Performing Vadose Zone Experiments and Interpreting Hydrologic Observations at Hanford

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January 19, 2000

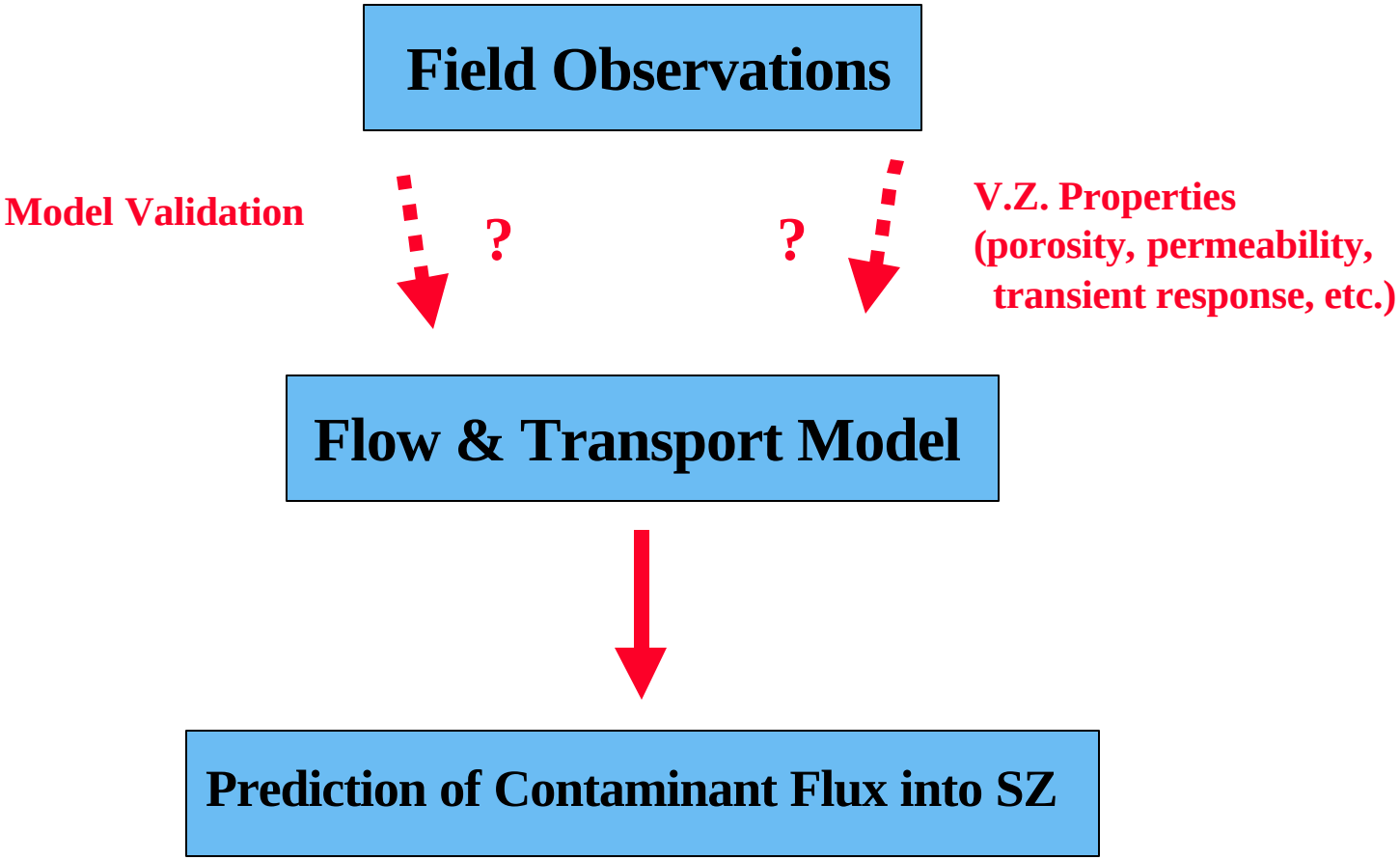
Important Questions Concerning The Vadose Zone At Hanford

1. **What is the current state of the vadose zone beneath the tanks?**
   a. Contaminant distribution (i.e., number and extent of plumes)?
   b. Flow pathways and storage (i.e., heterogeneity)?

