Evaluation of field N budgets and soil nitrate as indicators of N leaching to groundwater in a Pacific Northwest U.S. dairy grass field

Barbara Carey, LHg, and Charles Pitz, LHg, Washington State Department of Ecology and Joe Harrison, PhD, Washington State University

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Background

Nitrate concentrations in the transboundary (U.S./Canada) Abbotsford-Sumas Aquifer have exceeded the drinking water limit of 10 mg/L-N in a large portion of the aquifer for over 20 years (Figure 1). Dairy and berry production are intensive over the aquifer. Dairy farms use farm-field nitrogen **(N) budgeting (balancing N inputs and outputs)** to determine agronomic manure application rates for forage crops.
Post-harvest soil nitrate is used as an indicator of N left over at the end of the growing season (and vulnerable to leaching in the high-precipitation climate of the Pacific Northwest).

Questions:

- How reliable is **farm-field N budgeting** as an indicator of potential nitrate leaching to groundwater?
- Is **post-harvest soil nitrate** information adequate to protect groundwater quality? Can it be used as an indicator of nitrate impacts to groundwater nitrate?

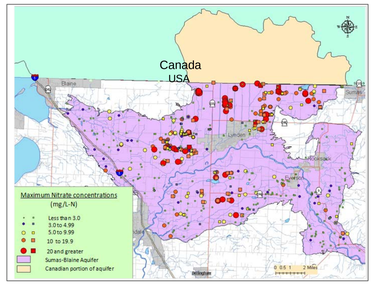

Figure 1. Maximum nitrate-N concentrations in the U.S. portion of the aquifer (1981-2008) .

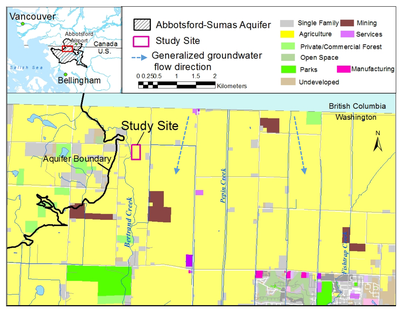

Figure 2. Study site location in the Abbotsford-Sumas Aquifer near the U.S.-Canada border in northwest Washington State, USA.

Outputs:

- Model-predicted groundwater nitrate concentrations based on: (1) N budget and (2) post-harvest soil nitrate concentrations.
- Comparison of model predictions with data from 6 wells screened across the water table (Figure 3).

Approach:

Mass balance mixing model and intensive sampling at a manured grass field (Figures 2 and 3), including:

- **N inputs, N outputs**, and residuals
- Hydrologic characteristics

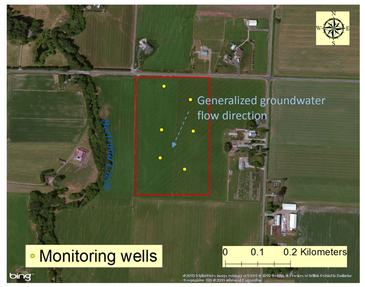

Figure 3 . Study site showing monitoring well locations.

Field Results

- N_{Inputs} and $N_{Outputs}$ were in balance in 2006 and 2007 (Figure 5)
- N_{Inputs} exceeded $N_{Outputs}$ by 230-360 kg hectare^{-1} (200-320 lb acre^{-1}) in 2005 and 2008 (out of balance).
- N_{inputs} include 114 kg ha^{-1} yr^{-1} (102 lb acre^{-1} yr^{-1}) from soil organic matter.

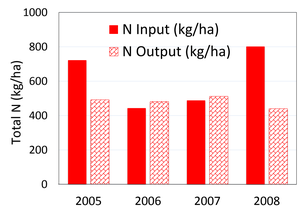

Figure 5. Annual N $_{Inputs}$ and N $_{Outputs}$

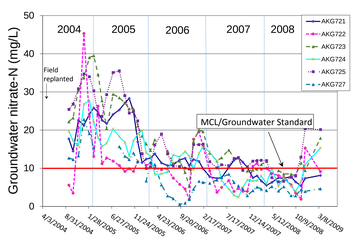

Figure 6. Nitrate-N concentrations in shallow monitoring wells.

High spatial variability in groundwater nitrate-N concentrations (Figure 6). We used the mean value (October 1-February 1) for average winter nitrate concentration.

