Groundwater quality: change takes a long time

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the best things come to those who wait...

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What is groundwater age?

- The time elapsed since water first entered groundwater and lost contact with the atmosphere

Unsaturated zone travel time is not included

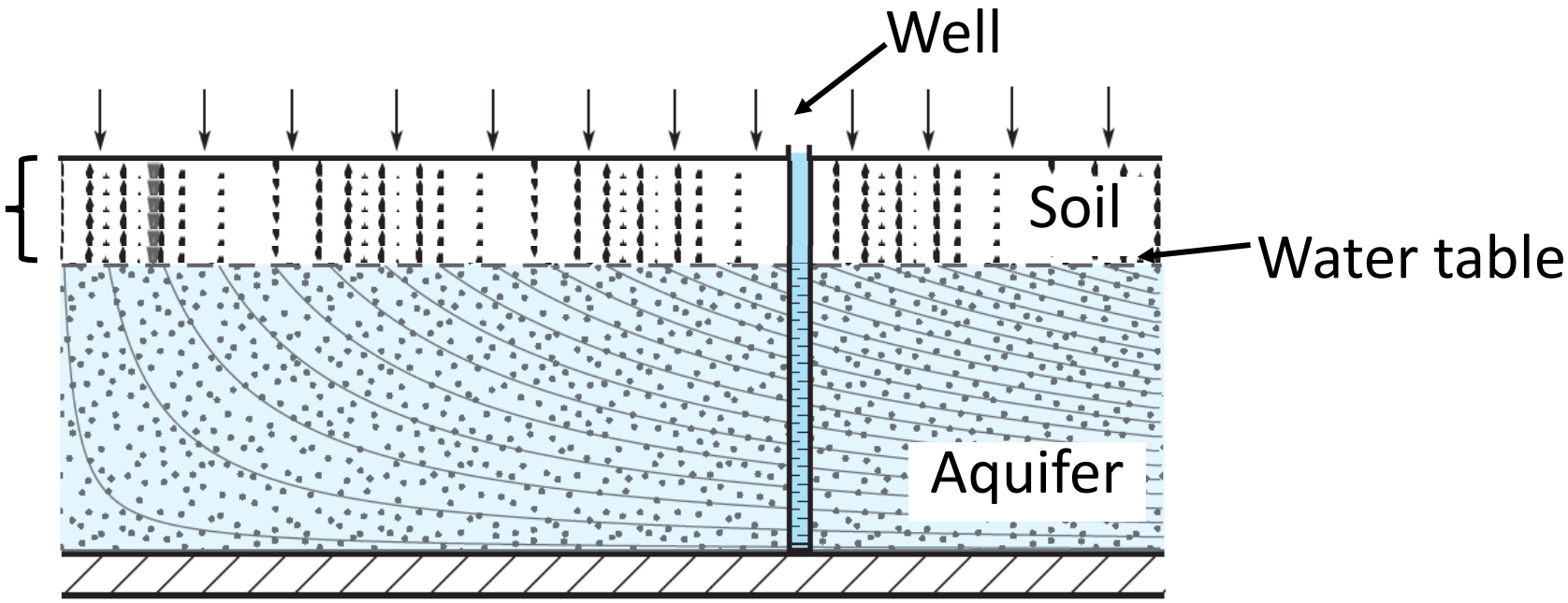
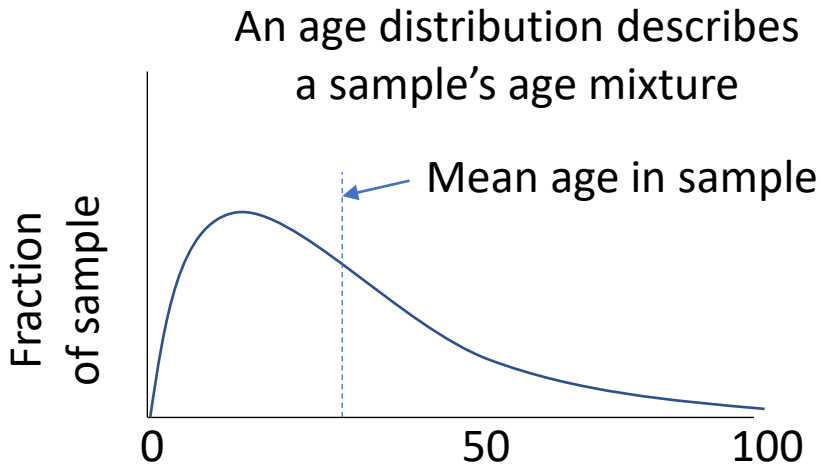


Image adapted from Jurgens and others, 2012

What is groundwater age?

- A single groundwater sample contains a mixture of ages.
- A groundwater sample consists of many discrete “parcels” that followed different flow paths to the sample site.
- Each “parcel” represents a discrete groundwater age



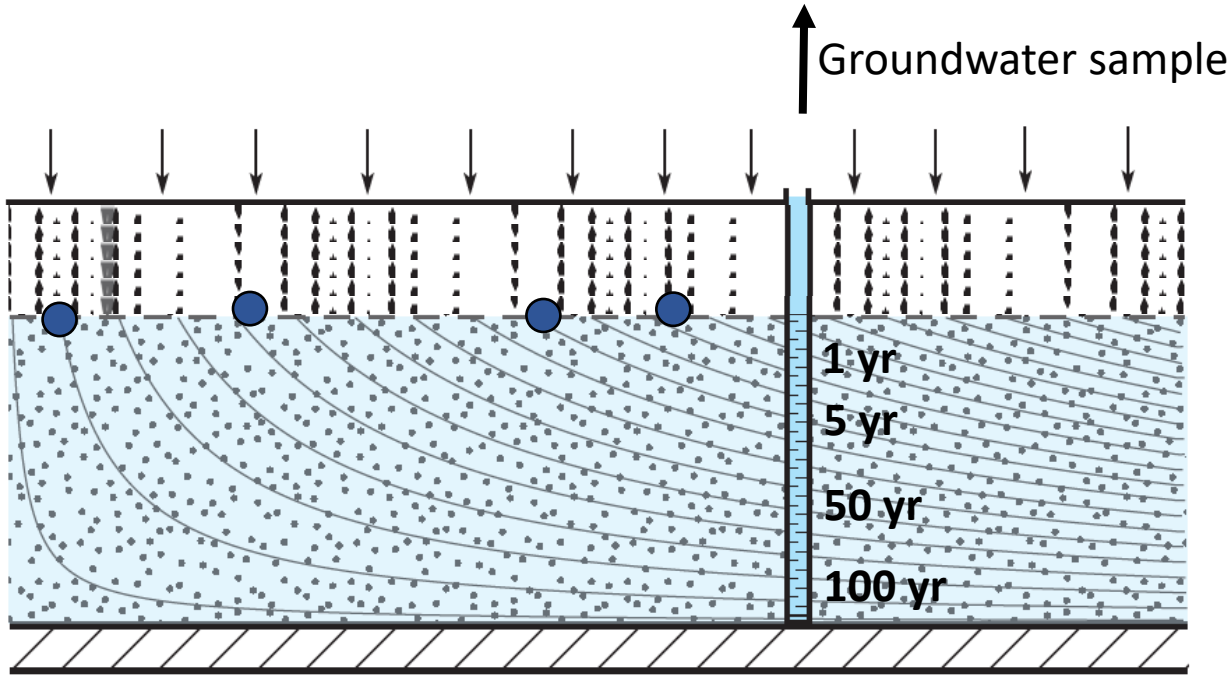
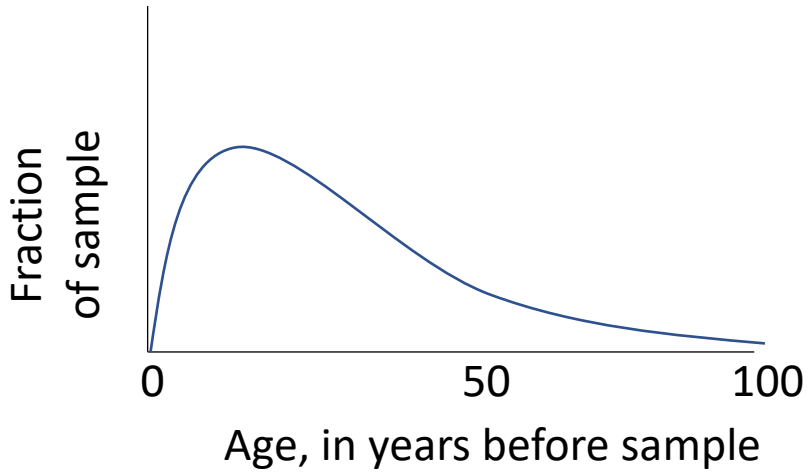


Image adapted from Jurgens and others, 2012

How is an appropriate age distribution determined for a sample?



Tracers!

- Atmospheric
- Known input history
- Move with water
- Don't degrade, or have known stable degradation rates

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National Water-Quality Assessment Program
National Research Program

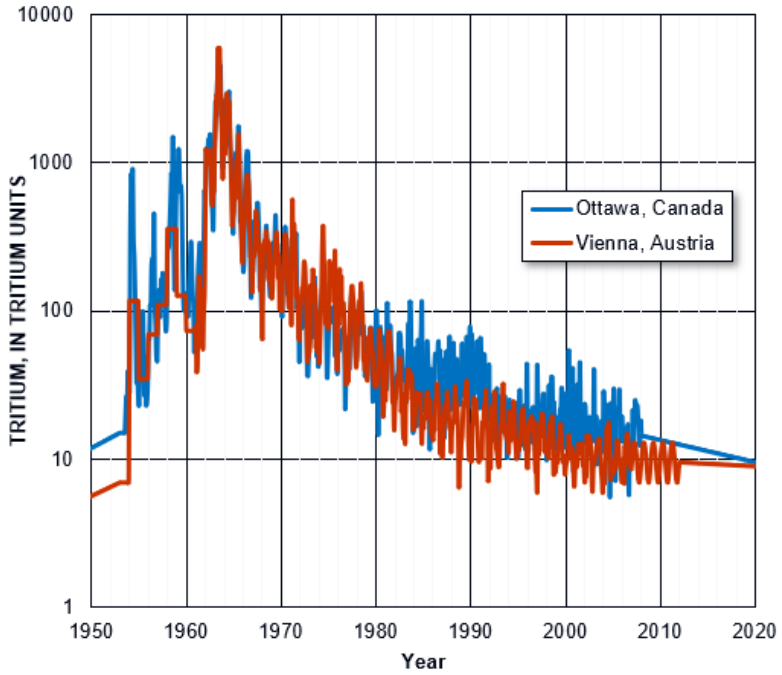
TracerLPM (Version 1): An Excel® Workbook for Interpreting Groundwater Age Distributions from Environmental Tracer Data