2. **How does infiltrated water move across the vadose zone at Hanford?**
   a. Degree of interaction with contaminated pore water?
   b. Relationship between surface flux at the top of VZ and induced flux at water table? (e.g., response to pulse, VZ residence time, breakthrough)

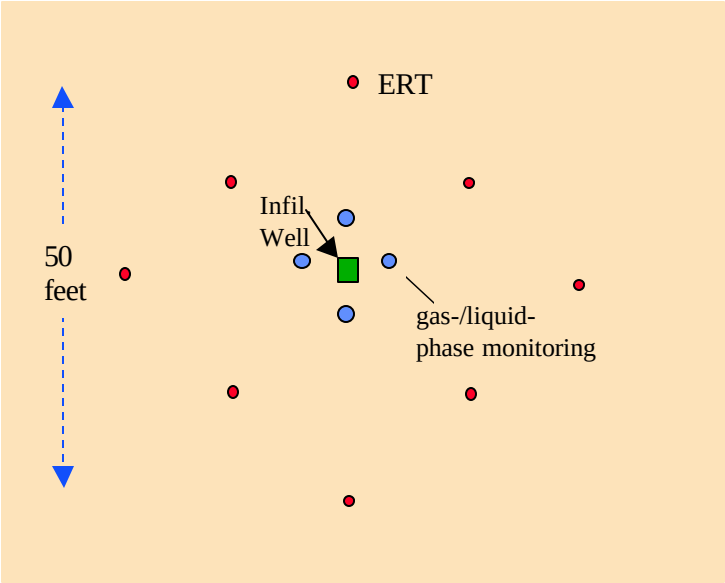
Driver: Prediction of Contaminant Flux into SZ versus time and different conditions

