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Remedy Monitoring Using ERT at the 100-K Soil Flushing Site

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on Environmental Remediation
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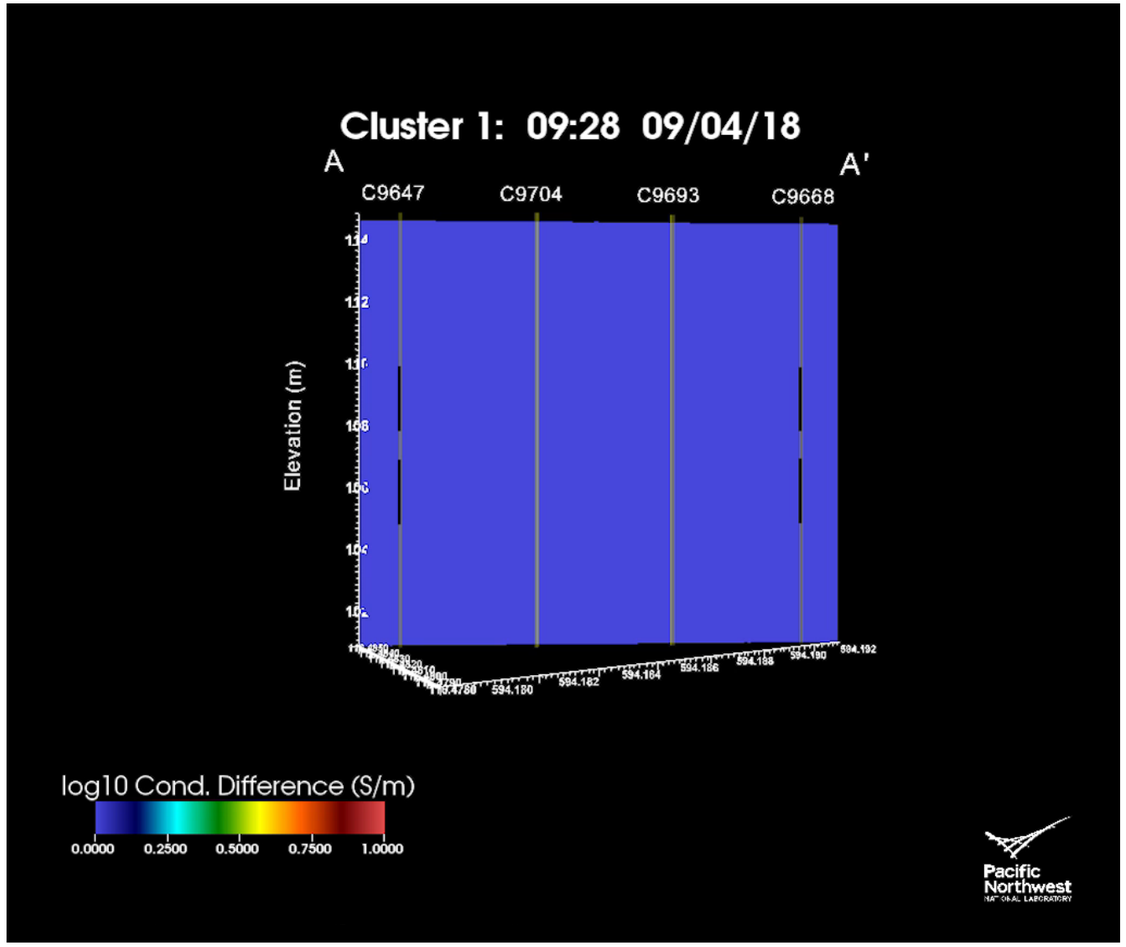
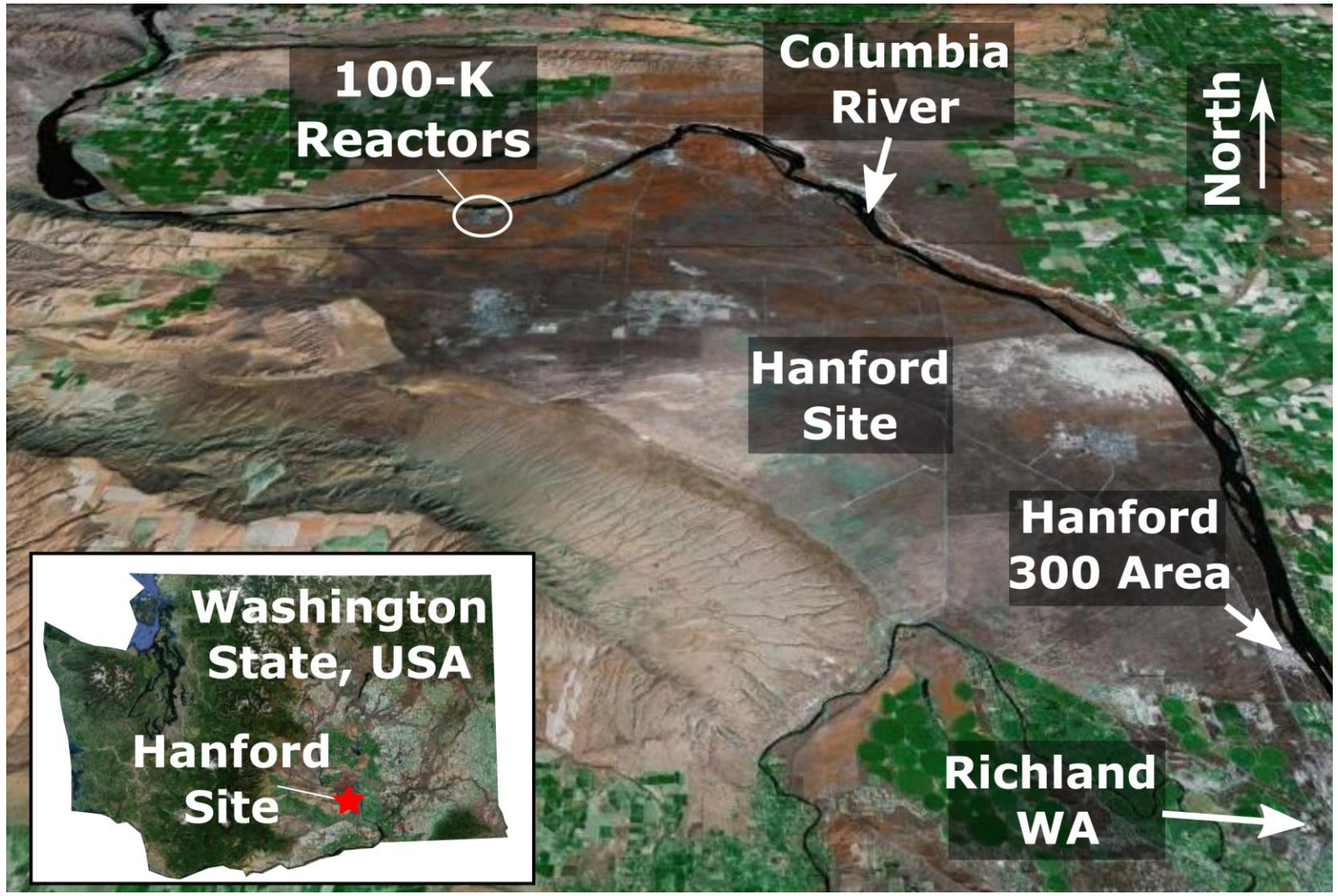
Key Points

