Screening-Level Assessments of Public Water Supply Well Vulnerability to Natural Contaminants

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U.S. Department of the Interior
U.S. Geological Survey

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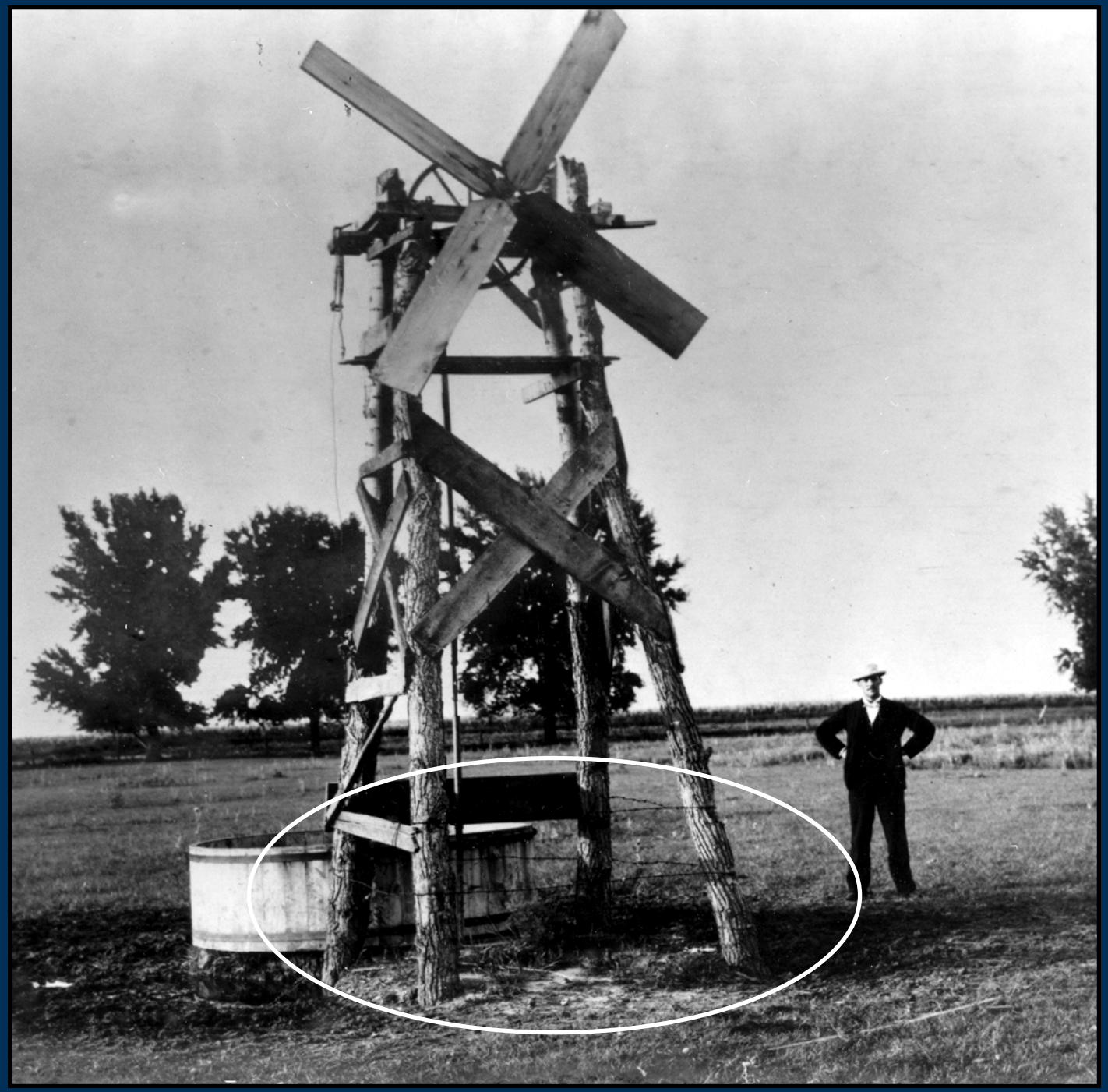
Screening-Level Assessments of Public Water Supply Well Vulnerability to Natural Contaminants

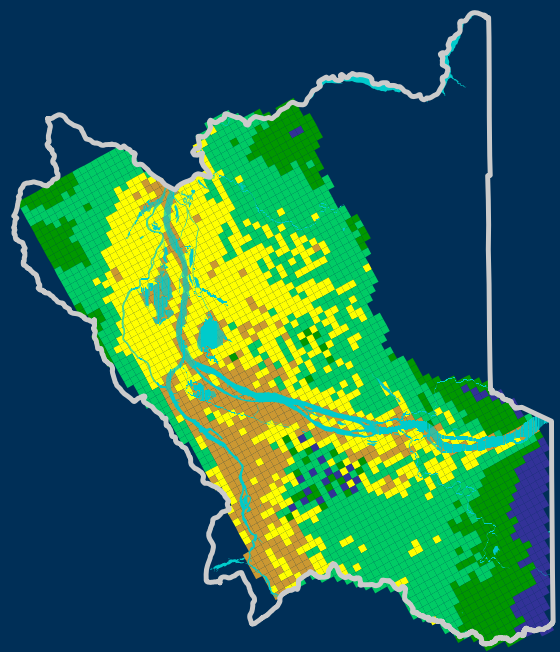
Part of the NAWQA Transport of Anthropogenic and Natural Contaminants Topical Study

U.S. Department of the Interior
U.S. Geological Survey

Well vulnerability then . . .