Getting Answers To Questions About Transport In The Hanford Vadose Zone

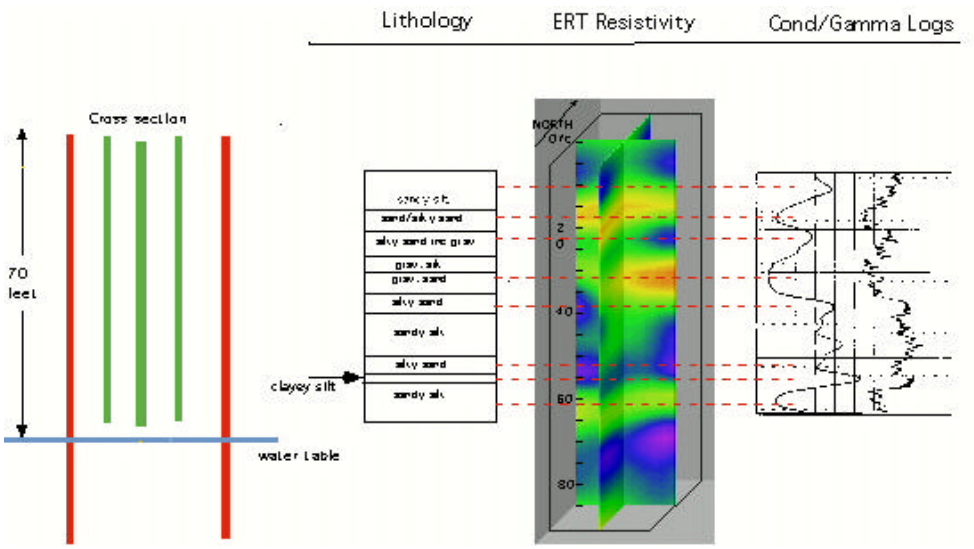


Vadose Zone Observatory: Experiments Supporting Hanford Field/Modeling Studies

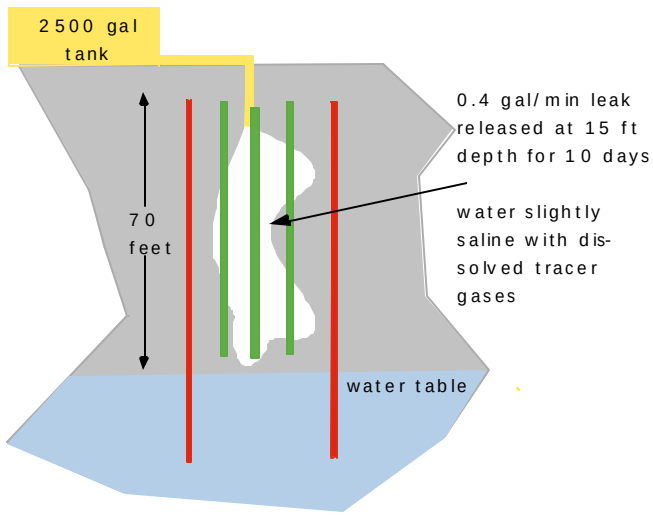
VZO Monitoring Well Planview

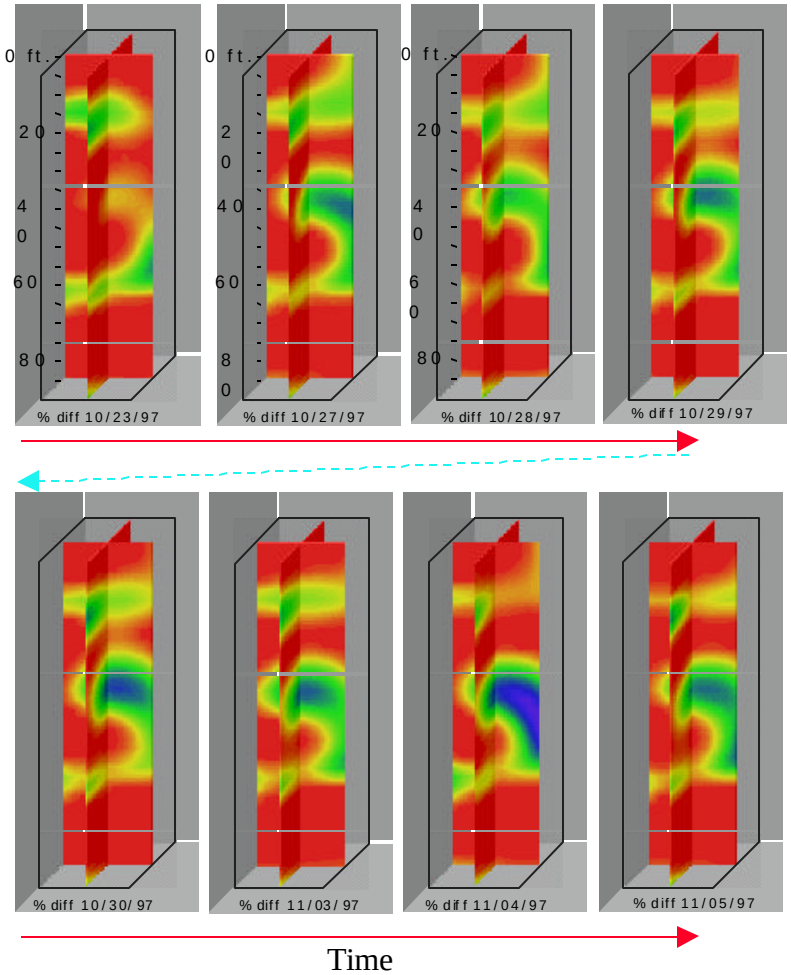


Site Characterized by Geological Logs, ERT and Borehole Logs



Analog Experiments: Monitoring Infiltration Events With Multiple Techniques Improves Understanding of Techniques and Transport Processes