- Real-time ERT can provide a feedback mechanism for controlling/optimizing remediation operations “on the fly”
- Real-time 3D ERT is accessible
- Autonomous ERT can provide enhanced remediation performance monitoring understanding at reduced cost.



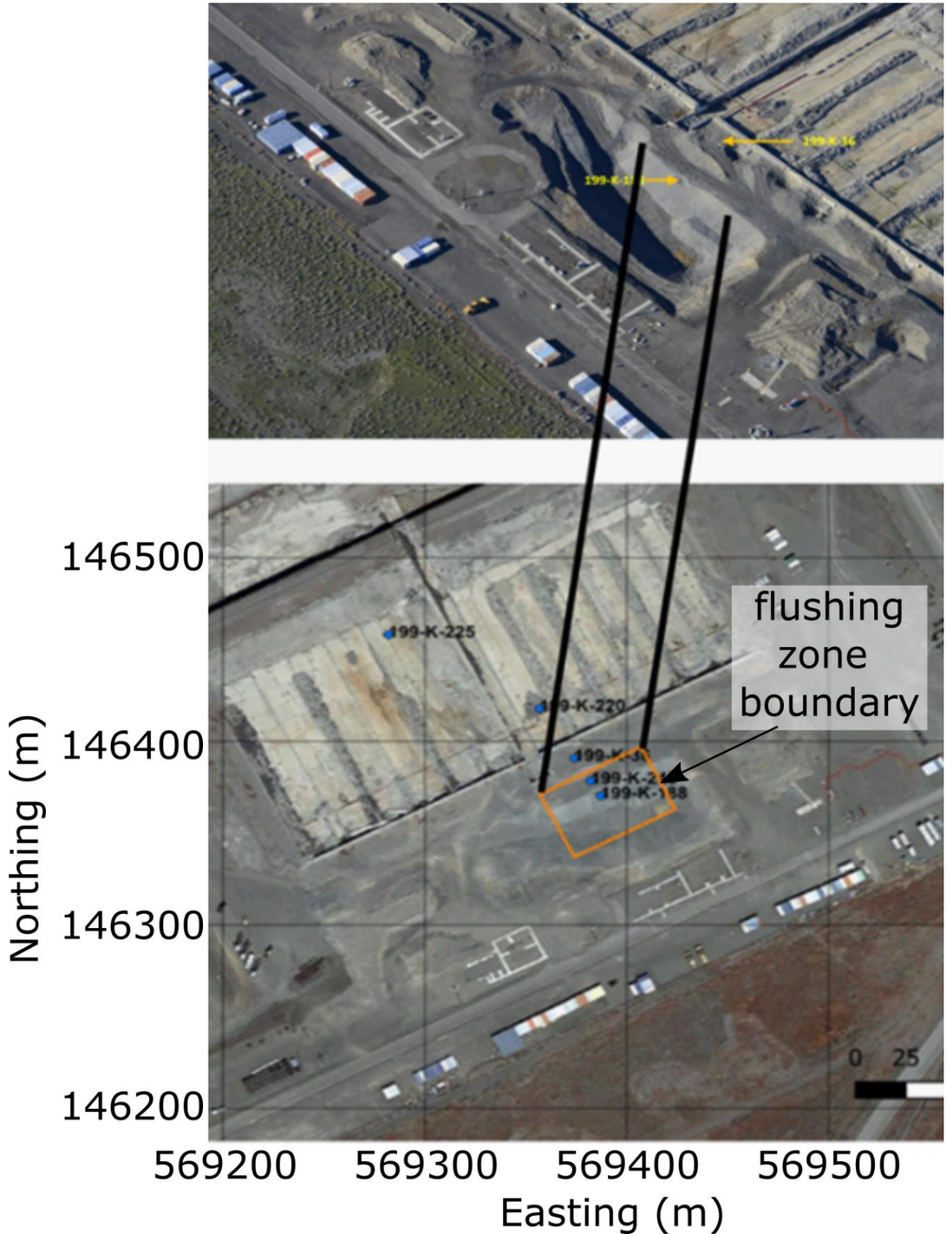
Hanford Site

- Produced plutonium for U.S. weapons production
- 9 production reactors
- 5 plutonium extraction facilities
- 212 million liters high level waste stored in tanks
- 1.7 trillion liters lower-level liquid waste discharged to ~100 m thick vadose zone.
- Cleanup operations since late 1980’s



