discharge, and has applied the resulting software to improve the understanding of spatial variability of shallow recharge and discharge in northeastern Illinois, thereby addressing a research priority of national importance and of broad interest.

### **Methodology**

The first task addressed the development of a pattern recognition utility to identify recharge zones within noisy spatial data and estimate recharge and discharge rates for each zone. The utility is a graphical user interface (GUI) tool, compatible with ArcGIS 9.X (ESRI, 2001), that implements several advanced image-processing methods and couples these to the recharge and discharge estimation codes of Stoertz and Bradbury (1989), Bradbury et al. (2000), and Lin and Anderson (2003). The software has been tested using a dataset from the Buena Vista Groundwater Basin in the Central Sand Plains of Wisconsin, a well-understood system for which calibrated groundwater flow models are available (Stoertz and Bradbury, 1989; Lin and Anderson, 2003).

The software has been delivered to the Wisconsin Water Science Center, USGS to improve a USGS internal project (Krohelski et al., 2003) in Wisconsin to determine trends (spatial and temporal) in recharge rates and investigate dominant recharge processes occurring in selected undeveloped, agricultural, and urban watersheds. This approach also has been used to assist in the estimation and mapping of recharge and discharge for the groundwater models of several water resource assessments in Illinois (e.g., Meyer et al., 2002). Previous studies for regional recharge and discharge in this region were limited and the software has been applied to estimate recharge and discharge to the shallow aquifers within a much shorter preparation time than current methods.

### **Principal Findings and Significance**

Software release for PRO-GRADE: the Pattern Recognition Organizer (PRO-GIS) and Groundwater Recharge And Discharge Estimator for Geographic Information Systems (GRADE-GIS) was announced at the Geological Society of America Annual Meeting 2007 in Denver, Colorado. PRO-GRADE is a software package that includes two GIS plug-in tools for image and map pattern recognition and groundwater recharge and discharge estimation for 2D steady-state conditions. Two executable programs, user's manuals, example cases, and an ISWS

website for public download were completed and published online in October, 2007.  
URL: <http://www.sws.uiuc.edu/gws/sware/prograde/>

PRO-GRADE was tested using a dataset from the Buena Vista Groundwater Basin coupled with post-processors using MODFLOW 2000 (Harbaugh et al., 2000) and PEST (Doherty, 2005). This test procedure is similar to the process suggested by Lin and Anderson (2003) for comparing with their results. The similarity of results from both studies was published in a journal paper (Lin et al., in-review) to demonstrate the validity of the PRO-GRADE computations. For example, the flux error in this study is much smaller than the three cases from the previous study by Lin and Anderson (2003). Using the recharge and discharge map generated by PRO-GRADE, prior information and additional parameters were not necessary for efficient calibration like in the previous study because the map has more detailed and reliable patterns resulting from application of more superior image-processing methods and comparisons with ancillary field information (such as the National Hydrography Dataset, soil type and land slope). It is expected that the results from the PRO-GRADE approach are superior to the previous studies since improvement of computational algorithms (e.g., PRO-GRADE) and hardware enables users to generate more complex and accurate patterns with less preparation and computing time than before.

The application of estimating a recharge and discharge map of Kane County in northeast Illinois was very challenging due to the hydrogeological complexity of the shallow aquifer system and groundwater / surface water interactions (Meyer et al., 2002). There were several approaches used to generate alternative water table surfaces in order to use GRADE-GIS, which is only applicable to 2D systems. Several alternative recharge and discharge maps were generated using PRO-GRADE based on the various water table surface inputs. The comparison of the recharge and discharge maps in ArcGIS showed a great degree of consistency in recharge and discharge patterns from all alternative maps. The refinement of alternative recharge and discharge maps was easily performed based on the consistency of the patterns. The refined alternative recharge and discharge maps have been used as the initial conditions of recharge and discharge for several groundwater modeling studies in northeast Illinois.

In brief, PRO-GIS has the ancillary benefit of providing pattern recognition functions supporting virtually any Spatial Decision Support System (SDSS) used in land and water resources management. By coupling with GRADE-GIS, initial recharge and discharge maps and rates can be quickly generated using widely-available geospatial and hydrologic data. This fast production of initial alternative maps can be used as initial conditions for numerical models, screening tools for selection of alternative models, and guidelines for field study planning and decision making in a timely manner.