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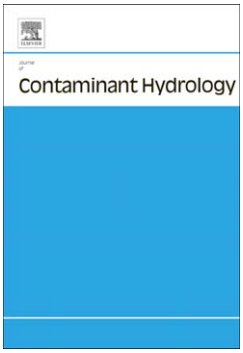

Using generalized additive mixed models to assess spatial, temporal, and hydrologic controls on bacteria and nitrate in a vulnerable agricultural aquifer

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ACCEPTED MANUSCRIPT

Using generalized additive mixed models to assess spatial, temporal, and hydrologic controls on bacteria and nitrate in a vulnerable agricultural aquifer

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Abstract
The Abbotsford-Sumas aquifer (ASA) has a history of nitrate contamination from agricultural land use and manure application to soils, yet little is known about its microbial groundwater quality. The goal of this study was to investigate the spatiotemporal distribution of pathogen indicators (*E. coli* and total coliform [TC]) and nitrate in groundwater, and their potential relation to hydrologic drivers. Sampling of 46 wells over an 11 month period confirmed elevated nitrate concentrations, with more than 50% of samples exceeding 10 mg-N/L. *E. coli* detections in groundwater were infrequent (4 of 385 total samples) and attributed mainly to surface water-groundwater connections along Fishtrap Creek, which tested positive for *E. coli* in every sampling event. TC was detected frequently in groundwater (70% of samples) across the ASA. Generalized additive mixed models (GAMMs) yielded valuable insights into relationships between TC or nitrate and a range of spatial, temporal, and hydrologic explanatory variables. Increased TC values over the wetter fall and winter period were most strongly related to groundwater temperatures and levels, while precipitation and well location were weaker (but still significant) predictors. In contrast, the moderate temporal variability in nitrate concentrations was not significantly related to hydrologic forcings. TC was relatively widespread across the ASA and spatial patterns could not be attributed solely to surface water connectivity. Varying nitrate concentrations across the ASA were significantly related to both well location and depth, likely due to spatially variable nitrogen loading and localized geochemical attenuation (i.e., denitrification). Vulnerability of the ASA to bacteria was clearly linked to hydrologic conditions, and was distinct from nitrate, such that a groundwater management strategy specifically for bacterial contaminants is warranted.

Keywords
Bacteria, nitrate, groundwater, spatial patterns, temporal trends, generalized additive mixed model

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