100 K Chromium Source Term Remediation

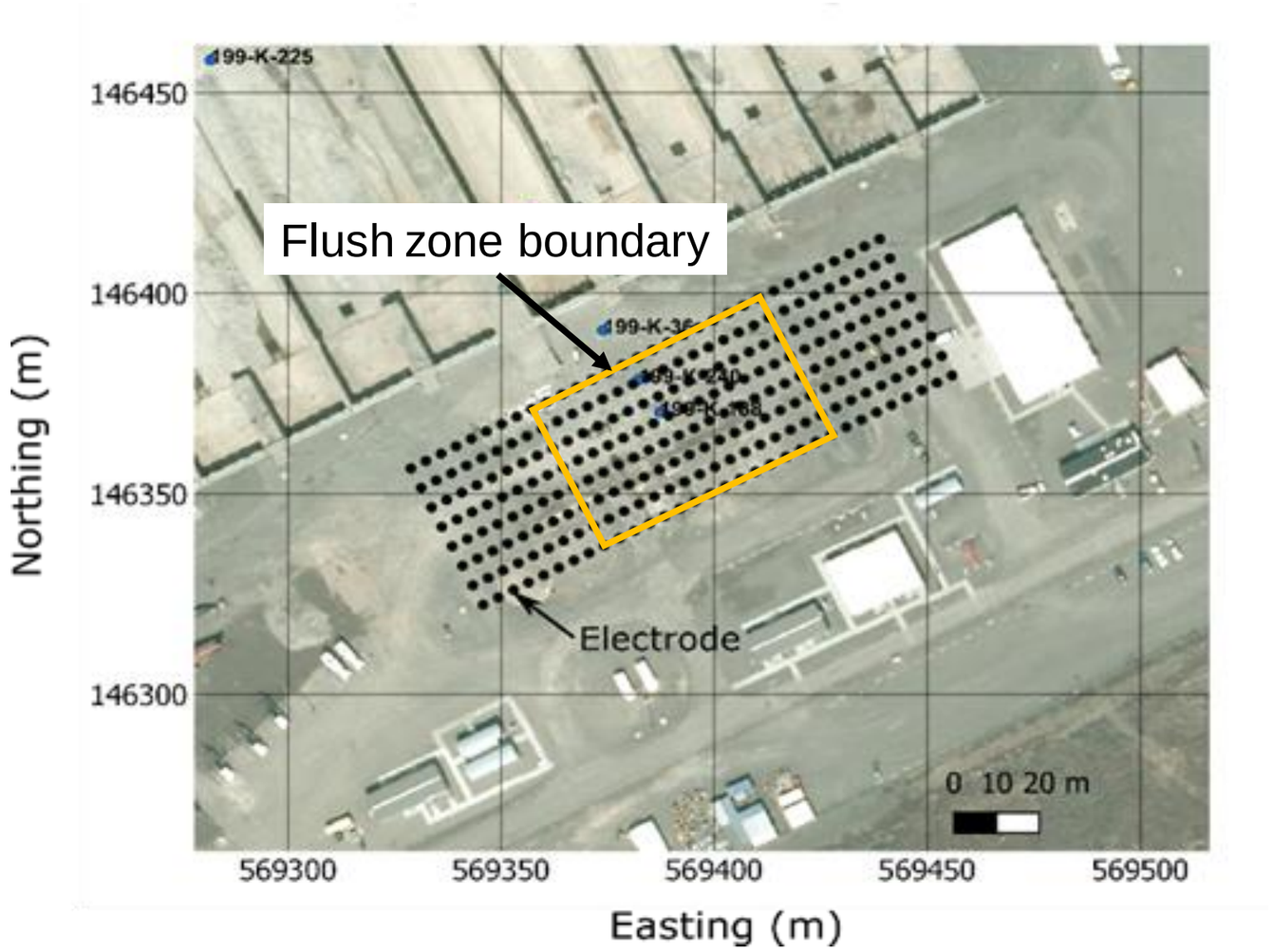
- Plan A: Excavate
  - Incomplete source removal
- Plan B: Soil Flushing
  - Backfill excavation pit
  - Apply clean water at surface to flush chromium to water table
  - Pump and treat

