From Realizations to Relevance

Ensemble Refinement and Composite Plume Mapping for Contaminant Fate and Transport Modeling

November 5, 2025

RSI ENTECH

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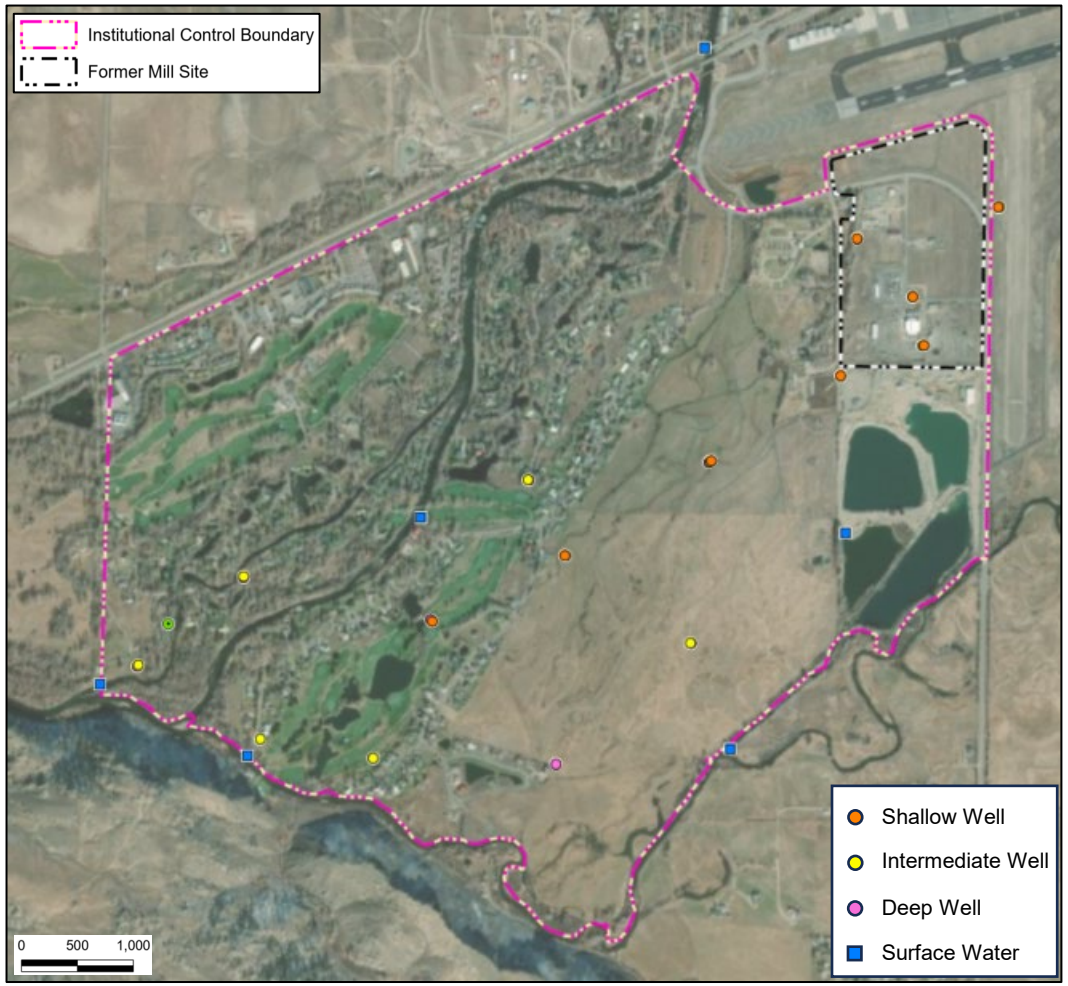
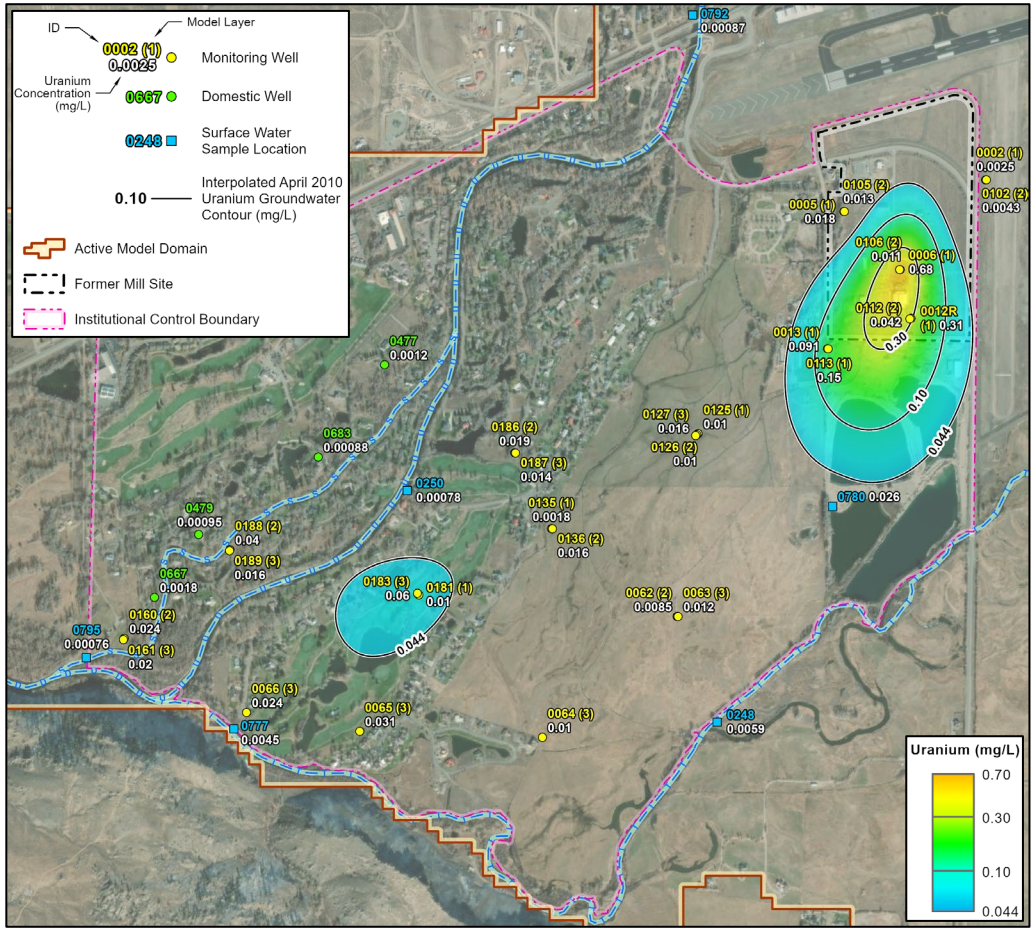
Background



