U.S. DEPARTMENT OF ENERGY | Legacy Management

Secondary Uranium Sources Remain in the Unsaturated Zone After Tailings Removal: Now What?

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Battelle 2024 Remediation of Chlorinated and Recalcitrant Compounds

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Outline

DOE LM Mission: Protect human health and the environment, for groundwater, often done through institutional controls

- Background:
  - Tailings removal
  - Plume persistence
  - Secondary uranium sources
- Unsaturated zone uranium release rates
  - Column data
  - Field-scale data
- Results: Long time frame for natural flushing (or monitored natural attenuation)
- What's next?: Evaluation of other remedial options with reactive transport modeling

Uranium in the unsaturated zone can be very complicated.

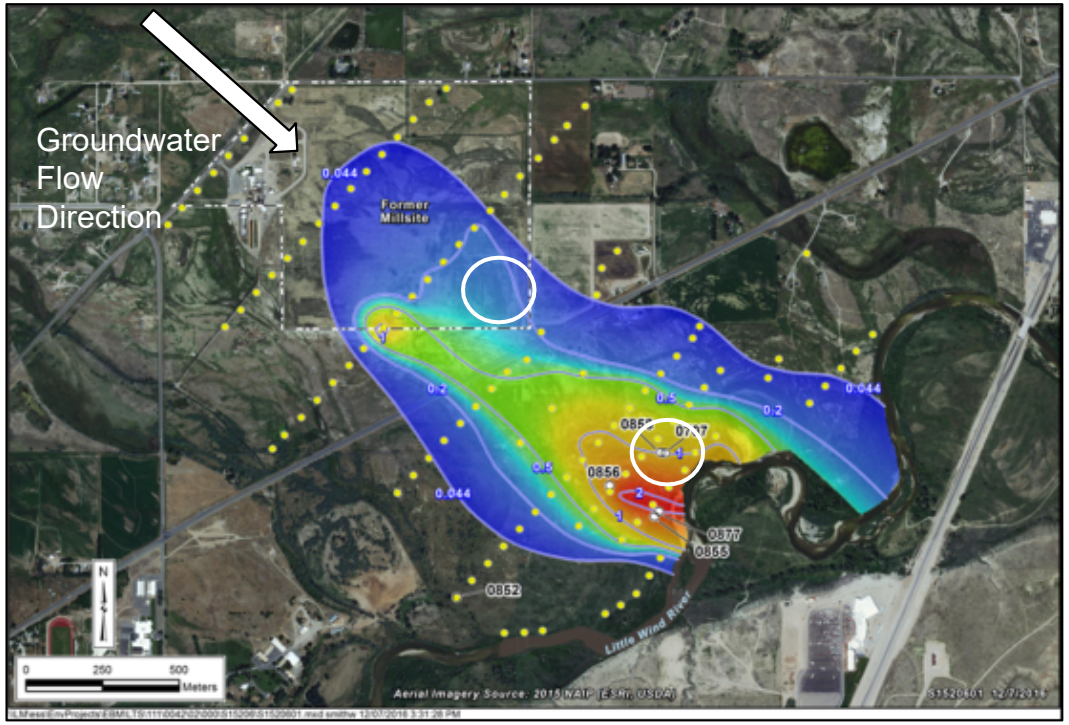
Uranium Tailings Management in the United States

- In 1978, remediation of 22 mill tailings sites became the responsibility of the U.S. Department of Energy (Title I)
  - Eleven sites had tailings moved to a disposal facility
  - For six sites, a 100-year natural flushing period (monitored natural attenuation [MNA]) is in place or proposed, as allowed by a 1995 U.S. Environmental Protection Agency (EPA) decision
- All other licensed mill tailing sites eventually transfer to the Office of Legacy Management for long-term care and maintenance **after remediation is deemed complete** (Title II)