Jurgens and others, 2012

https://pubs.usgs.gov/tm/4-f3/

Basic tracer age dating process

Step 1: Select tracers



Tritium in precipitation

Graph courtesy of B. Jurgens, USGS

Common tracers

- Tritium
- Chloro-fluorocarbons (CFC-11, CFC-12, CFC-113)
- Sulfahexafluoride

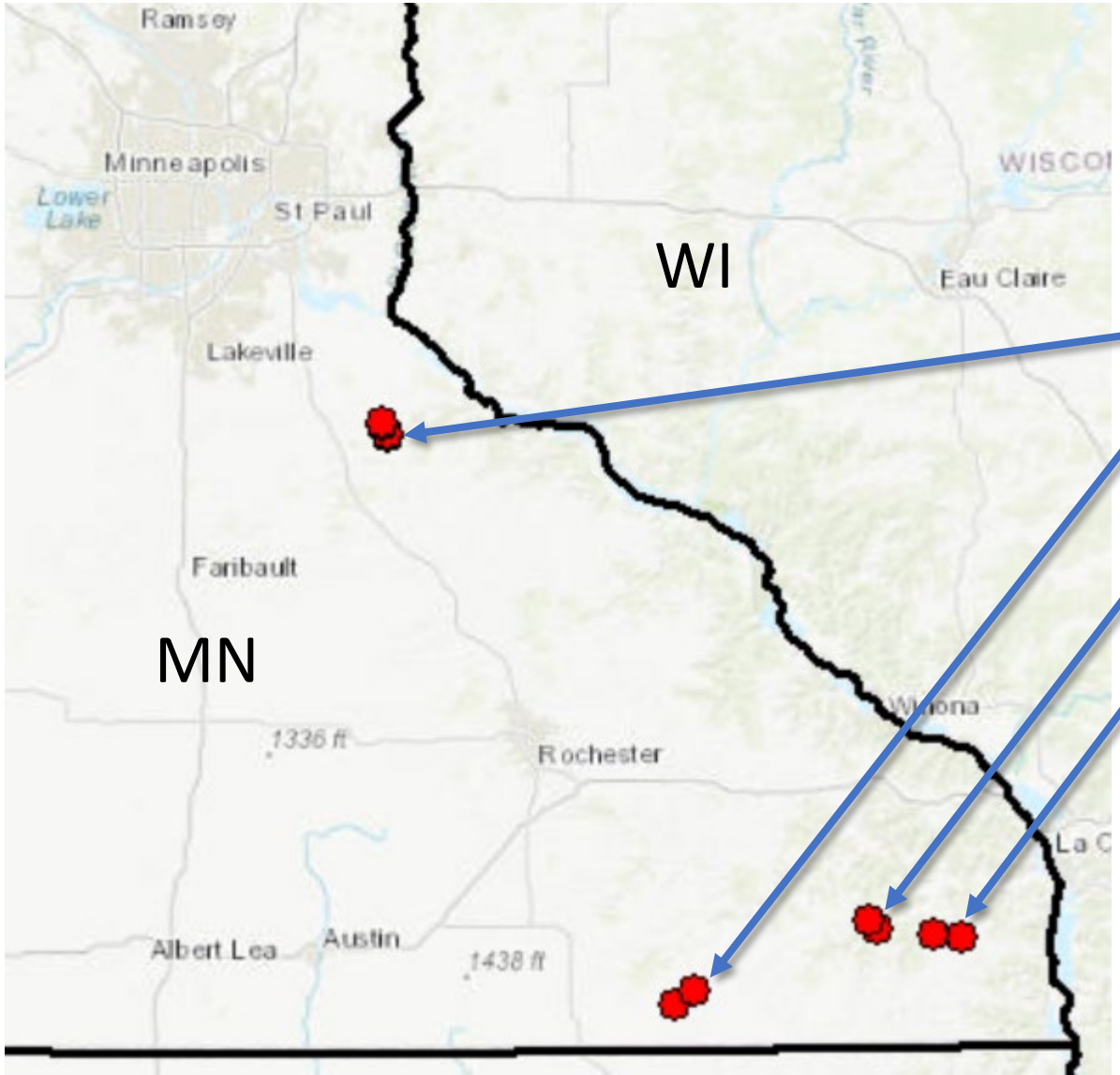
Step 2: Collect samples

Photo by J. Trost, USGS

Step 3: Calibrate age model with sample concentrations (computer program)

Step 4: Predict (use calibrated age models to predict water quality changes)

Southeast Minnesota sites sampled for age tracers



Trout Brook: 5 sites (Dakota Cty)

Crystal Creek: 2 sites (Fillmore Cty)

Bridge Creek: 2 sites (Houston Cty)

Hwy 76 spring: 2 sites (Houston Cty)

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Calibrated GW age summary

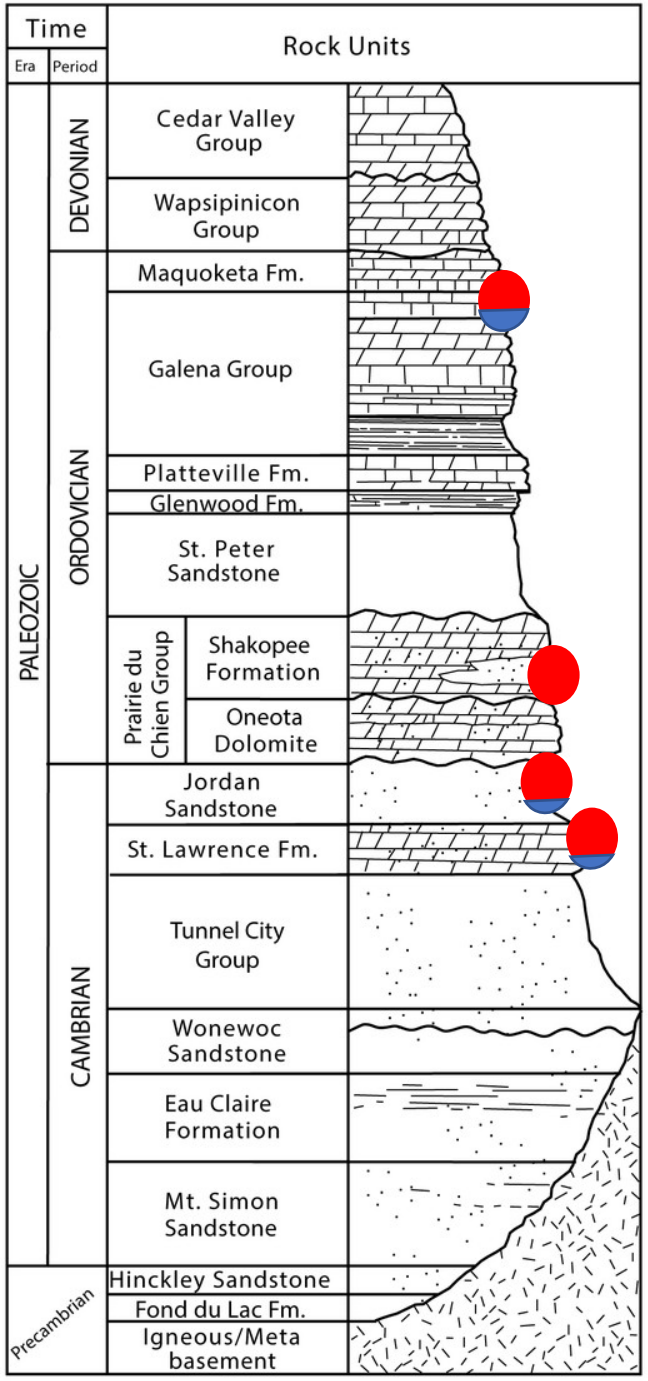


image from Lively, 2020

Modern (post-1953)

Pre-modern (before 1953)

- 4 samples from springs
  - 3 of 4 were mixed modern and premodern suggesting complex age distributions at springs

