Causes of Historical Changes in Ground-Water Recharge Rates in Southeastern Wisconsin

Project Number R/UW-HDG-005
by

Douglas S. Cherkauer, Professor, Department of Geosciences, University of Wisconsin-Milwaukee, and Craig J. LaCosse, Research Assistant, Department of Geosciences, University of Wisconsin-Milwaukee

Contract: July 1, 1999 to June 30, 2001
Funding: University of Wisconsin System (UWS)
Focus Area: HDG
Key Words: Recharge, ground-water resources

BACKGROUND / NEED

Recharge is the process by which rain, snowmelt and surface waters infiltrate to and replenish ground water. As such, it is the ultimate source of all of our ground-water resources. Yet it is also very difficult to measure, because of its diffuseness. Information on the rates of ground-water recharge is usually sparse. To date there has been very little examination of how recharge rates vary through time in response to climatic or land use changes, making long-term planning for ground-water dependent communities difficult.

The PI examined the spatial distribution of recharge in southeastern Wisconsin during a previous Ground Water Research Program project, showing that it can be quantitatively linked to a number of topographic, hydrogeologic and land use properties. That work is now being used to provide estimates of recharge inputs for the regional flow model for southeastern Wisconsin being developed by the USGS, WGNHS and SEWRPC. It also assumed, however, that the recharge rates are static, which they clearly are not. As areas undergo droughts or extended wet periods, recharge undoubtedly varies. As regional or global climates changes, so too will recharge. The question is, how much?

OBJECTIVES

The purpose of this work was to find out how recharge rates change through time in response to precipitation changes and then to ascertain what factors control that response.

METHODS

Stream baseflow was used as a surrogate measure for recharge. Baseflow is ground-water discharge, so it is equivalent to surface infiltration less evapotranspiration, a net recharge. The use of baseflow opens up the entire USGS streamflow monitoring data base as a source of recharge information. There are hundreds of gaging sites in Wisconsin alone, and most have an extensive historical record. Net recharge was obtained for 14 watersheds in southeastern Wisconsin using stream baseflow separation (the USGS HYSEP program).

For each of the watersheds, precipitation and temperature were obtained using Thiessen polygon weighting of values daily from nearby NOAA weather sites. A 34 year time period (1963 through 1997) was selected for analysis. In addition, measures of topography (surface slope, watershed area and shape, among others), hydrogeology (depths to water table and rock, water table gradient, composite subsurface transmissivities and porosities), and land cover (natural, developed and agricultural) were obtained using GIS data bases.

The procedure used was to determine what factors control the baseflow/recharge response to precipitation changes in southeastern WI, which has relatively uniform geologic conditions. Then these relations were tested on another 14 watersheds distributed around WI to ascertain whether they are universal. These watersheds were selected to include very different bedrock and surficial geology from that in southeast WI.

RESULTS / DISCUSSION

Time (precipitation, temperature and baseflow) series data were plotted as cumulative departure from average graphs. During the study period, most of Wisconsin experienced drier than normal conditions from 1963 to 1971. The period 1971 to 1993 was wetter than average, and from 1993 to 1997, precipitation has dropped below normal again. Baseflow in some watersheds in southeast WI follows the precipitation trend almost exactly; precipitation 20% below normal produces baseflow 20% below normal. In other watersheds, the baseflow response is smaller than the precipitation change, and in a few urbanized watersheds, baseflow and precipitation appear almost unrelated .

The rate of baseflow change with respect to precipitation change (dQ/dP) was compared to all the independent controlling factors measured for the southeast WI watersheds. It was found that dQ/dP is directly related to the product of land surface slope and length of overland flow (S*L), which explains over 80% of the variation. No other factor or combination thereof showed any significant relation to dQ/dP. When the observed relationship was used to calculate dQ/dP for the other 14 watersheds in WI, it explained 75% of the variance in all areas except the unglaciated southwest.

CONCLUSIONS / IMPLICATIONS / RECOMMENDATIONS

The variation of recharge through time in Wisconsin is controlled directly by the temporal variation of precipitation. In areas of steep slopes, or where water must travel a long distance before it encounters a channel (often regions with less-developed drainage networks or very permeable soils), the response is essentially 1:1. Precipitation 20% above normal will produce recharge 20% above normal. In areas where slopes are gentle and/or drainage channels are more closely spaced, recharge changes at only a fraction of the rate of change of precipitation. In urban watersheds with their extensive storm drain network, for example, precipitation 20% above normal may only produce a 2% or 3% increase in recharge.

The relation uncovered is valid for all of Wisconsin, except the Driftless Area. We do not yet have an explanation for that. However, the relation can be coupled with climate change projections to give communities a handle on how much their ground-water supply is likely to change in the foreseeable future.

RELATED PUBLICATIONS

None.

FINAL REPORT

A final report containing more detailed information on this project will be available from the Water Resources Institute Library. Call 608-262-3069 or email AskWater@wri.wisc.edu.