- The mill operated from 1958–1962, processing uranium ore and generating millions of gallons of acidic tailings fluid, much of which infiltrated the underlying alluvial aquifer.
- Surface remediation was completed in 1995, and waste materials were consolidated in an engineered disposal cell.
- Gravel mining near the site has since altered groundwater flow patterns.

Background



- A groundwater model is needed to:
  - improve understanding of site hydrogeology
  - assess plume behavior
  - identify potential secondary uranium sources
  - support long-term compliance decisions
- The current monitoring well network is sparse and spatially-limited.
- Modeling can also inform where additional monitoring is needed.

0 250 500 1,000 Feet

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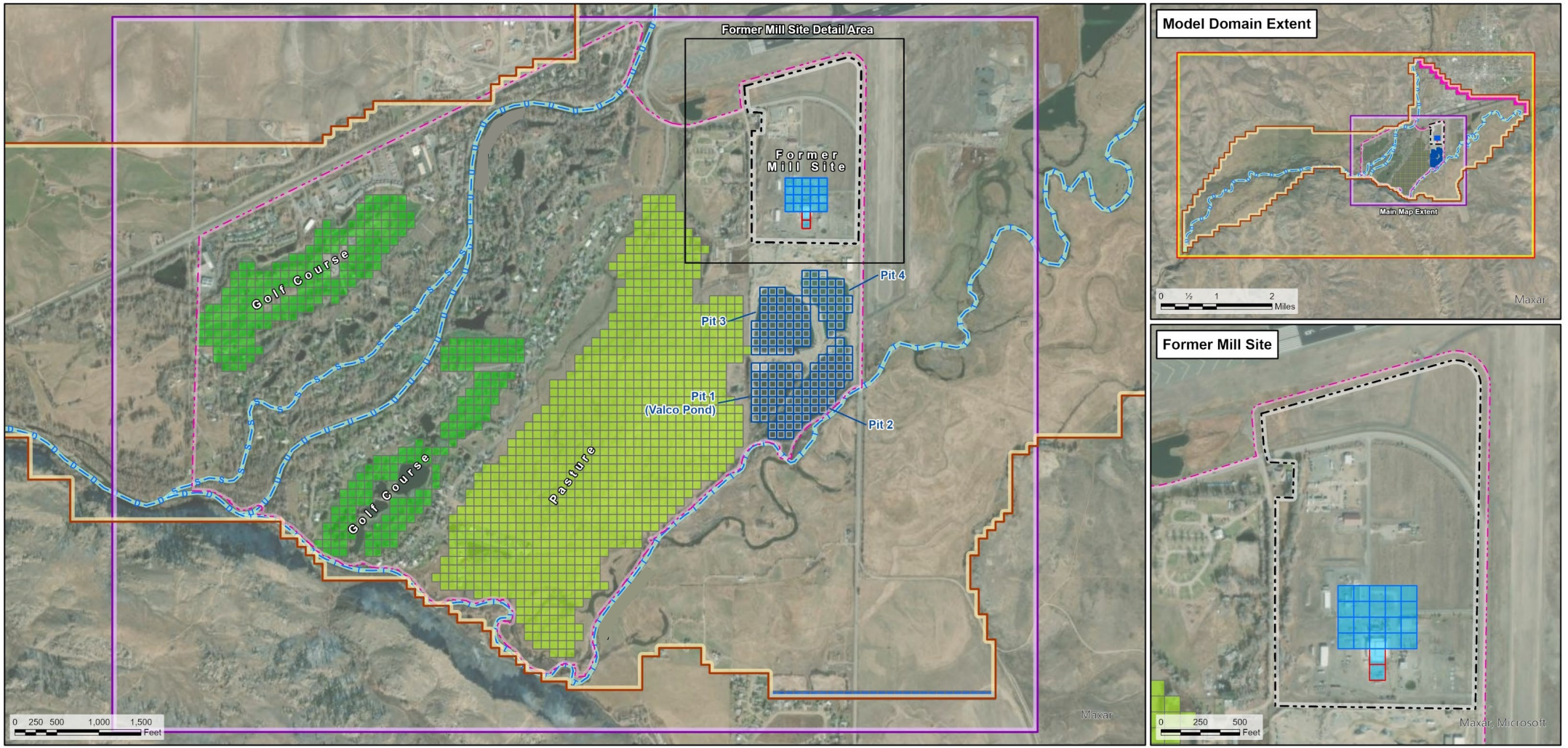
Modeling Approach