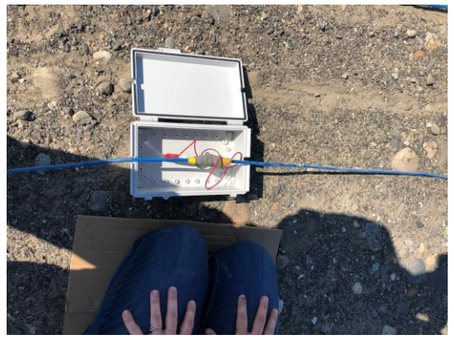


Surface ERT Monitoring Array

ERT Monitoring Array

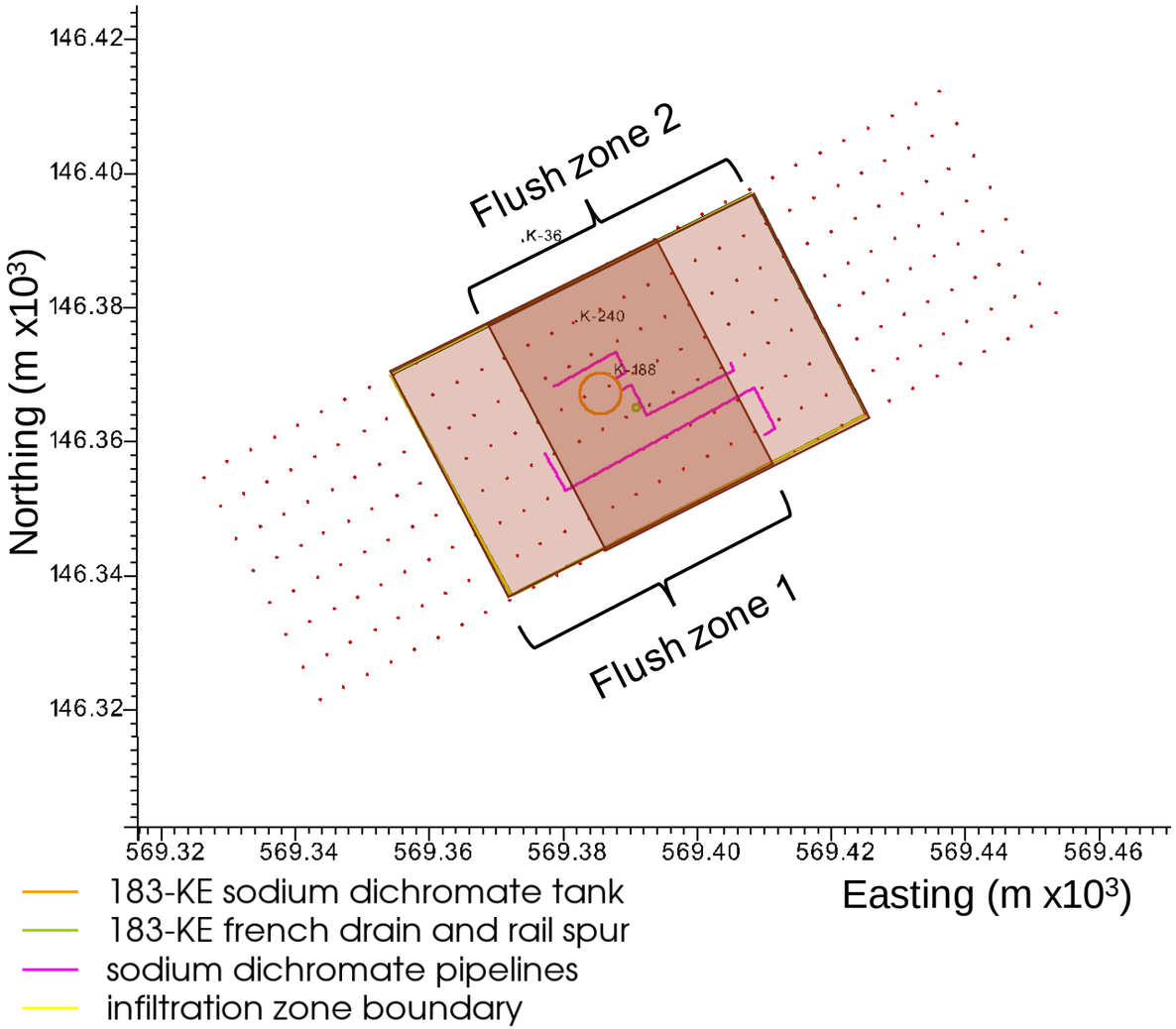
- 8 lines (124m / 407 ft long)
- 5.4m between lines
- 4 m between electrodes
- 256 electrodes
- 3D acquisition
- Surveys every 2 hrs. for 3 months.





Flushing Operations

- Flush water application alternated weekly between zones 1 and 2
- Continuous application
- Started at 340 liters/min (90 gal/min)
- Increased to 454 liters/min (120 gal/min) over time



