NATIONAL CENTRAL UNIVERSITY
GRADUATED INSTITUTE OF APPLIED GEOLOGY

Stochastic Inversion of Pneumatic Tomography Survey in Hanford Site

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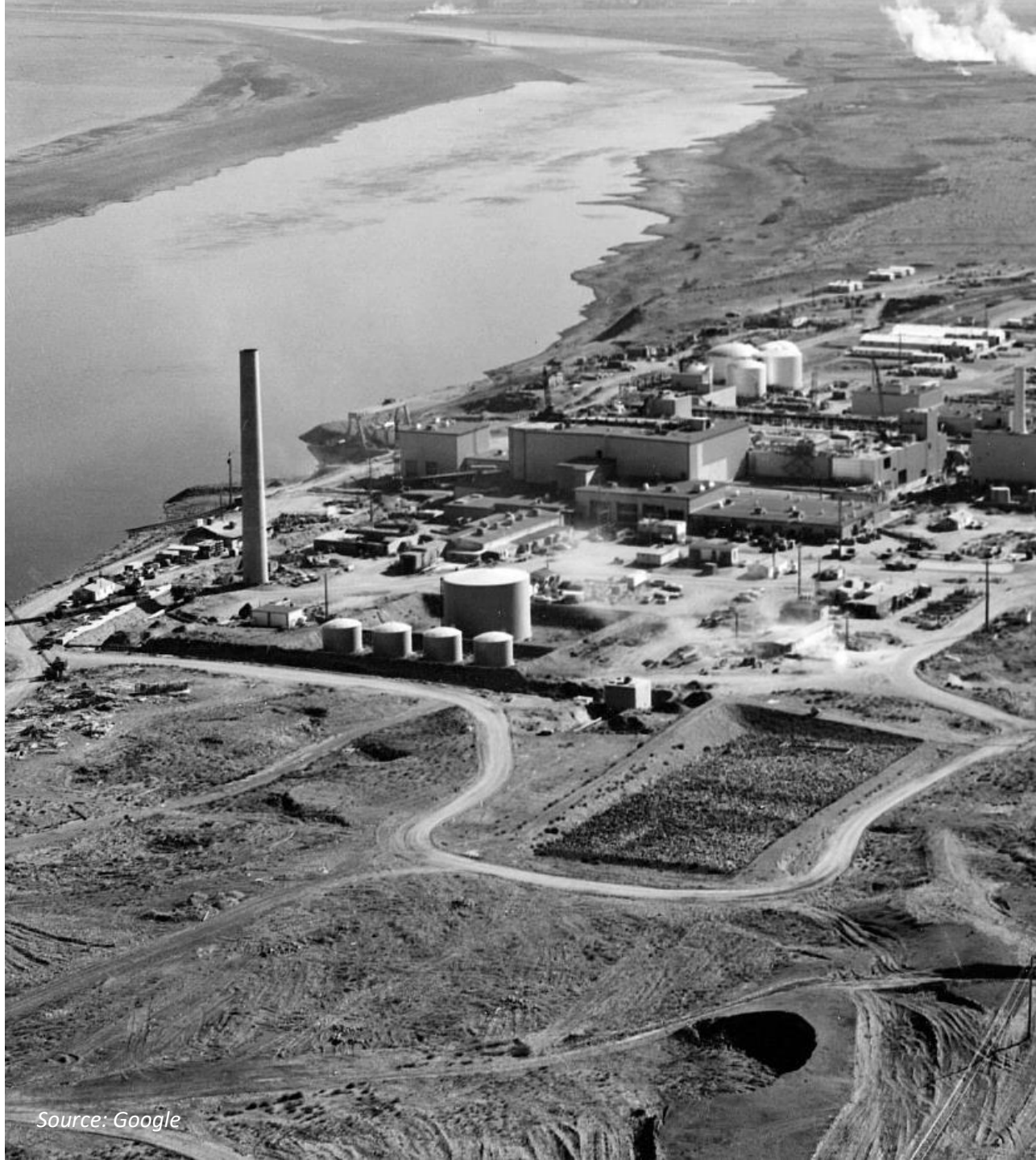
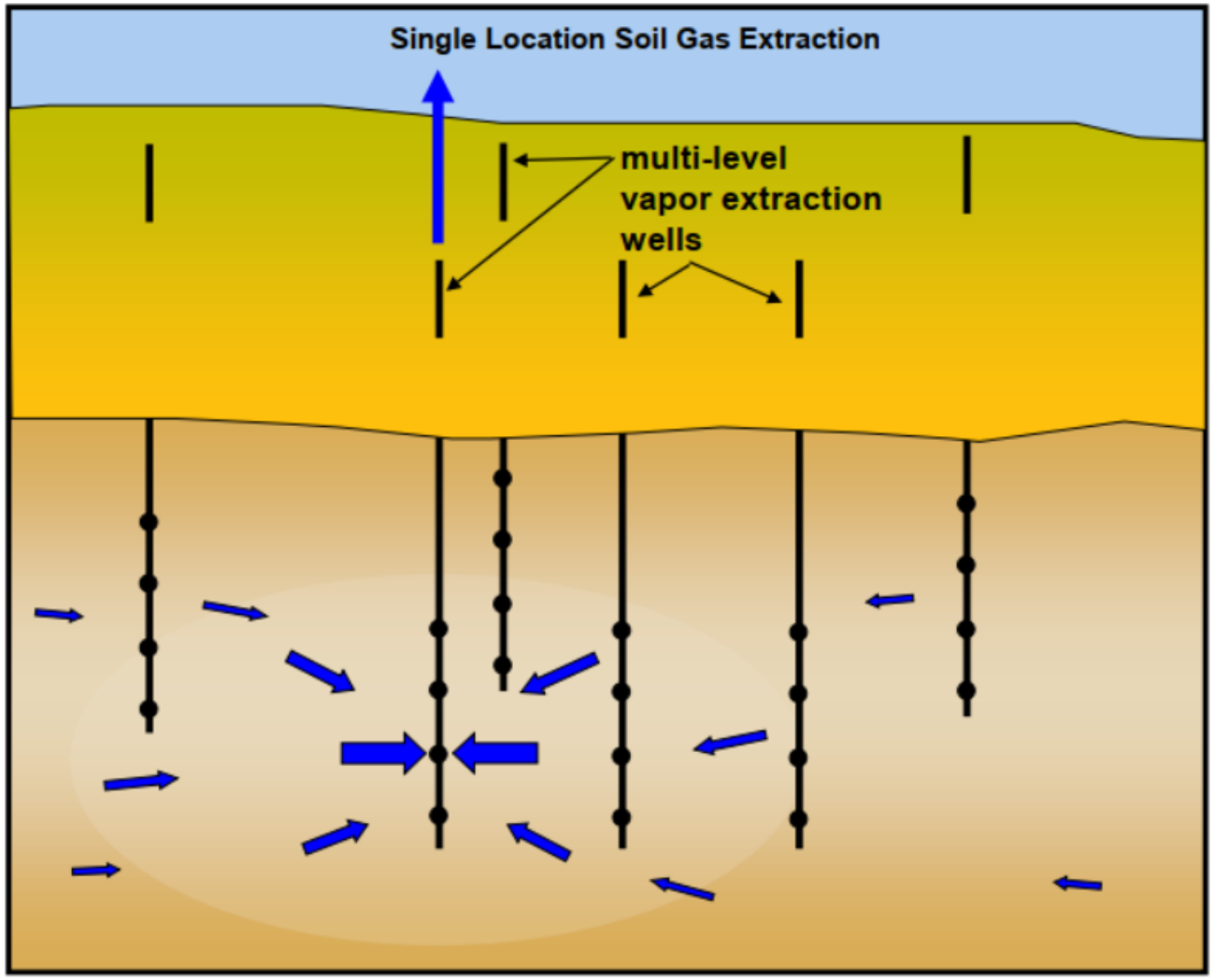
CONTENT