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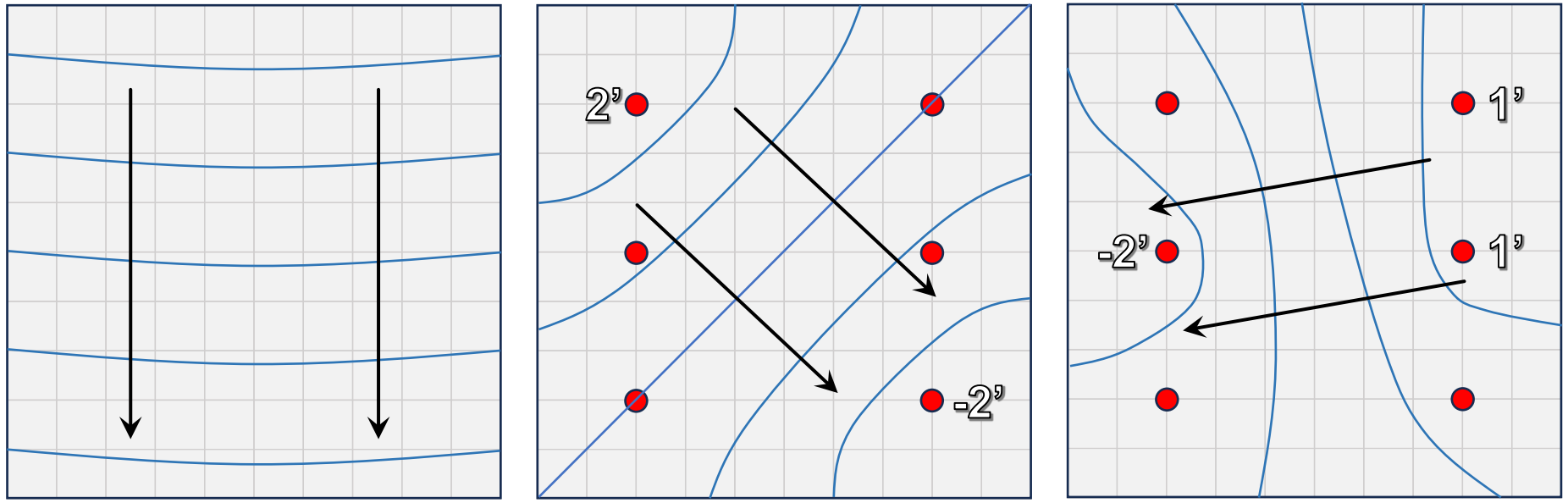
Challenges

Iterative ensemble smoothing (IES) focuses on statistical error reduction, but does not ensure consistent spatial error distribution across the model domain

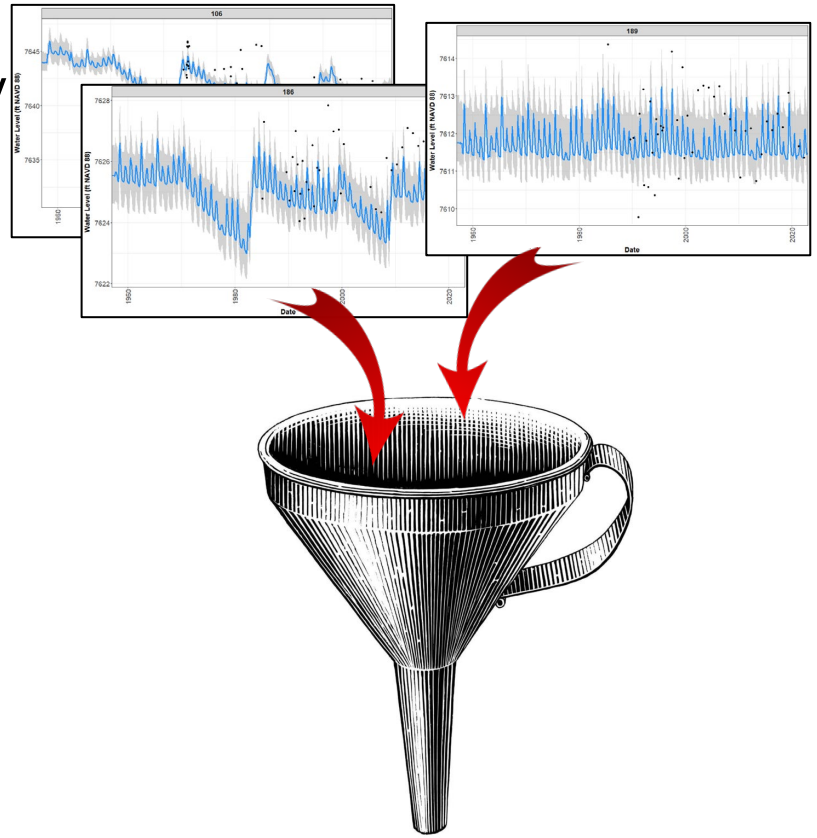


Different realizations can be statistically equivalent, yet produce very different spatial error patterns, leading to divergent flow directions and contaminant transport predictions

