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Using Logistic Regression to Assess Regional Ground-Water Vulnerability: High Plains Aquifer

Jason J. Gurdak[1]

[1]U.S. Geological Survey, Colorado Water Science Center, M.S. 415 Denver Federal Center, Lakewood, CO 80225, jjgurdak@usgs.gov

Abstract

Interest in predicting nonpoint-source contamination in ground water has increased because of widespread detections of nitrate and consequent implications for human and aquatic health and resource sustainability. As part of the U.S. Geological Survey's National Water-Quality Assessment Program, a novel ground-water vulnerability assessment was developed to predict the occurrence probability of elevated nitrate (> 4 mg/L) concentrations in recently (< 50 -years) recharged ground water of the High Plains regional aquifer (451,000 km^2). This empirically based assessment coupled particle-tracking simulations and multivariate logistic regression within a geographic information system (GIS) framework, thereby incorporating site-specific estimated hydrogeologic parameters, ground-water flow regime, and data from a network of 336 ground-water quality monitoring wells. The results of the logistic regression model indicate the probability of detecting nitrate > 4 mg/L is best explained by the extent of non-irrigated and irrigated agricultural lands, organic content of the soil, depth to the regional water table, and clay content of the unsaturated zone. Since statistical relationships were developed between monitoring well-specific nitrate concentrations and GIS-based explanatory variables, it was possible to interpolate the vulnerability predictions spatially across the entire regional aquifer using a GIS map-algebra technique. This spatial distribution is presented as a vulnerability map. Validation using an independent subset of wells (R^2 = 0.823) suggests the model is a reasonably good predictor in areas currently lacking monitoring wells. Predicted vulnerability corroborated the conceptual model that elevated nitrate is directly related to nitrogen loading at land surface, and inversely related to denitrification in the soil zone and impedances to downward advective chemical movement through the unsaturated zone. The nitrate vulnerability model and map offer a predictive tool for water resource managers to identify likely areas of non-point source contamination and evaluate the impact of anthropogenic activity on nitrate distribution in ground water.