Pneumatic test

Pneumatic permeability is defined as a product of intrinsic permeability and relative air permeability. Intrinsic permeability is defined as solely a function of soil pore structures, while relative air permeability is a function of air saturation in soil pores. **(Cho et al. 1992)**



The investigations of airflow and gas-phase transport in unsaturated formations have received increasing attention owing to the arising environmental issues such as the remediation and prediction of contaminants and evaluations of potential sites for radioactive waste (e.g. **Berkowitz 2002**; **Illman and Neuman 2001**; **Vesselinov et.al 2001a**; **Vesselinov et.al 2001b**)

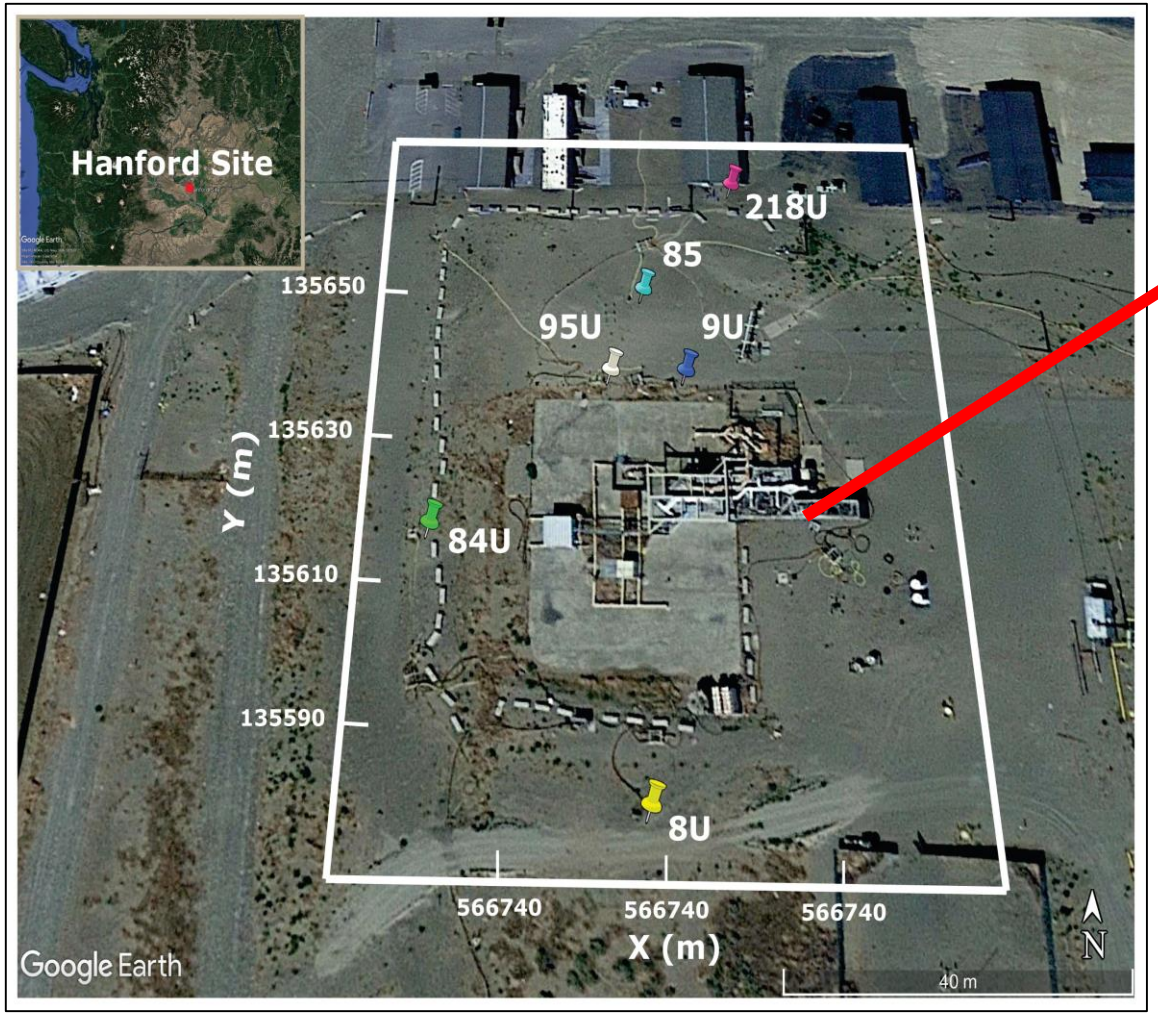
Problems:

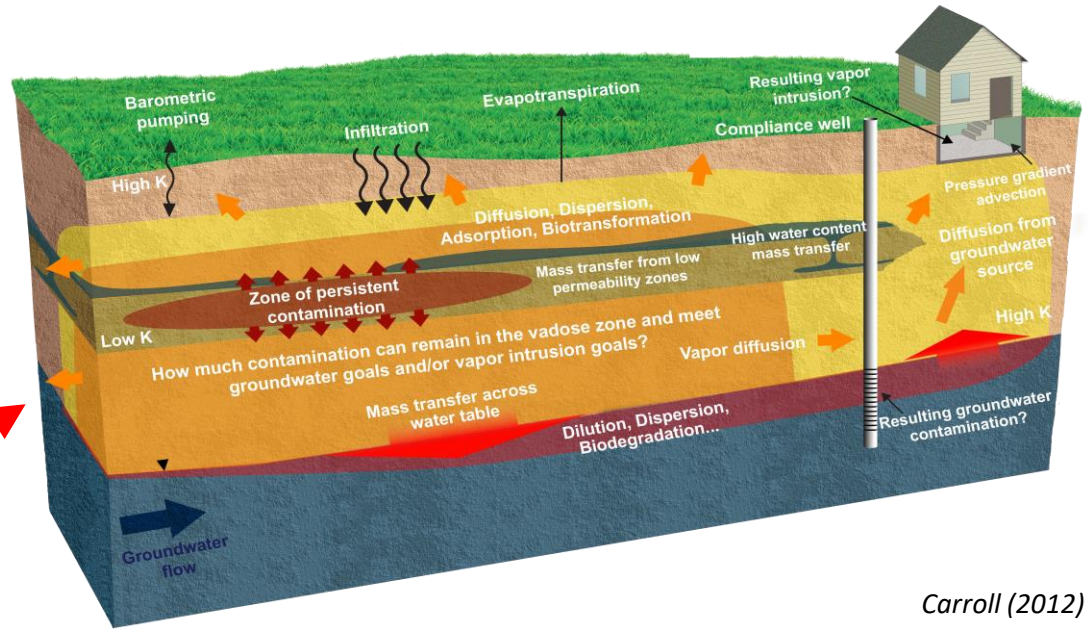
+ The complex nature of unsaturated formations

+ The ways and tools that are employed to collect and analyze the data from interesting sites

+ The effect of scale

Hanford site





Carroll (2012)

The unsaturated zone (UZ) of highly heterogeneous, fractured tuffs at the Hanford Site, has been extensively investigated, as the proposed site of a geological repository for storing high-level radioactive waste.

Literature review

Several types of quantitative analyses have been developed previously to characterize the geologic properties in the Hanford site (**Last et.al 2007**; **Lindsey et.al 1994**; **Lanigan et.al 2010**)

Limitations:

+ Conducted without the consideration of small-scale heterogeneities

+ Not be captured in the high-resolution to represent the hydrogeological structure due to coarse grid cell size platform (**Oostrom et.al 2005, 2007, 2010**; **Carroll et.al, 2012**).

+ Physical characterization of the heterogeneous flow and pollutant distribution in the unsaturated zone cannot be deterministically quantified accurately.(**Jennings and Patil 2002**; **Olson et.al 2001**; **Rohay et.al 1993**, **Rossabi and Falta 2002**; **Riha 2005**; **Truex et.al 2012**)

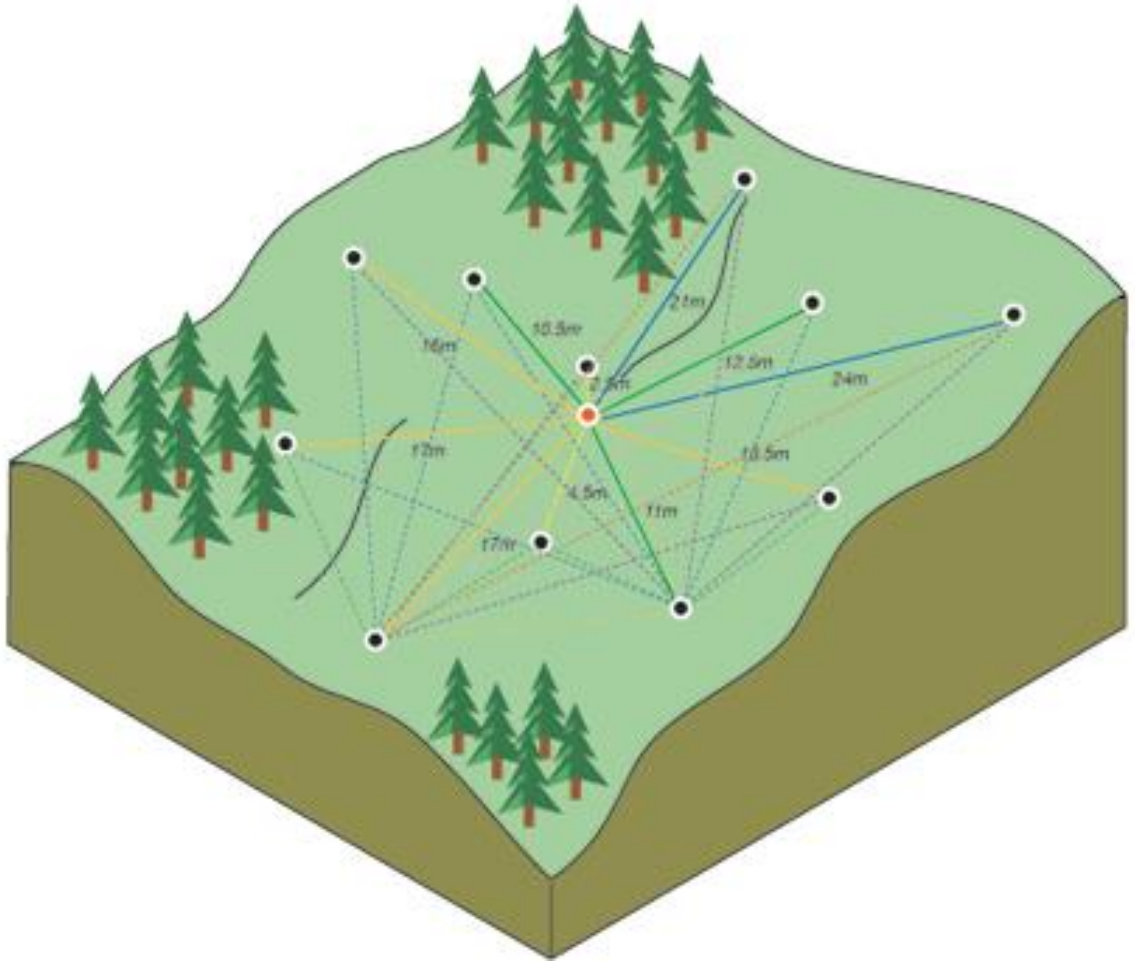
Objectives

(1) to make a comparison using the traditional approach with kriging is to be estimated the directional permeability distribution map using the pneumatic data from the single-hole test

(2) to examine a pneumatic inverse model to enhance the resolution of the air-permeability pattern.

