STATISTICAL EXTRAPOLATION OF RECHARGE RATES AND SOLUTE FLUXES WITHIN FIVE AGRICULTURAL WATERSHEDS

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Abstract

Water and solute fluxes through the unsaturated zone are being intensively monitored in five agricultural watersheds as part of the U.S. Geological Survey's National Water Quality Assessment (NAWQA). Data collected from this work are used to calibrate one-dimensional simulations of water flow and solute transport through the vadose zone. This study describes how estimates of recharge and solute flux from a limited number of point models are extrapolated to estimate the quantity and quality of water recharging the aquifer in Morgan Creek, Maryland (33 km²), one of the five NAWQA agricultural watersheds.

Three vadose-zone models are calibrated to fit moisture content and porewater chemistry observed at Buckel field, an intensively monitored site subject to corn-soy crop rotations with winter wheat. Input data for these simulations include meteorological observations, as well as particle size, bulk density, organic matter, soil moisture, soil tension, and pore-water chemistry at various depths between the land surface and the water table. The depth to the water table under Buckel field exceeds 7 meters at the highest well cluster underlain by highly transmissive sandy soils, and diminishes to zero near Morgan Creek. Vadose-zone processes at each intensive site are simulated using the National Resource Conservation Service's Root Zone Water Quality Model (RZWQM), and two methods available in the Leaching Estimation And CHemistry Model (LEACHM) developed by John Hutson of Flinders University, Australia. RZWQM solves Richard's equation numerically to simulate water flux at each time step. LEACHM is run using both the Richard's-equation WATer-FLOw routine (WATFLO) and the simpler, CALculated Flow CALF) algorithms. LEACHM run with the CALF routine uses a tipping-bucket approach that offers significant computational advantages over the version run with WATFLO, and therefore is used exclusively when a large number of model runs are necessary to estimate water and solute fluxes for the range of soil types, vadose zone thicknesses, and agricultural management practices observed within the 33-km² Morgan Creek watershed.

For sites in Buckel field, the tipping-bucket (CALF) and analytical (Richard's equation) models (WATFLO and RZWQM) are calibrated by adjusting soil characteristics and chemical retardation and transformation parameters in an effort to match the observed variations in soil moisture and porewater chemistry. Parameter sensitivity analyses and *a priori* estimates of uncertainty in input data and parameters are used to estimate the uncertainty in the final model predictions of recharge and solute flux. An ensemble of CALF models is then built without further calibration to simulate fluxes for other areas in the Morgan Creek watershed that have crops, soils, and irrigation, chemical application rates, and cultivation methods distinct from those observed at Buckel field. To describe the spatial heterogeneity of the larger watershed, maps of crops, properties of soils, and vadose zone thickness are sampled at 100-m grid spacing within a geographic information system. The approximately 3300 observations are then subjected to a cluster analysis to identify regions with similar characteristics and to estimate the variance of specific characteristics within each region. Multiple CALF runs then are conducted in a stochastic mode to estimate recharge and solute fluxes for a range of depths using parameter ranges constrained by the cluster analysis. Finally, results from the individual model runs are weighted according to the fractional areas of each cluster within the watershed, in order to estimate the mean fluxes for the entire watershed. Overall model performance is evaluated by comparing simulated solute concentrations in the vadose and saturated zones against observed concentrations, and by comparing simulated recharge with that independently estimated using Darcian flow, chloride balance, and water-table-fluctuation methods.