Calibrated GW age summary

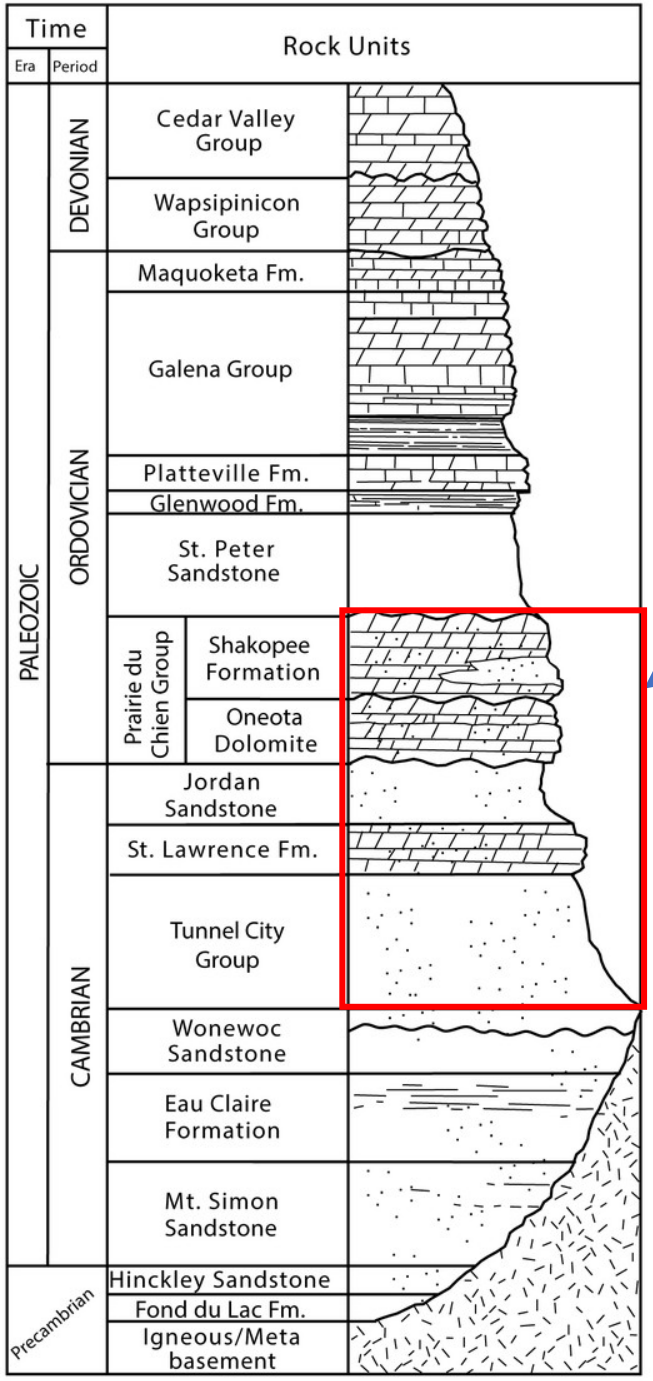
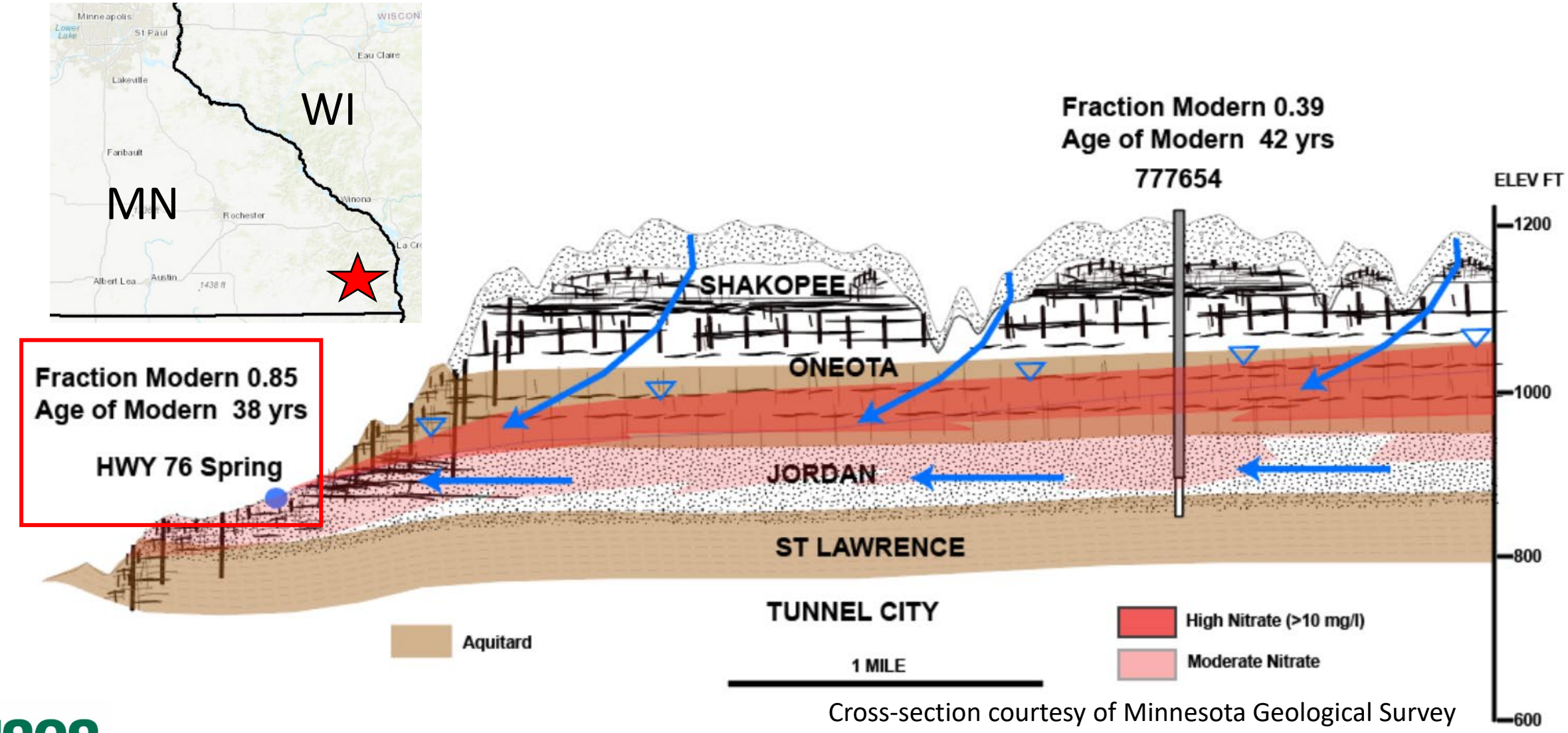


image from Lively, 2020

- 10 samples from springs or wells in frequently-used water supply aquifers
  - 3 of 10 samples 100 percent modern (post-1953 water)
  - 7 of 10 samples mixed modern and premodern
  - Most (7 of 10 samples) had mean age of modern fraction between 32 and 42 years old

What can the past tell us about the future?

Hwy 76 spring, Houston County, Jordan aquifer



Cross-section courtesy of Minnesota Geological Survey

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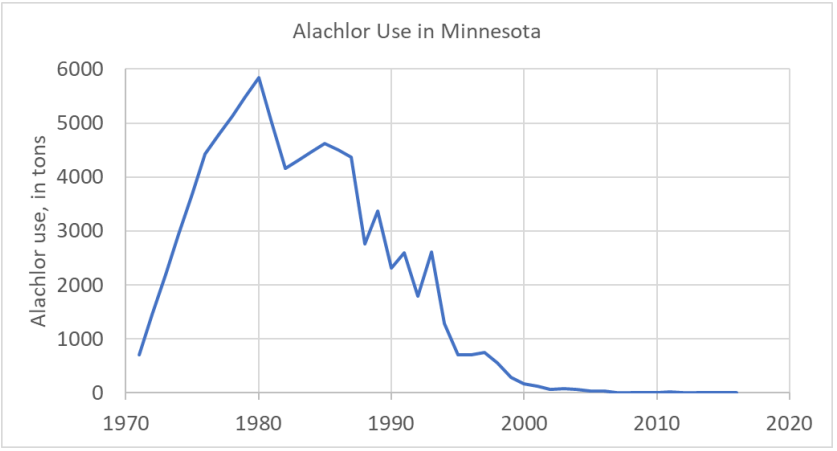
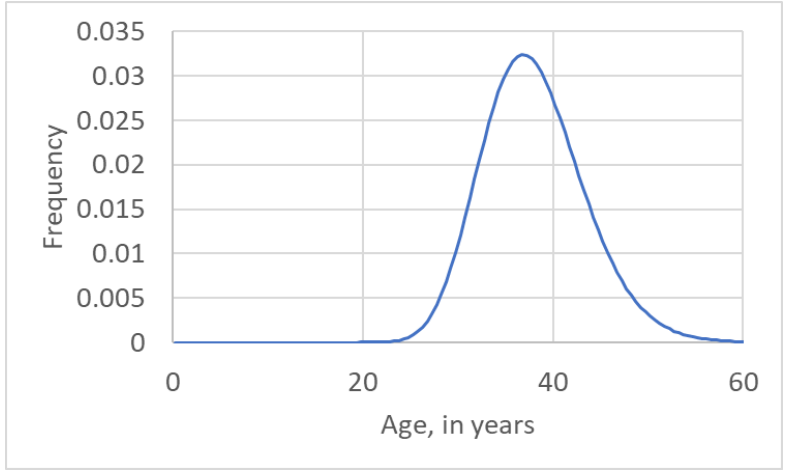
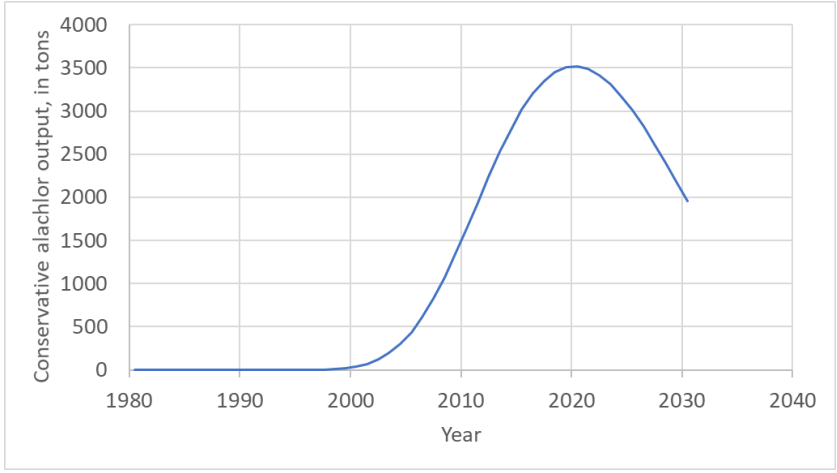
Alachlor (ESA) simulations at Hwy 76 spring

CONTAMINANT HISTORY + GW AGE → PREDICTED TRENDS IN WATER QUALITY

Alachlor sales → Calibrated age distribution from TracerLPM → Trend at discharge point (e.g. spring)