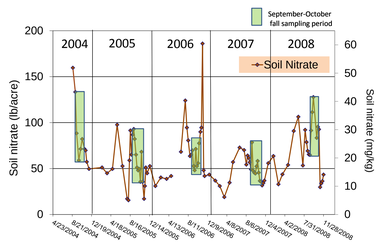

Figure 7. Soil nitrate concentrations (10-30 cm). Green shaded area represents post-harvest soil nitrate sampling period.

High temporal variability in soil nitrate concentrations (Figure 7).

Chloride tracer for manure indicated an average of 28% denitrification and was included in the model.

Model Results

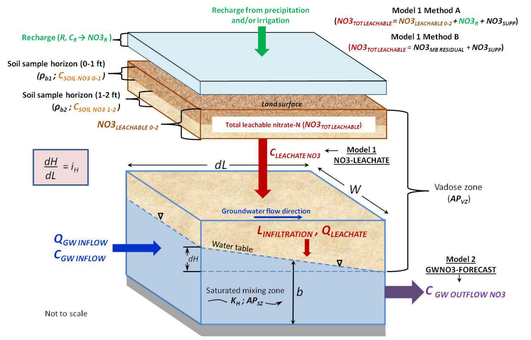

Figure 8. Schematic for groundwater NO3 conceptual model.

Input: Two options were input to GW NO3 model to predict groundwater nitrate-N concentrations: (1) Mean values for post-harvest soil nitrate (5 years) and (2) mass balance residual (4 years) (Pitz, 2014; Figure 8).

Results:

- Post-harvest soil nitrate over-predicted winter groundwater nitrate-N by a factor of 2 (Figure 9).
- Mass balance underestimated winter groundwater nitrate-N by a factor of 3 (Figure 9).

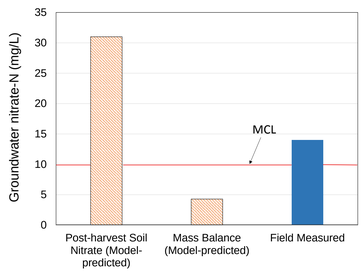

Figure 9. Four-year field-measured winter groundwater nitrate-N concentration compared to model-predicted concentrations using (1) post-harvest soil nitrate and (2) mass balance difference between N_{inputs} and $N_{Outputs}$.

Methods

During 2005-2008, sampled at 8-hectare (20-acre) manured grass field with silty loam soil (Figure 4):

- N and chloride applied in manure, fertilizer, and irrigation water.
- Soil nitrate concentration: weekly September-December (0-30 cm).
- Groundwater nitrate and chloride monthly at 6 shallow wells.
- N harvested in grass.
- Precipitation and irrigation.

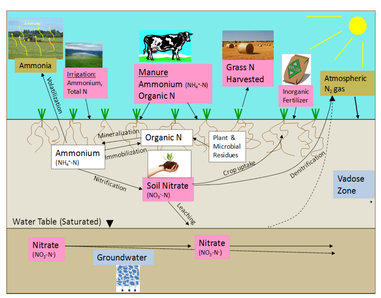

Figure 4. Components of the N cycle included.
Pink boxes are media monitored; brown boxes were estimated.

References

Carey, B.M. and J.H. Harrison (2014). Nitrogen dynamics at a manured grass field overlying the Sumas-Blaine Aquifer in Whatcom County. Washington State Dept. of Ecology, Olympia, Washington. Pub. No. 14-03-001. https://fortress.wa.gov/ecy/publications/SummaryPages/1403001.html

Pitz, C (2014). Spreadsheet models for determining the influence of land applications of fertilizer on underlying groundwater nitrate concentrations. Washington State Dept. of Ecology, Olympia, Washington. Pub. No. 14-03-018. https://fortress.wa.gov/ecy/publications/documents/1403018.pdf

Conclusions

- Despite intensive quantification of N inputs and N outputs for nearly 5 years, neither N mass balance surplus nor post-harvest soil nitrate were good indicators of early winter groundwater nitrate-N.
- Under conditions of heavy precipitation during the non-growing season and shallow depth to water, groundwater samples were the most reliable method for tracking impacts of soil-crop-manure management on nitrate in groundwater.
- **N additions and losses in the subsurface** can be the most significant factor determining N leaching and resulting groundwater nitrate-N concentrations. These additions and losses **are difficult to estimate** and are ignored by the methods most commonly used by farmers to minimize groundwater quality impacts from manure application.

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