Improved understanding of groundwater age and nitrate trends

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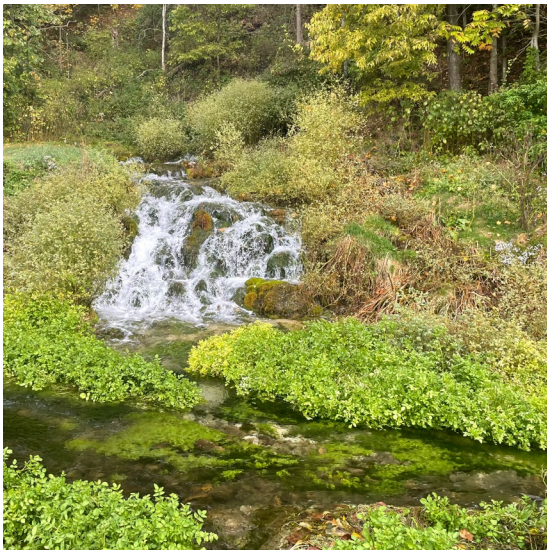
Minnesota Department of Agriculture

Minnesota Department of Natural Resources

Minnesota Geological Survey

Key findings

- ✓ Groundwater ranged from 10 to 40 years old in many shallow springs and wells, to thousands in deeper aquifers.
- ✓ Younger water typically has high nitrate levels that are relatively stable or declining.
- ✓ At many older water sites with lower nitrate, levels are slowly increasing. This trend will continue until current and historical land-use practices are in balance.
- ✓ Although it may take more time to measure the impact of clean water activities in certain aquifers, the cumulative effect of today's best management practices will help reduce nitrate entering groundwater over the long term.



Groundwater emanating from a spring and flowing to a cold water trout stream in the study area.

Background

- Scientists reveal new information about groundwater age in southeast Minnesota (Figure 1).
- Groundwater residence time or 'age' is the time it takes for water to move from the land surface to underlying aquifers.
- Understanding groundwater age helps improve the interpretation of water quality trends and predictions of future conditions.

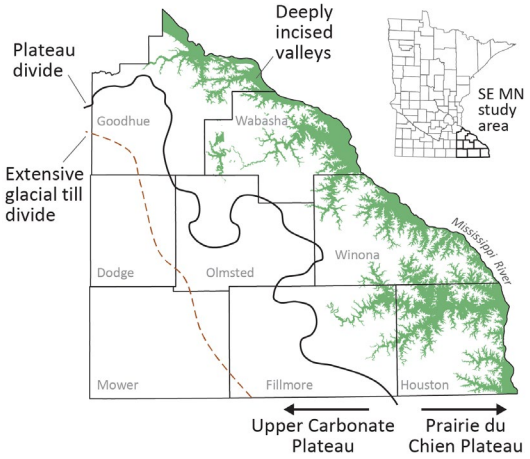


Figure 1. Southeast Minnesota study area

Methods

- Groundwater age was estimated by measuring current concentrations of a discontinued row-crop herbicide that was commonly used in the 1970s and 1980. Results were combined with independent age-dating methods.
- Nitrate trends between 2000 to 2021 were analyzed for nearly 1,200 combined monitoring locations in wells, springs and streams.
- Combining groundwater ages, historical land use data, and climatic information improved the interpretation of nitrate trends.

Results

- 2 to 13% of the spring, stream, and well sites had decreasing trends; while 13 to 63% of the sites had increasing trends, and 39-49% of the sites had no trend (Figure 2). Outside of the study area in tile-drained watersheds (extensive glacial till) (18 sites), most stream sites had no trend (56%) or decreasing (39%).
- The region's groundwater age ranged from 10 to 40 years in many shallower springs and wells, to thousands of years old in deeper aquifers (Figure 3b).
- In general, monitoring sites with elevated nitrate had groundwater less than 20 years old and either no trend or decreasing trends (Figures 2, 3). Improved conservation practices may have contributed. Dilution from record-setting precipitation over the last two decades could also be a factor.
- Typically, water older than 20 years had lower nitrate, and a higher likelihood of increasing trends (1 to 4% increase per year), particularly in the center study area (Figure 3, Prairie du Chien Plateau).