. . . and well vulnerability now



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Vulnerability to Natural Contaminants

- Typically not assessed in the U.S.
- Inorganic chemicals had the highest percent of MCL violations (public supply wells during 1993 - 1998; USEPA, 1999)

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Goals

- Generate an understanding of public supply well vulnerability to natural contaminants
- Focus on large spatial scales
- Existing ground-water flow models and geochemical data
- Demonstrate a simple screening-level model with As and U

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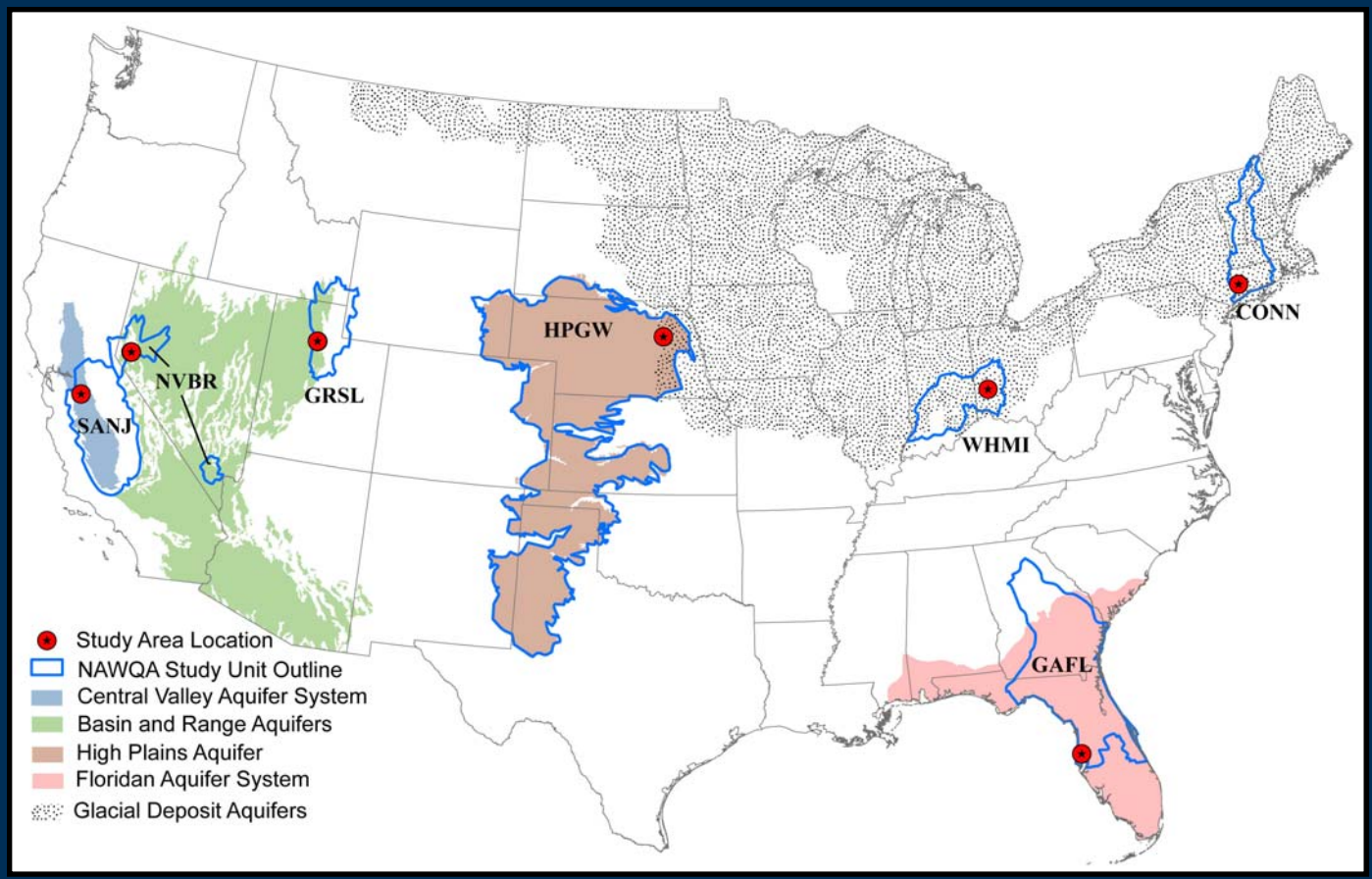
Study Areas