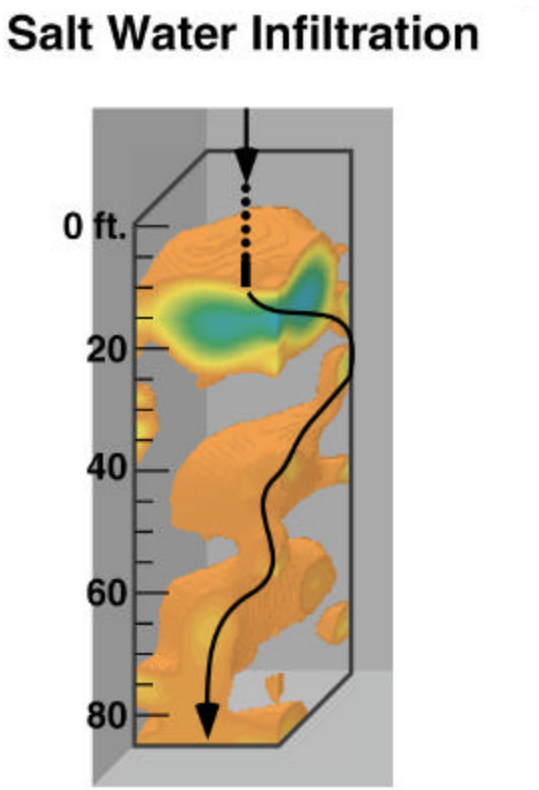




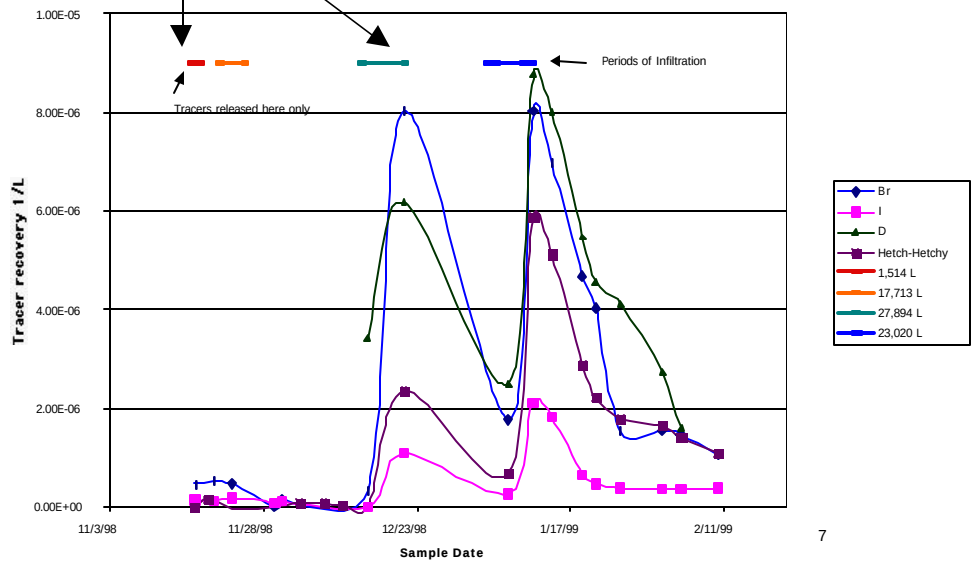
Infiltration Parameters Monitored

* Liquid phase location versus time (ERT/tracers)
* Gas phase location versus time (noble tracers)
* Gas-phase pressure at various depths
* Liquid phase saturation
* Gas & liquid phase sampling

VZO: Using Tracers & ERT To Improve Understanding Of Relationship Between Saturation Changes In VZ & Chemical Transport



Bulk of tracer arrives more than a month after release



Saturation Changes at bottom of VZ in less Than 6 hours

BUT

Significant amounts of tracer do not arrive for more than a month

Using Geostatistics to Integrate Geology and Geophysics into Subsurface Characterization

❶ Assemble existing data and geologic knowledge.

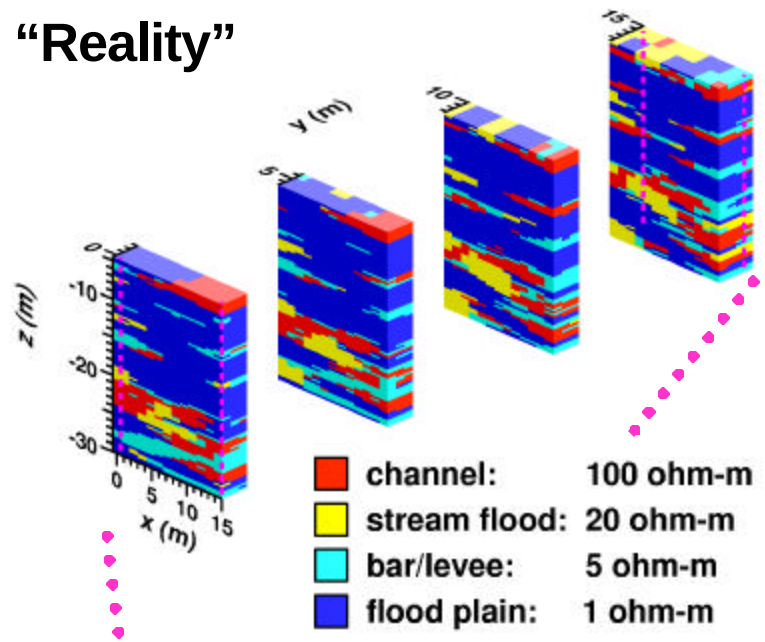
- Borehole logs, outcrop studies, etc.
- Site stratigraphy - formation, facies, and within-facies characterization.
- Geophysical properties: resistivity, seismic velocity, etc.

