Evaluation of Mass Discharge to Surface Water in Tidally-Influenced Aquifer by Passive Flux Meters

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Background/Objectives. Impacted groundwater at a former chemical facility flows into a tidally-influenced river. Quantifying mass discharge of chemicals of concern (COCs) to the river is critical to the conceptual site model and necessary to meet regulatory requirements. Thus, accurate and defensible estimates of the mass discharge of COCs from groundwater to the surface water are required. However, tidal effects on temporal variability in groundwater flow and spatial variation in groundwater and mass flux make it difficult to accurately estimate mass discharge to the river. Since tidal effects change groundwater flux throughout a day, hydraulic gradients derived from discrete measurements of groundwater levels in monitoring wells did not provide an accurate estimate of the average groundwater discharge to the river. In addition, concentrations of COCs in wells along the river varied significantly with sample depth and well location.

Approach/Activities. Two methods were used to quantify mass discharge to the river. The transect method combined the average Darcy flux and COCs concentrations in wells within a transect parallel to the river. The second method used passive flux meters (PFMs) in wells within the transects to directly measure spatial variability in groundwater and mass flux. The transect method required accurate measurement of groundwater elevations with level sensors and data loggers to estimate the direction and magnitude of the effective hydraulic gradient over several days. Using the effective hydraulic gradient and a homogeneous assumption for hydraulic conductivity, a uniform groundwater flux was estimated for the transect. Mass discharge through the transect was then estimated by multiplying the concentration of each COC to the uniform groundwater flux and the area of the transect represented by each well. Although the transect method is the most common approach to estimating mass discharge through a transect, significant error in the mass discharge estimate is introduced by assuming uniform flow in heterogeneous systems that likely contain preferential flow paths that concentrate mass flux.

In the second approach, PFMs were deployed to measure the vertical variability in groundwater and mass flux at each well within the transect. Results from the PFMs are interpolated across the transect and used to estimate mass discharge to the river that is expected to be more representative and accurate for heterogeneous flow. In addition, the spatial and vertical variability in mass flux with the transect was used to identify likely locations of the upgradient source of COCs.

Results/Lessons Learned. The tidal study revealed the near real-time changes in the magnitude and direction of the hydraulic gradient. The overall effective hydraulic gradient was estimated from high-frequency data collection and improved the estimate of the average uniform groundwater flux in comparison to single snapshots of groundwater elevations. Deployment of PFMs to measure spatial variability in mass flux improved the accuracy and confidence in the estimate of mass discharge to the river. The results from the PFMs were also compared to analytical models of potential mass flux from NAPL dissolution and matrix-back diffusion to evaluate the nature of the COCs source discharging to the river.