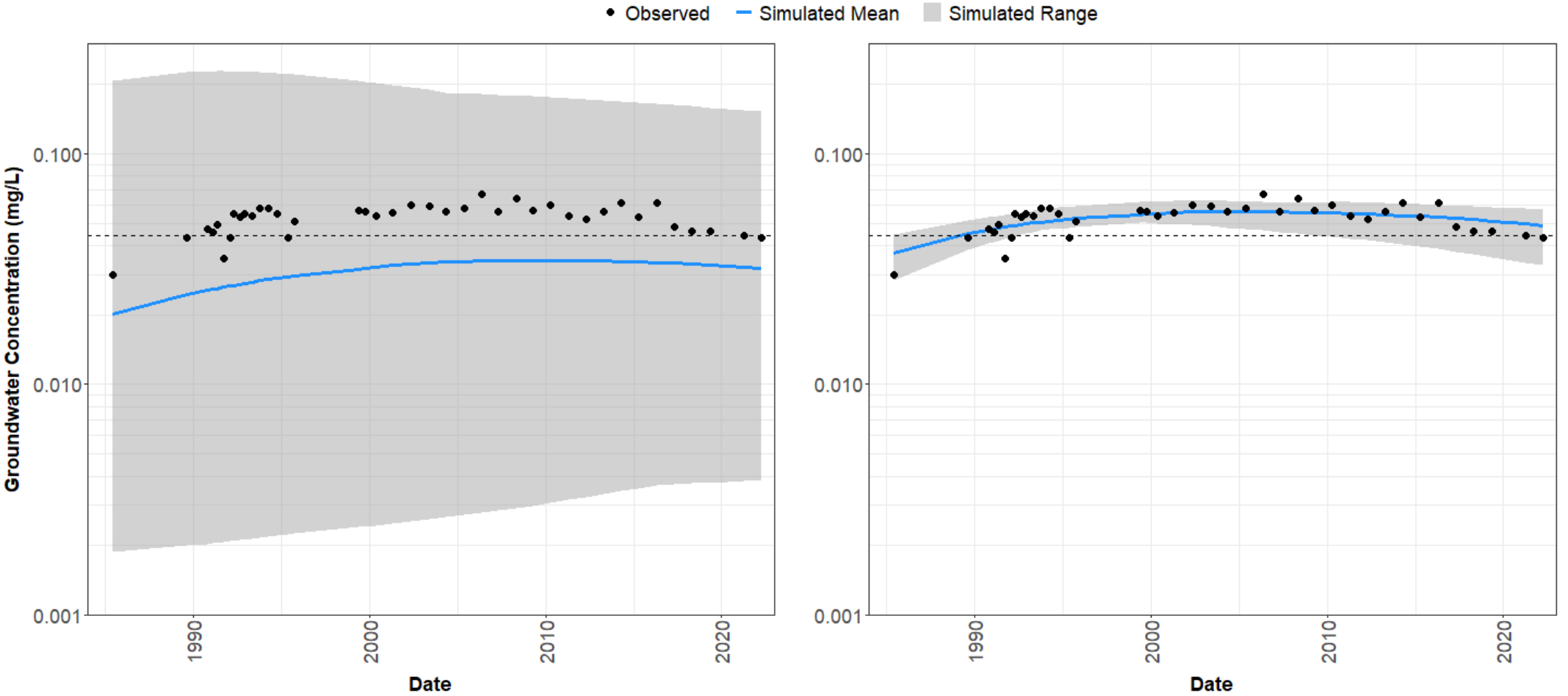
This can result in unrealistic model outputs and non-representative parameter fields, highlighting the importance of expert review and post-calibration filtering to identify physically plausible realizations

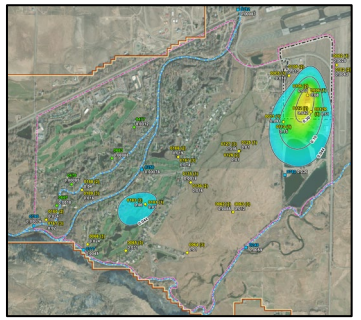
Locations of Truth

- Locations of Truth are key observation points identified as critical to the system's behavior and model's predictive accuracy
- Model realizations are filtered based on their ability to match observed data at these locations within a predefined error threshold
- Only realizations that accurately reproduce conditions at these critical points are retained, improving the physical realism of the ensemble
- This approach enhances model reliability by ensuring the ensemble reflects the true system behavior where it matters most