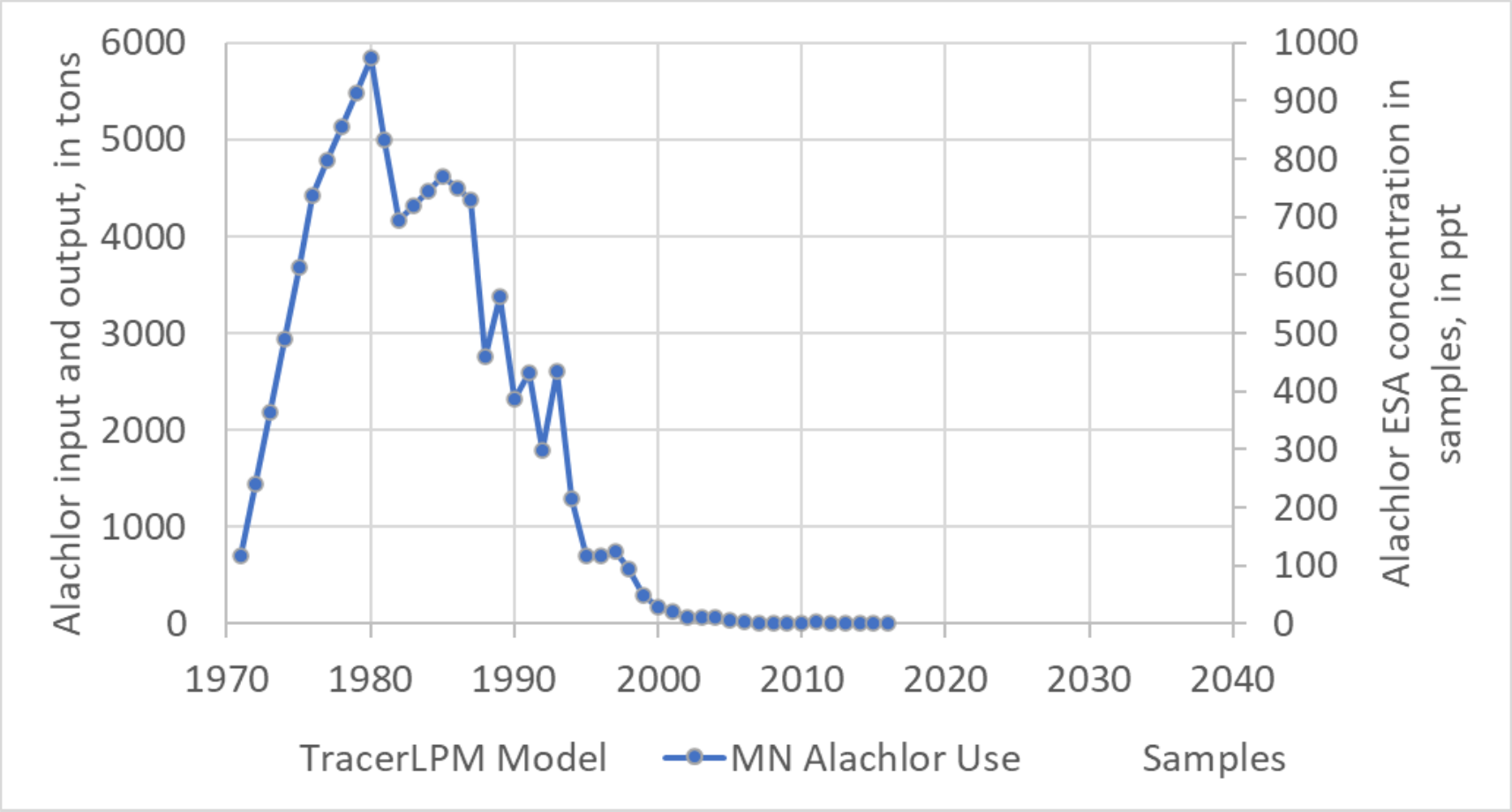




Alachlor data courtesy of K. Kuehner, MDA

Big assumption: statewide sales data reflect application in SE MN

Simulations indicate alachlor ESA concentrations may begin declining about 40 years after peak use



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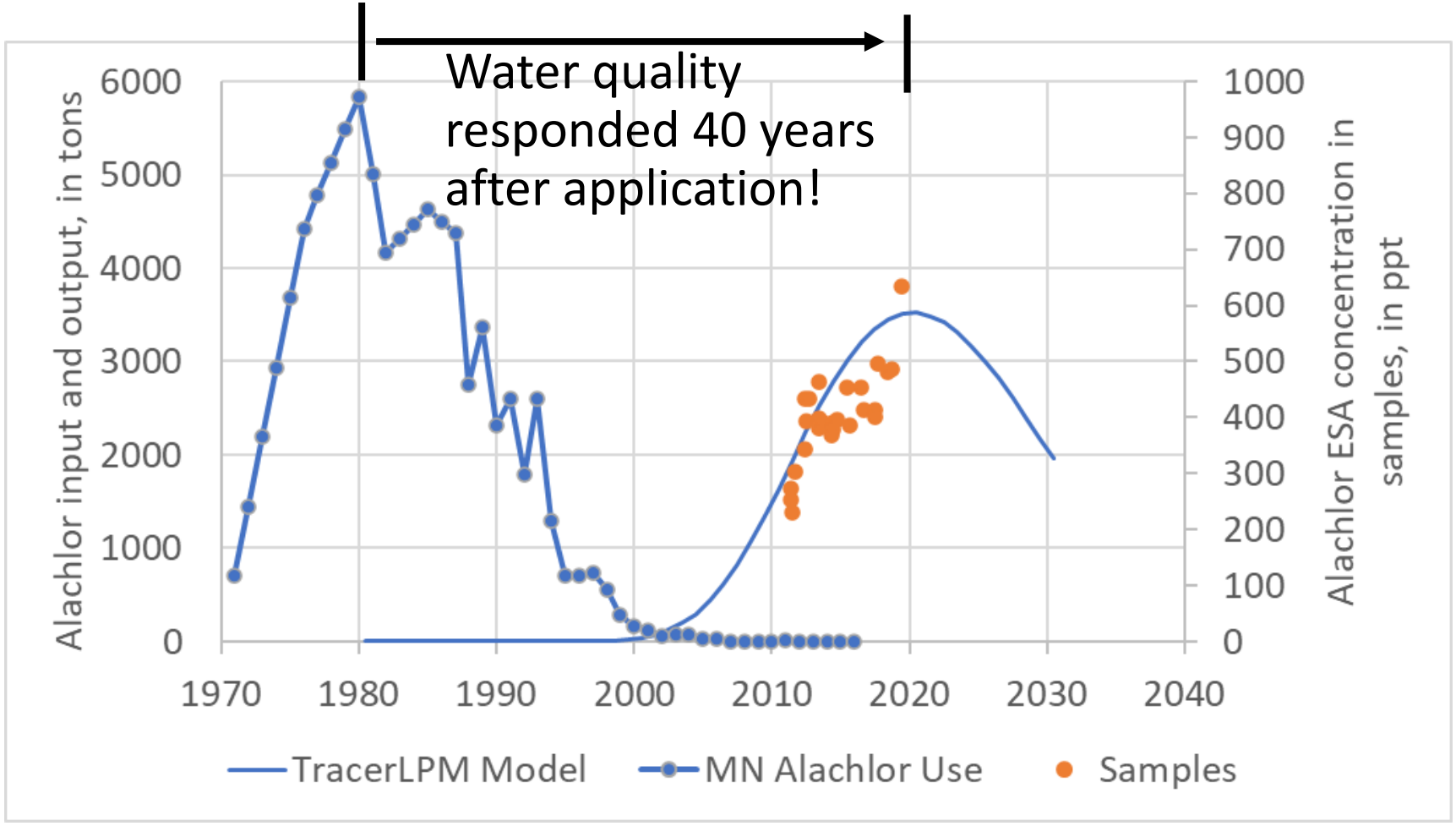
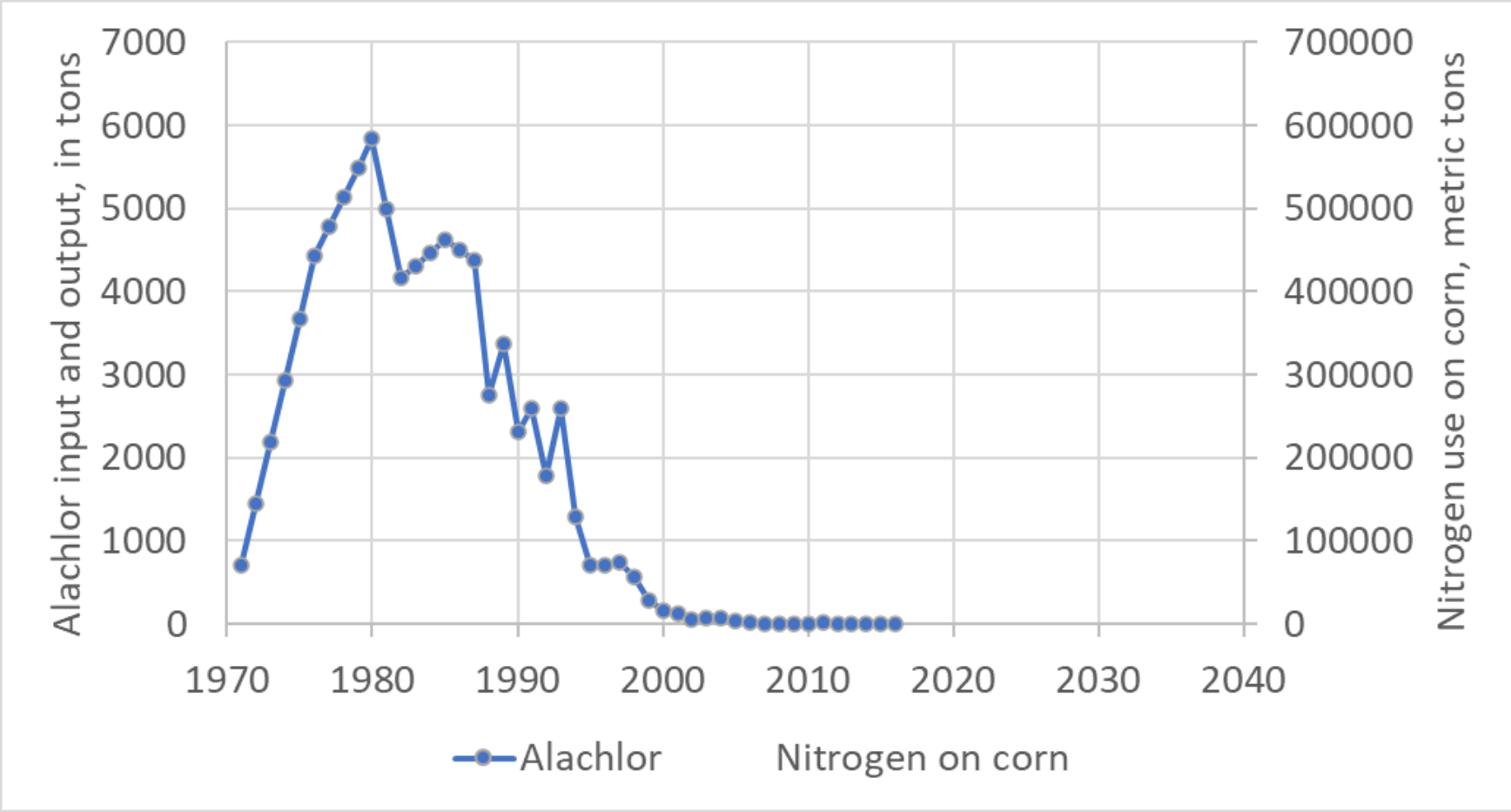


- Compare patterns
- Simulated trend compares well to observed trend in alachlor ESA concentrations

Alachlor use and alachlor ESA data courtesy of K. Kuehner, MDA

What do you hypothesize that nitrate concentrations will do at this spring for the next 40 years?



