Groundwater Nitrate Distributions and Denitrification in a Portion of the Abbotsford-Sumas Aquifer, Northwest Washington

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Abbotsford-Sumas Aquifer

The aquifer covers approximately 200 km² and serves as a water supply for approximately 110,000 people in BC and WA.
The aquifer is unconfined and comprised of glacial outwash sands and gravels (Sumas Outwash) deposited about 10,000 years ago.

The groundwater flows from north to south in the aquifer at a rate of about 1 to 5 meters per day (Cox and Kahle, 1999).
Land use on the aquifer is dominated by agriculture because the surface soils are productive. The lowlands over the aquifer are agriculturally productive.
Frasier and Nooksack Lowlands

Land use on the aquifer is dominated by agriculture because the surface soils are productive. Whatcom County's Raspberry Industry is #1 in the Nation. Whatcom County's Dairy Industry is #2 in the State (~60,000 cows).
Southern British Columbia is dominated by Raspberry and Poultry Industries

Abbotsford

Whatcom County, WA

Lynden
Elevated nitrate concentrations (> 10 mg N/L) occur in the aquifer due to

- heavy rain
- permeable soils
- agricultural land use
- shallow water table
Our Objectives at

- Quantify nitrate concentrations and distributions in a study site adjacent to the International border.

- Attempt to distinguish BC nitrate sources from sources in Washington.
  
  ✓ Monitor groundwater quality using shallow and deep domestic wells.
  
  ✓ Measure nitrogen isotope values as a means to identify nitrogen sources.
  
  ✓ Monitor surface-water quality in perennial streams.

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Study Area

~ 6 sq miles
Study Area

Legend
- Blue Circle: Deep Wells
- Purple Circle: Stream Sampling Sites
- Red Circle: Shallow Wells
- Blue Line: Streams

26 wells
10 surface-water sites

CANADA
UNITE STATES

Judson Lake
Pangbor Lake
Van Buren Rd
Pangborn Rd
Halverstic Rd

± 0.5 1.1 0.25
Miles

± 0.35 0.7 1.4 2.1
Kilometers
Domestic wells were sampled monthly for 2 years
Surface Water was Sampled Bi-Monthly for 2 years
Nitrogen Isotopes were measured quarterly for 2 years
Water Quality Parameters were measured at the Institute for Watershed Studies Water-Quality Lab
Nitrogen Isotopes were measured at the Colorado Plateau Stable Isotope Laboratory, Northern Arizona University
Numerous factors may influence a nitrate concentration measured at well, including:

- nitrate originating in BC
- vadose zone thickness and residence time
- well depth below the water table
- up-gradient nutrient loading (timings and types)
- seasonal precipitation and irrigation
- vertical and lateral mixing due to intermingling plumes
- mixing due to excessive well pumping
- nitrate recirculation due to irrigation, and
- denitrification (especially due to peat deposits in the area).
21 out of 26 wells had median nitrate values > 3 mg-N/L

14 out of 26 wells had median nitrate values > 10 mg-N/L (> EPA MCL)

Shallow wells had higher values than deeper wells, highest value was 43 mg-N/L
Nitrate+Nitrite (mgN/L)

- Shallow wells (< 25 ft)
- Deep wells (> 25 ft)

EPA MCL (10 mgN/L)
tau = 0.95
p-value < 2.2e16
Nitrate concentrations were higher in wells north of Pangborn Lake and Creek.

12 out of 15 wells had median nitrate values > 10 mg-N/L.

Lower values at V7, V10 and V12 are likely due to denitrification.
Wells near the border are likely receiving groundwater and (nitrate) from BC.
Deep Wells Near the Border

![Graph showing nitrate concentration over time for wells H3, H4, V8, and V9. The graph includes data from March 2002 to August 2004, with nitrate concentration measured in mg-N/L. The graph also indicates the Maximum Contaminant Level (MCL) for nitrate.]
The nitrate concentrations measured in BC wells are similar in magnitude to bordering WA wells.
Shallow wells in the study area had the highest nitrate concentrations due to a combination of BC and Whatcom County sources.
Shallow Wells in the Study Area

![Graph showing nitrate concentration over time for different wells (H7, T1, V5, V6) with MCL (Maximum Contaminant Level) indicated.]
Wells south of Pangborn Bog and the creek had low nitrate concentrations due to denitrification in the organic-rich peat.
Soils Map

(peat is blue)
Peat has excellent denitrification potential
Peat has excellent denitrification potential

- high organic content
Peat has excellent denitrification potential

- high organic content
- reducing conditions
Peat has excellent denitrification potential

- high organic content
- reducing conditions
- iron and manganese
Peat has excellent denitrification potential

- high organic content
- reducing conditions
- iron and manganese
- nitrate input
Denitrification Evidence

- low nitrate concentrations
- low DO (< 1 mg N/L)
- enriched $\delta^{15}$N values (> 12 $^{0/00}$)
- high ammonia (> 100 $\mu$g/L)
- excess N$_2$ gas (2 to 10 mg/L)
It is likely that peat occurs at various depths due to multiple glacial phases during the Sumas Stade.
Indicators such as low DO, high metals, and/or enriched $\delta^{15}$N values suggest denitrification at a variety of wells.
YSI Dissolved Oxygen (mg/L, field meter)

Nitrate+Nitrite (mgN/L)

tau = 0.36
pvalue <2.2e16
Nitrate Concentration Stratification

The nitrate concentrations are higher near the water table because it’s closer to the surface sources (median of 15.7 mg N/L).

Lower concentrations occur deeper in the aquifer because of mixing and dilution (median of 11.3 mg N/L).
Site T2

Nitrate+Nitrite (mgN/L) vs. Depth to Water (ft)

- ▲ Nitrate+Nitrite
- ● Depth

irrigation well 50 feet below the water table
Site T2

Nitrate+Nitrite (mgN/L)


Nitrate+Nitrite

Depth

2 0 10 20 30 40

Depth to Water (ft)

irrigation well
50 feet below the water table

drawdown

static water level
Nitrogen Isotope Results (7/02 to 6/04)

Nitrogen Isotope values ($\delta^{15}N$) indicate animal N sources and mixed animal and commercial N sources.
Nitrogen Isotope Ratio ($\delta^{15}$N, ‰)

shallow wells

deep wells

inorganic N source

organic N source

mixed N sources

inorganic N source
tau = 0.86
p-value < 2.2e16
Ammonia ($\mu$gN/L)
Nitrogen Isotope Ratio ($\delta^{15}$N, ‰)

organic N source
Conclusions

• Nitrate concentrations remain high in both surface water and groundwater in the study area.

• Nitrate concentrations transported across the border from BC range from about 10 to 25 mg-N/L and reflect a mix of manure and inorganic N sources.

• Nitrate concentrations in shallow wells in Washington range from about 15 to 35 mg-N/L and correlate to a combination of BC and local N sources.

• **Denitrification is occurring** in the peat in Pangborn Bog resulting in lower nitrate concentrations south of the bog.

• Denitrification is also occurring at other isolated locations.
Resulting Works


Site T1
Nitrate+Nitrite (mgN/L)
6 10 14

Site T2
Nitrate+Nitrite (mgN/L)
6 8 10 14

Site V1
Nitrate+Nitrite (mgN/L)
0.0 0.04 0.08

Site V2
Nitrate+Nitrite (mgN/L)
0.00 0.04 0.08

Site V3
Nitrate+Nitrite (mgN/L)
2 2.5 3.0

Site V4
Nitrate+Nitrite (mgN/L)
5 10 15