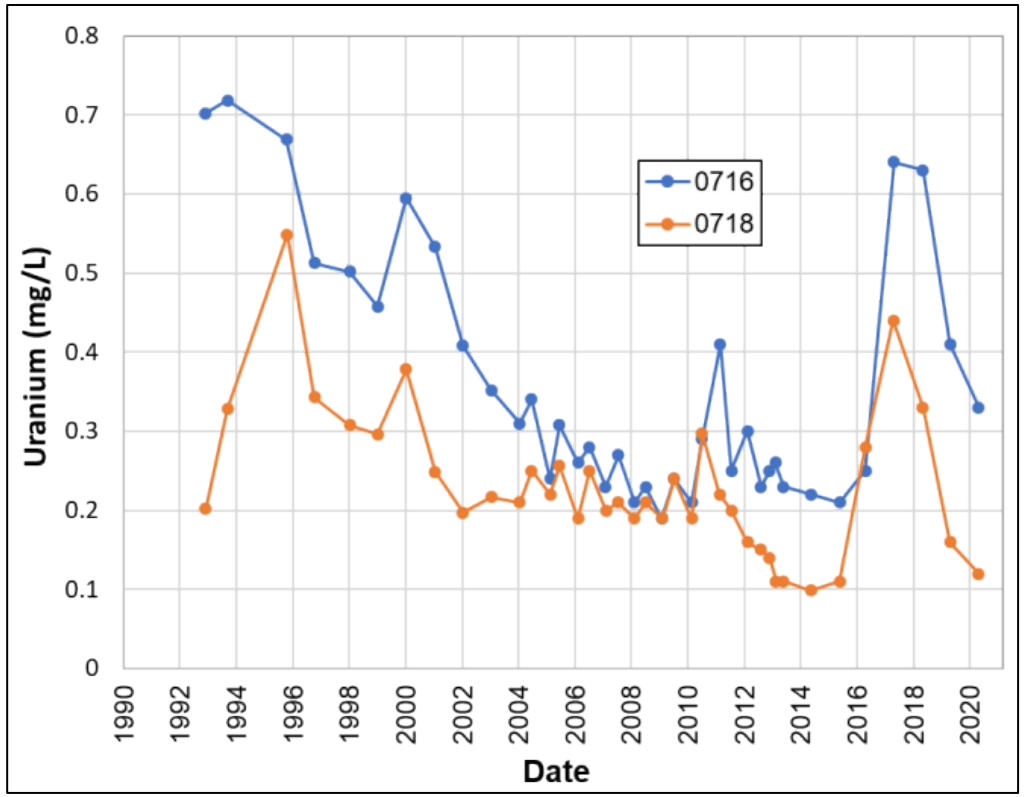
Riverton, Wyoming, Processing Site

Gas Hills, Wyoming, Disposal Cell

Moving a Tailings Impoundment ≠ Clean
Plume Persistence = Remaining Sources

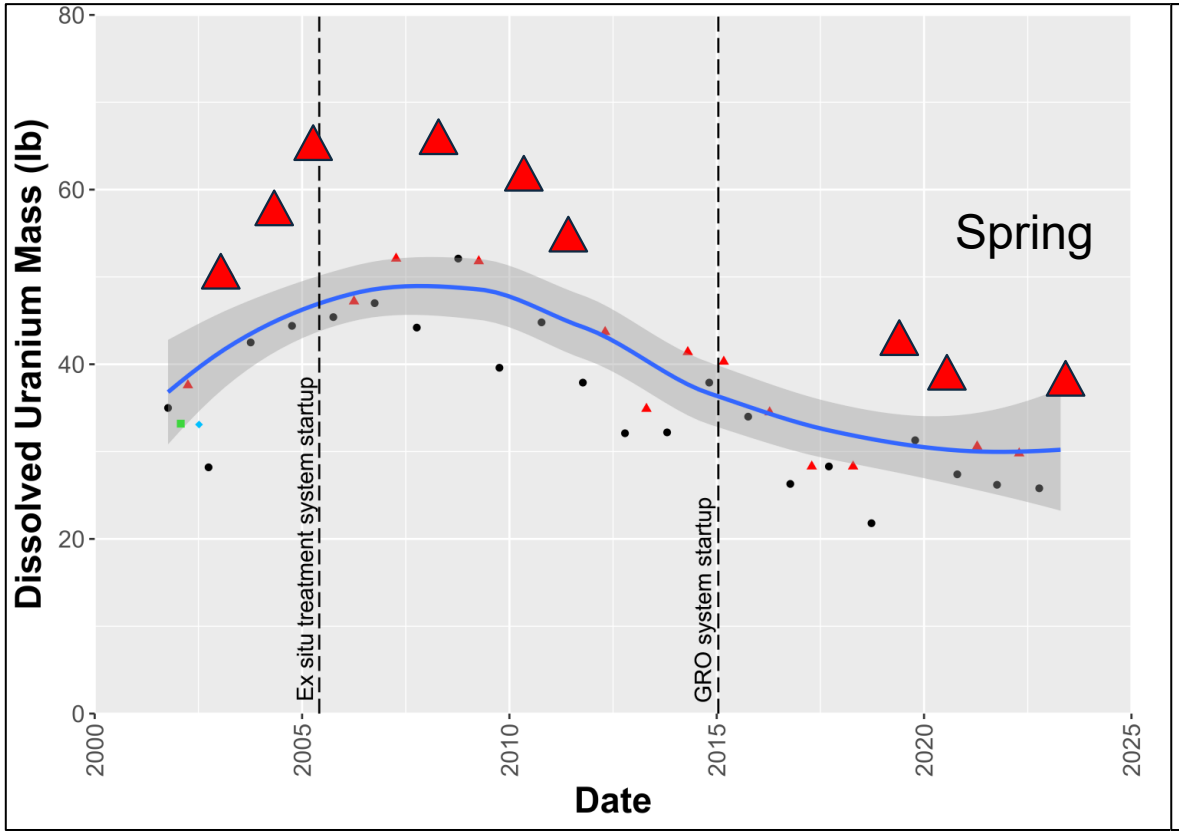


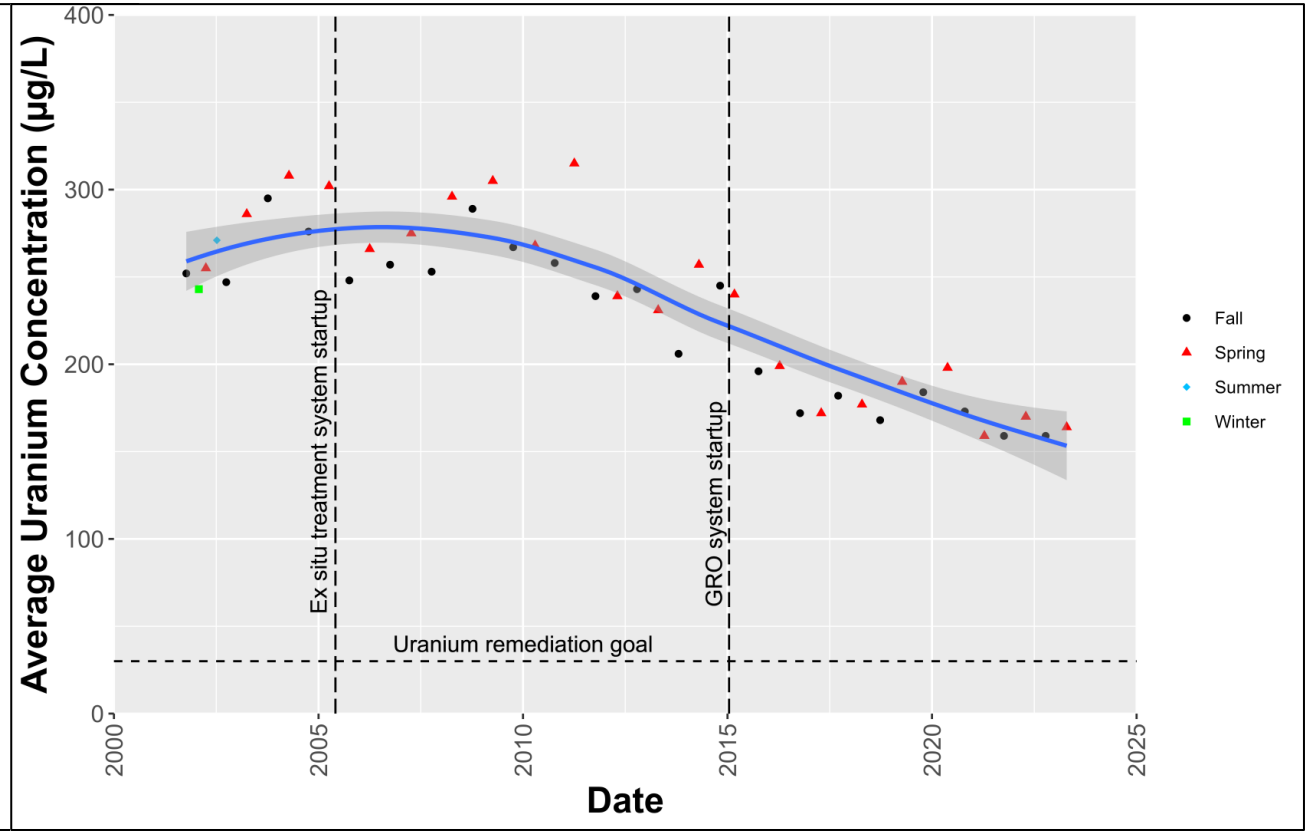
2015 Riverton Uranium Plume



YES, secondary uranium sources in the unsaturated zone

Seasonal Unsaturated Zone Uranium Release



