Title: Refinement of Two Methods for Estimation of Groundwater Recharge Rates

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Objectives:

The ability to account for recharge heterogeneity is important to groundwater modelers, planners, and policy makers to ensure an accurate water budget, critical for planning and modeling purposes. Consequently, we set out to develop a practical, physically-based model that uses readily available data to estimate the spatial distribution of groundwater recharge at the watershed scale for humid areas like Wisconsin. The specific goals of this study were to develop and refine a Thornthwaite – Mather soil-water balance model for the estimation of recharge rates and to test this model against results from USGS models for the Pheasant Branch Creek watershed in Dane County, Wisconsin.

Background/Need:

There is currently no standard, accepted method for estimating groundwater recharge rates, yet such information is essential for reliable groundwater models and for rational real-world groundwater protection. Despite the inherent spatial and temporal variability of recharge, there have been few attempts to quantify or incorporate this variability into water resource planning and groundwater modeling efforts. Groundwater modelers often ignore recharge heterogeneity and assume a uniform recharge distribution for their model area.

This project focuses on the Thornthwaite-Mather soil-water balance approach linked to a GIS-based rainfall runoff model, with the goal of developing a method for the relatively rapid delineation of groundwater recharge rates and areas using widely-available data.

Methods:

We have developed a practical, physically-based model that uses readily available data to estimate the spatial distribution of groundwater recharge at the watershed scale for humid areas like Wisconsin. The water balance approach offers the greatest ability to estimate and account for recharge heterogeneity. Consequently, our model uses a water balance technique to estimate recharge on a grid cell-by-grid cell basis.

Specifically, we estimate recharge using a modified Thornthwaite – Mather approach coupled to a digital elevation model (DEM). Our model uses typically available soil, land cover, topographic, and climatic data to calculate the spatial distribution of annual groundwater recharge.

For each model grid cell, a simple mass balance is calculated for a specified time period:

Changes in Soil Moisture Storage = Precipitation - Runoff – Evapotranspiration

The mass balance quantitatively accounts for soil water conditions on a cell-by-cell basis, based on the spatial and temporal distribution of climatic, soil, and vegetation characteristics. These characteristics dictate the amount of water potentially available for recharge.

The model operates on a monthly time step and is designed to be used at the watershed scale for watersheds in humid regions. The code is written in Visual Basic and requires Microsoft Excel 2000 to run.

Results:
The project produced maps of the recharge distribution for the Pheasant Branch watershed located just west of Middleton, Wisconsin. Model results compare very favorable with other estimates of recharge based on extensive field data and detailed rainfall-runoff modeling. Recharge in the watershed varies both temporally and spatially.

Conclusions:
Conceptually, our model is a marked improvement over existing water balance models as it allows for routing and downslope infiltration of surface runoff. The model calculates recharge on a cell-by-cell basis, and consequently can represent the spatial distribution of recharge, which few other models consider. This technique is physically-based, does not require extensive parameterization, uses typically available data, and can be practically applied in a relatively short time frame. The model output was not particularly sensitive to the soil moisture storage coefficient, the SCS curve numbers, or the grid spacing.

Recommendations/Implications:
Our model results suggest that a common approach of estimating recharge in Wisconsin using a fixed percentage empirical relationship between precipitation and recharge may be inappropriate in many instances. Not only does the amount of recharge increase with increasing precipitation, which is to be expected, but the percentage of rainfall that becomes recharge also seems to increase with increasing precipitation. The model results show that recharge can vary across a watershed such that the use of single estimate of recharge for an entire watershed may be inappropriate. This variability appears to be larger for drier years. The use of a spatially variable recharge array in flow models is both a conceptual and physical improvement on how recharge is typically represented in groundwater models. This model could be applied to other areas of Wisconsin for estimation of recharge rates over large areas, and is particularly appropriate for regional groundwater models. Additional testing and verification of the model results should take place as other investigators develop field measurements of recharge rates.

Key Words: Recharge, GIS, groundwater models

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Final Report: A final report containing more detailed information on this project is available for loan from Wisconsin's Water Library, University of Wisconsin - Madison, 1975 Willow Drive, Madison, Wisconsin 53706 (608) 262-3069.