- 8 Study Areas
- 7 NAWQA Study Units
- 5 Principal Aquifers



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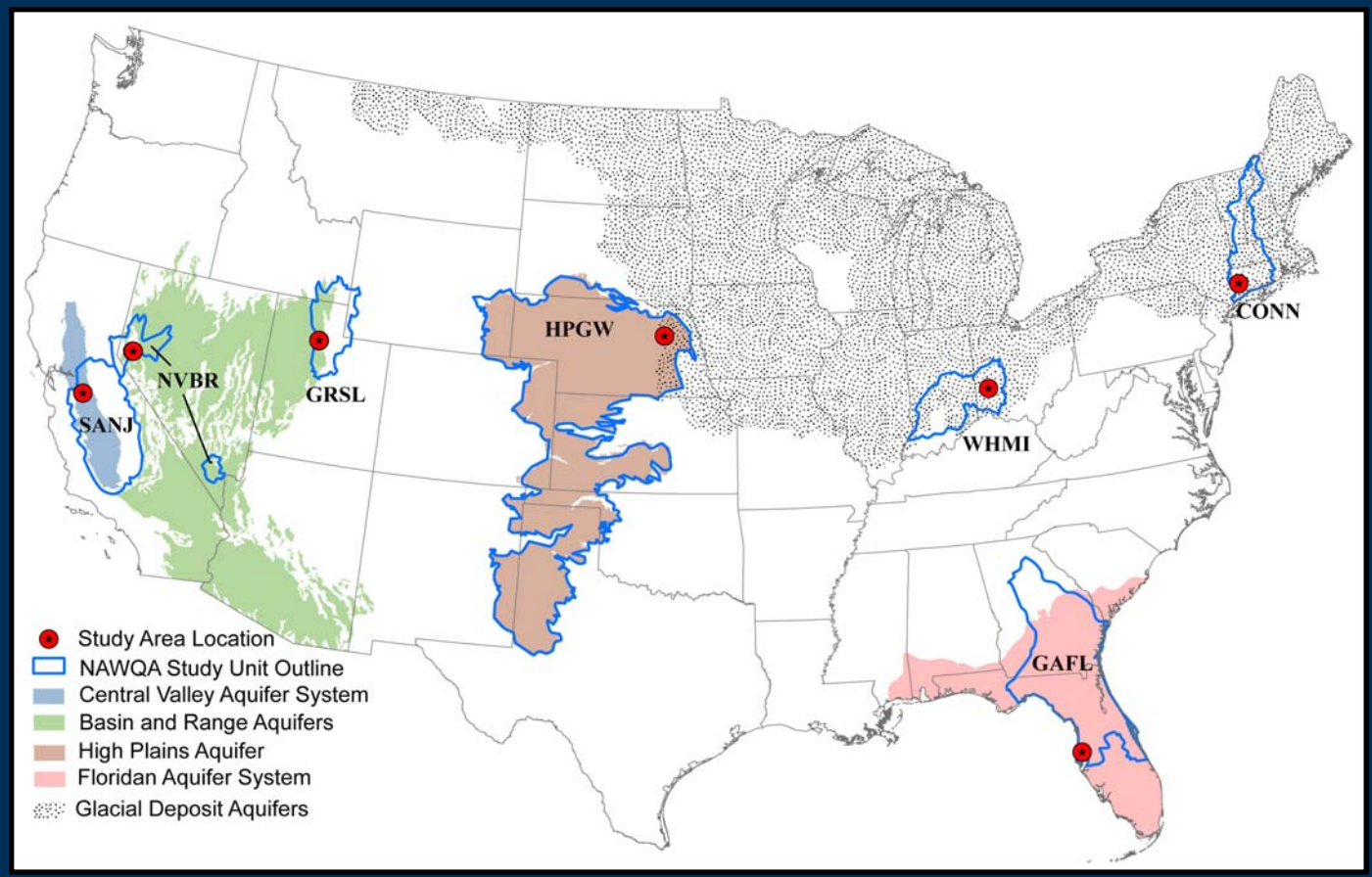
Occurrence

USEPA MCL Exceedances
(Public Supply Wells with Particle Tracking):

