Groundwater Nitrate Below A Manured Dairy Field Over the Sumas-Blaine Aquifer

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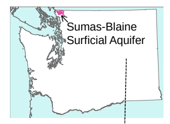
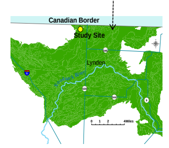
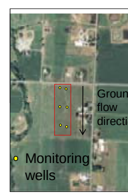
Introduction

Nitrate concentrations are higher than the Maximum Contaminant Level (MCL) for drinking water of 10 mg/L in many wells in the shallow Sumas-Blaine Aquifer (Redding, 2008; Erickson, 2000; Cox and Kahle, 1999). A substantial source of nitrate is dairy waste/manure used as fertilizer on crops (Cox and Kahle, 1999).





Heavy winter precipitation quickly moves available soil nitrate to the water table, which is less than 10 feet in most of the glacial outwash aquifer.



The aquifer is 50 feet thick in most areas and is the drinking water source for rural residents of northern Whatcom County.

The purpose of the study was to observe nitrogen dynamics in groundwater, soil, manure, and harvested grass at a typical field receiving dairy manure. We were also able to observe some effects of balanced versus non-balanced manure application / crop uptake and possible effects of tillage on groundwater nitrate concentrations.

Methods

We monitored nitrogen in manure, soil, groundwater, and grass crop in a 22-acre manured grass field over the Sumas-Blaine Aquifer for four years (2004-2008). Six shallow monitoring wells were installed in the field (13 feet deep) and one deep well at the bottom of the aquifer (38 feet deep). The monitoring scheme included:

- Manure nitrogen loading (ammonia and total nitrogen) to field.
- Soil nitrate at 1-foot depth (weekly August-November and monthly throughout the year).
- Groundwater nitrate, ammonia, total nitrogen, chloride, phosphorus, organic carbon, dissolved oxygen, total dissolved solids, conductivity, and pH in monitoring wells (monthly).
- Grass nitrogen harvested (each cutting).

The field was re-seeded in spring 2004, just prior to the start of the study. Tillage during re-seeding usually results in rapid mineralization of soil organic nitrogen to nitrate available for plant uptake and leaching.

Figure.1. Dairy manure is applied by injector (1st photo) and aerial methods. 2nd photo is water sample being collected at monitoring well. 3rd photo is grass clipping standard unit.

Results

In 2006 and 2007, total nitrogen applied in manure was in the same range (350-450 lb/acre) as the amount of nitrogen removed in the grass crop (Figure 2). During these years, the mean groundwater nitrate levels were relatively low (7-12 mg/L) as shown in Figure 3. This was a relatively balanced period.

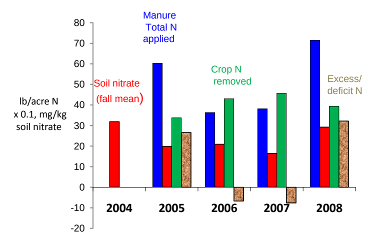


Figure 2. Fall soil nitrate (top one foot), total nitrogen applied in manure, crop nitrogen removed in grass, and excess or deficit nitrogen (comparing nitrogen applied with that removed).

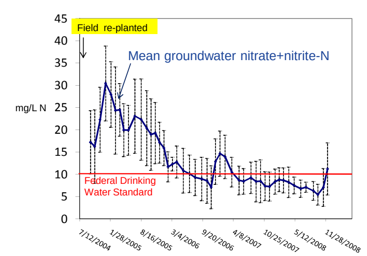
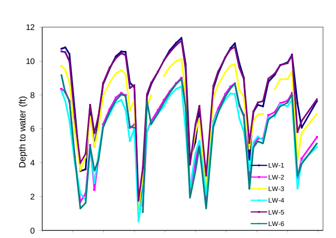


Figure 3. Mean groundwater nitrate+nitrite-N concentrations. Each point represents the mean concentration for 6 monitoring wells.