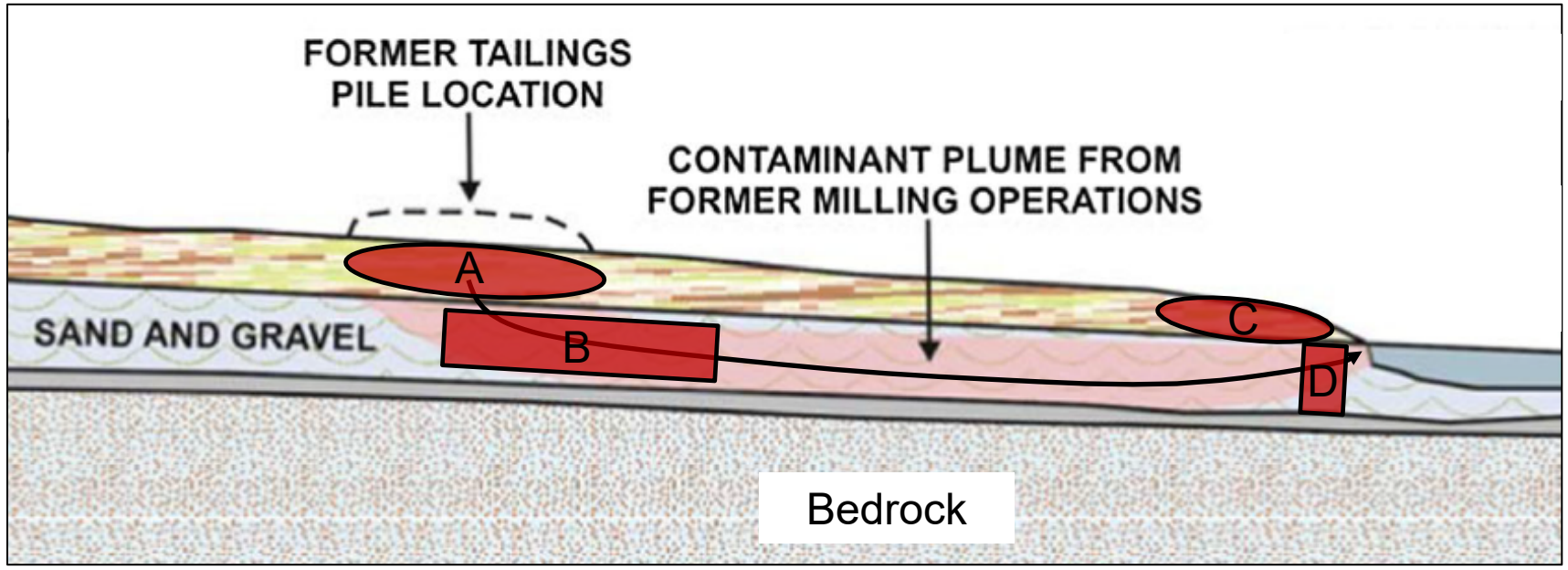


YES, secondary uranium sources in the unsaturated zone

Where Are the Secondary Uranium Sources?

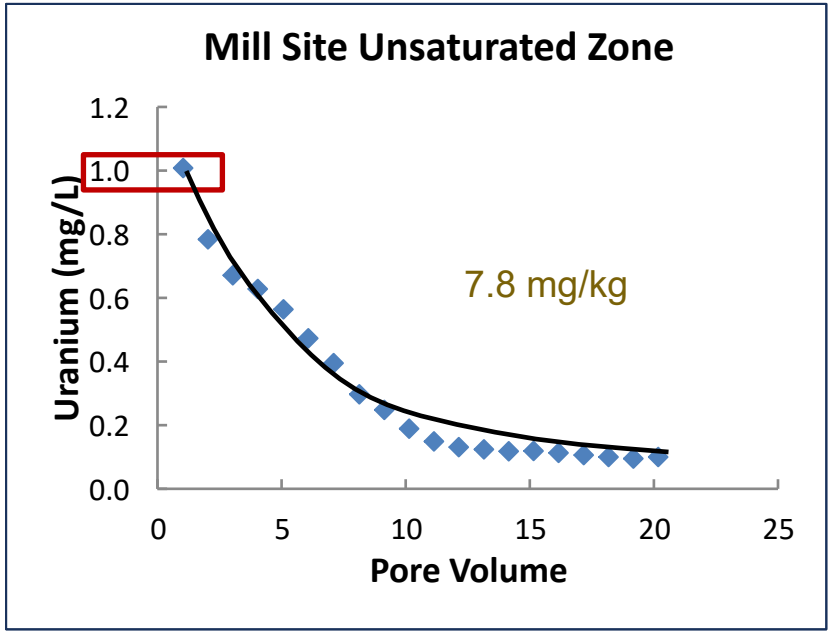
- Quantified by drilling and solid-phase sampling
  - Residual below former tailings
  - Saturated zone below former tailings
  - Downgradient, above shallow plumes, areas with high evapotranspiration
  - Downgradient with high organics (naturally reduced zones)

