Vulnerability of recently recharged ground water in the High Plains aquifer to nitrate contamination

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Groundwater vulnerability assessments aid water resource managers by identifying likely areas of non-point source contamination. Non-point source contamination is a key factor to consider in discussions of water resource sustainability. We present a novel methodology for groundwater vulnerability assessment using nitrate detection in the High Plains aquifer. The objective of the vulnerability assessment was to estimate the probability of detecting nitrate above the relative background concentration (4 mg/L as N) in recently recharged groundwater, defined as water less than 50 -years old. This was accomplished by coupling particle-tracking simulations and multivariate logistic regression analysis within a GIS framework, thereby incorporating site-specific hydrogeologic parameters and the groundwater flow regime. Contributing areas were delineated by a 90-degree sector, representing the capture zone up gradient from the well location, and were used to extract GIS-based explanatory variables for statistical modeling. Particle-tracking simulations identified the appropriate radial length for the sector and well screen depths corresponding to recently recharged groundwater. Horizontal and vertical particle movement exhibited sensitivity to hydraulic conductivity and estimates of recharge, respectively. Therefore, an optimization step included adjustment of the radial length based on hydraulic conductivity and selection of wells based on screen depth and estimates of diffuse recharge rates. The final logistic regression model demonstrated statistical significance ($p < 0.001$), produced an excellent model fit ($R^2 = 0.936$), and was validated with independent nitrate data ($R^2 = 0.823$). Predicted aquifer vulnerability corroborated our conceptual model that nitrate concentrations are directly related to nitrogen loading at land surface and infiltration in the soil zone, and inversely related to impedances to downward advective chemical movement through the unsaturated zone. The final model and map illustrate the relative vulnerability across the entire High Plains aquifer and offer a predictive tool to assess how land use change may impact nitrate distribution in this aquifer.