Locations of Truth Application





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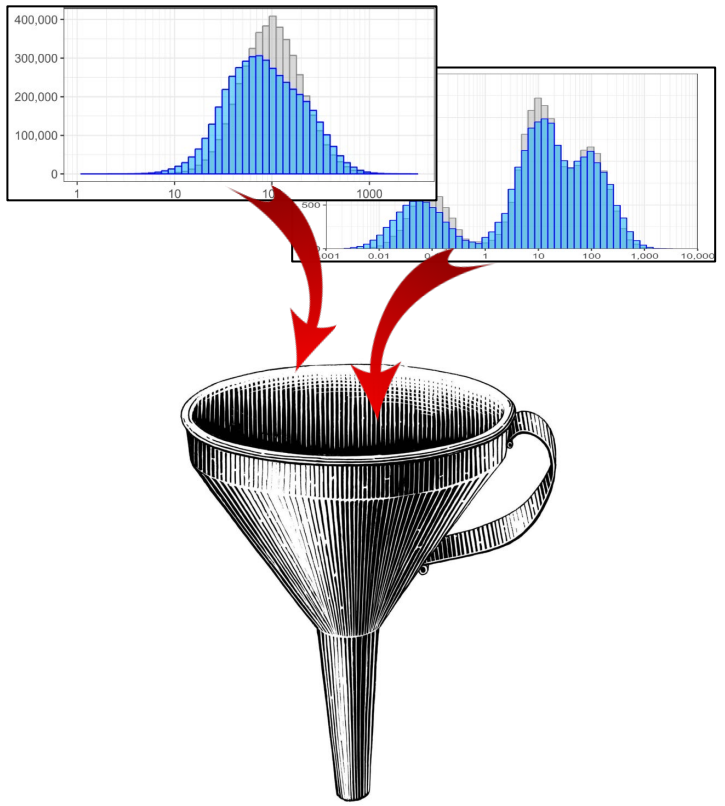
Parameters of Truth

- Parameters of Truth filters the model ensemble based on physical plausibility, ensuring parameter values align with the CSM
- Evaluates posterior parameter ranges against defined acceptable ranges derived from field measurements and expert knowledge
- Realizations with unrealistic or non-representative parameter values are excluded, even if they statistically fit the observed data
- When combined with Locations of Truth, this approach produces an ensemble that is both data-consistent and physically credible, strengthening confidence in model predictions



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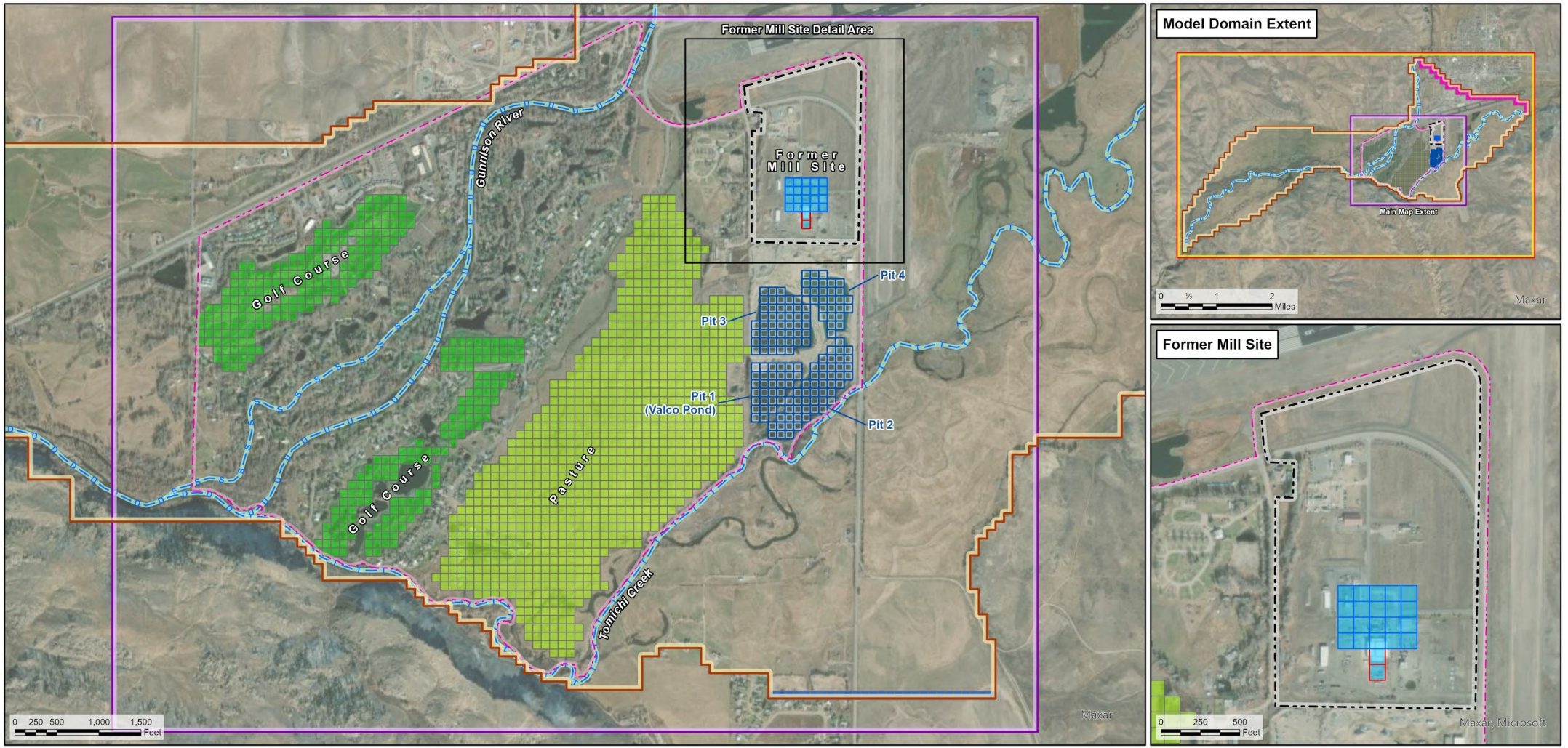
Parameters of Truth Application



