3D Site Characterization and Autonomous Remedial Process Monitoring Using High Performance Electrical Resistivity and Induced Polarization Tomographic Imaging

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NAVFAC Naval Facilities Engineering Command ENGINEERING SERVICE CENTER

INL Idaho National Laboratory

USGS science for a changing world

SKY RESEARCH

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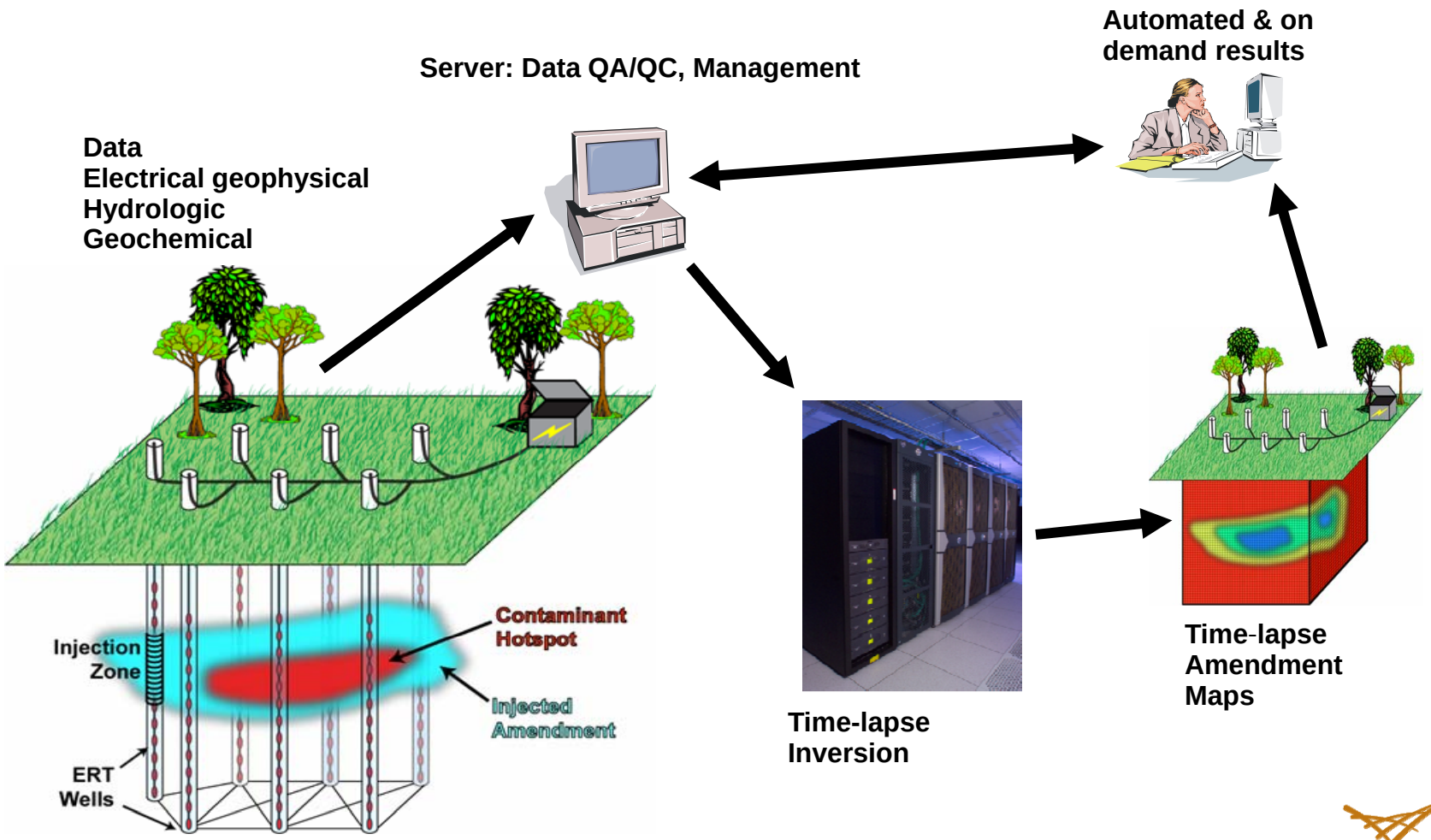
Acknowledgements

- **ESTCP – Environmental Resotoration**
  Optimized Enhanced Bioremediation Through Four-Dimensional Geophysical Monitoring and Autonomous Data Collection, Processing, and Analysis, ER-2001717
- **Andrews AFB**
- **CH2MHILL Plateau Remediation Company**