Kriging method

- Check your dataset to find out whether:
  - ✓ normal distributed
  - ✓ stationary
  - ✓ no trend
- Define **variogram model**. How?
  - ✓ nugget effect
  - ✓ partial sill
  - ✓ range
  - ✓ distance



Stochastic inverse model- Sequential successive linear estimator (SSLE)

Prior information:
- Mean
- Variance, correlation scale +model

Sensitivity matrix (J),
Covariance
Cross-covariance
λ, μ from the analytical solution

$$\xi_*^{(1)} = \lambda^T \xi_{obs} + \mu^T \varepsilon_{obs}$$
$$\varepsilon_{ff}^1 = R_{ff}^{(0)} - \lambda^T R_{ff}^{(0)} - \mu^T R^{(0)}$$

Forward modeling

Difference between observed vs. estimated values

$$\xi_*^{n+1} = \xi_*^n + \varpi^n(\varepsilon_{obs} - \varepsilon^n)$$
$$\varepsilon_{ff}^{n+1} = \varepsilon_{ff}^n - \omega\, \varepsilon_{fh}^n$$

Check convergence:
Maximum iteration n?
Spatial variance stabilized?
Fitted error L2 stabilized?

Yes

NO

$J^{(n)}, \varepsilon_{ff}^n, \varepsilon_{fh}^n, \varepsilon_{hh}^n$

Yes

NO

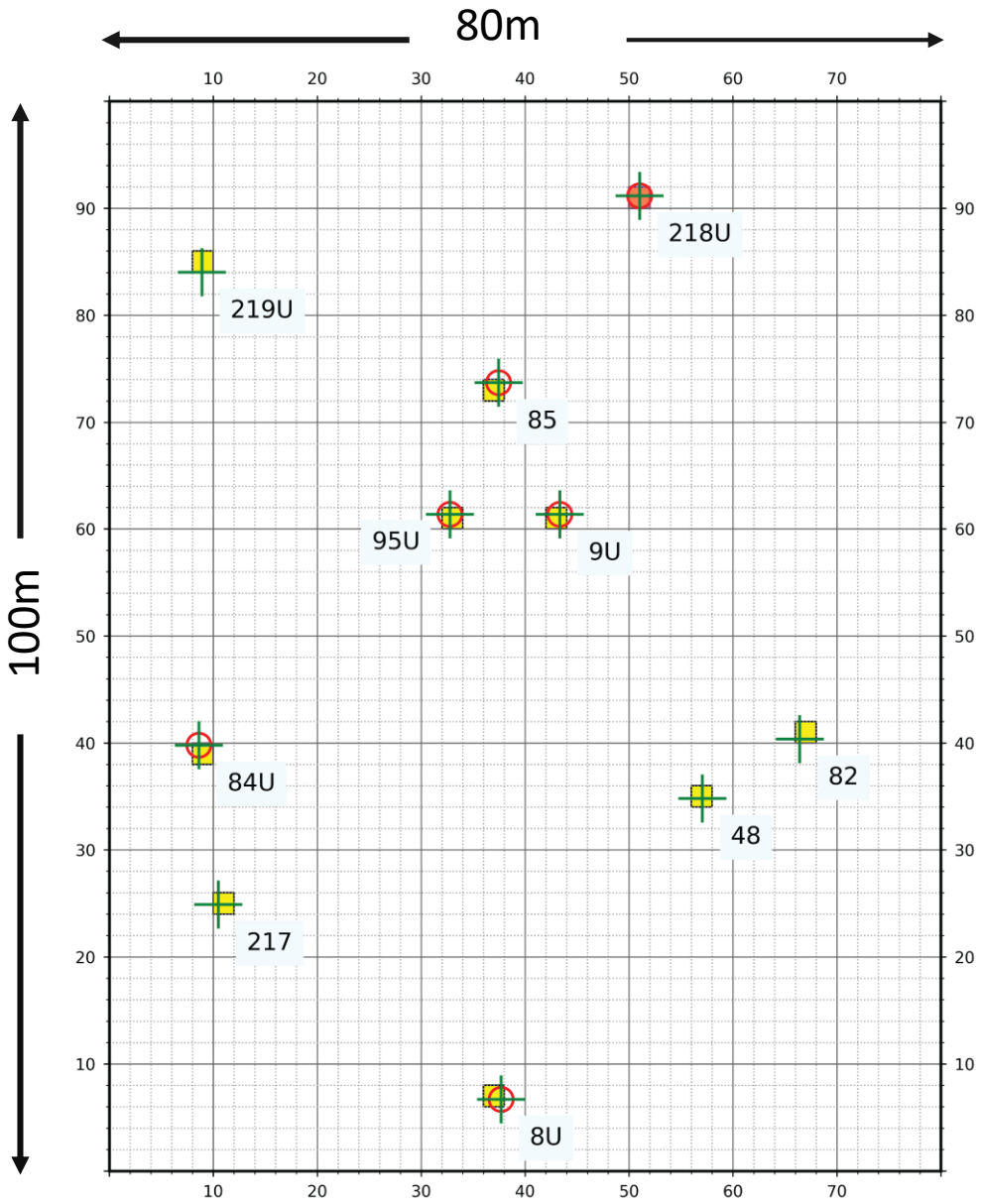
Another current transmission

Transmission=total

Yes: stop

Conceptual model

- Two-dimensional model
- Homogeneous and isotropic
- Steady-state condition
- Area : 80m x 100m
- Discretized to 2000 cells
- Grid size: Δx: 2m ; Δy: 2m
- Geometric mean (K) : 1.36E-12