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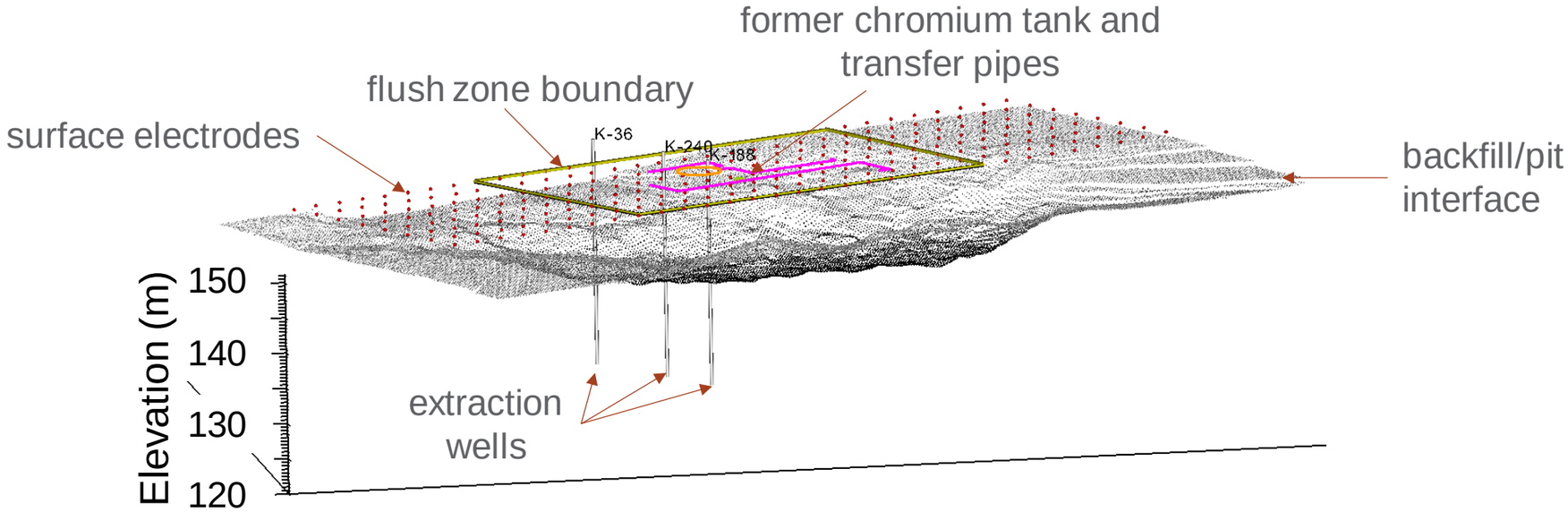
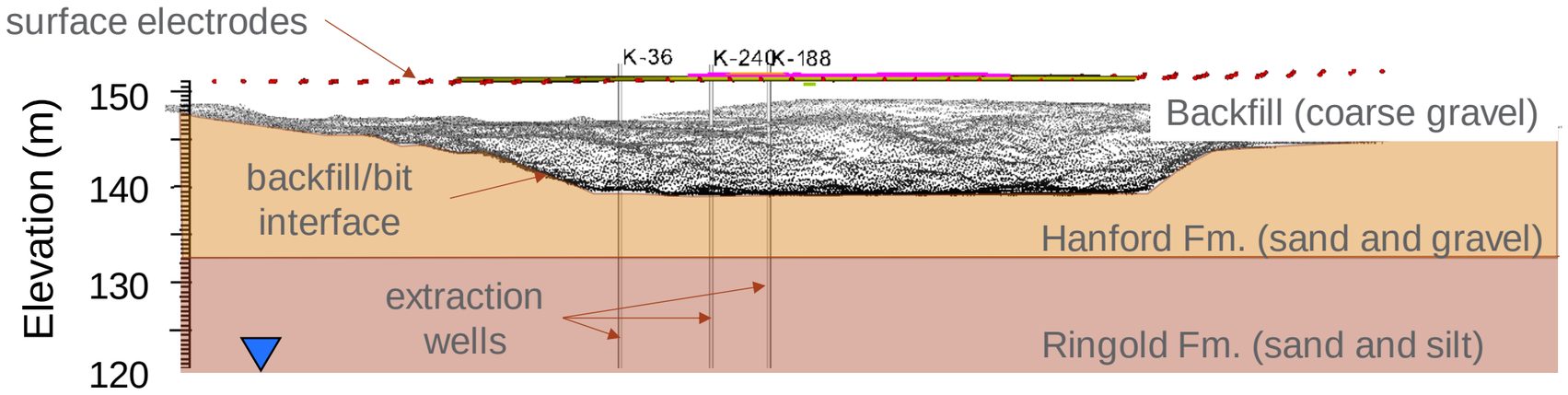
100 K Geology





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Soil Flushing in Action …

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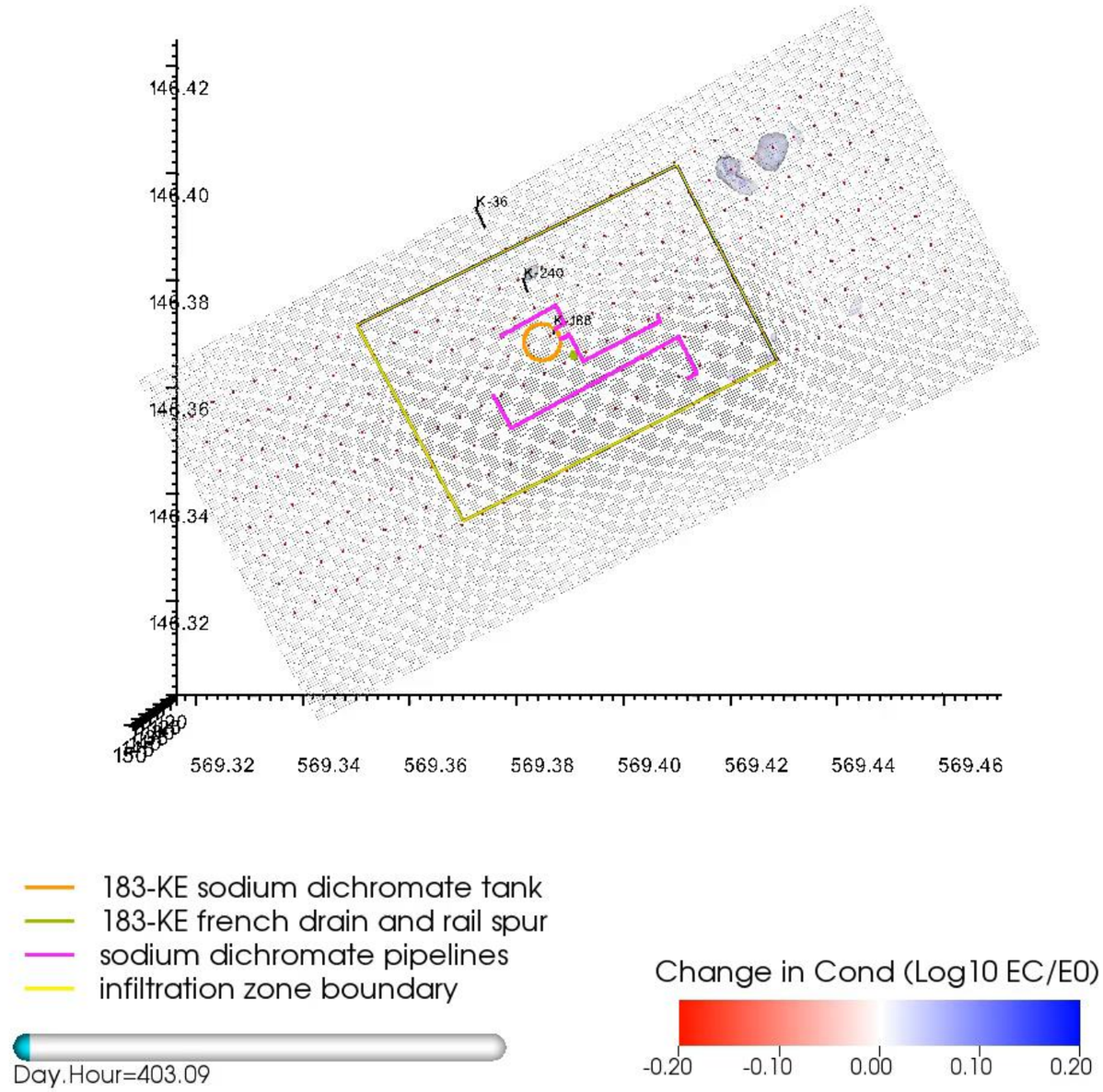
Time-lapse Inversion Constraints