Alachlor application had a rapid increase and decrease

Alachlor and nitrogen data courtesy of K. Kuehner, MDA

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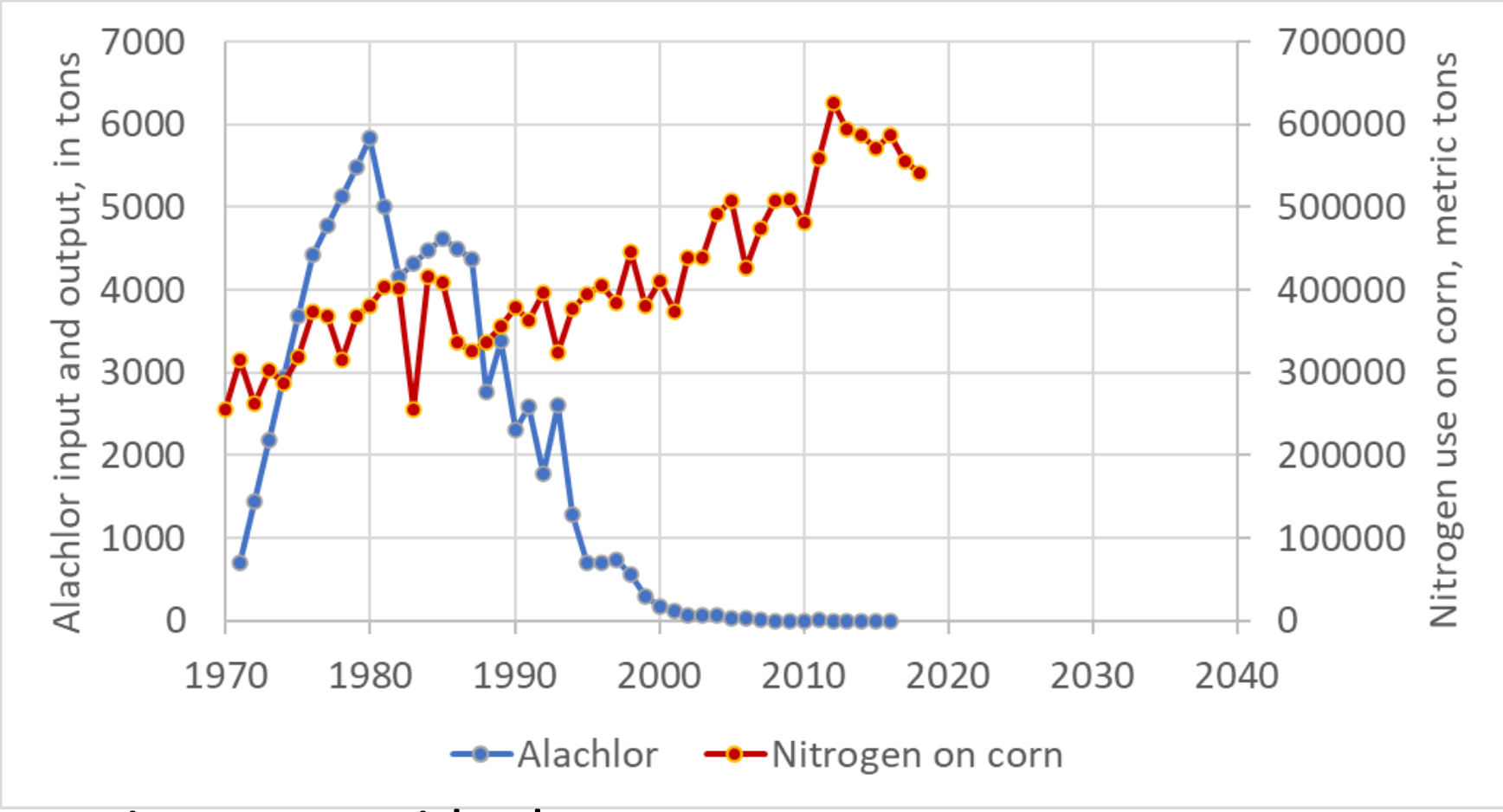

Nitrogen application on corn has increased for 5 decades

Increasing nitrate trend in samples 2010 – 2020

Limited denitrification

Big assumption: statewide data reflect application in SE MN

Alachlor and nitrogen data courtesy of K. Kuehner, MDA

Conclusions

- Multiple tracers with known input histories were used to calibrate groundwater age distribution models for samples.
  - Reasonable agreement between simulated output and observed trends a Jordan spring for a pesticide
- Most groundwater samples had a mean age of at least 30 years before present
- Most springs (3 of 4) had mixed modern and premodern water

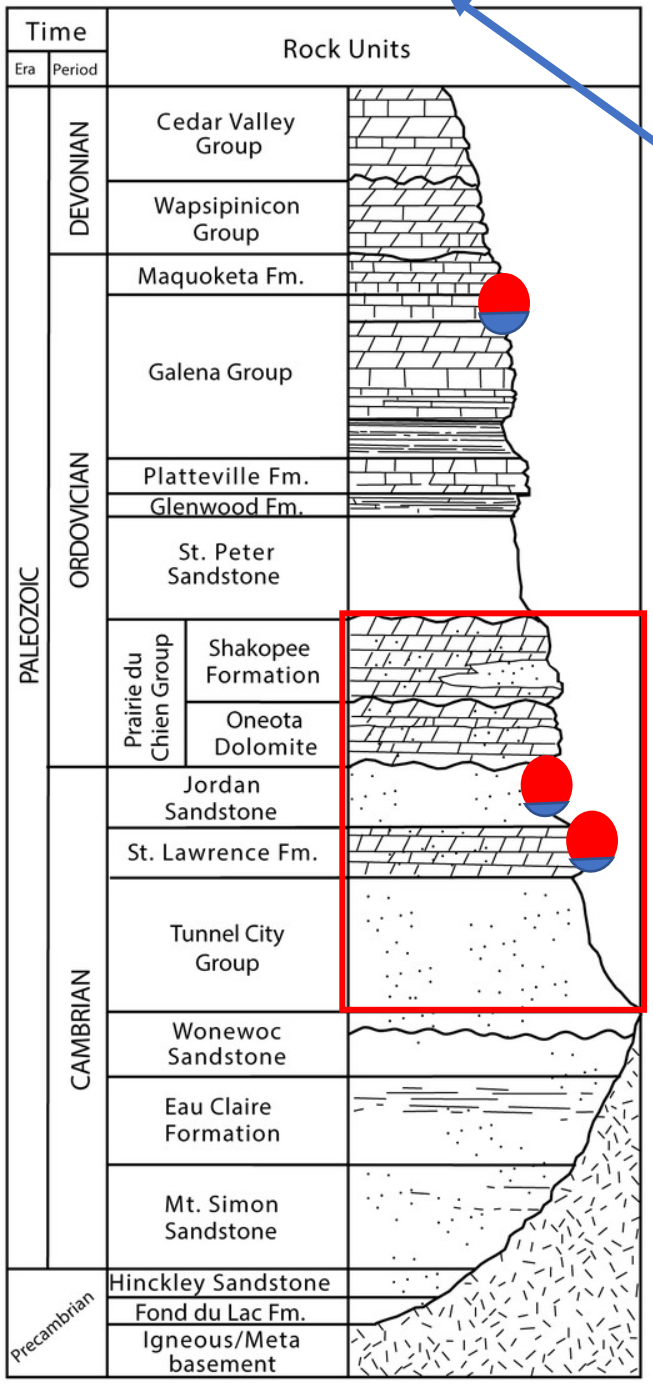

image from Lively, 2020

Implications-patience is required!

Invest in understanding decades of history it will help us understand what's coming

Many springs have mixtures of young and old fractions making contaminant trends difficult to interpret

Most sites sampled in water supply aquifers likely require at least 3-4 decades before a major contaminant input change could be observed

- That's up to 10 election cycles!
- Contaminant concentrations may increase for decades after contaminant input ends at land surface

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Next steps

- This approach does NOT describe WHERE to make changes on the landscape to improve water quality
- Other modeling approaches are needed to answer questions of “where” to make changes. The next presentations will discuss methods.

Thanks for your time

- Jared Trost
- jtrost@usgs.gov

Root River near Lanesboro, Minnesota

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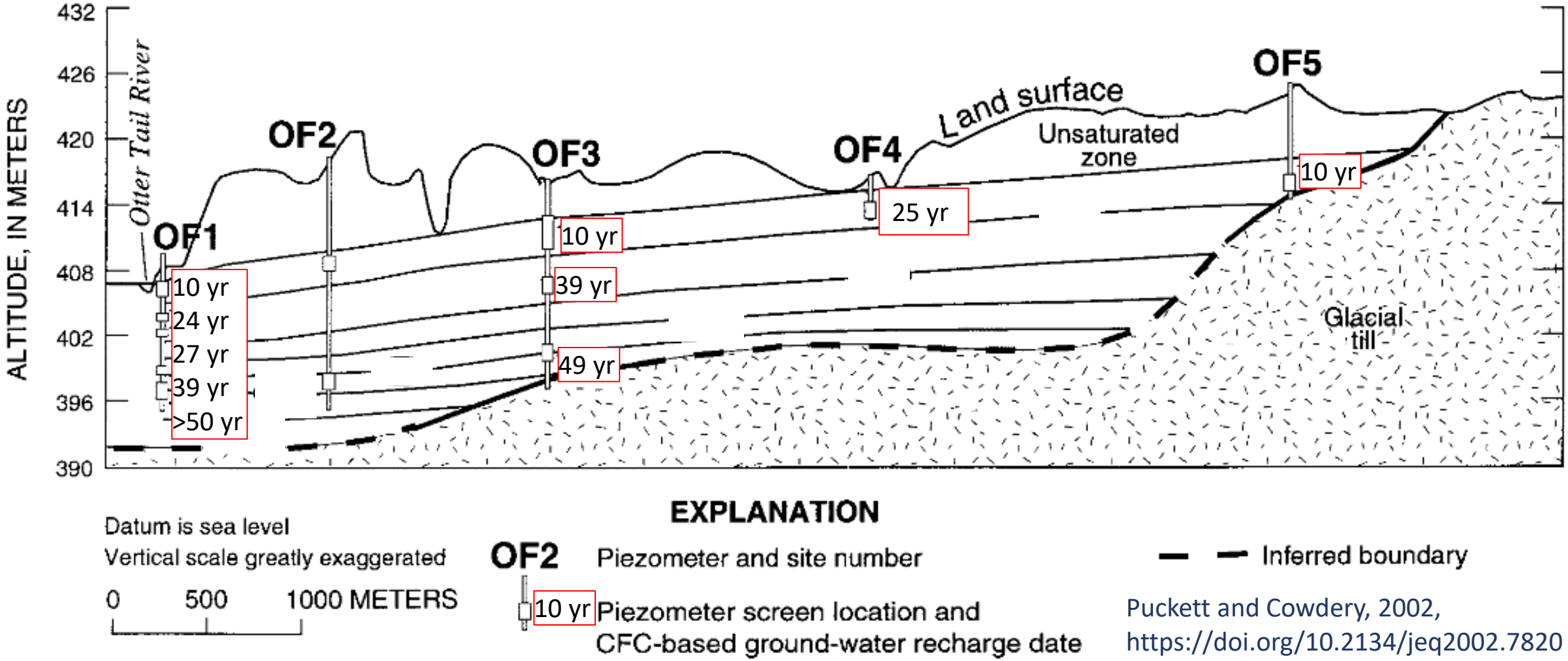
Extra slides

What about shallow aquifers?