Outline

- Autonomous Electrical Resistivity Tomography (ERT) characterization and monitoring systms.
- What and how we measure
- How we monitor spatial and temporal changes in electrical properties (time-lapse inversion)
- What does it mean in terms of properties we're interested in
- Examples
  - Brandywine MD DRMO Superfund Bioremediation Monitoring
  - Soil desiccation characterization and monitoring at the Hanford BC Cribs
- Concluding comments

ELECTRIC GEOPHYSICAL MONITORING COMPONENTS



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Field scale electrical geophysical measurements

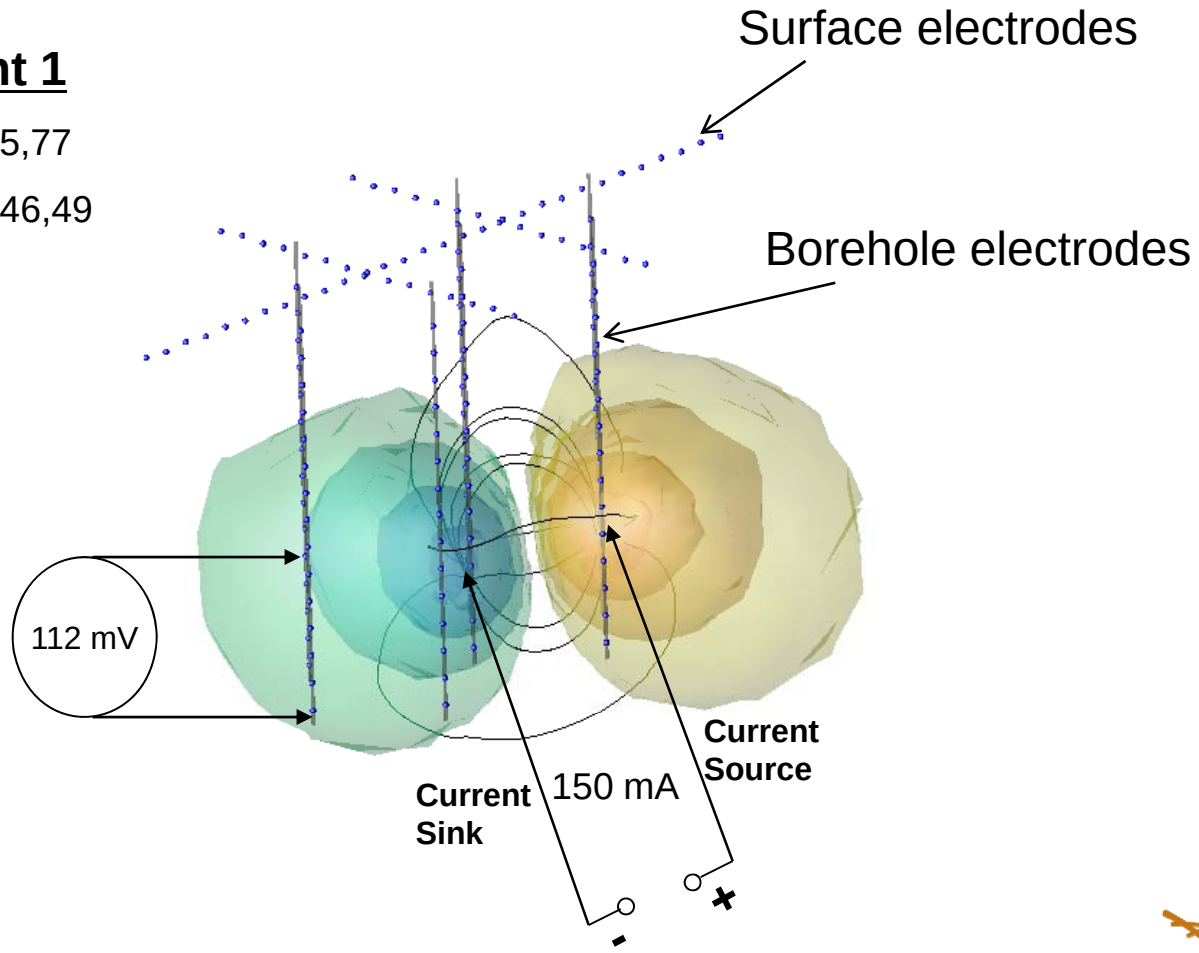
Measurement 1

Current Electrodes: 55,77

Potential Electrodes: 46,49

Current: 150 mA

Voltage: 112 mV



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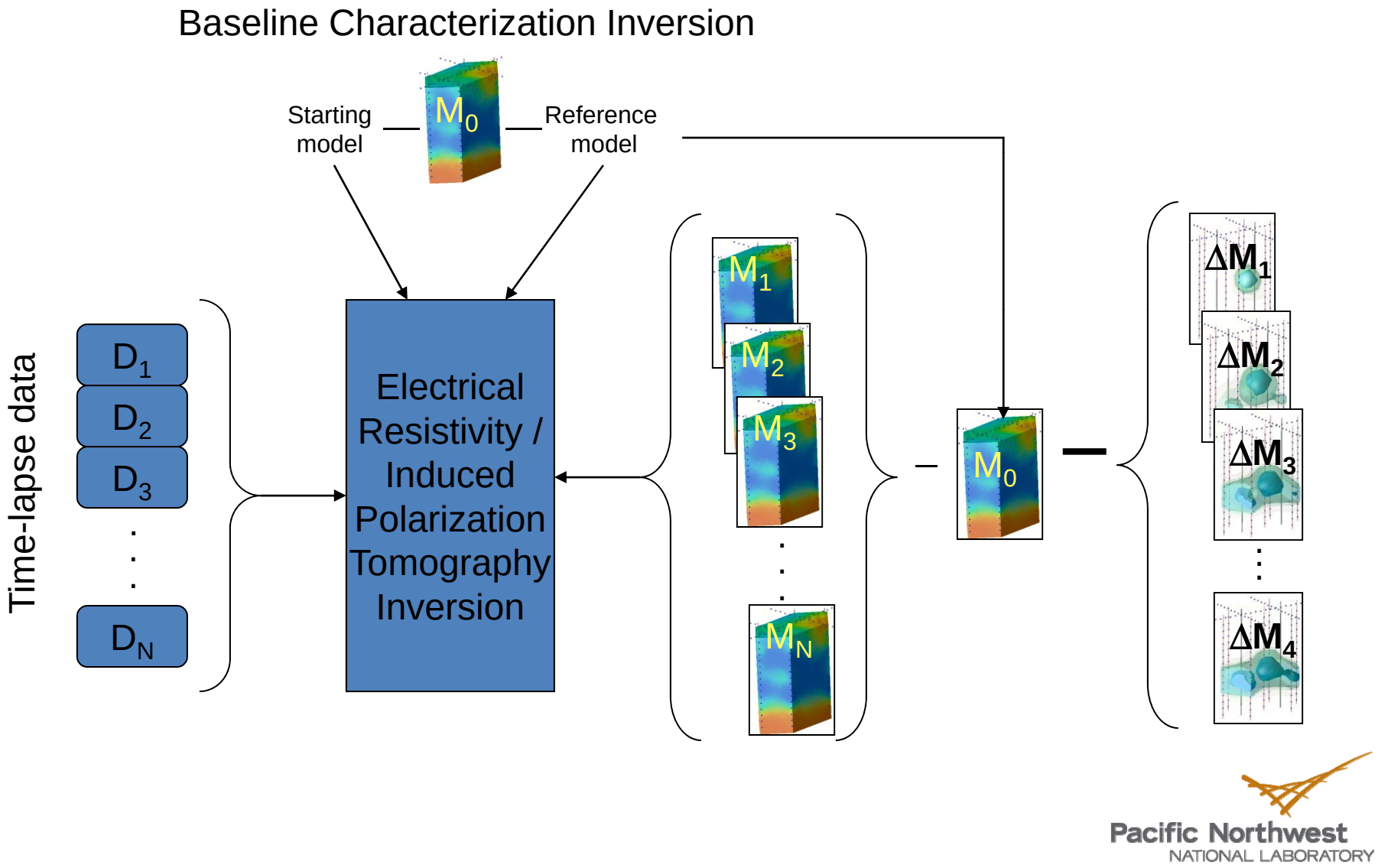
3D characterization and monitoring flowchart



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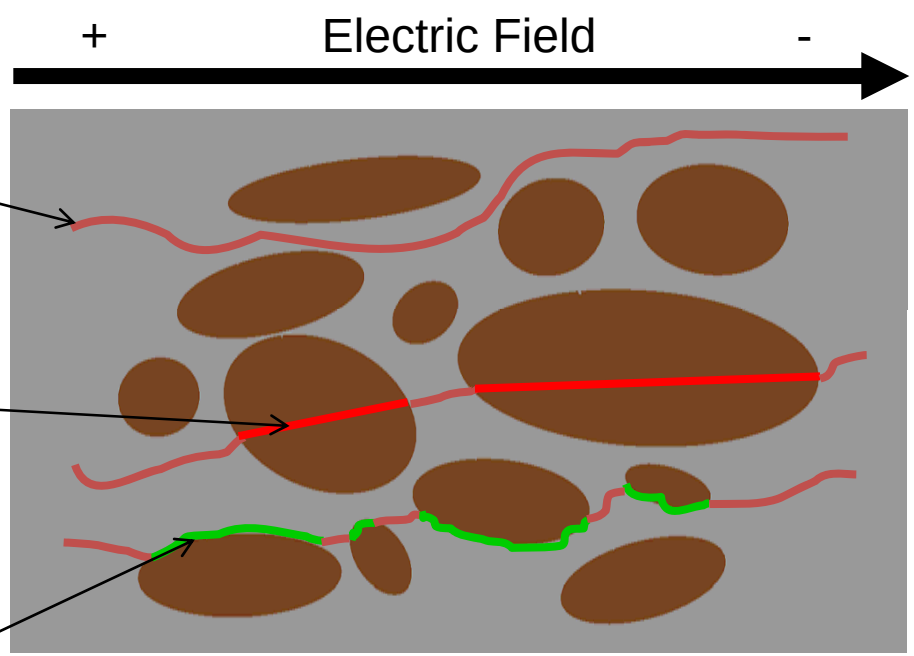
Pore-scale current conduction mechanisms

