PROJECT SUMMARY

Title: An Assessment of Aquifer Storage Recovery for Selected Representative Hydrogeologic Settings in Wisconsin

Project I.D.: WR03R005

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Background/Need: Owing to increased demand on groundwater accompanied by increased drawdown in water levels, emerging technologies, such as aquifer storage recovery (ASR), are being used in the State of Wisconsin to optimize available water resources and reduce adverse effects of pumping. ASR is defined as the injection and storage of water in a suitable aquifer when demand is low and recovery from the aquifer when demand increases. ASR reduces the effects of peak demand on an aquifer by supplementing water in storage in the aquifer when demand is low. An ASR pilot facility in Green Bay, Wis., was recently closed owing to concerns over mobilization of arsenic. An ASR facility in Oak Creek, Wis., near Milwaukee, has gone through several test cycles and is awaiting final approval from the Wisconsin Department of Natural Resources. Another facility is contemplated for the City of Waukesha.

Objectives: The objectives of this research were to: (1) investigate the hydraulic controlling factors on ASR as they relate to the amount of water that can be recovered, i.e., the recovery efficiency, in selected representative hydrogeologic settings in Wisconsin; (2) develop a methodology using numerical flow and transport models whereby the hydraulics of ASR systems can be investigated.

Methods: Three representative settings in Wisconsin were chosen to evaluate the hydraulic controlling factors on recovery efficiency: a confined sandstone aquifer, a glacial drift system and an unconfined dolomite aquifer. Flow models were created using the groundwater flow code MODFLOW (McDonald and Harbaugh, 1988) linked to the particle tracking code MODPATH (Pollock, 1994) and transport code MT3DMS (Zheng and Wang, 1999) in order to simulate movement of injected and ambient water. The effects of regional hydraulic gradient, hydraulic conductivity, effective porosity, dispersion (mixing), volume of injected water, storage period, and rates of injection and recovery were considered.

Results and Discussion: Results from the three settings were qualitatively similar. Dispersion, as quantified by the dispersivity parameter, controls the mixing between injected and ambient water and is the most important control on recovery efficiency. Recovery efficiency varies inversely with dispersivity, effective porosity, regional hydraulic gradient and storage period. High values of dispersivity caused more mixing while high regional gradient and high values of effective porosity caused high flow velocities causing water to move more quickly away from the ASR well. Under high velocities, injected water moved down gradient rapidly and out of the capture zone of the ASR well. Under long storage periods there was more time for the injected water to mix with the ambient water and move down gradient. Recovery efficiency increased asymptotically with volume of injected water. Increasing the hydraulic conductivity in a layer intersected by the ASR well caused an initial increase in recovery efficiency that leveled off and then decreased. Injection and recovery rates had little effect on recovery efficiency. Groundwater mounding and dewatering occurred in the unconfined dolomite aquifer when large volumes of water were injected and removed. Low values of transmissivity, characteristic of the dolomite aquifer, also caused significant groundwater mounding under some injection scenarios.

Conclusions: ASR is most suitable for confined systems such as the Sandstone Aquifer in the southeastern portion of the state and confined glacial drift systems. Groundwater mounding, which could cause flooding at the ground surface, and dewatering will limit the use of ASR systems in unconfined systems such as the Silurian Dolomite Aquifer in the northeastern portion of the state. The methodology developed in this project, in combination with site specific hydrogeologic data, will be useful to water utilities, consultants, and state agencies to determine suitable locations for ASR systems. With a clear understanding of controlling factors that affect recovery efficiency these agencies can determine if ASR potentially might meet a community's water supply needs before the initial test injection of water into the aquifer.

Related Publications:

Lowry, C.S. and Anderson, M.P., 2004, Modeling Aquifer Storage Recovery for a Representative Setting in Wisconsin, (abstract), *in* Wisconsin Ground Water Association Annual Conference Program: Wisconsin Dells, Wis., Wisconsin Ground Water Association, p. 4. Award: Best Graduate Student Paper.

Lowry, C.S. and Anderson, M.P., 2004, Defining Controlling Factors of Aquifer Storage Recovery Using Advection and Dispersion Models, (abstract), *in* Understanding and Managing Water Resources for the Future: Wisconsin Rapids, Wis., Wisconsin Section of the American Water Resources Association, p. 9

Lowry, C.S. and Anderson, M.P., 2003, An Assessment of Aquifer Storage Recovery for a Generic Hydrogeologic Setting in Wisconsin using Groundwater Flow and Transport Models, (abstract), *in* Ground Water in Coastal Zones: Availability, Sustainability, and Protection: Orlando, Fla., Assoc. of Ground Water Scientists and Engineers, p. 68-69

Lowry, C.S. and Anderson, M.P., 2003, Assessment of Aquifer Storage Recovery for a Generic Hydrogeologic Setting in Wisconsin, *in* Poeter, E., et al., editors, *MODFLOW and More 2003 Understanding Through Modeling*: Golden, Colo., p. 824-828

Lowry, C.S., 2004, Assessment of Aquifer Storage Recovery: Defining Hydraulic Controls on Recovery Efficiency at Three Representative Sites in Wisconsin, MS Thesis, Department of Geology and Geophysics: Madison, Wis., University of Wisconsin - Madison, 104 p.

Key Words: aquifer storage recovery, groundwater, modeling, recovery efficiency, water resources management, Wisconsin

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