Coring for solid-phase sampling

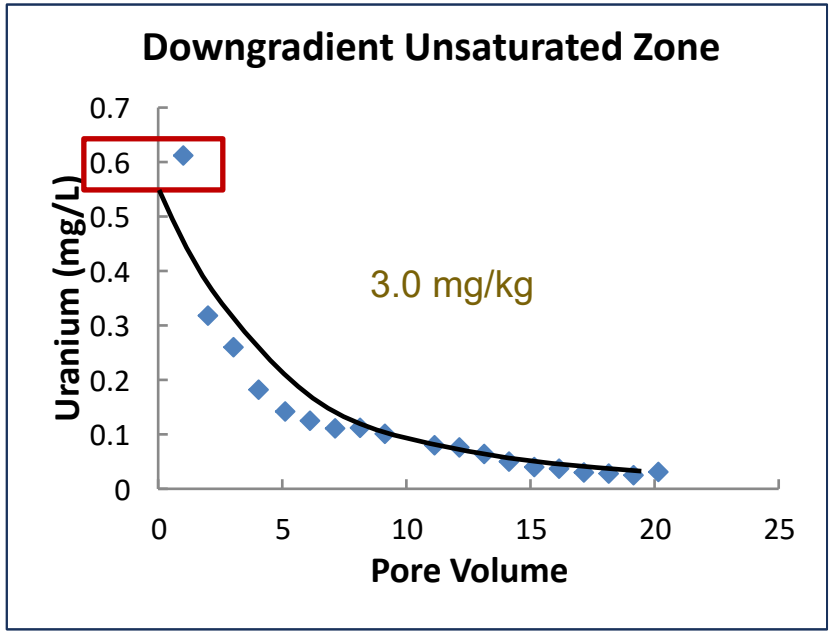


Uranium Release Rates Using Column Data

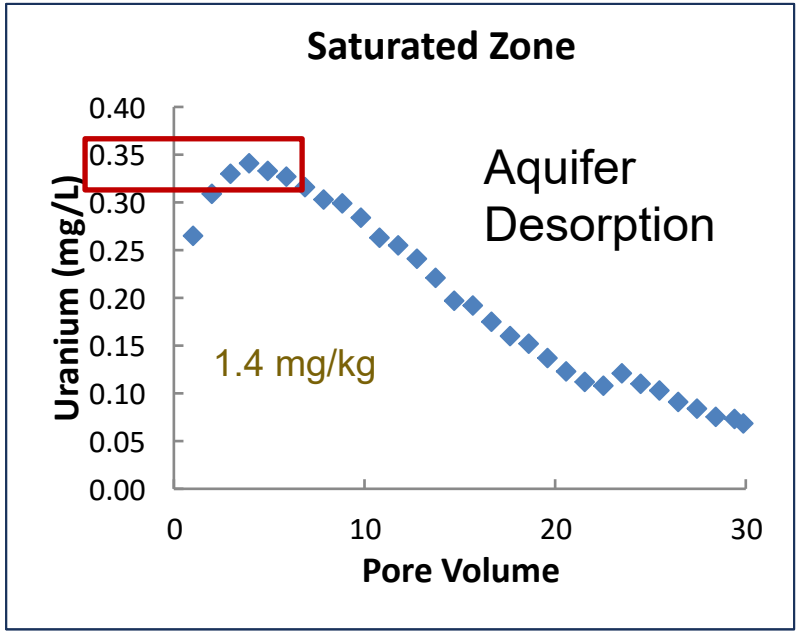
- Unsaturated zone: exponential decay or geochemical modeling
- Saturated zone: equilibrium sorption (K_d) or geochemical modeling



Influent = deionized (DI) water

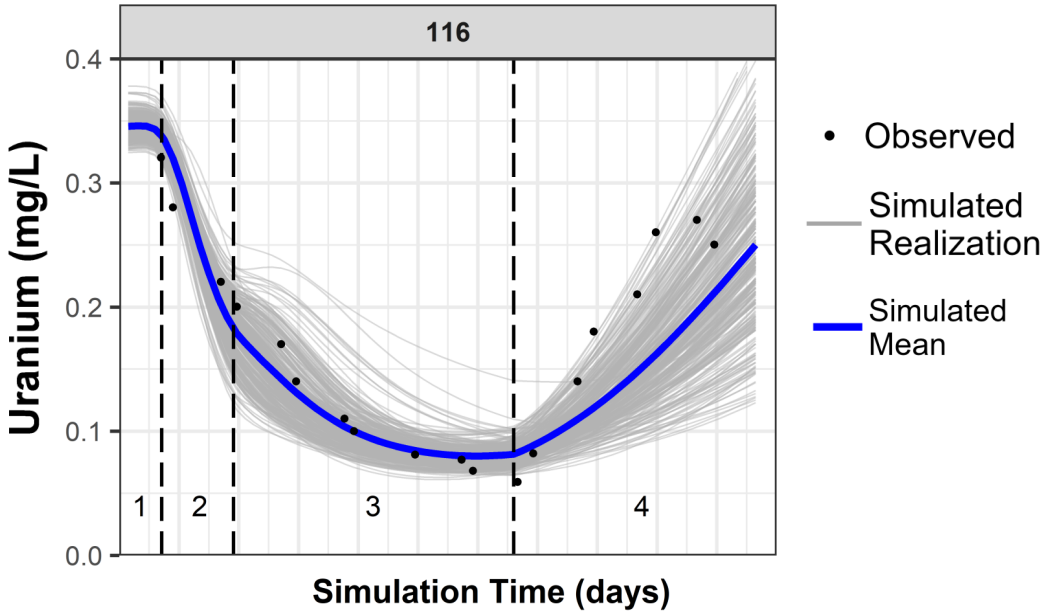


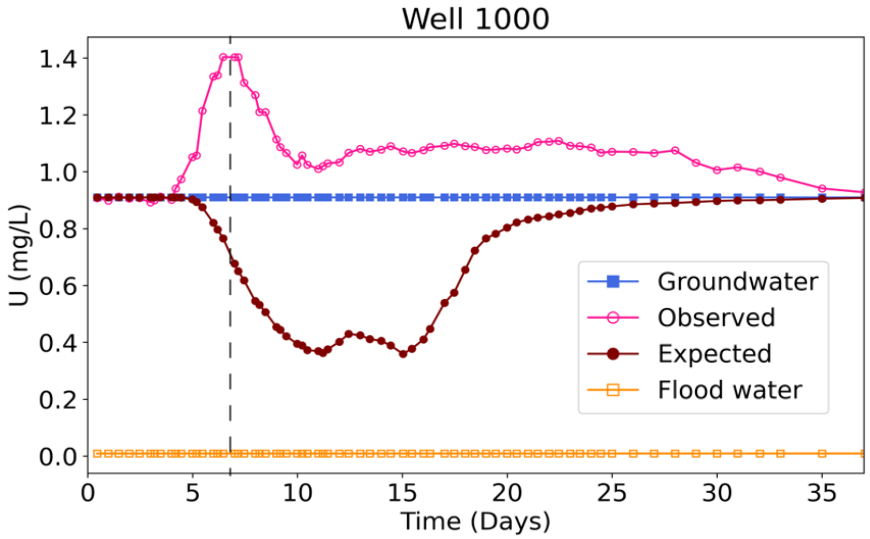
Influent = DI water



Groundwater influent

Uranium Release Rates Using Field Tracer Testing





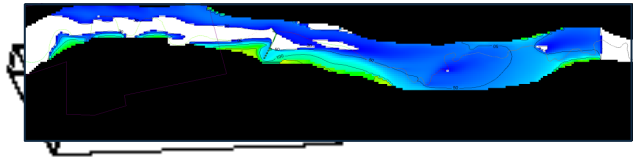
Summary of Steps

Amount of uranium

Uranium release rates

Input

Sitewide Reactive Transport Model (RTM)