Groundwater nitrate concentrations were higher in late 2004 through mid-2006 than afterward. Nitrate+nitrite-N reached 43 mg/L in one well. Two factors may have played a part:

1) The field was tilled in spring 2004, causing increased mineralization of accumulated organic nitrogen in the soil to nitrate. The new crop could not take up all the released nitrate, which led to excessive leaching when winter rains carried the nitrate to the shallow water table (0-2 feet in winter).
2) The total nitrogen applied as manure in 2005 was higher than that applied in 2006 and 2007 (600 lb/acre). This was a relatively unbalanced period. (Not all of total nitrogen is available for plant uptake or leaching.)

Manure application again exceeded crop uptake in 2008 which was reflected in increased winter groundwater nitrate (Figure 2).



Shallow depth-to-water caused quick movement of nitrate from soil to groundwater (Figure 4).

Figure 4. Depth-to-water in monitoring wells screened 6-13 feet below ground surface.

Results (Cont.)

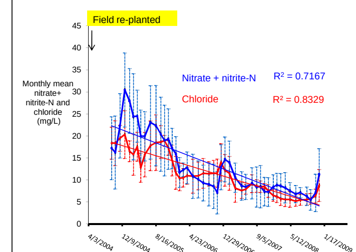


Figure 5. Mean monthly nitrate+nitrite-N and chloride concentrations in 6 wells and trends over time.

Chloride concentrations in groundwater followed a similar though muted trend to those for nitrate+ nitrite-N (Figure 4). Chloride is a conservative ion that can be used to trace manure application. Differences in concentration between the two analytes could be due to tillage, a larger input of nitrate than chloride to the water table following soil disturbance and mineralization of organic nitrogen. Uptake of nitrate by the crop and denitrification also probably account for some of the differences.

Denitrification played a role in nitrate dynamics in wells where the dissolved oxygen (DO) was less than 2 mg/L. Where DO was consistently greater than 2 mg/L, nitrate+nitrite-N and chloride followed consistent patterns (Figure 5). During periods of low DO in other wells, however, nitrate+nitrite-N concentrations corresponded to DO and not to chloride concentration.

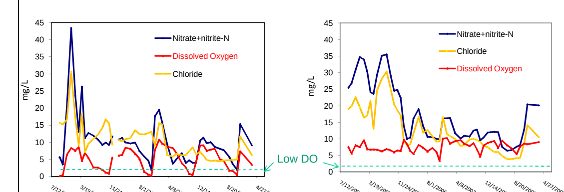


Figure 6. Results from two wells, one with seasonally low dissolved oxygen (left) and one with consistently high dissolved oxygen (right).

Temporal variability in weekly soil nitrate values makes it difficult to infer impacts on groundwater nitrate concentrations. In 2004, following tillage of the field, 2 out of 9 fall soil nitrate values indicated excess nitrate available for leaching (52 and 43 mg/kg), and indeed the mean groundwater nitrate in December 2006 increased by 14 mg/L to 3 times the MCL (Figure 7). Six out of 9 weekly soil nitrate values would not have indicated a large input of nitrate to groundwater. In 2006, only one out of 10 fall soil nitrate values was elevated (60 mg/kg). The December 2007 mean groundwater nitrate value increased by 7 mg/L. Soil nitrate variability in the fall makes one-time sampling insufficient as an indicator of potential nitrate leaching to groundwater.

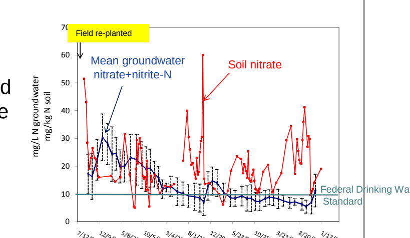


Figure 7. Soil nitrate and groundwater nitrate+nitrite-N concentrations, 2004-08.

Conclusions

- Mean groundwater nitrate+nitrite-N was below 10 mg/L following growing seasons when the total nitrogen applied as manure was close to or less than the nitrogen removed in the grass crop (2006, 2007, and first half of 2008).
- Tillage and replanting of a field that had received manure for over 20 years was followed by more than one year of elevated nitrate in groundwater—up to a mean of 30 mg/L nitrate+nitrite-N.

Figure 8. Grass field following spring manure application.

- Denitrification in oxygen-deficient areas of the field reduced the groundwater nitrate concentration.
- Elevated fall soil nitrate concentrations preceded winter groundwater nitrate increases but were not proportional to groundwater nitrate concentrations.

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For More Information

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