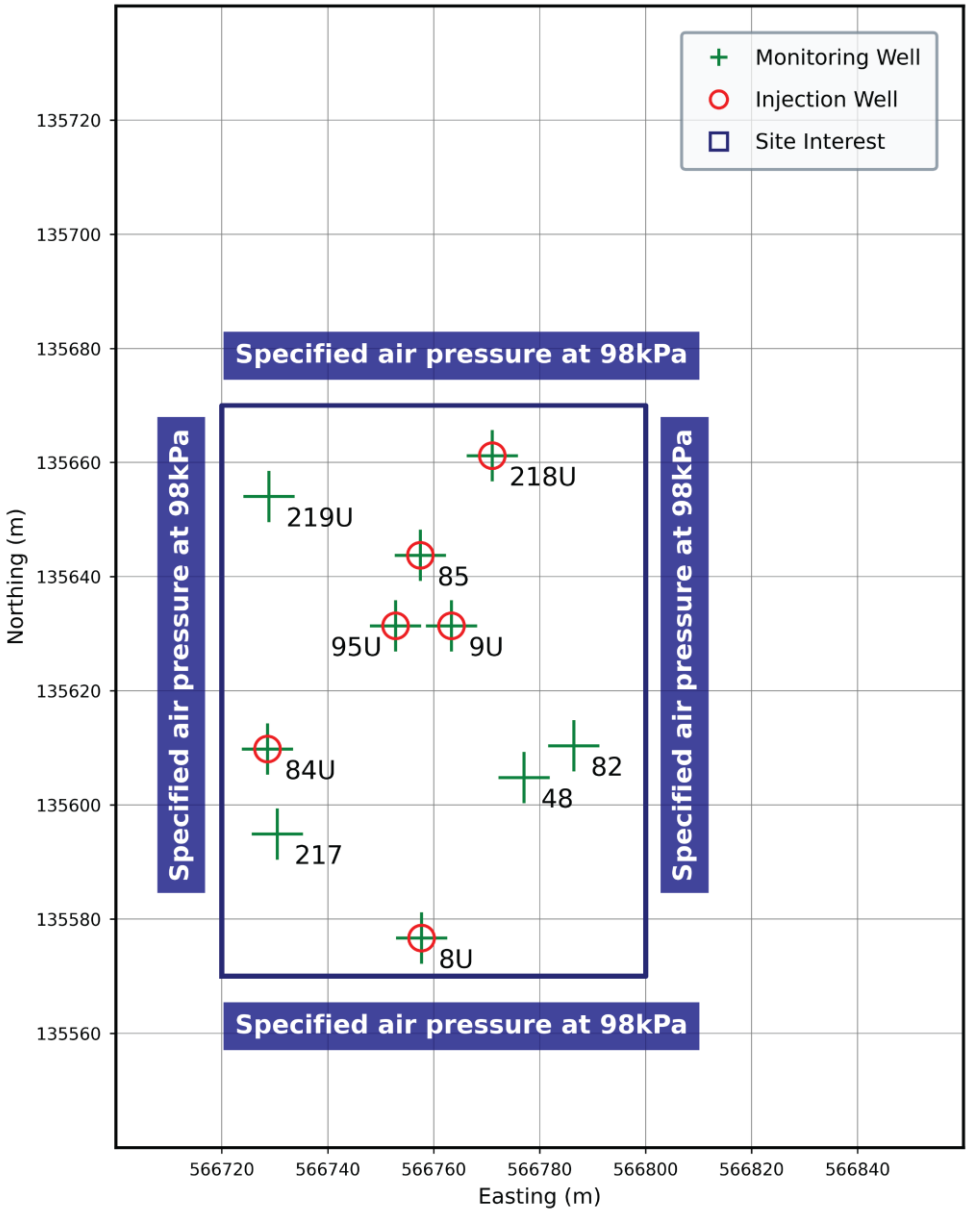
Model set up

❖ Boundary/initial condition

Initial value each node at 98.0 (kPa)

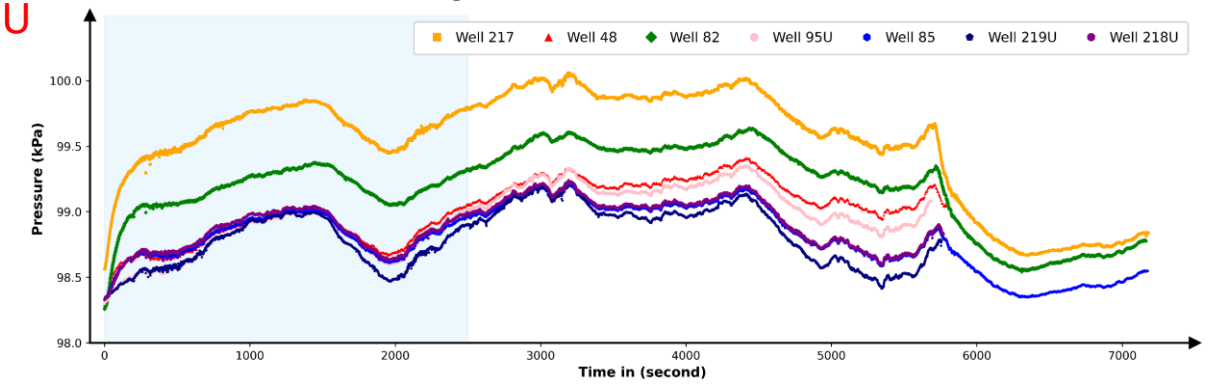
❖ Injected events

Events	Stressed Well	Observation Wells
1	8U	217,48,95U,85,219U
2	9U	85, 82
3	84U	95U,219U, 85,218U
4	85	9U,82,8U
5	95U	218U, 8U
6	218U	85, 9U,82,8U