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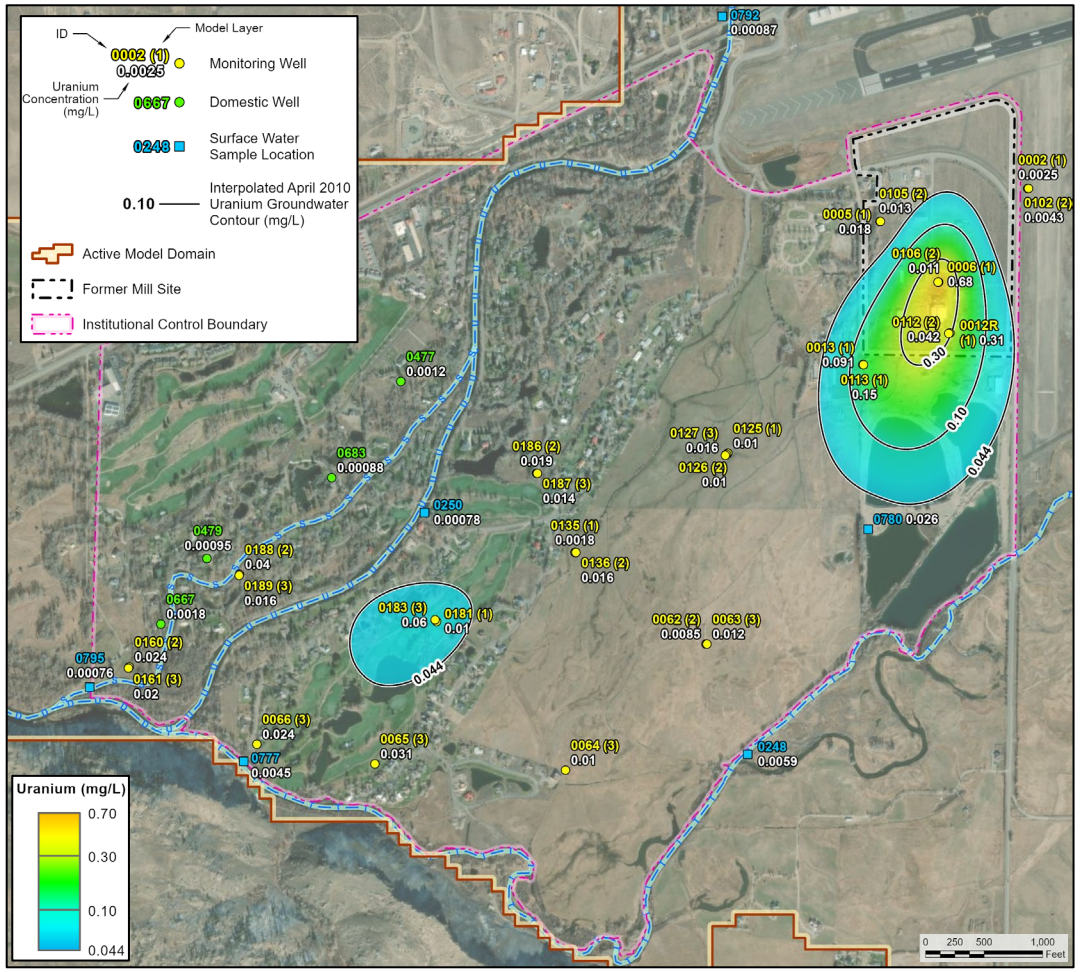
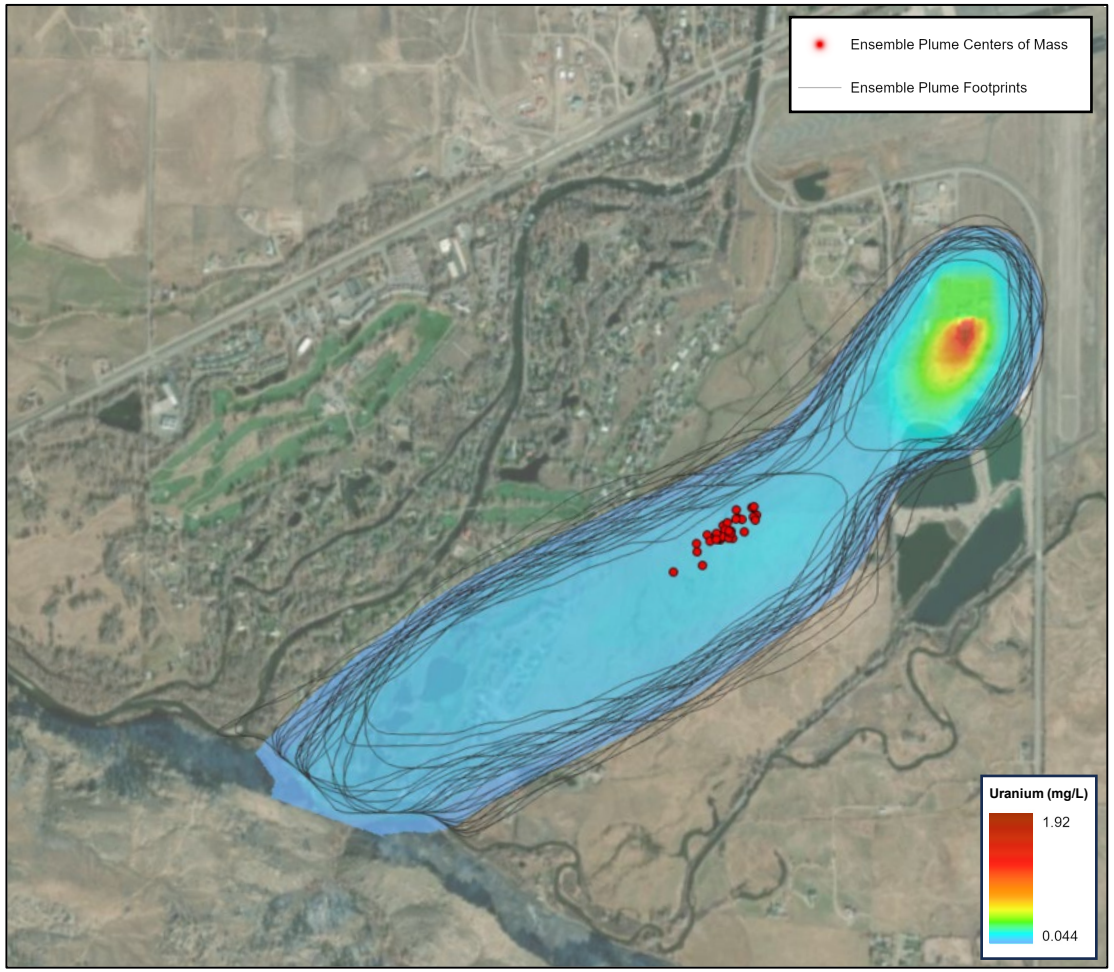
Super Plume: coming soon to an aquifer near you