With saturated zone transport

Use RTM for predictions, remedial scenarios, and decisions

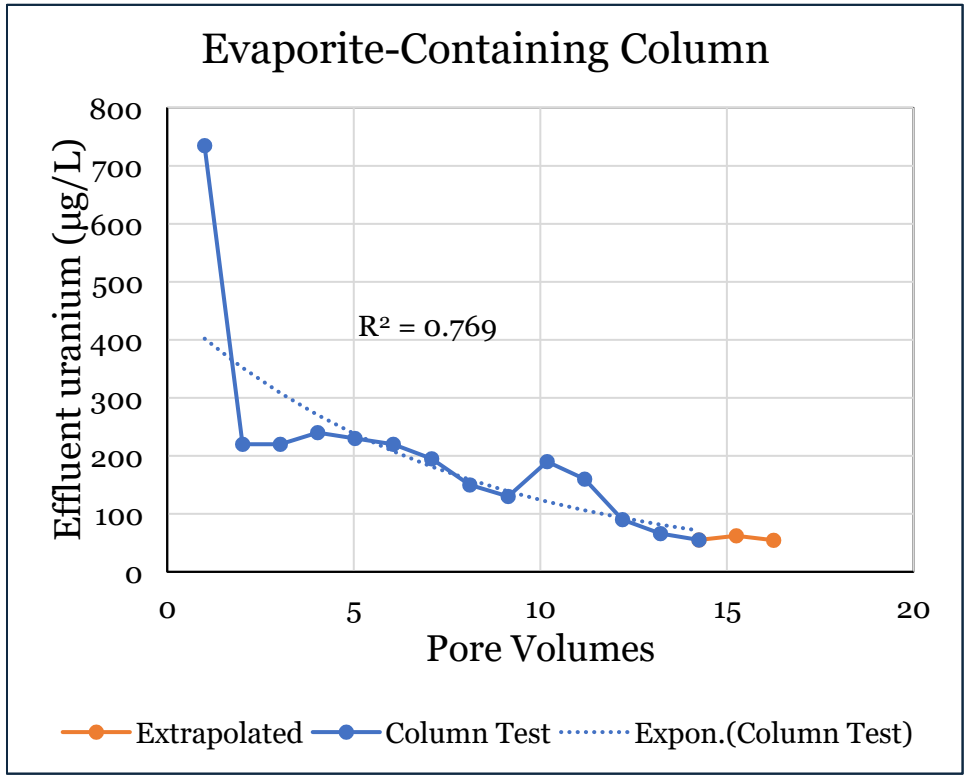
Two Site Examples

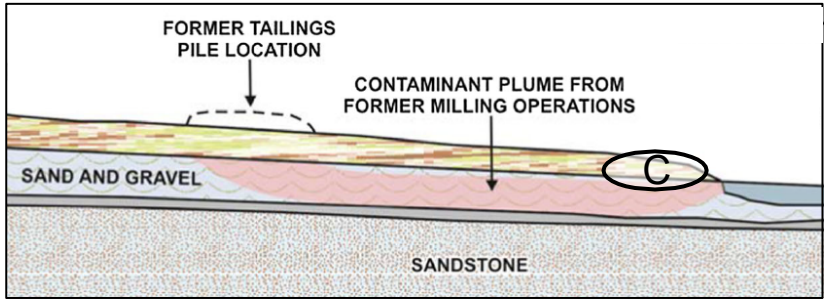
Riverton, Wyoming, Processing Site

Monticello, Utah, Processing Site

Riverton, Wyoming, Processing Site

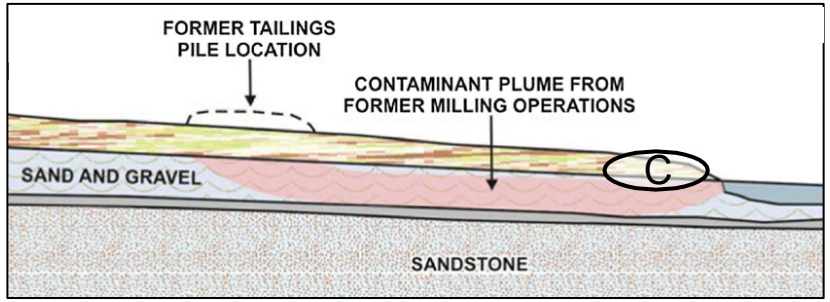
- Use mass balance and release rates from columns
- 3 mg/kg of “excess” uranium produces 0.74 mg/L of uranium in column effluent





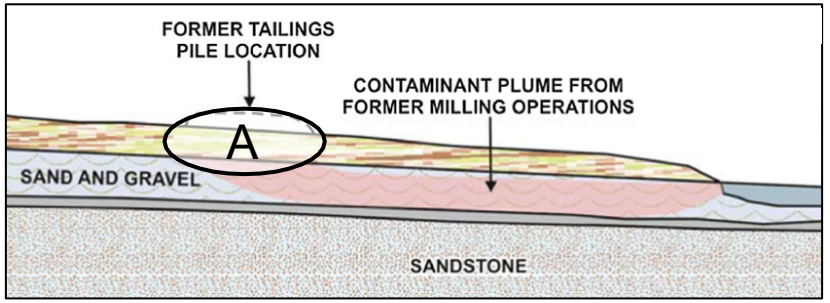
Riverton (continued)

- Evaporites with uranium near the river are released with flooding events, and can get re-emplaced
- Lot of uncertainty (how often, how big of an event?)
- This is in addition to 190 years of saturated source zone flushing (based on residual saturated zone mass and release rate)
- Estimate of over 300 years for natural flushing.
- Next step — sitewide RTM, then use for decision making.