Summary of study in shallow sediments near Perham, Minnesota



Puckett and Cowdery, 2002, https://doi.org/10.2134/jeq2002.7820

How does a sample's age distribution affect water quality?

The current situation for some shallow aquifers

Decades of farming have leaked nitrate into groundwater

Nitrate persists if nothing consumes it

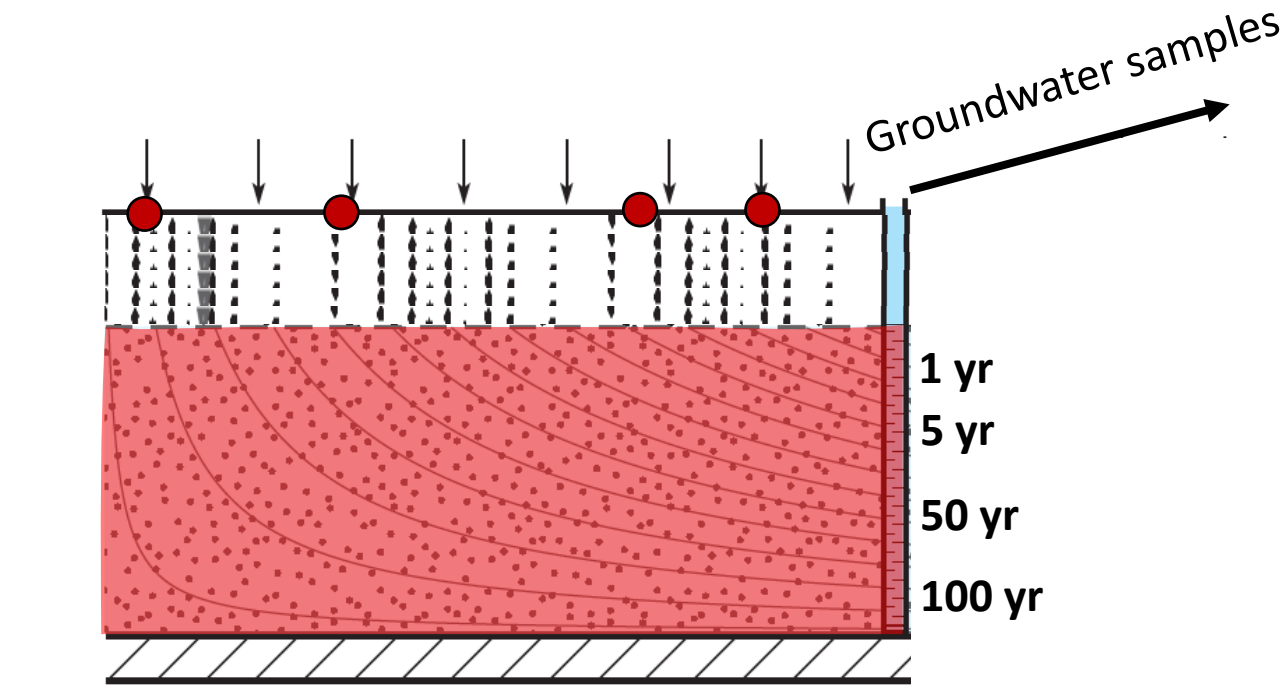
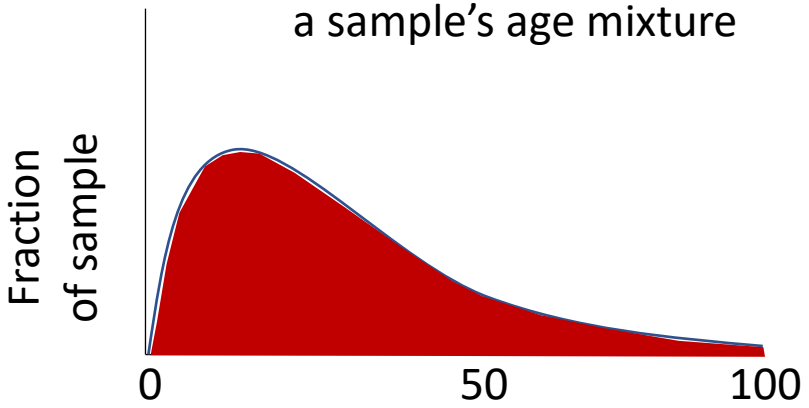
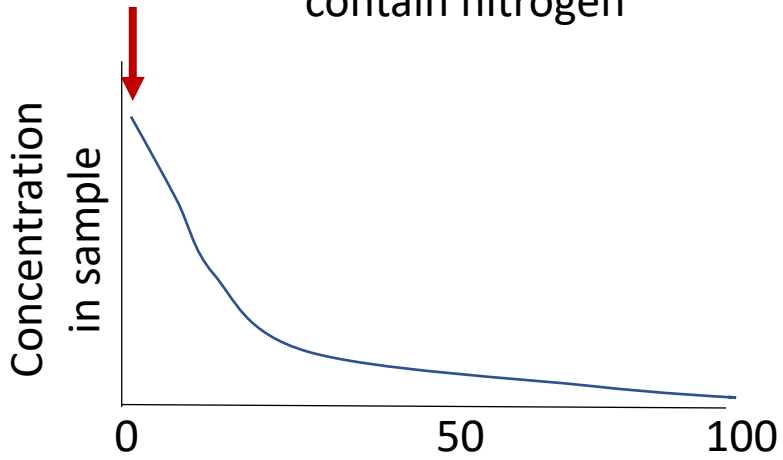


Image adapted from Jurgens and others, 2012

An age distribution describes a sample's age mixture

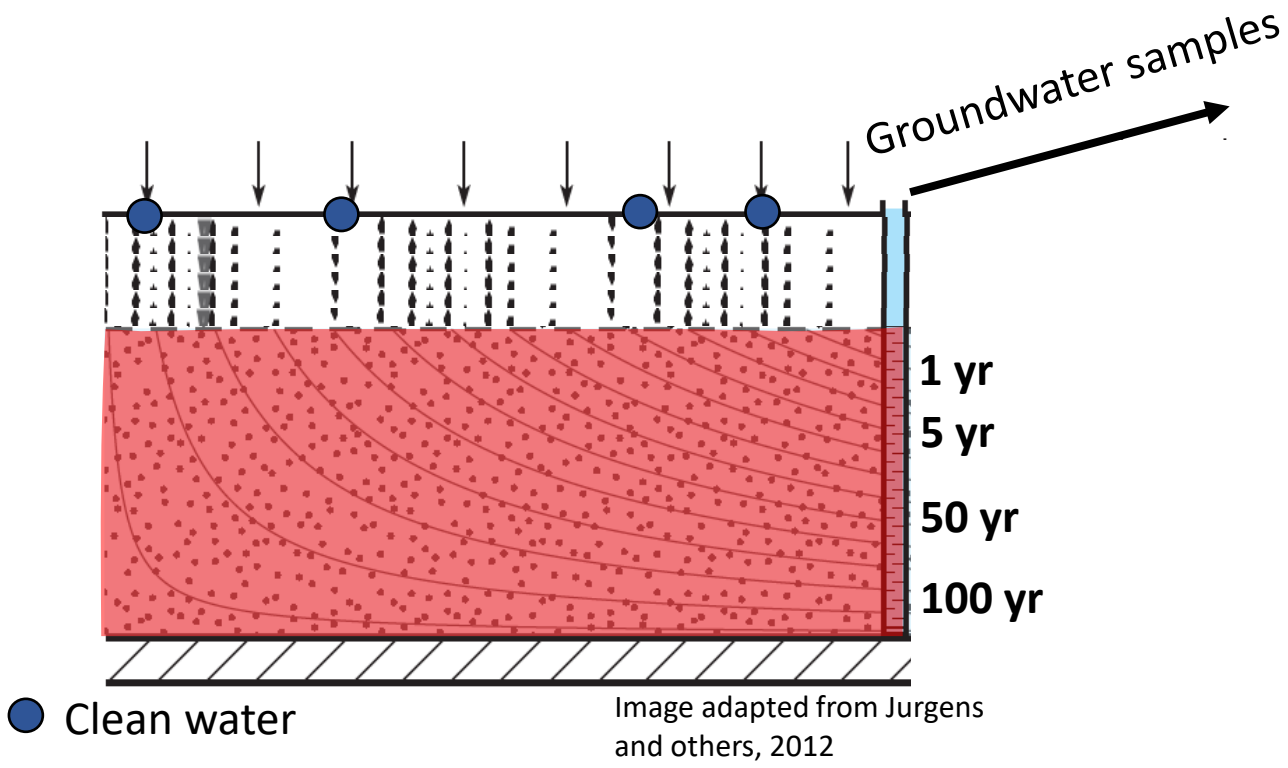


Essentially all of the water parcels contain nitrogen



If a change is made to eliminate nitrate leakage, and we stick to it

The system will slowly get flushed of nitrate



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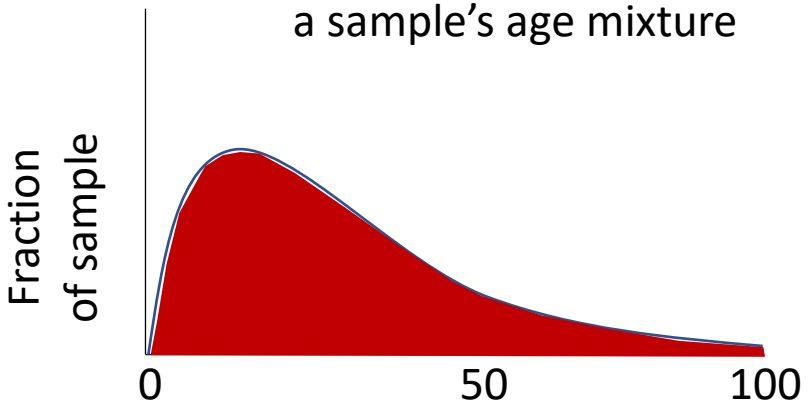