- Super Plume aggregates all calibrated realizations into an average plume map that captures both expected behavior and uncertainty
- Normalization and averaging highlight the most probable contaminant distribution while showing areas of higher and lower prediction confidence
- Bulk plume metrics track plume magnitude, extent, and movement over time
- Ensemble-based view replaces single-scenario results, supporting more realistic risk assessments and informed decisions

Super Plume Uranium Distribution





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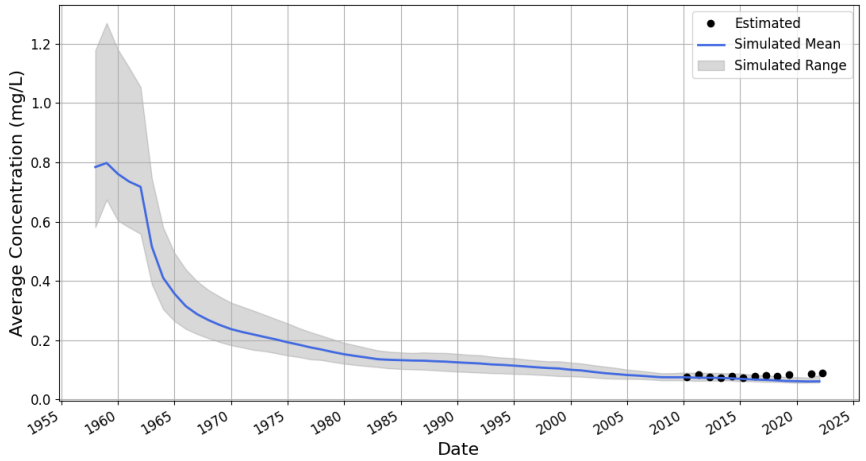
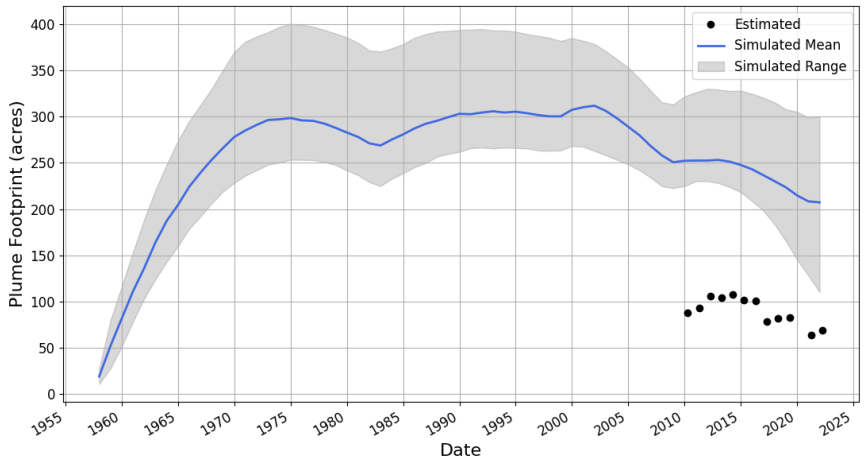
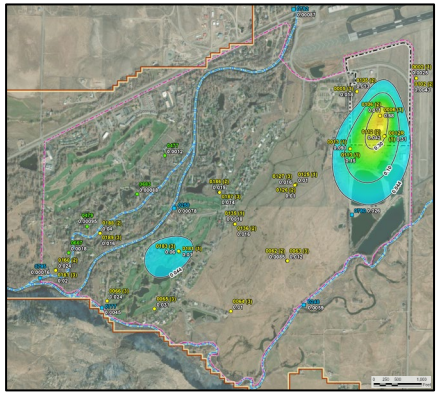
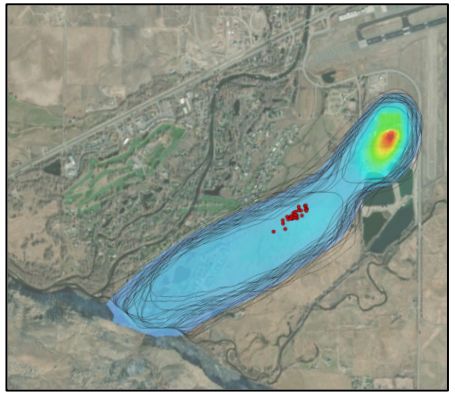
Super Plume Bulk Metrics