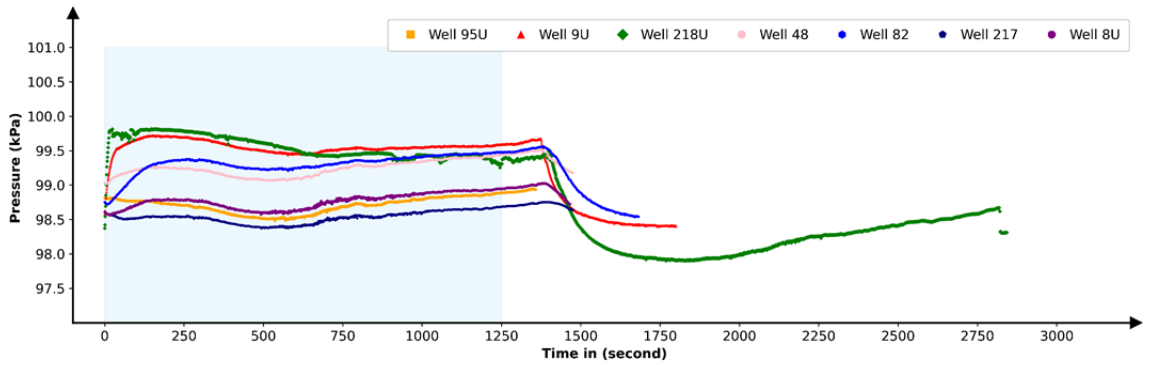


❖ Barometric pressures

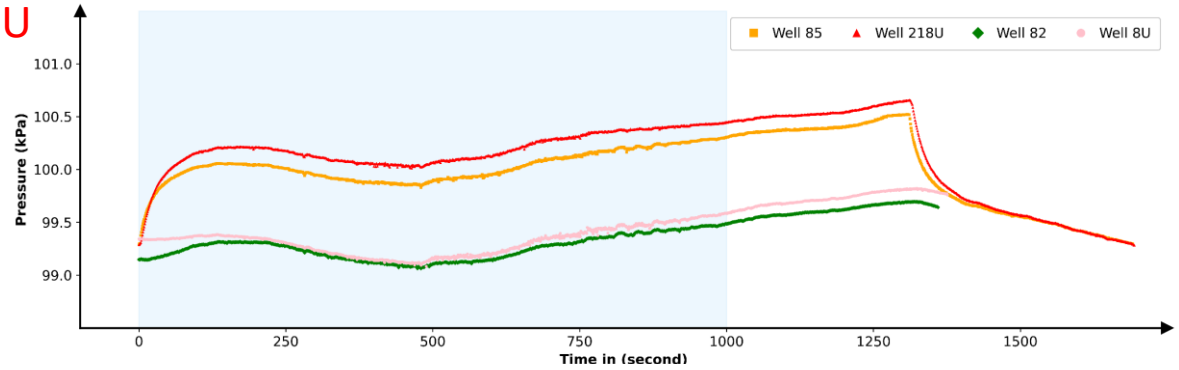
8U



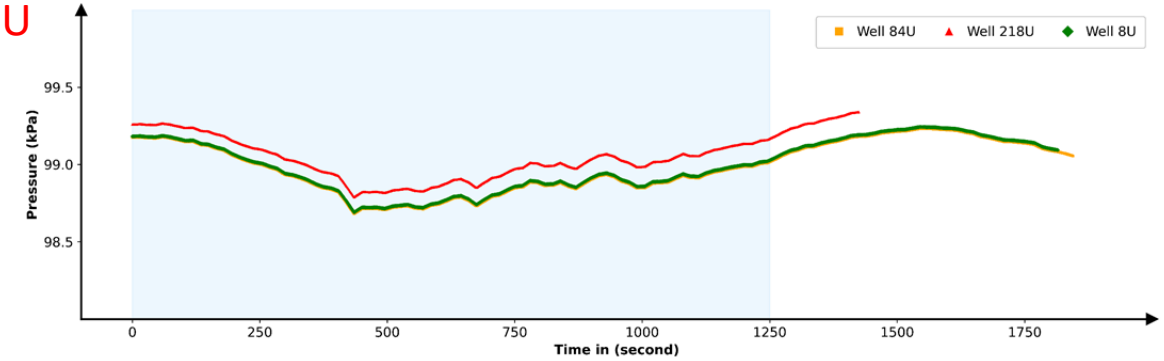
85



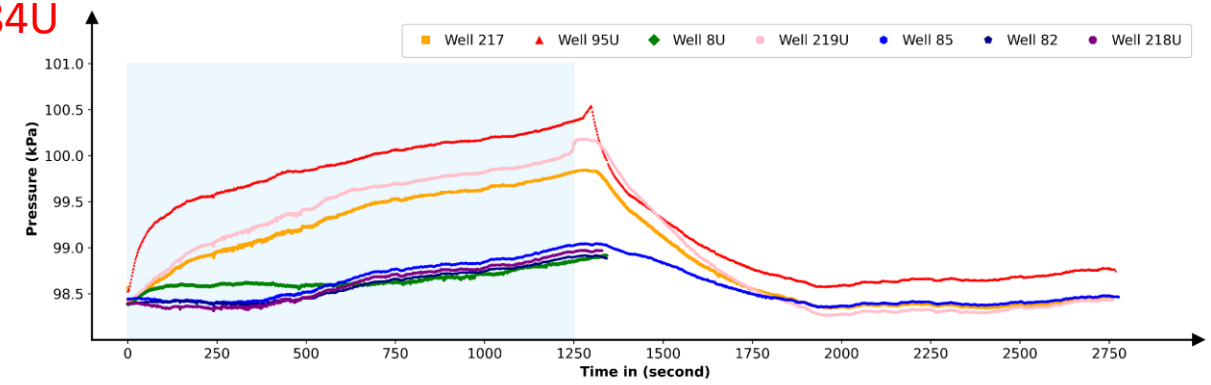
9U



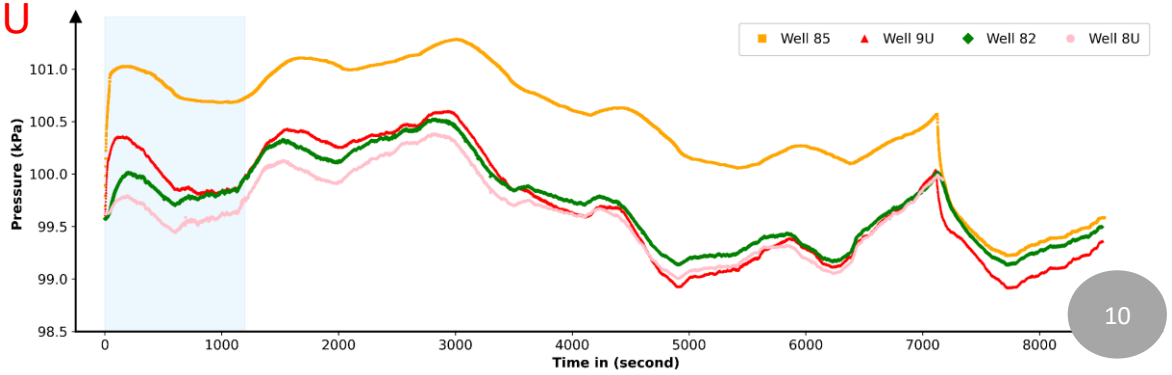
95U



84U

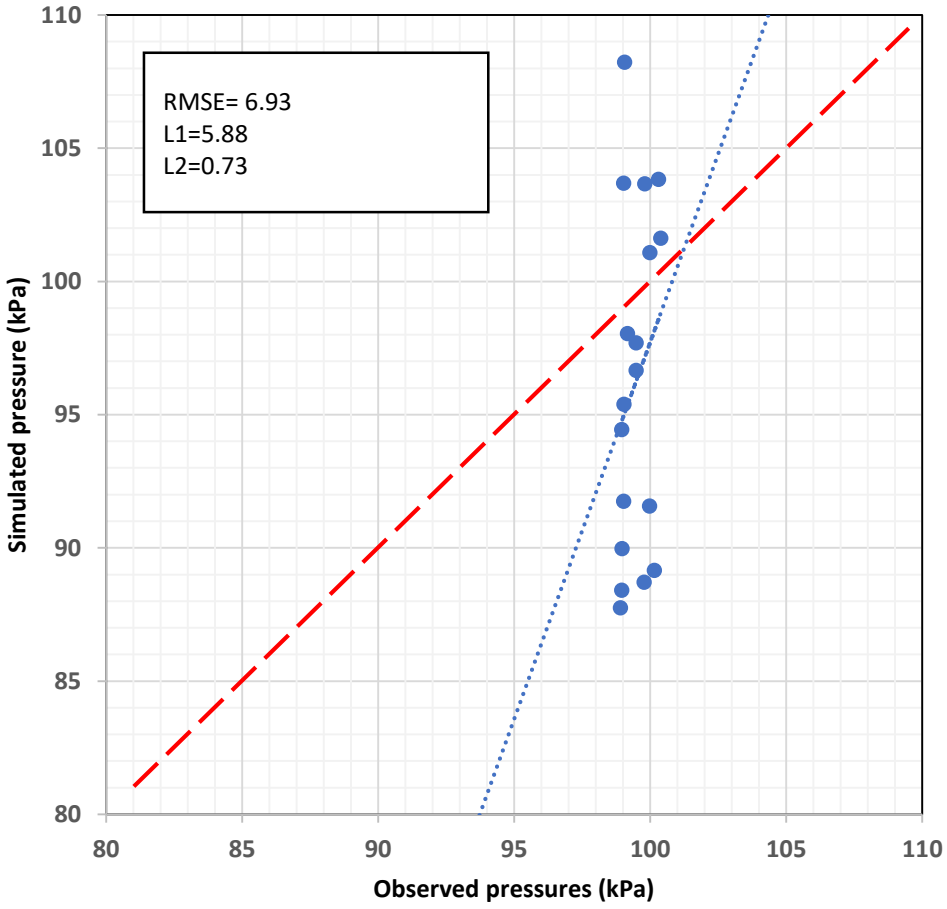


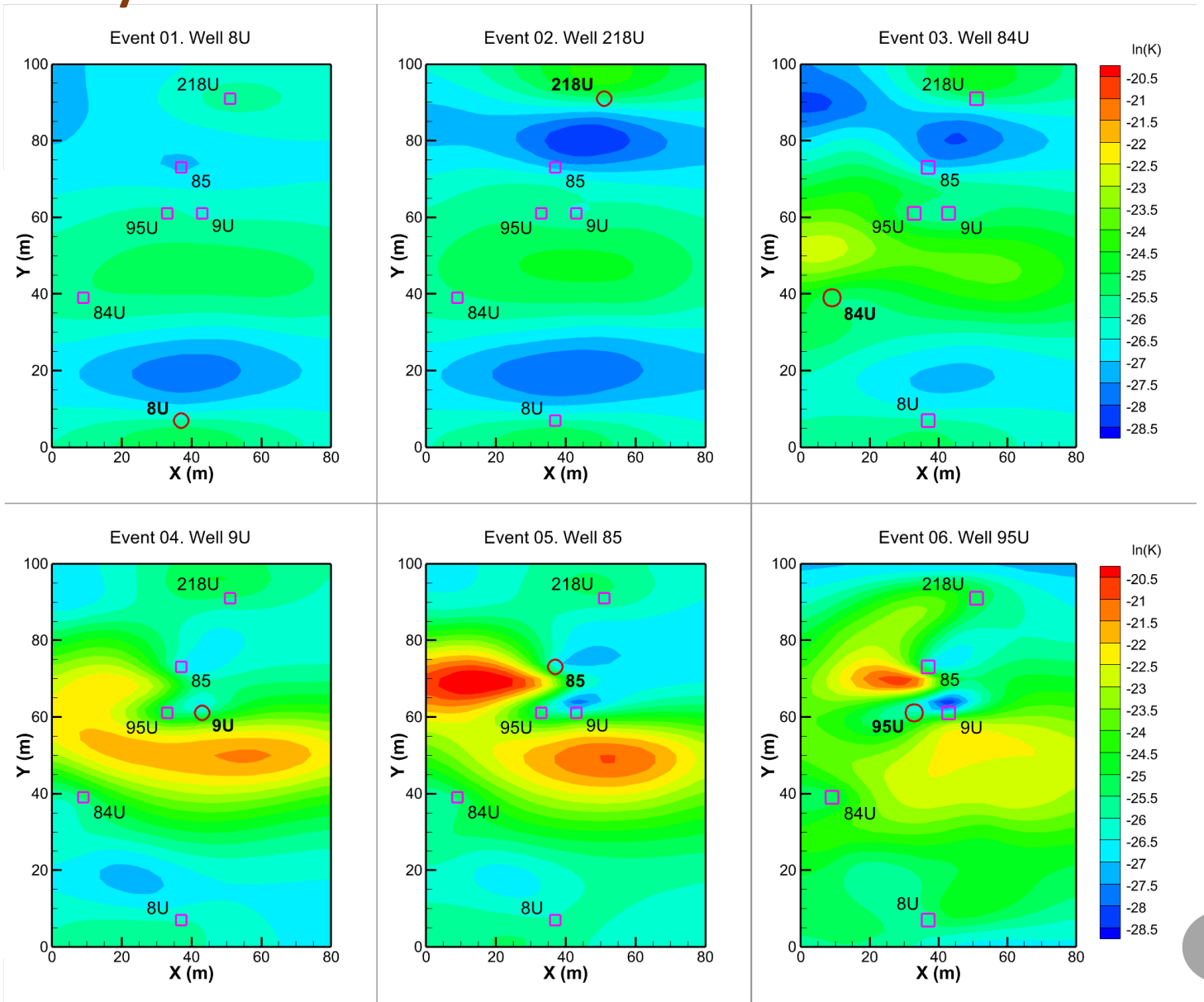
218U



The estimated pneumatic permeability

❖SSLE results