As: 12% of wells

U: 8% of wells



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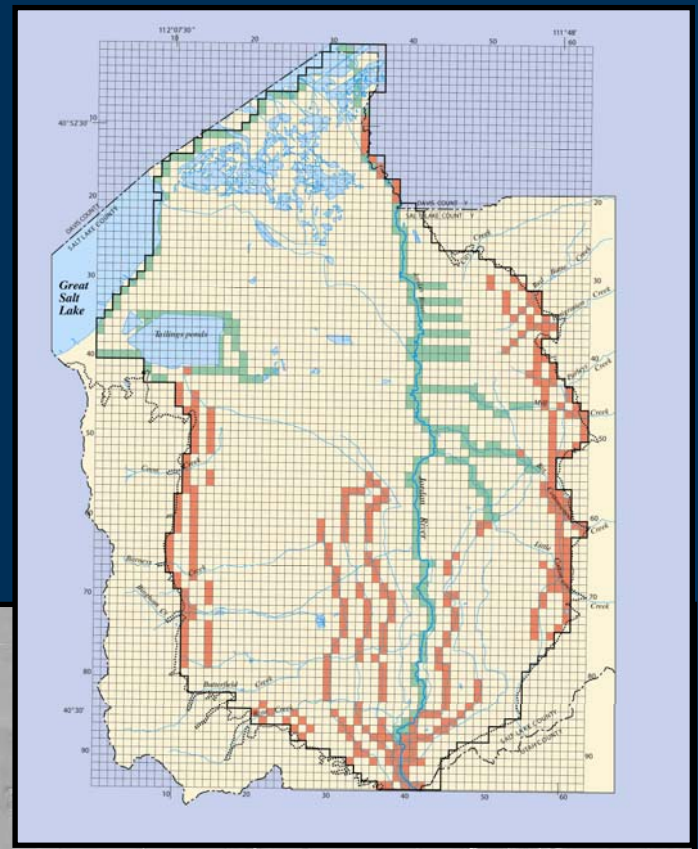
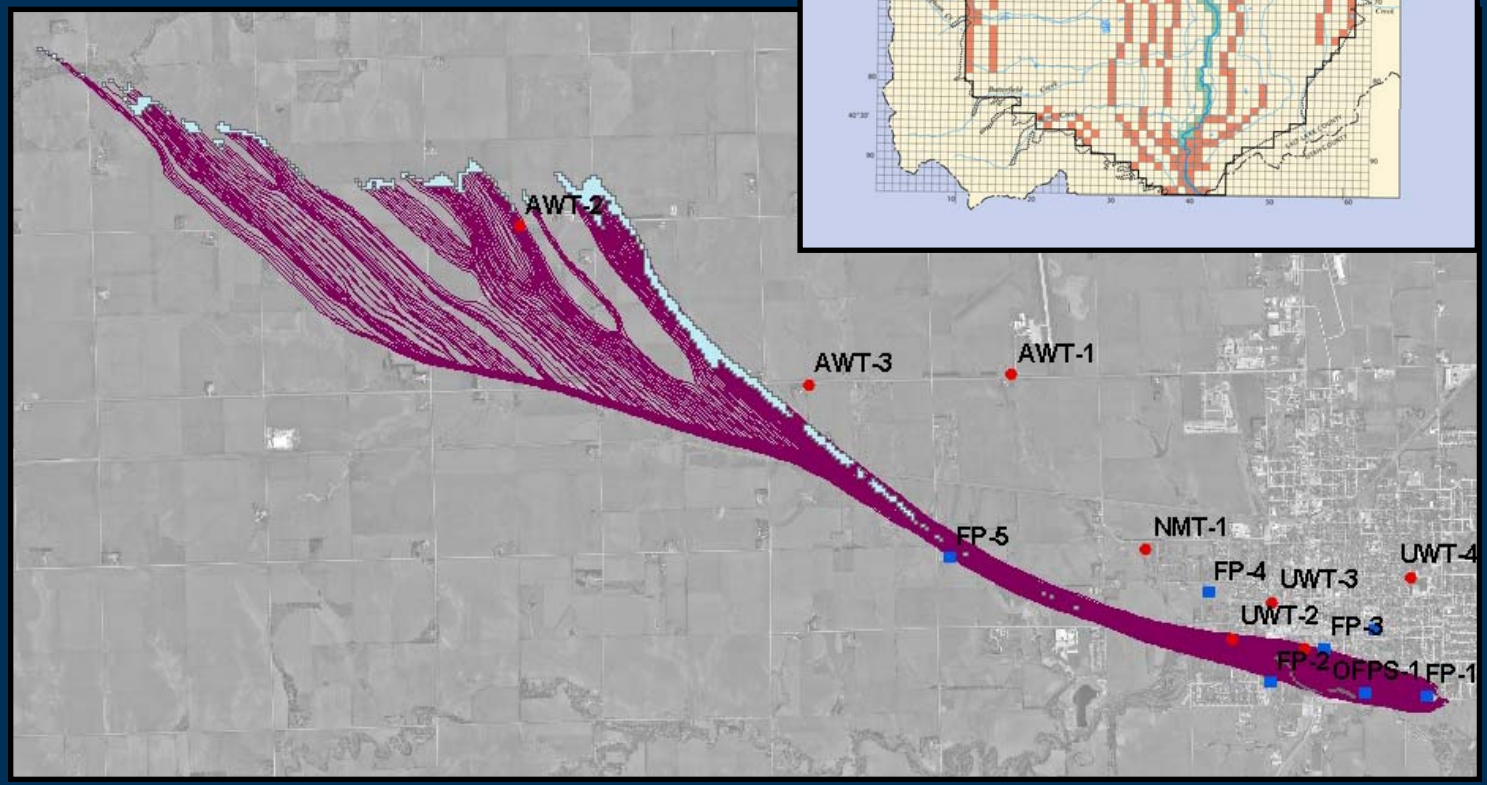
Time of Travel