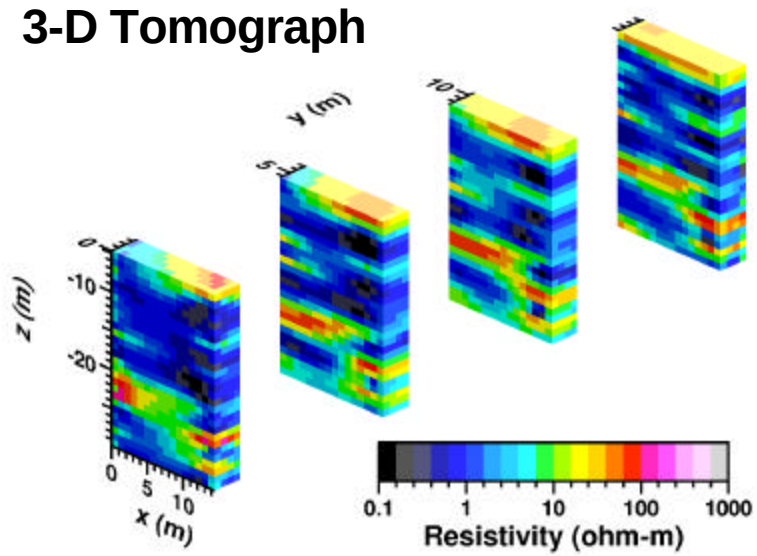
❷ Generate realistic geostatistical realizations of facies architecture and within-facies spatial variability of geophysical properties.

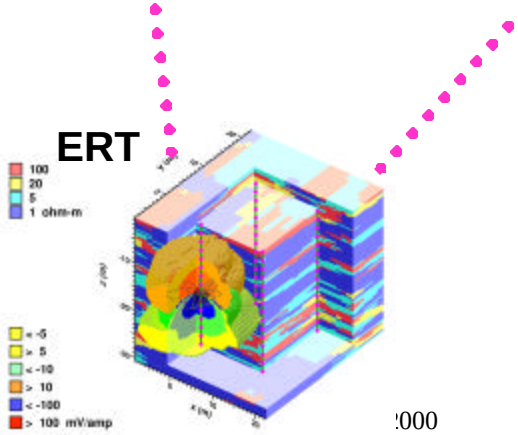
❸ Integrate geophysics (ERT, GPR, seismic, etc.)

- Forward model “synthetic” geophysical response on multiple realizations.
- Invert synthetic geophysical response on each realization.
- Quantify sensitivity of geophysical inversion to spatial variation of geophysical properties.
- Apply Bayesian approach to utilize geophysics as “soft” data.

Example: Integrating 3-D Electrical Resistance Tomography (ERT) into subsurface characterization.





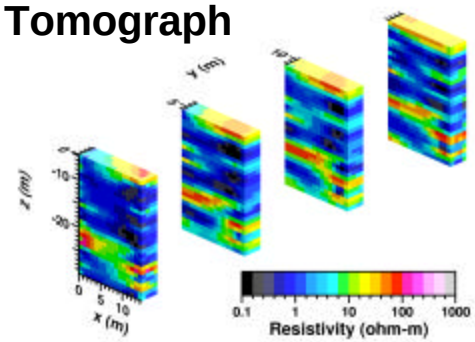


Problems with integrating 3-D ERT:

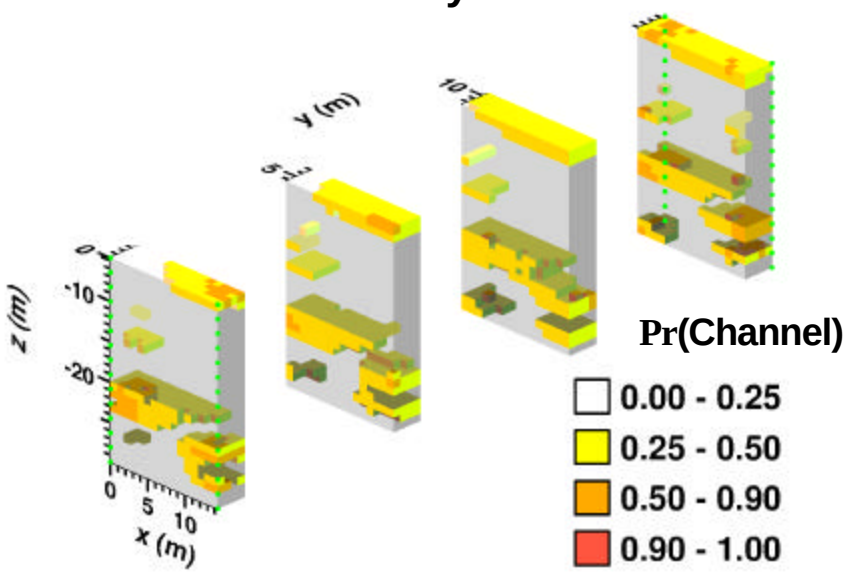
- Resolution imperfect and spatially variable.
- Not conditioned by "hard" data at boreholes.
- Prior knowledge of geology not considered.

Approach: Use ERT as "soft conditioning" to refine geostatistical realizations.

Tomograph

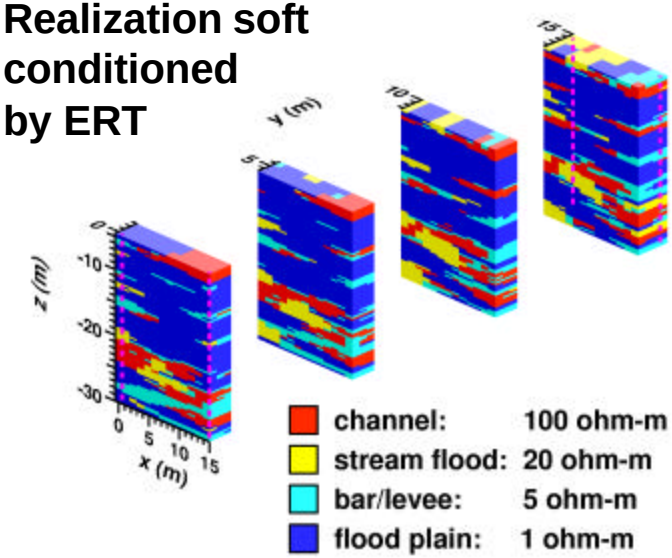


Local Facies Probability



- Map local facies probability from ERT tomograph.
  - Bayesian analysis of synthetic data is used to calibrate the tomograph to a map of local facies probability.
- Soft condition geostatistical realizations with local facies probability.
- Use geostatistics to honor borehole data and enforce realistic geology.