Results *(continued)*

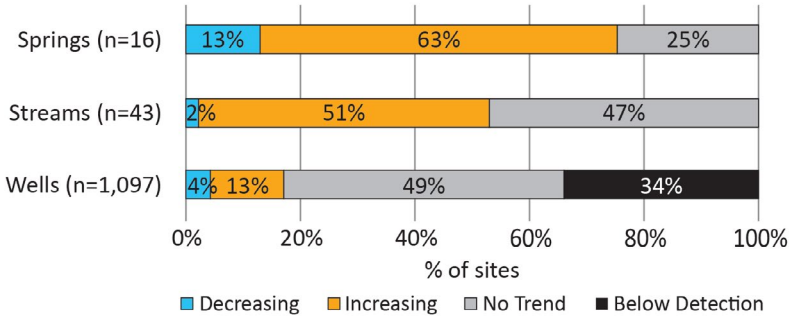


Figure 2. Nitrate-nitrogen concentration trends for 1,156 well, spring, and stream monitoring sites between 2000-2021 in southeast Minnesota. Streams include 22 sites in northeast Iowa. Median nitrate concentration for study springs, streams and wells was 8.2, 5.9 and 3.8 mg/L, respectively.

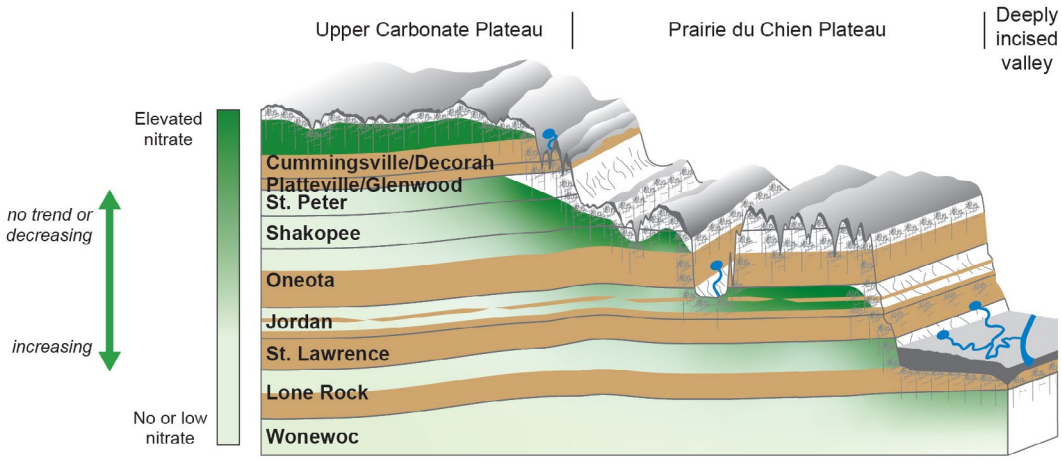


Figure 3a

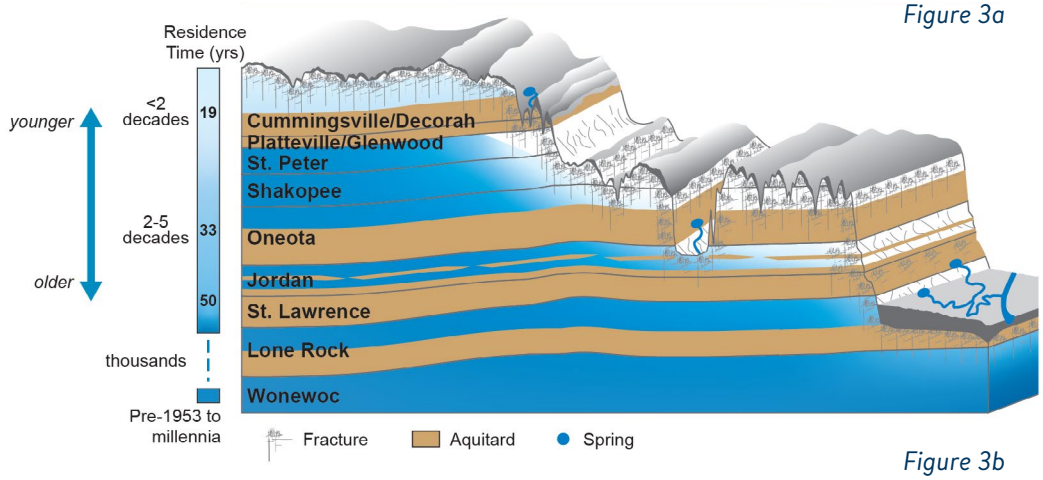


Figure 3b

Figures 3a and 3b. Geologic cross section and conceptual model of (a) groundwater nitrate concentrations and trends (b) groundwater residence time ('age') in southeastern Minnesota aquifers.

Citation

Kuehner, K.J., Runkel, A.C. & Barry, J.D. Informing nitrate concentration trends: estimating groundwater residence time in a karstic, multiaquifer system using anthropogenic tracers (Minnesota, USA). Hydrogeology Journal (2025).

Contact

Kevin Kuehner, Minnesota Department of Agriculture
Kevin.Kuehner@state.mn.us