- Flow Modeling
- Particle Tracking





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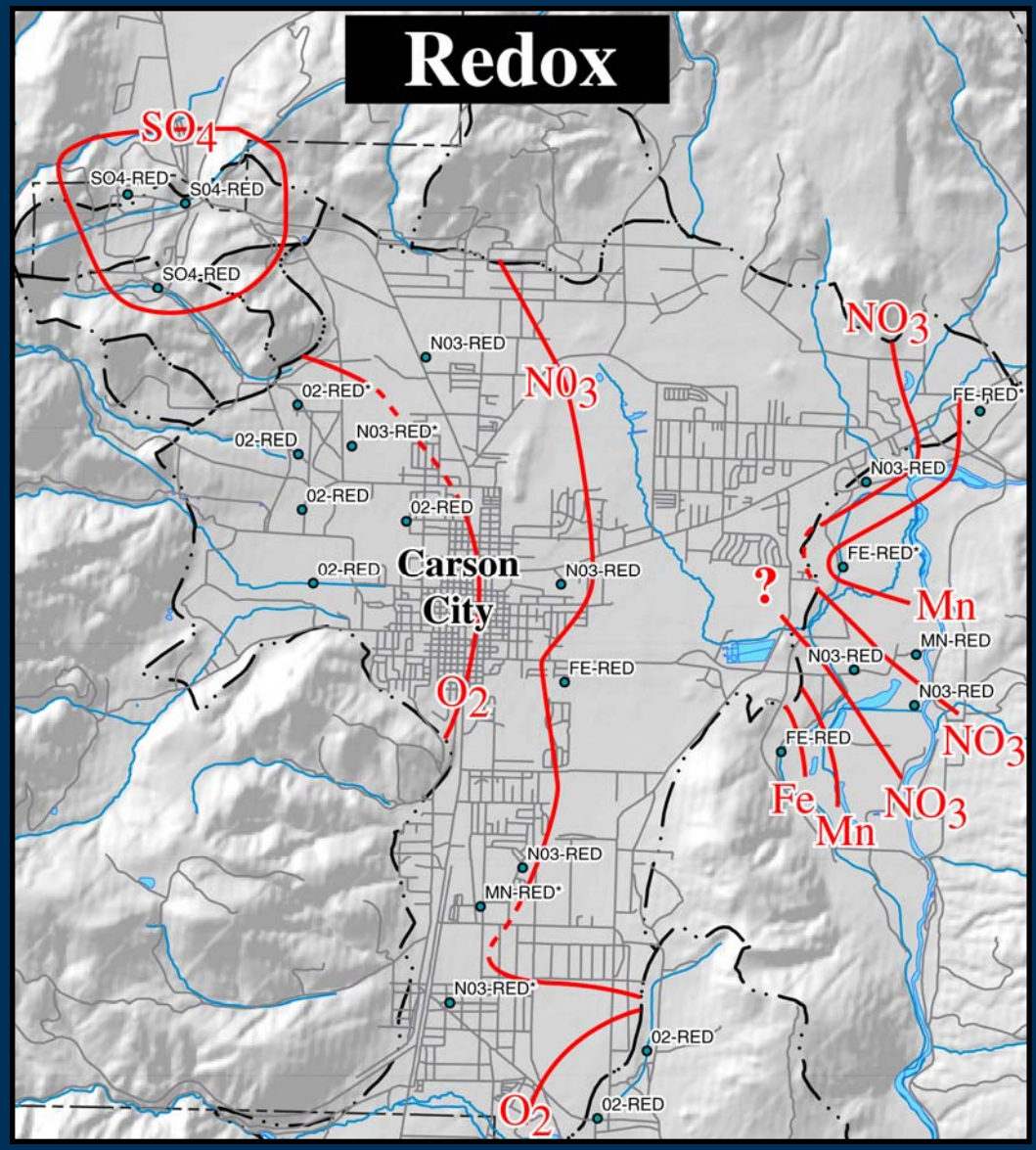
Redox zonation

Particle tracking to simulate

- **Time-of-travel**
- **Flux**

Through different redox zones



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Variables

- Time-of-travel and flux variables
  - Including geochemical-zonation-based variables
- Aqueous geochemical variables
- A set of general solid-phase trace-element variables

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Principal Components Analysis

- Objectively reduce a large number of variables to a few principal components that capture much of the total dataset variability
- Identify associations among variables

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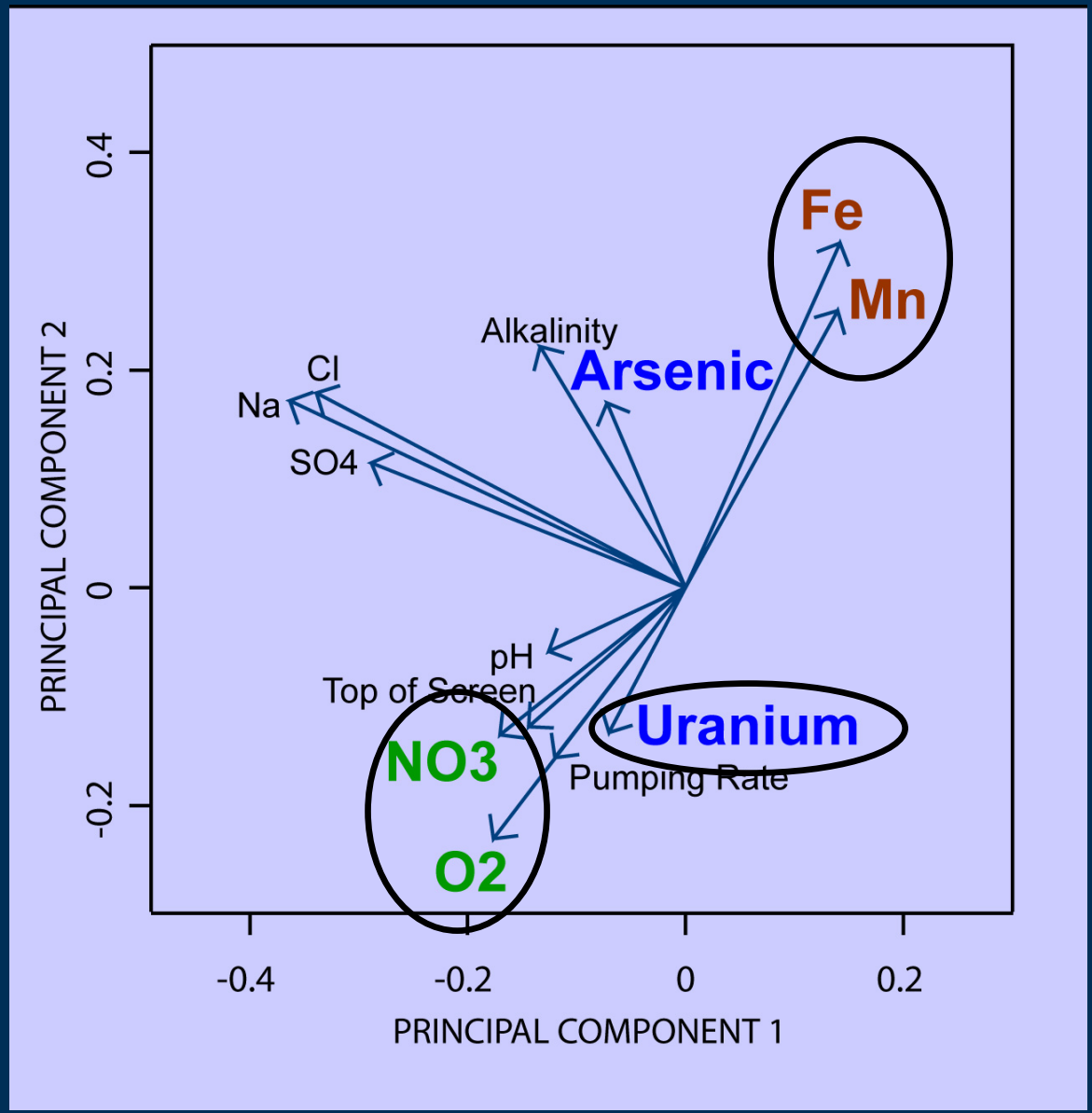
Principal Components Analysis