	Flushing Times (years)		
	10 yr, 0.5 PV	**5 yr, 1 PV**	**2 yr, 2 PV**
Uranium	450	110	22

Monticello, Utah, Processing Site

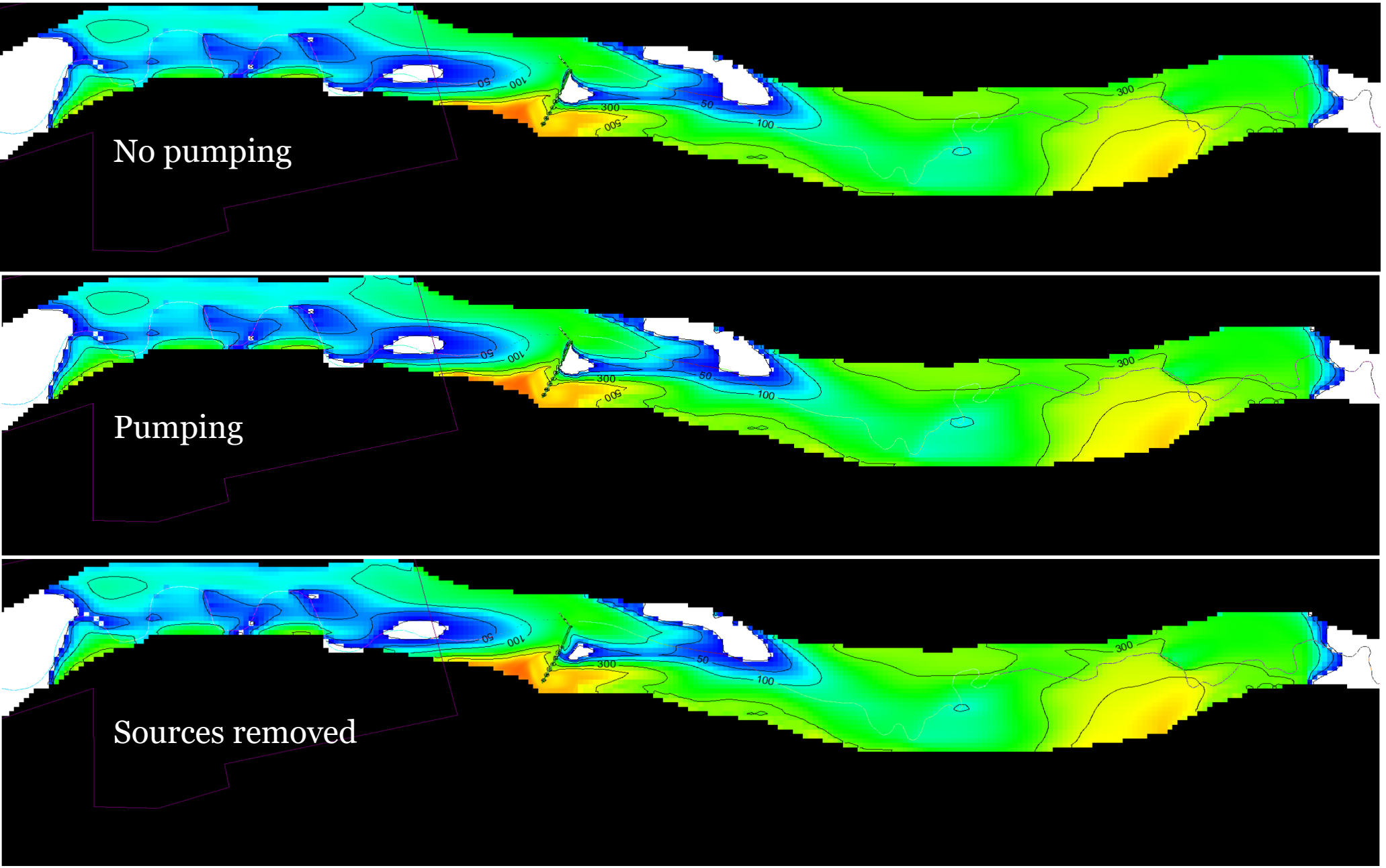


- Prior model with no residual sources: MNA in ~ 40 years
- Updated with secondary source in the unsaturated zone **(40% of remaining mass)**: MNA is 1,500-3,200 years
- Current site remedy — 30 years of pumping
  - Does it help? Can we stop pumping?
  - Need to move more dirt?