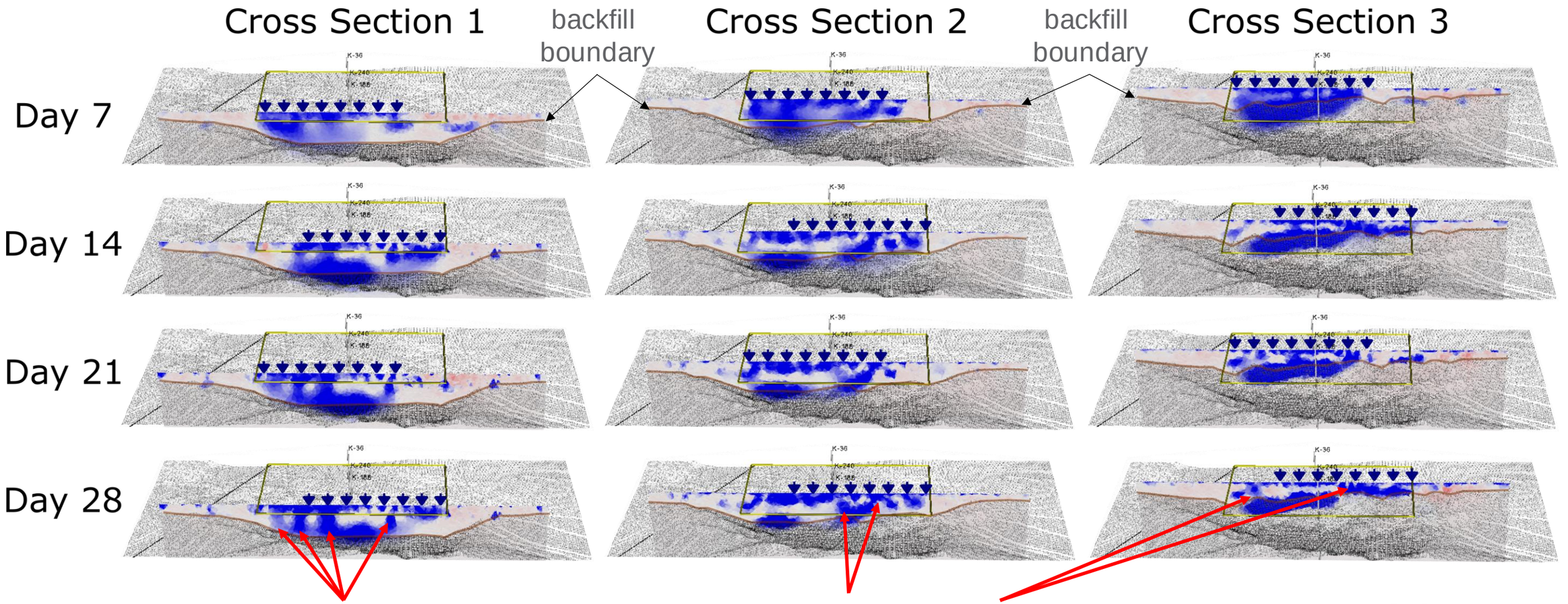
- Spatio-temporal smoothing regularization
  - Constrains changes from the previous time-step to vary smoothly in space
- Positive change inequality constraint
  - Bulk Conductivity at current time >= Bulk Conductivity at time zero.
- Metal wellbore casings explicitly simulated in forward modeling step.
- Executed in parallel on 65 cores (desktop workstation)
  - ~25 iterations for baseline, 2-3 per time-lapse survey … (2-5 minutes)
- Open Source E4D code (https://www.pnnl.gov/projects/e4d)

Real-Time 4D ERT Imaging Summary: April 2023

- 10 baseline (pre-flushing) data sets collected to assess data quality and set filter parameters.
- 12 surveys/day
  - Autonomously transferred to offsite computing resources, processed, inverted, archived
- Posted to secure interactive website accessible to operators and stakeholders



Interpretation …



Development of preferred flow paths (unsaturated “finger flow”) develops in the pit backfill over time