- Ensemble matches observed concentrationtrends 2010–2022, confirming reliable plume behavior
- Footprint shifted with gravel pit excavations, shrinking during deeper pumping phases
- Simulated and observed footprints differ in size but show consistent declining trends





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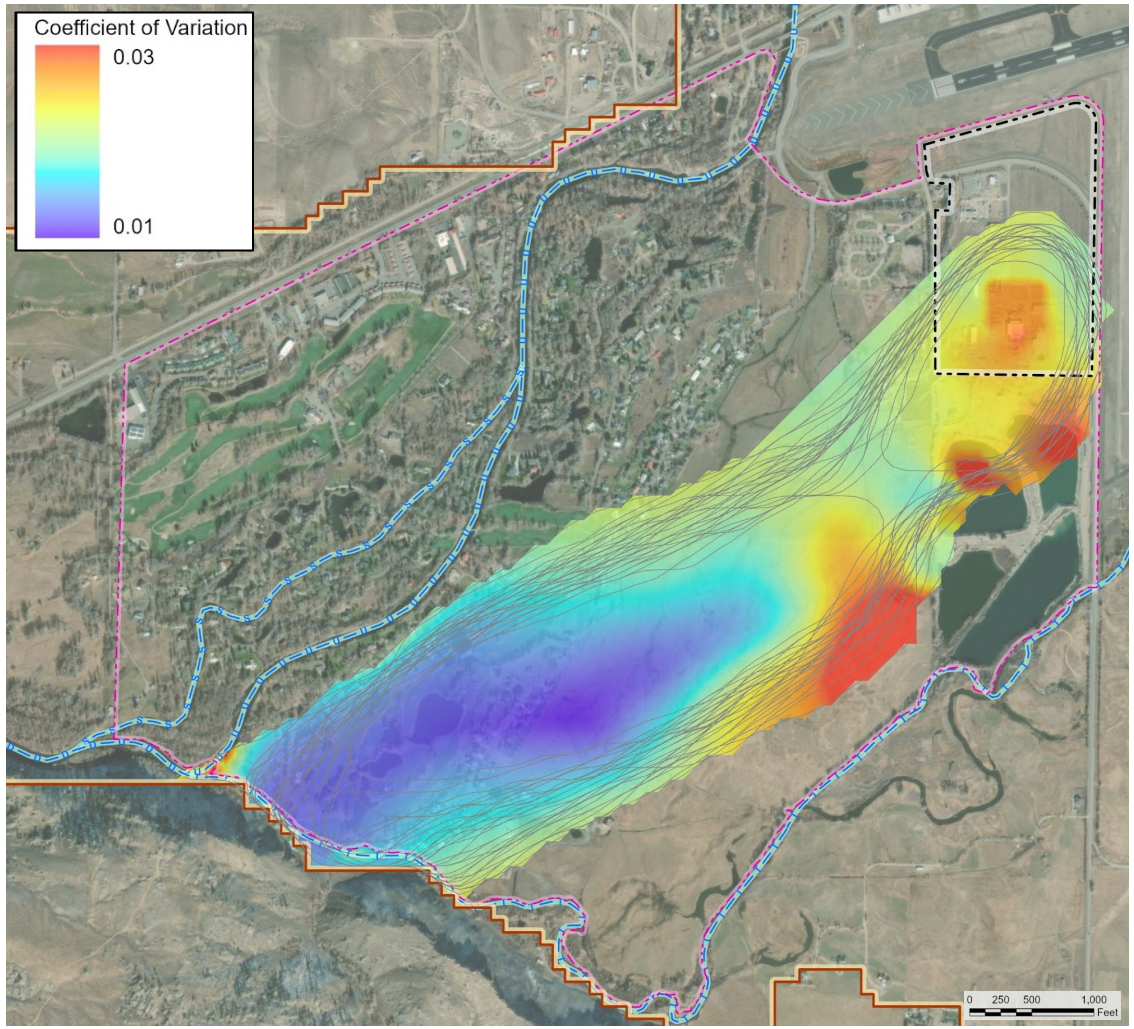
Implications for Data Worth



- Coefficient of variation reflects how much concentrations vary relative to their average values
- Identifies locations where concentrations are inconsistent among ensemble members
- Reveals data-poor zones where additional observations most effectively reduce uncertainty

Key Takeaways

Targeted filtering builds credibility

- Locations and Parameters of Truth reduced 1200 realizations to 32 that are both data-consistent and physically plausible

Super Plume enhances decision-making

- Aggregated plume maps and metrics capture both expected migration and uncertainty, guiding risk assessments

Monitoring gaps remain critical

- High variability and data-poor zones highlight where new observations would most reduce uncertainty

Expert oversight is essential

- Even with advanced calibration techniques, filtering and interpretation are needed to ensure realistic system behavior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Questions?