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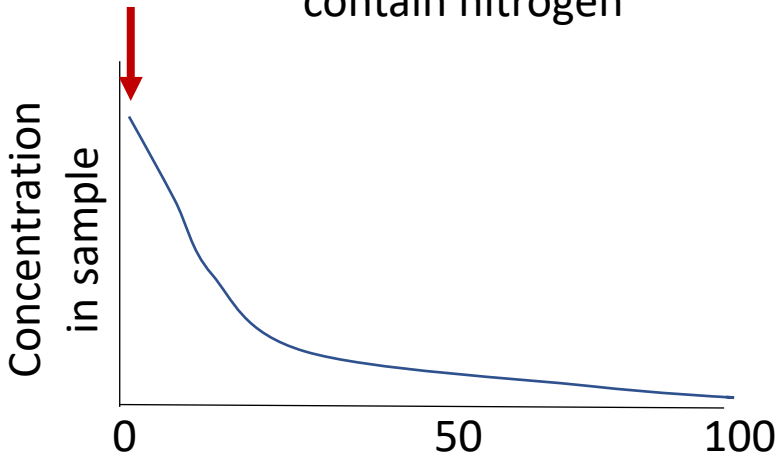
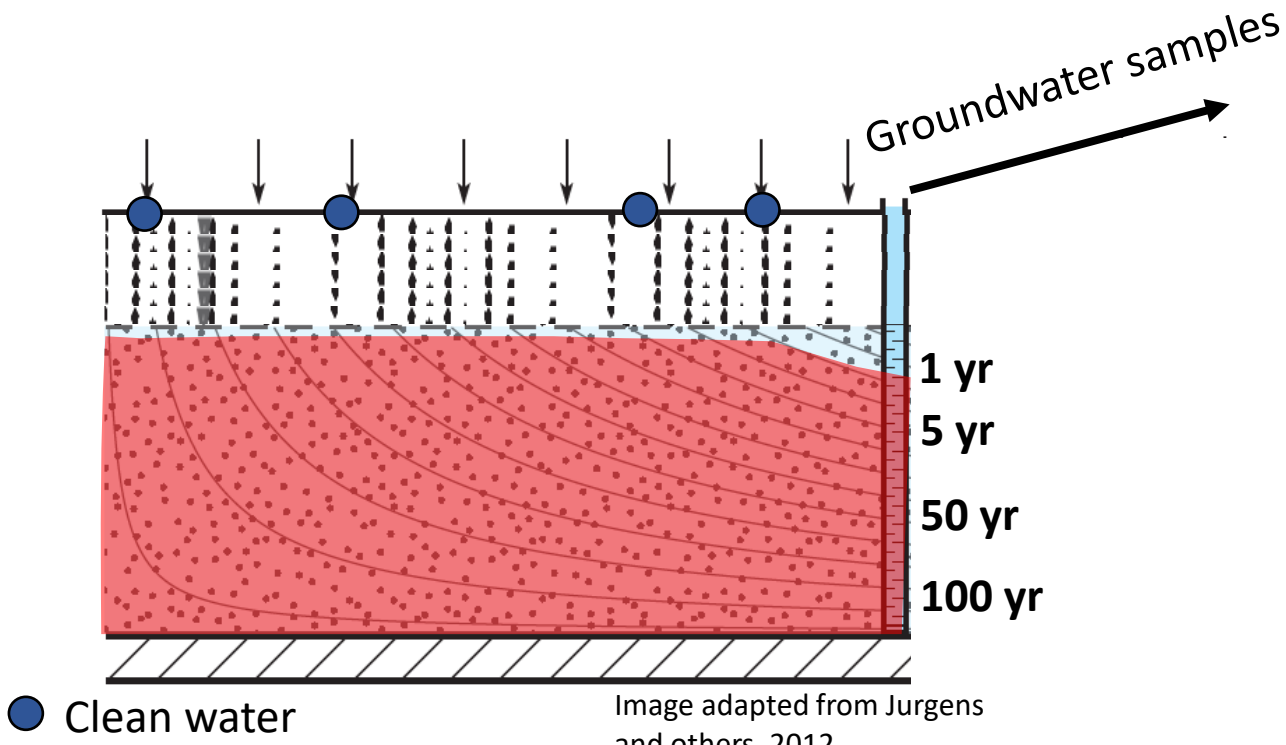


If a change is made to eliminate nitrate leakage

The system will slowly get flushed of nitrate.

1 year



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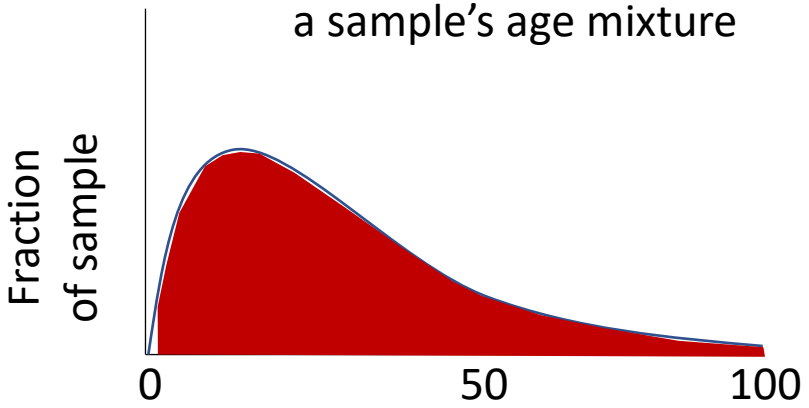
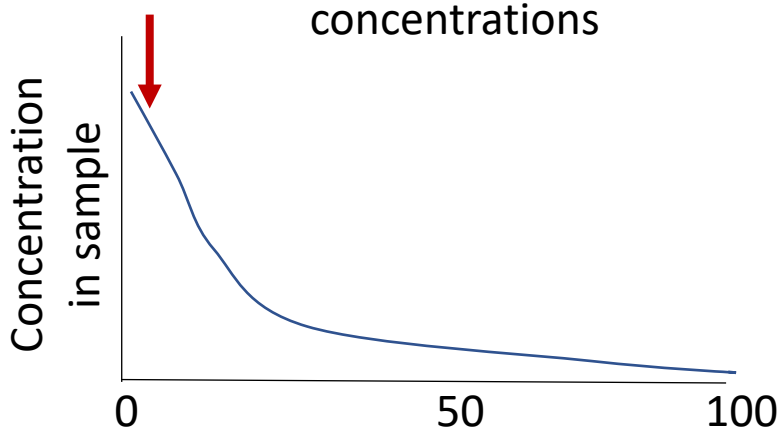


Clean water begins to re-enter the well and lower the sample concentrations



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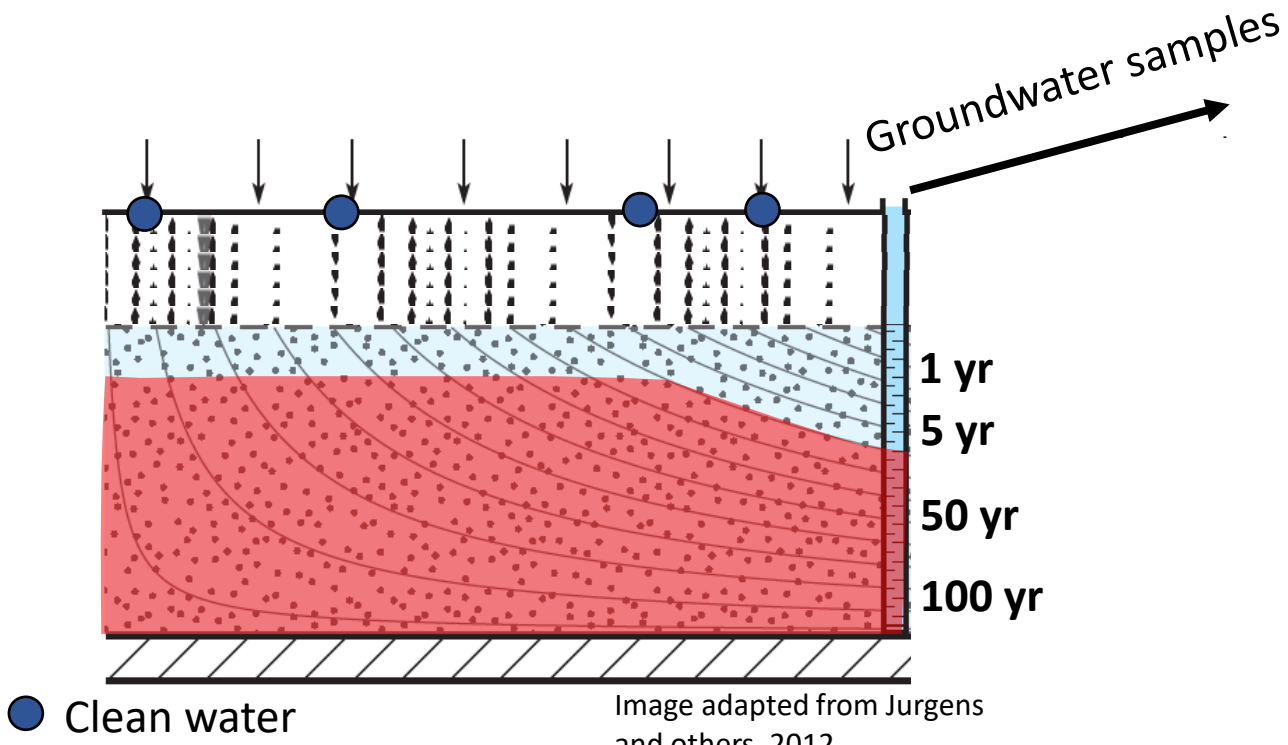
5 years



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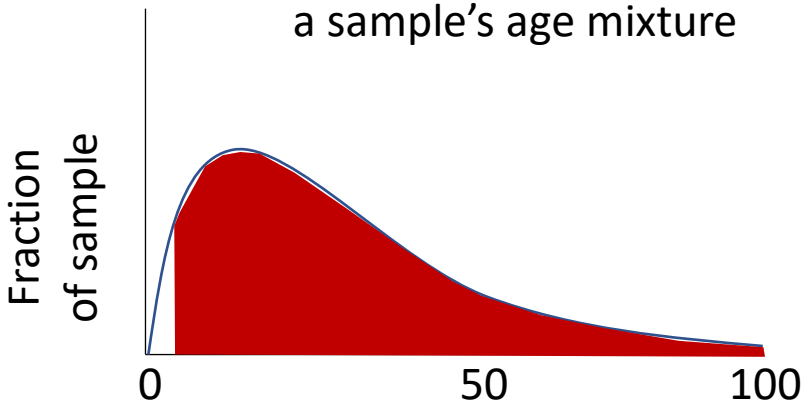