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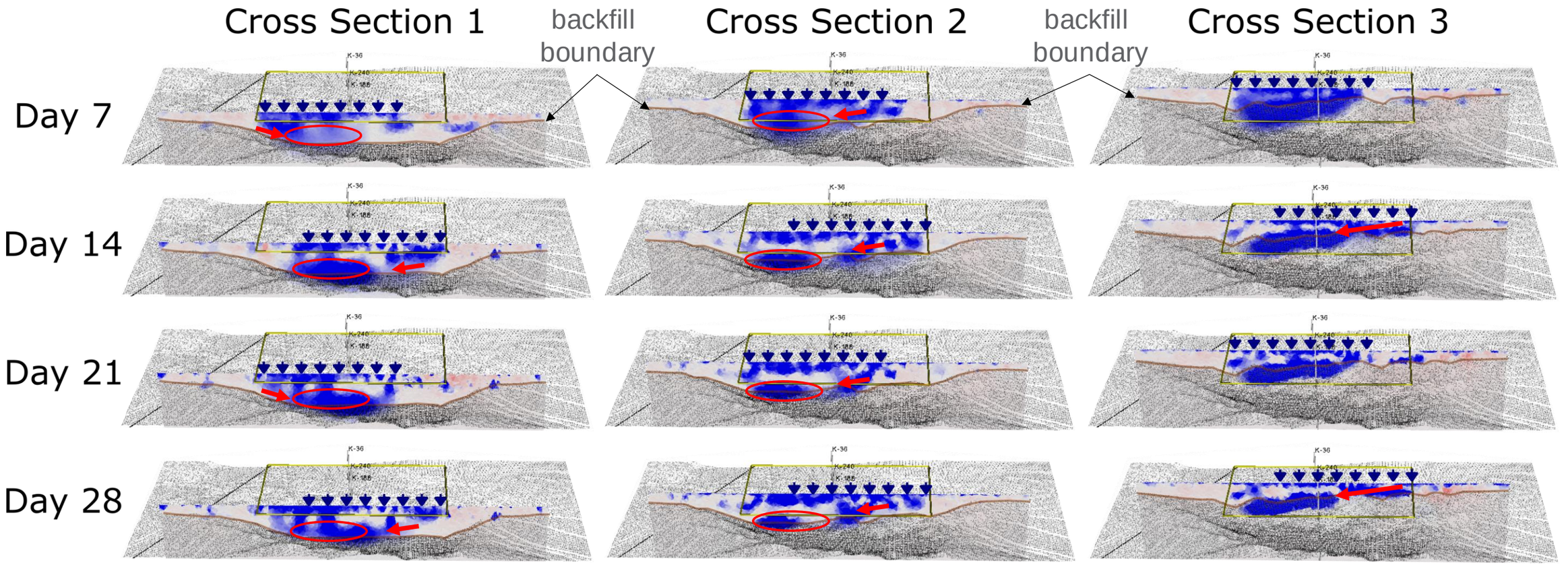
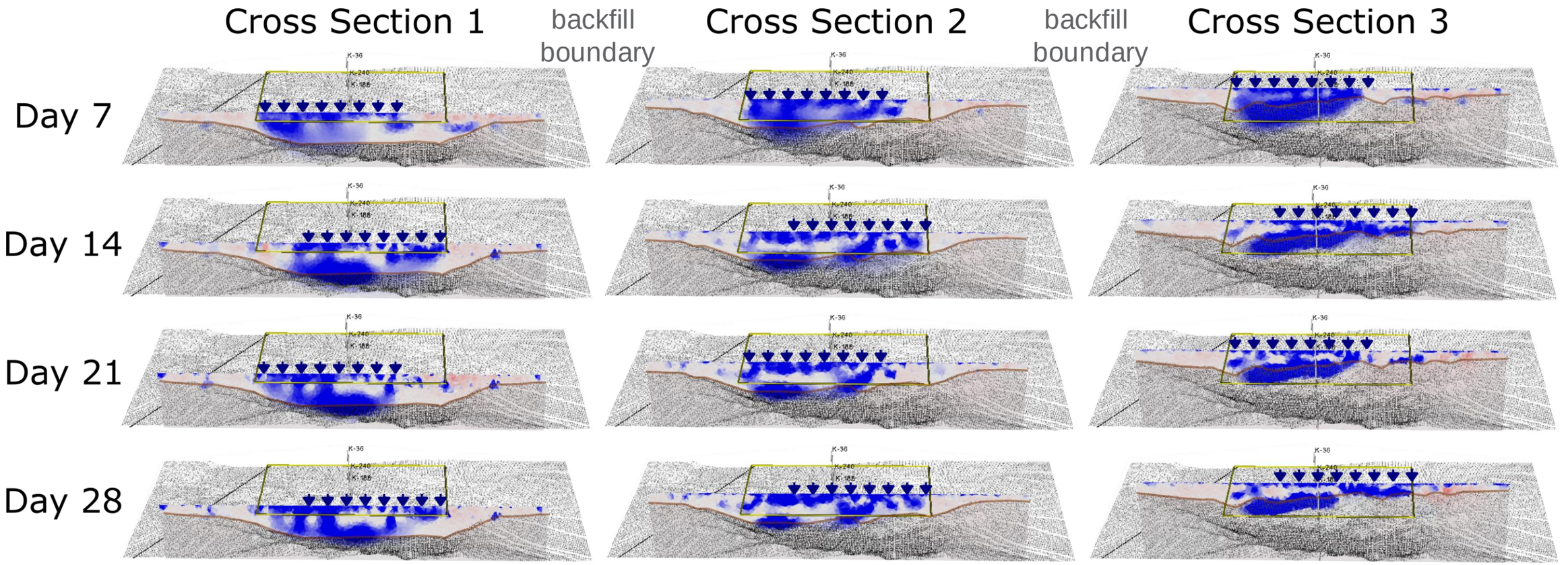
Interpretation …



Flush water flows along backfill boundary with Hanford Fm., perches at deepest points, redistributes before flowing downward

Interpretation …



The presence of backfill material has a significant impact on the distribution of flush water to the Hanford Fm., and therefore on remediation performance.