Uranium is associated with oxidizing variables



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Uranium mine

Bradford Canyon, San Juan County, Utah

Redox controls uranium attenuation

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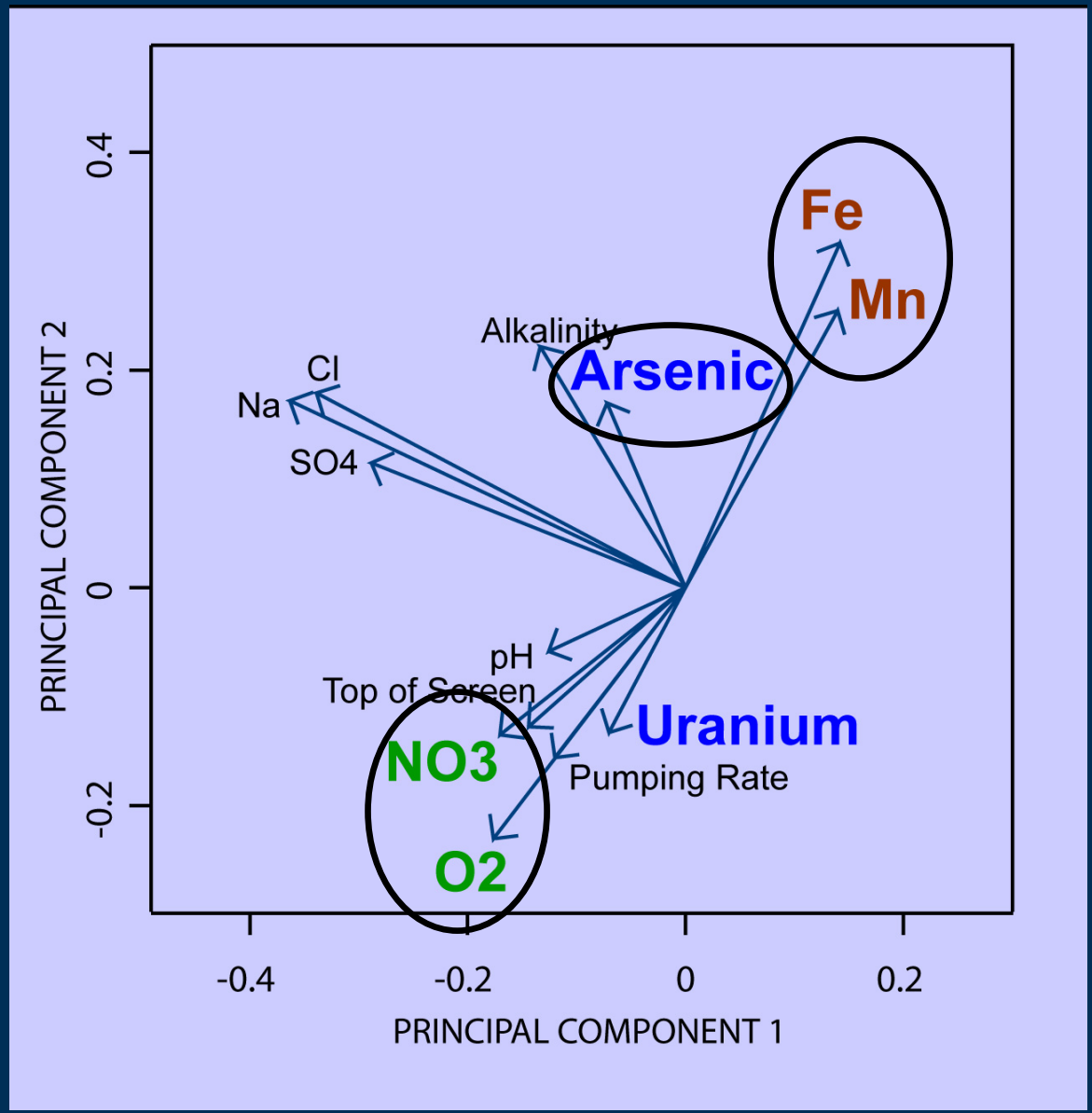
Principal Components Analysis