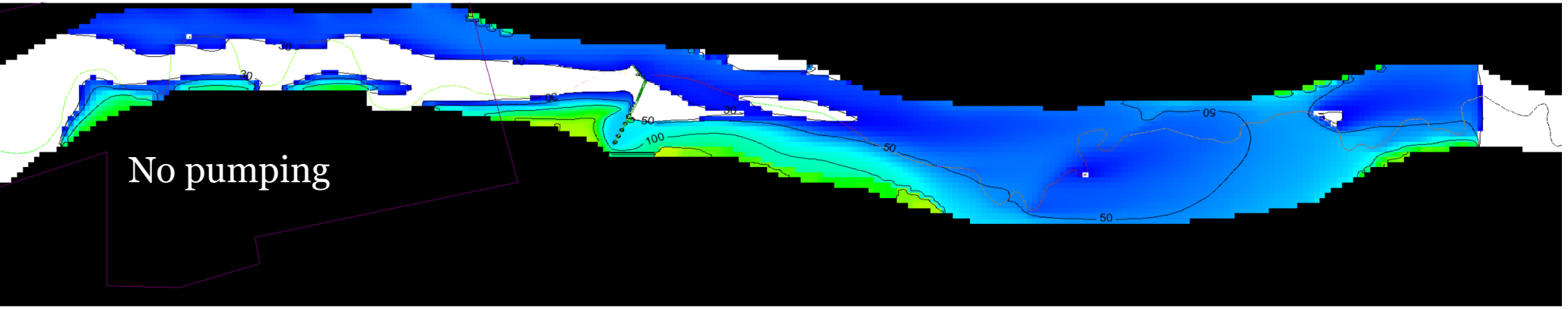
Monticello site before remediation

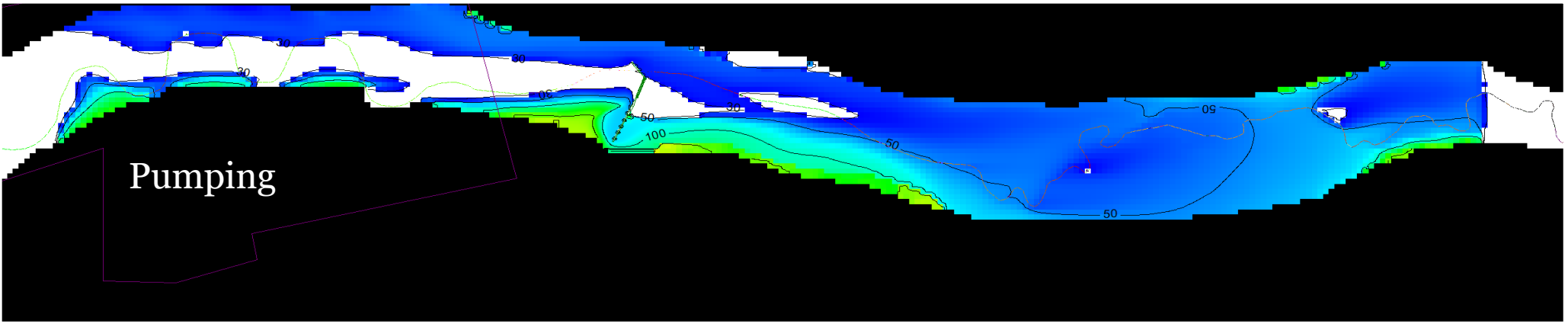
Tailings being moved

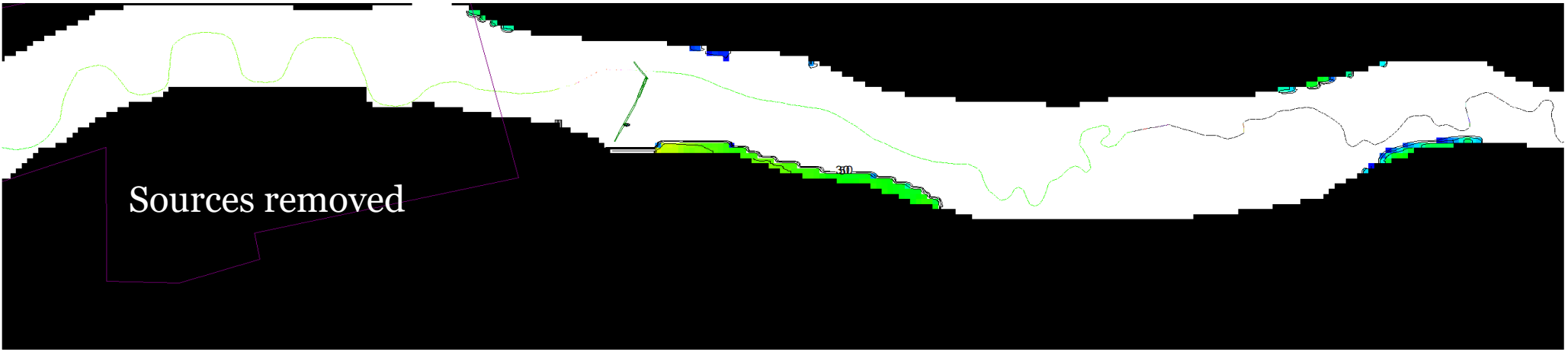
Current

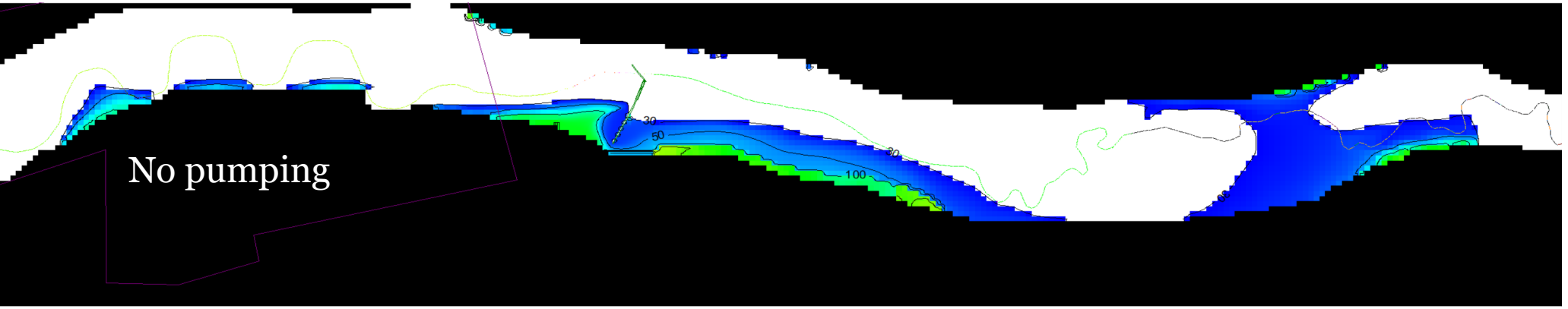


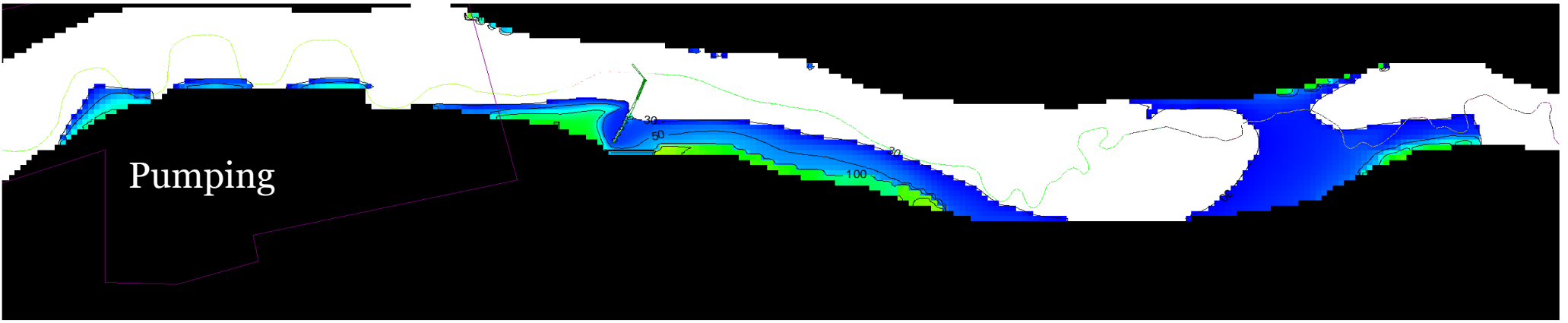
500 years

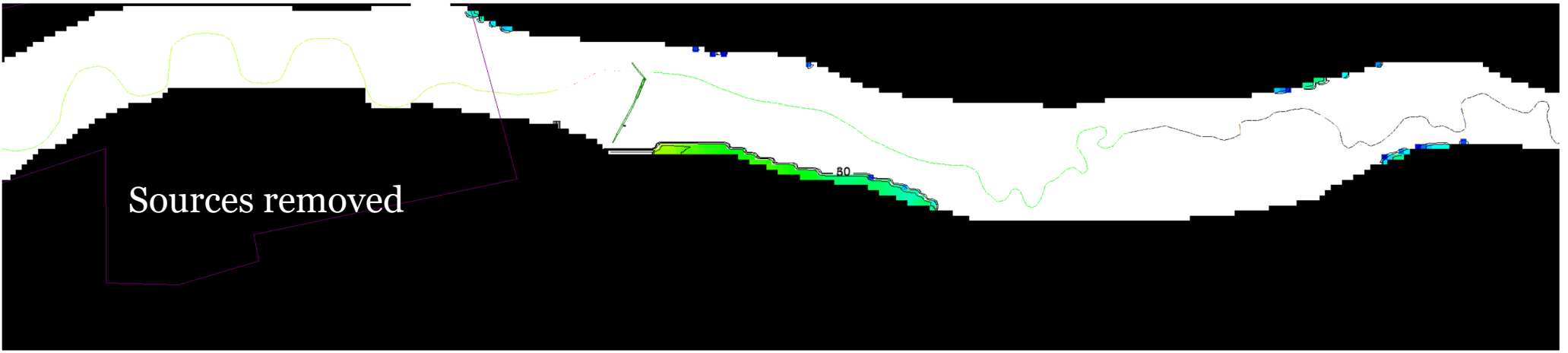






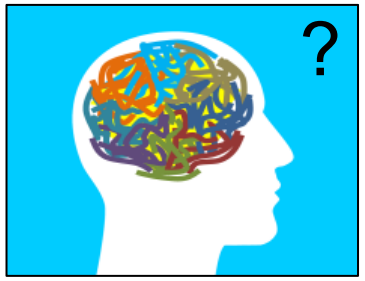






1,000 years

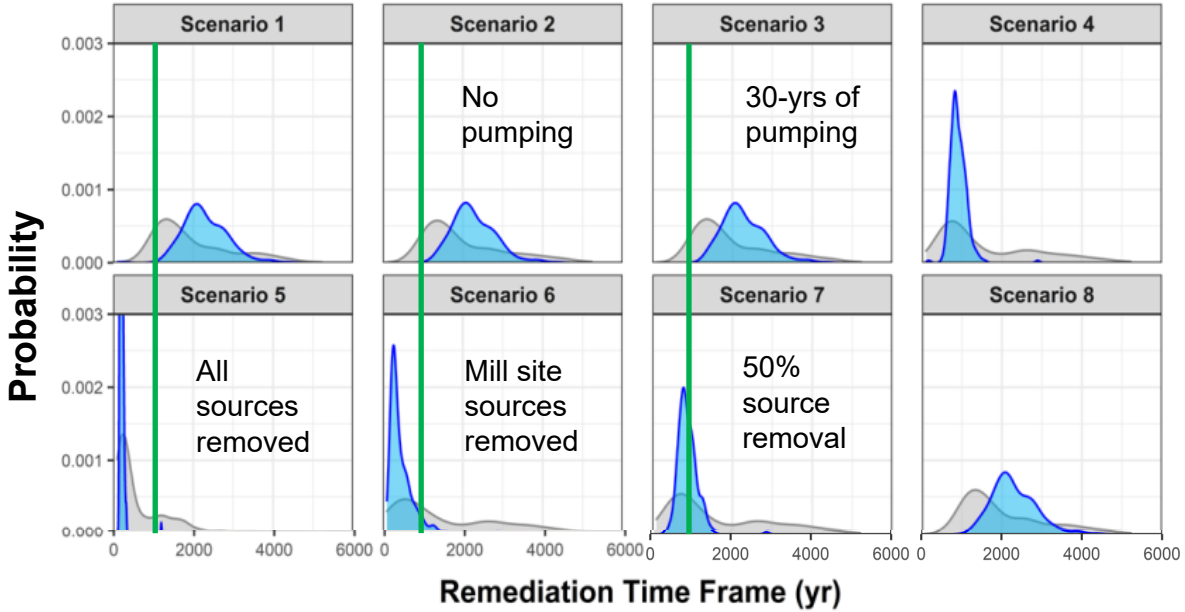
What's Next: Remedial Options to Consider



- Can't pump it out until it gets to the saturated zone!
- Continue MNA with long-term institutional controls
  - What is a reasonable time frame?
  - Need a thorough risk assessment
- Dig it up and remove the source
  - Cost vs. benefit?
- Mobilize it
  - Unsaturated zone heterogeneity
  - What if 80% removal, but last 20% is enough to exceed groundwater standards?
- Fix it in place (strong sorbent or precipitate as a mineral)