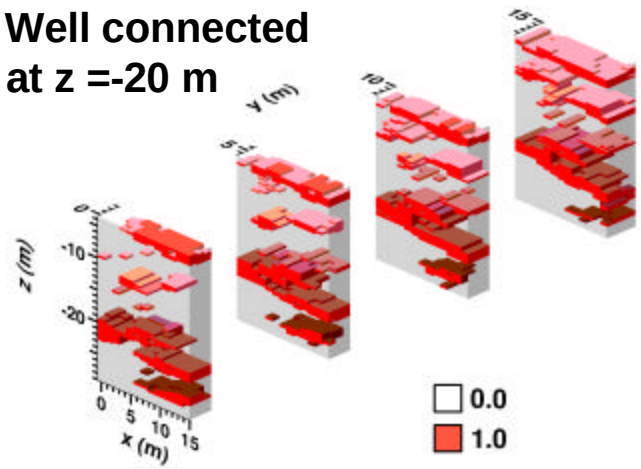
Realization soft conditioned by ERT

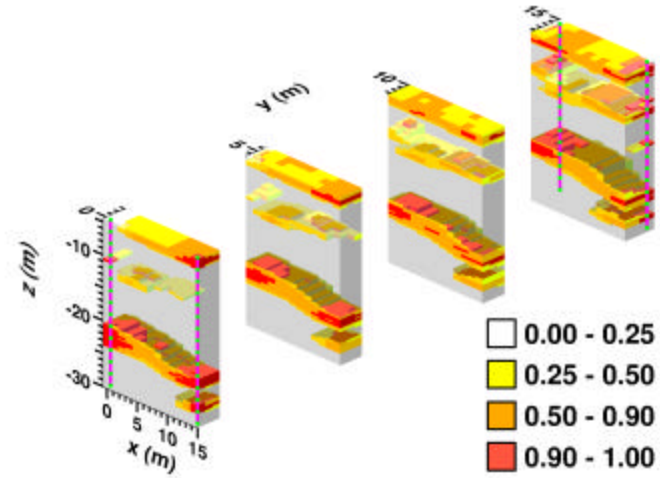


Results: Estimate the *probability* of locating the highest permeability (channel) facies.

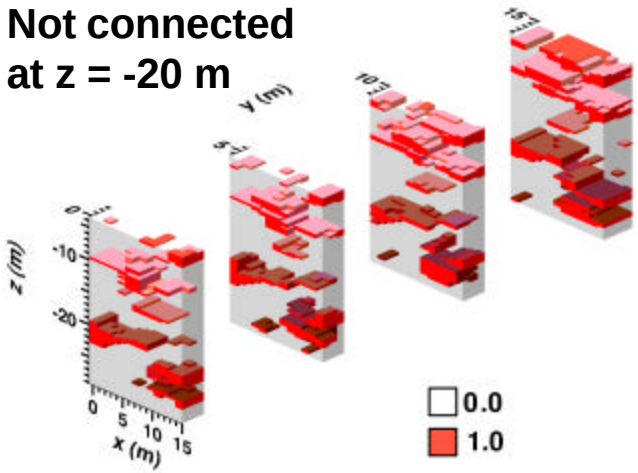
Reality: | **ERT & Geostatistics:**

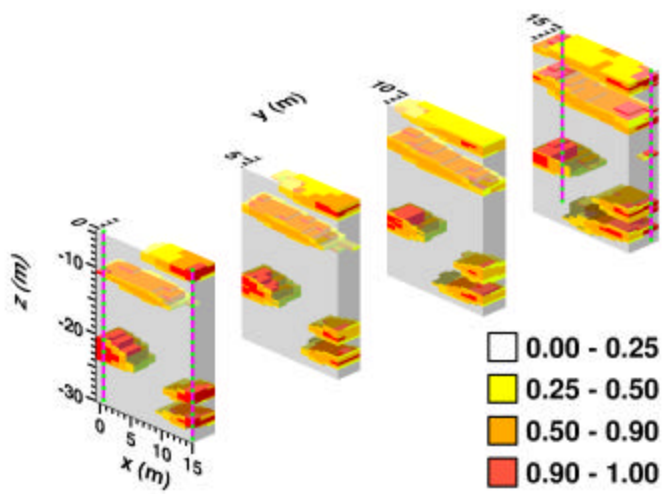
Well connected at z =-20 m





Not connected at z = -20 m





Possible Experiments At VZO
Validating Hanford Field & Modeling Techniques

1. **Vadose Zone Characterization:** Soft conditioning of field & lab derived data sets for heterogeneity in soils using ERT, GPR & seismic methods. (Ramirez, Daily, Knight, Berge, Long, Carle, Meyer, Majer, & others)

2. **Infiltration Characterization & Model Validation (I):** Saline infiltration experiment combining liquid-phase tracers with ERT and GPR imaging that is interpreted by 3-D flow and transport simulations based on (1). (Ramirez, Daily, Knight, DePaolo, Carle & others)

3. **Flushing Characterization & Model Validation (II):** Same as above but flushing of previously emplaced salt plume using different liquid-phase tracers with ERT and GPR imaging and interpreted by 3-D flow and transport simulations.