In the combined dataset, arsenic is not associated with a dominant redox group



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Spearman Correlation Analysis

A nonparametric correlation analysis to evaluate monotonic correlations that are nonlinear

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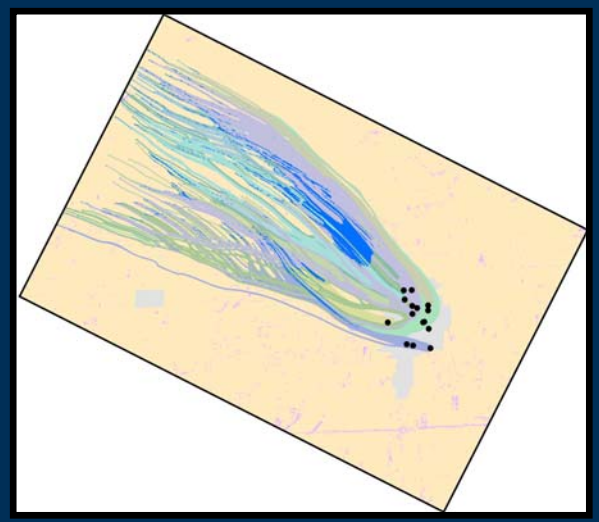
Spearman Correlation Analysis

- Uranium and arsenic concentrations significantly correlated with many particle-tracking variables
- For example, particle-tracking variables for arsenic (positive correlations; $p < 0.05$):
  - Mean and median time of travel
  - Minimum and maximum time of travel
  - Percent of simulated well inflow with time of travel > 200 years
- Time-of-travel variables important because many geochemical reactions are kinetically limited



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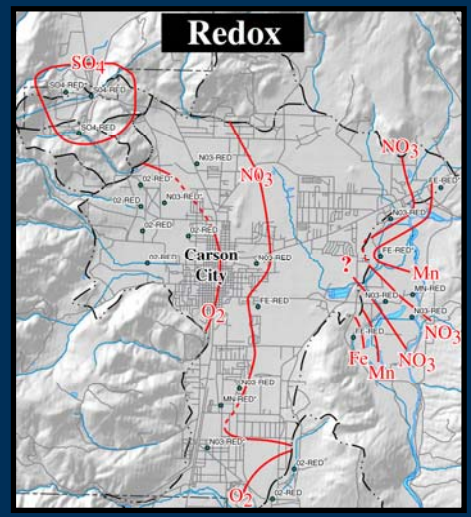
Spearman Correlation Analysis

- Uranium concentrations also were significantly correlated with time-of-travel variables computed for different redox zones
- Correlations between arsenic and redox-zonation-based time-of-travel variables were clearer at the study-area scale.



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Classification Tree Analysis

- Nonparametric method
- Dataset is partitioned recursively into increasingly homogeneous subsets
- Schematically resemble trees, similar to dichotomous classification keys
- Uncover relations that are logical, but difficult to identify with linear statistical models
- Demonstrate a potential application of the use of particle-tracking variables and other predictor variables in vulnerability analysis.