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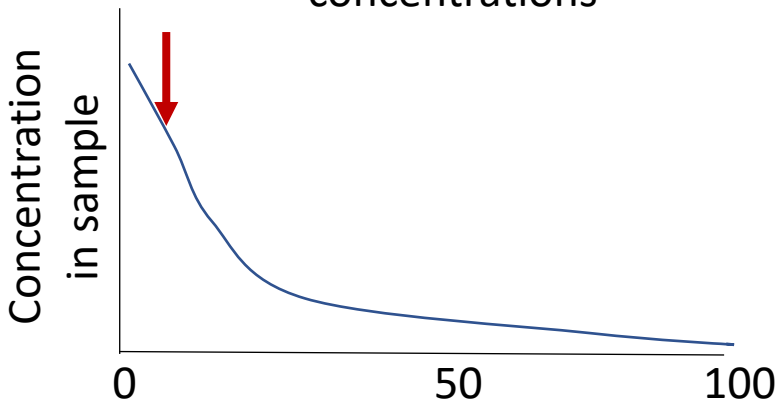

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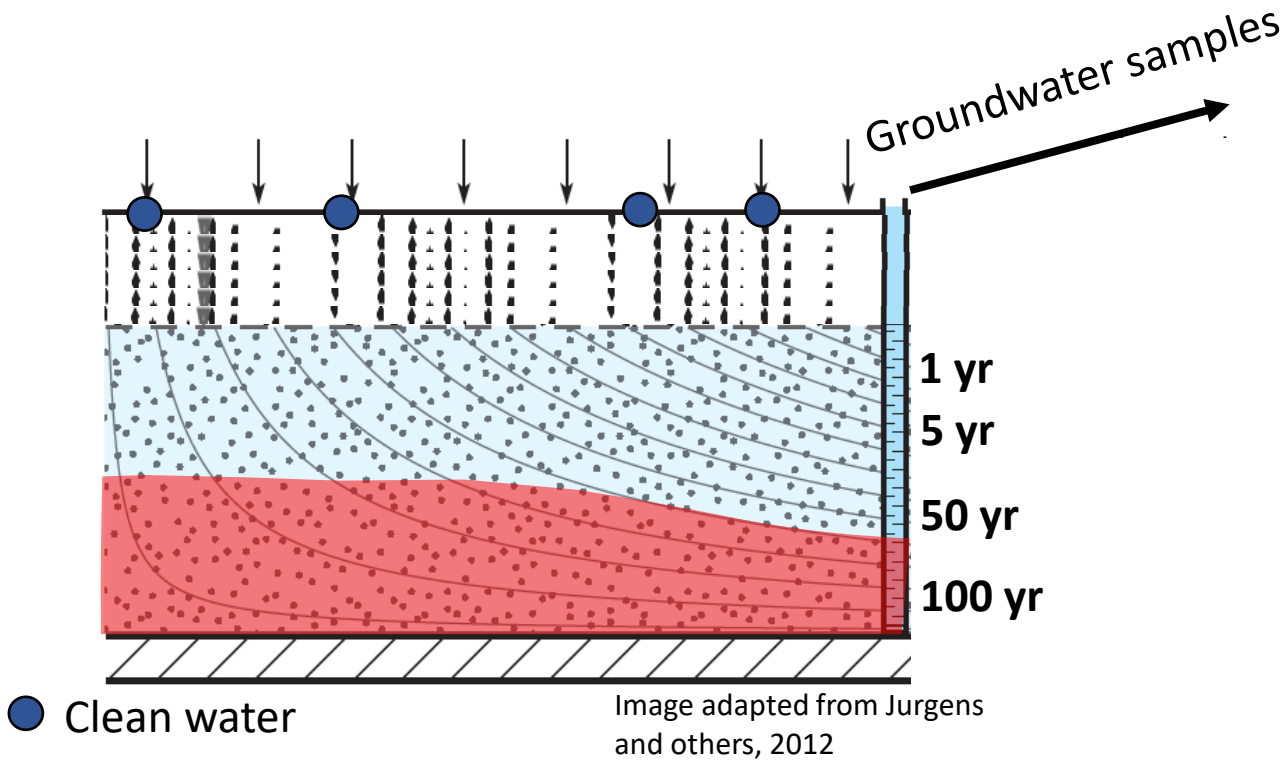
50 years



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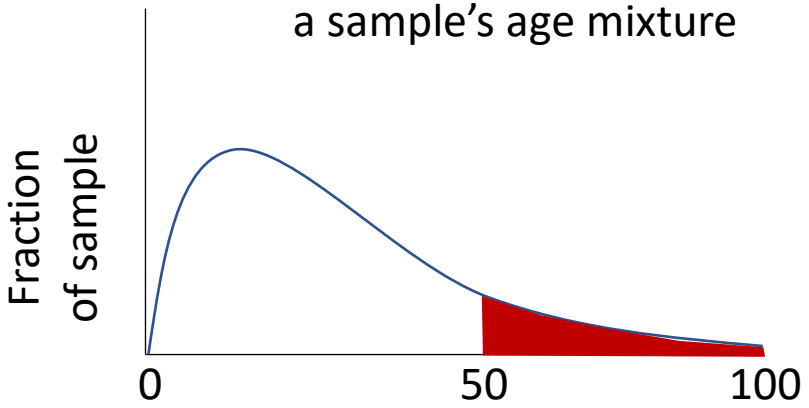

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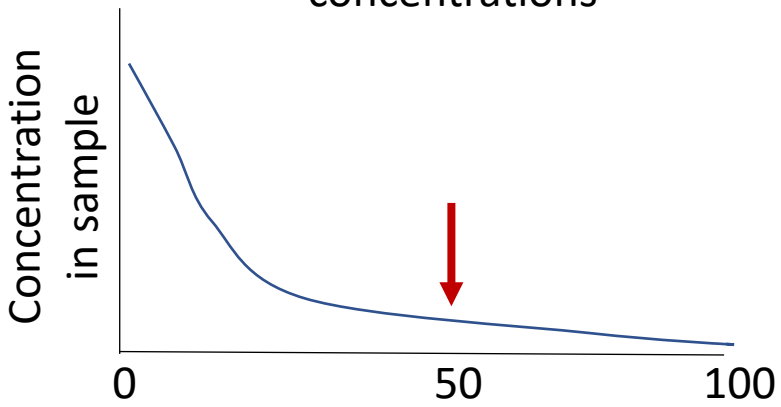

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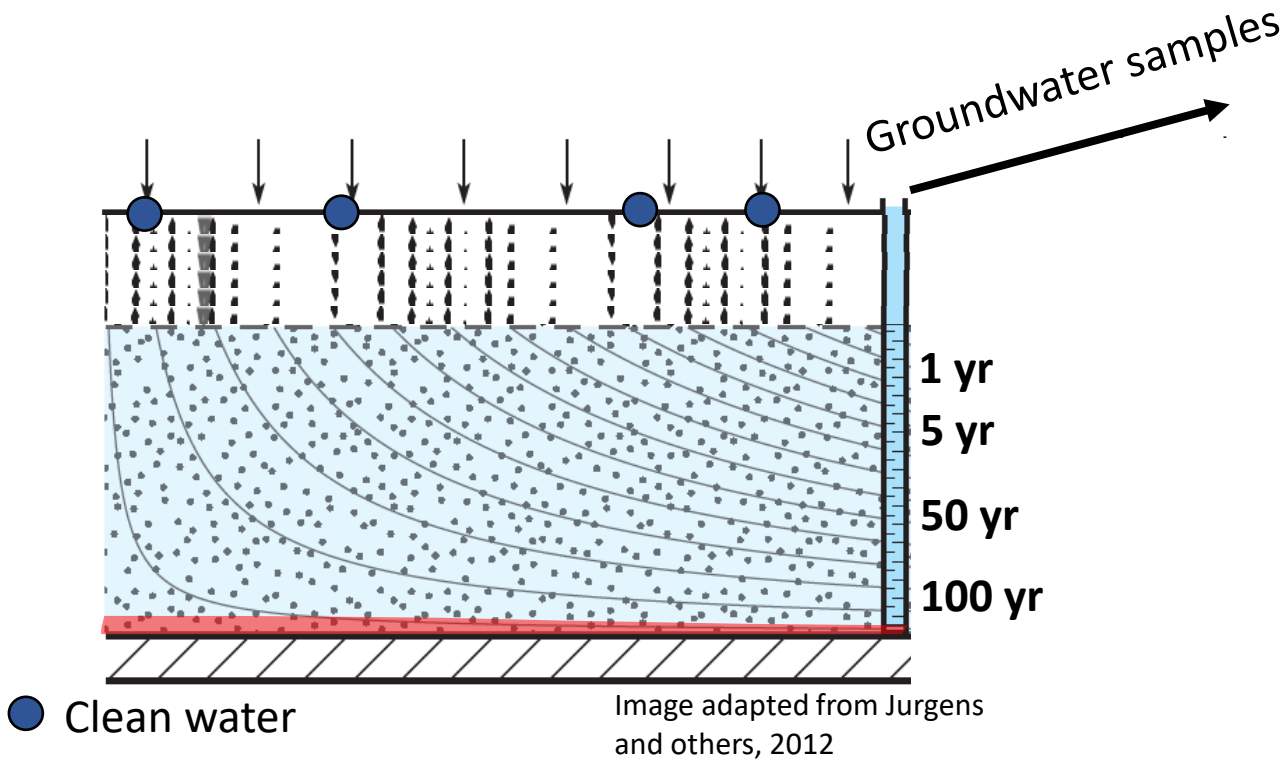
100 years



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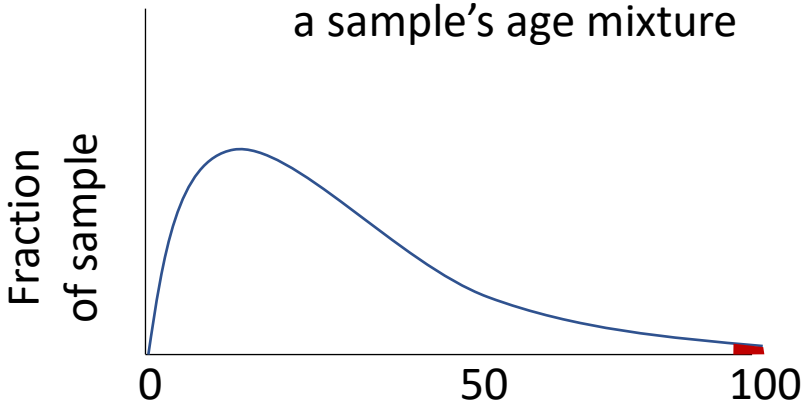

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