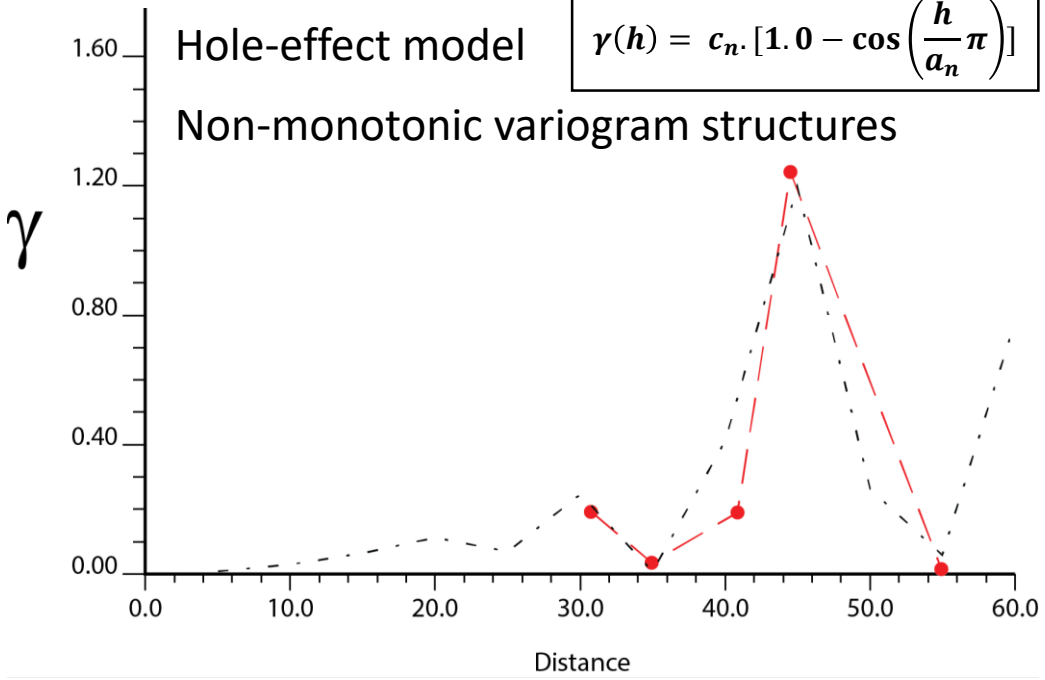
The estimated pneumatic permeability

❖ Kriging result

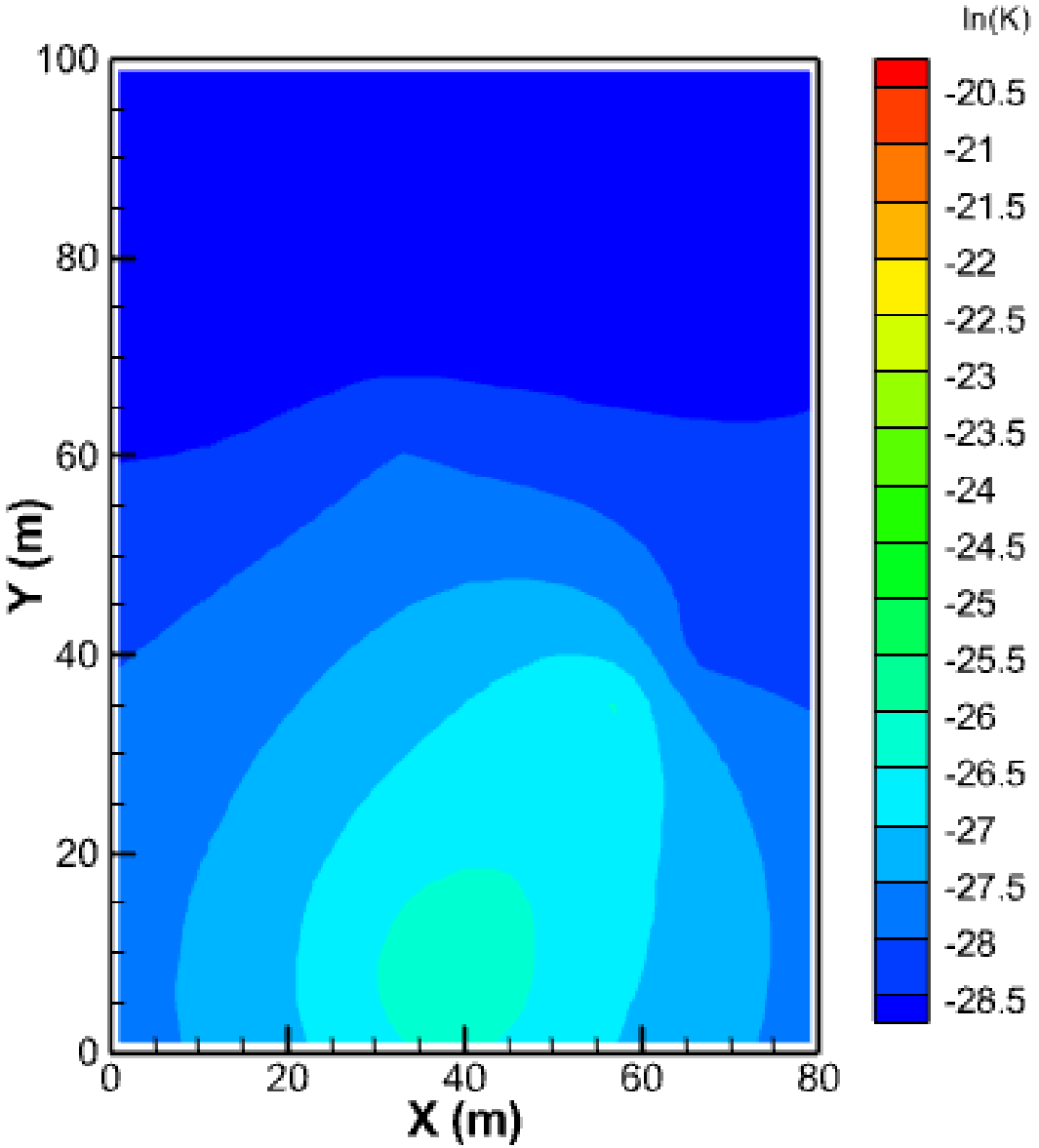
Hole-effect model

$$\gamma(h) = c_n.[1.0 - \cos\left(\frac{h}{a_n}\pi\right)]$$

Non-monotonic variogram structures



Parameters	Values
Number of lag	12
Lag tolerance	5
Distance between lags	1.5



Conclusion

- Pneumatic inverse model can detect detailed spatial variations of geologic parameters with a limited number of measurements for unsaturated and heterogeneous formations.

- For applications of realistic problems these hydrogeologic conditions may require sophisticate adjustments to meet conditions on sites.

- We need the element sizes to be small enough to well capture the variability of parameters in modeling areas

Future work

- Validation model
- Transient condition
- Uncertainty

Thank you for listening