  - Unsaturated zone heterogeneity
  - Any long-term release?

What's Next: Our Approach

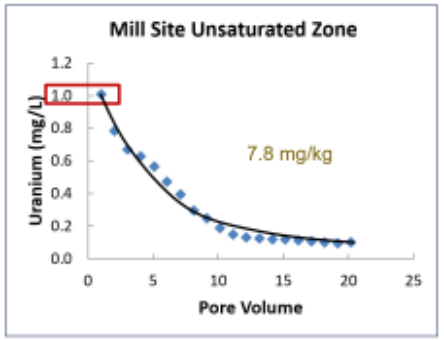
- Test remedial options with reactive transport models
- Include uncertainty analyses, like iterative ensemble smoothing
- Key idea is to look at differences between options, not an exact transport time prediction
- Allows for a focus on cost/benefit analyses and final remedy selection

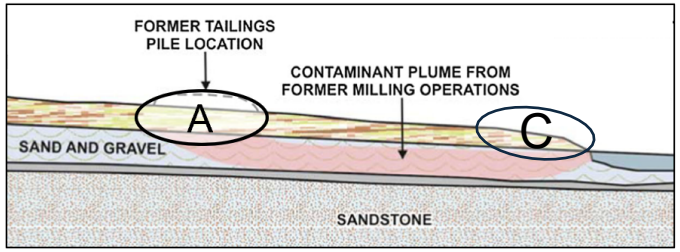


Look at 1,000 years as a decision point

Summary

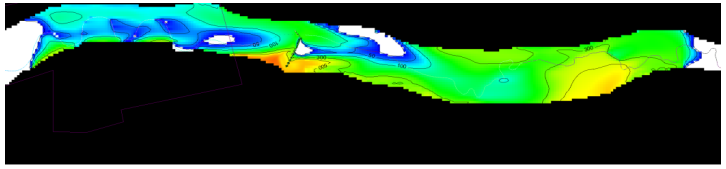
Secondary uranium in the unsaturated zone
=
big time recalcitrant compound





How long for MNA? Need data on amount and release rate.

What's Next?



RTMs to evaluate remedial options

Compare remedies with uncertainties, focus on option differences

Pump

Don't pump

Fix in place

Mobilize

MNA ?

Remove source