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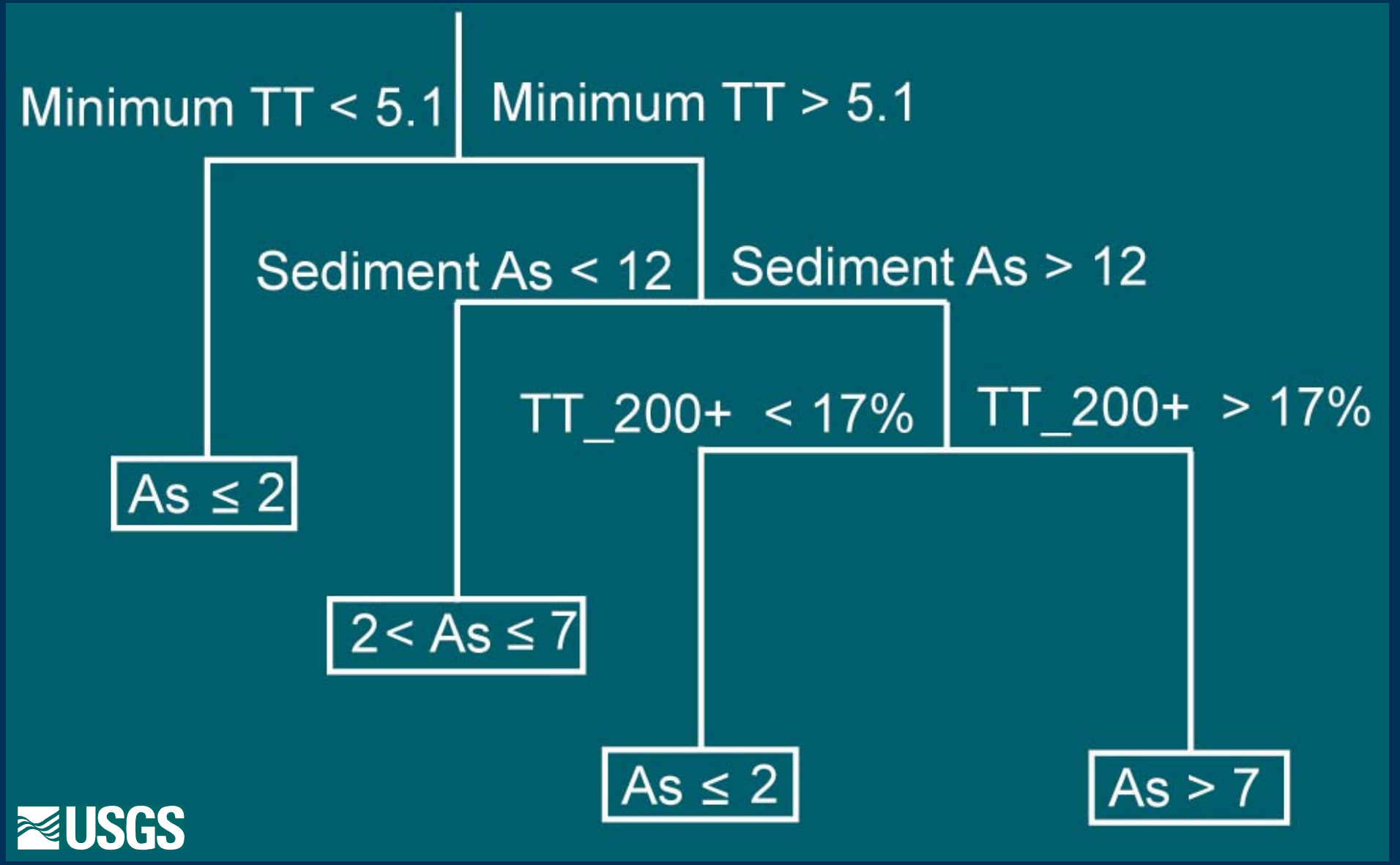
Arsenic Tree

("TT" = simulated time of travel)

Accuracy
70% (building)
79% (verification)



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Conclusions

- In these study areas, older ground water generally is more vulnerable to uranium and arsenic than is younger ground water

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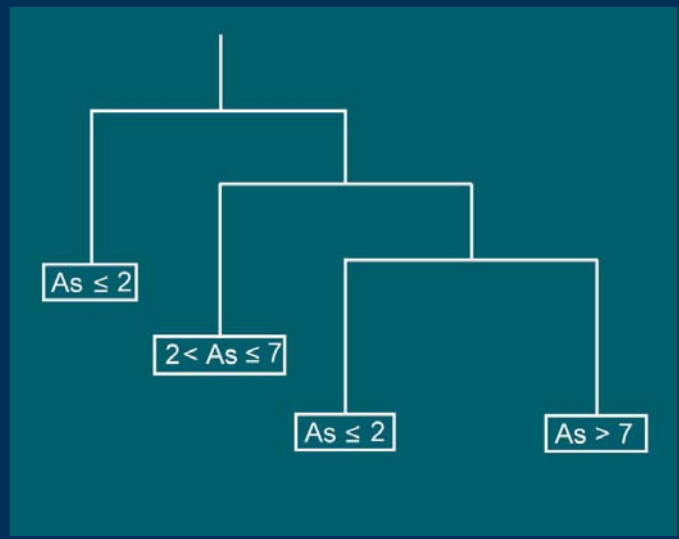
Conclusions

- **Particle-tracking variables can be used in simple statistical models for screening-level analysis**



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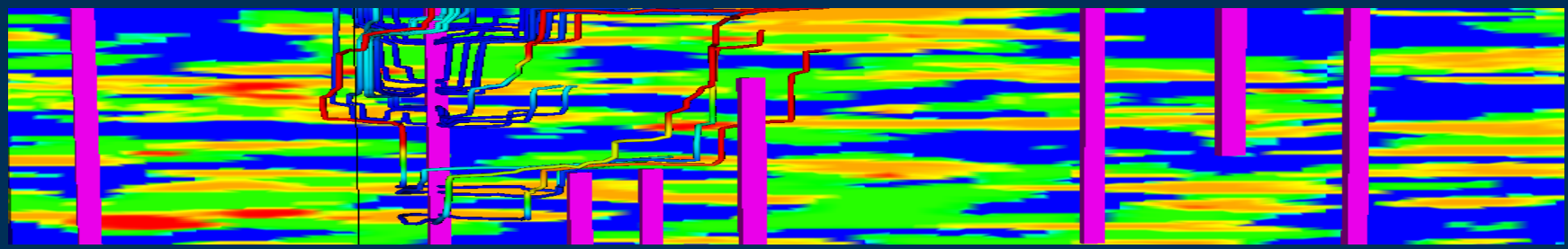
Conclusions

- Such simple models can serve as a basis for prioritizing the locations and guiding the types of more refined, site-specific vulnerability assessments that may be needed at smaller spatial scales



High-resolution particle tracking to a public supply well, Modesto, CA

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