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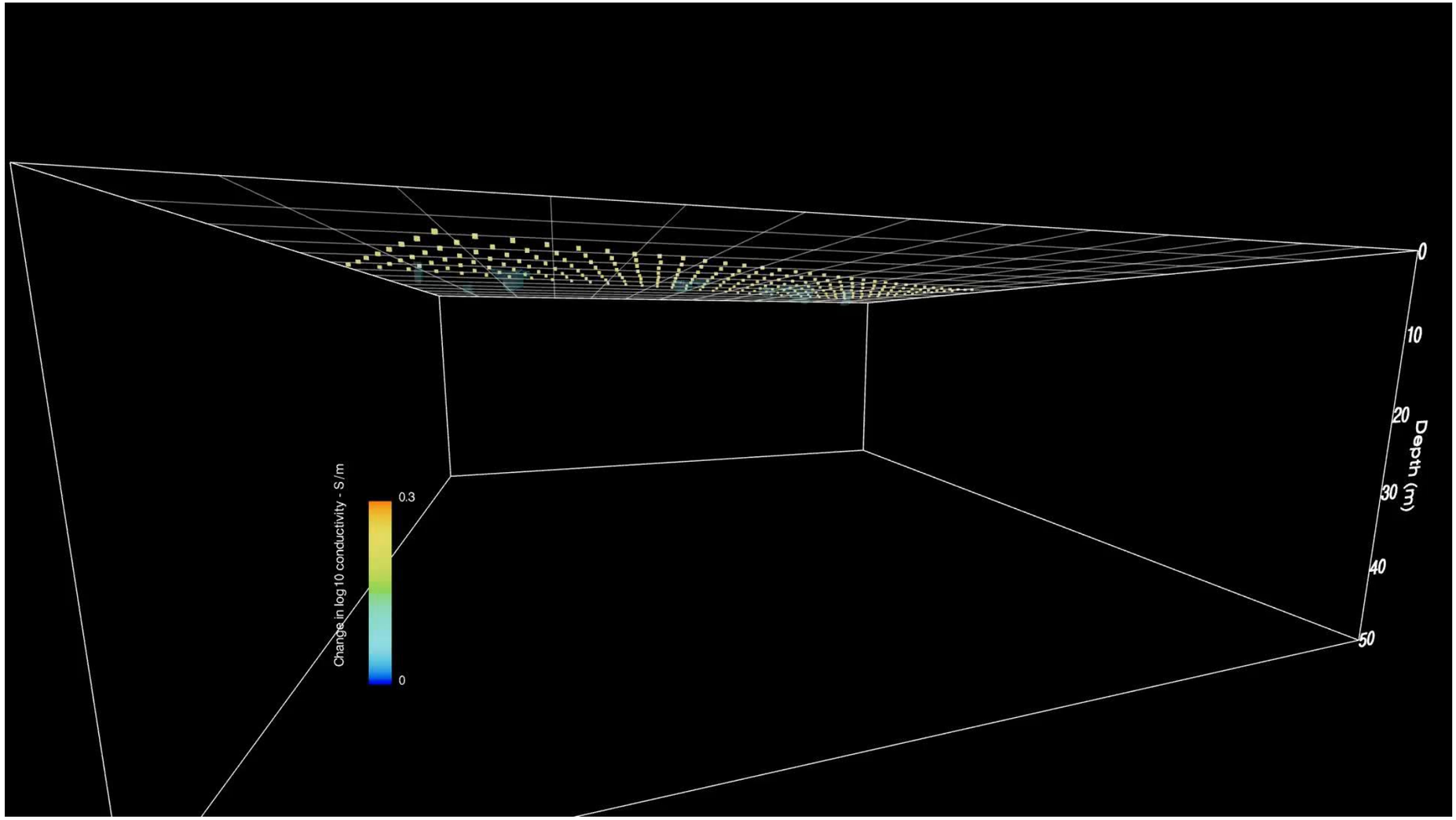
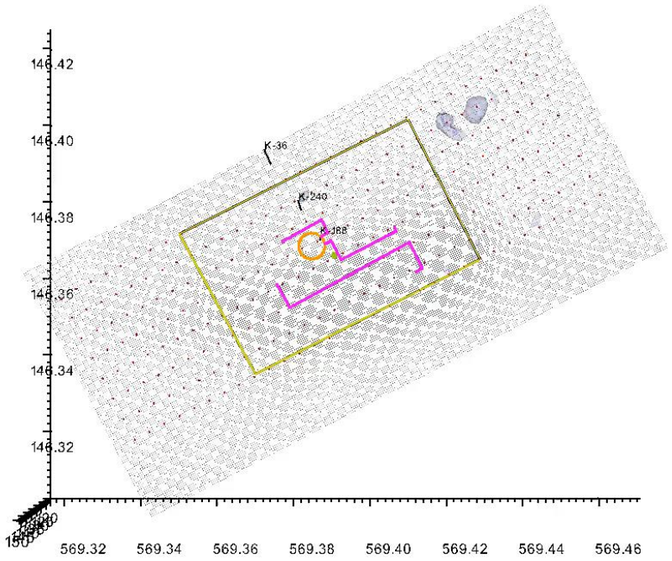
Real-time Visualization Web Interface



Summary

- ERT provided enhanced understanding
  - influence of backfill material
  - fast flow paths and heterogeneous flow distribution
- Near real-time 4D imaging
- Cost Effective



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Questions?

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