Ionic Conduction is sensitive to:
Pore fluid conductivity
Saturation
Temperature

Electronic Conduction is sensitive to:
Mineral conductivity
Temperature

Interfacial Conduction is sensitive to:
Interfacial electrochemistry
Temperature



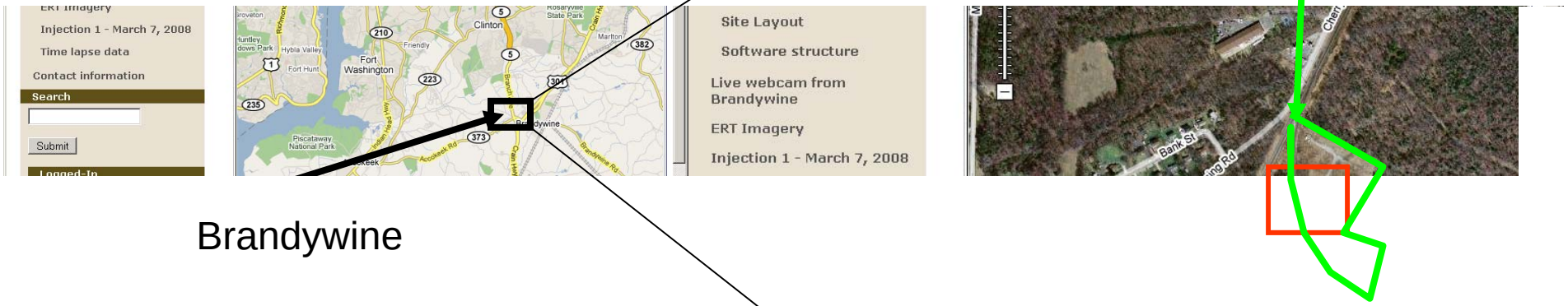
Total Conductivity = ionic + electronic + interfacial

Brandywine MD DRMO Superfind Site

Andrews AFB

Site location

Brandywine DRMO (green box)



Brandywine

- Primary groundwater contaminant is TCE
- Primary soil contaminants PCB
- Plume has spread from Air force property to residential property
- Contamination resides in upper 30 feet, sandy gravel, aquitard at 30 ft bgs

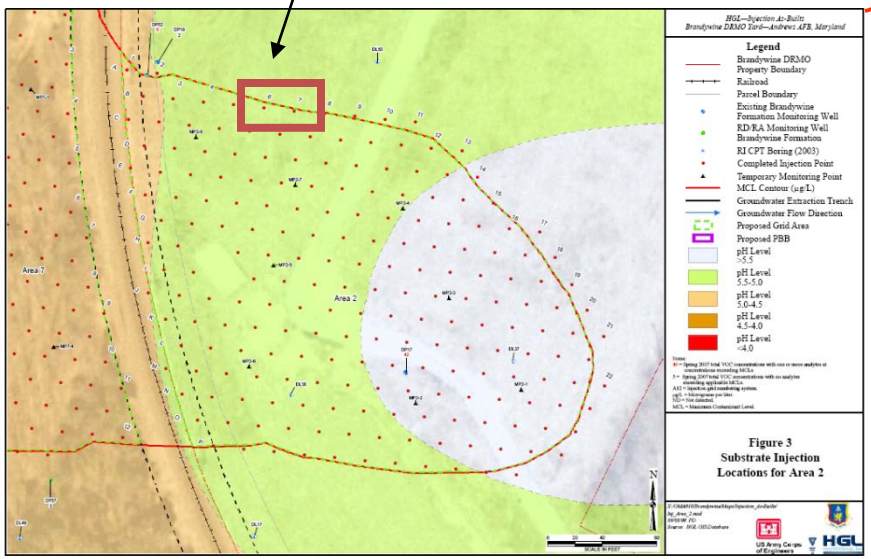
DRMO Enhanced Bioremediation

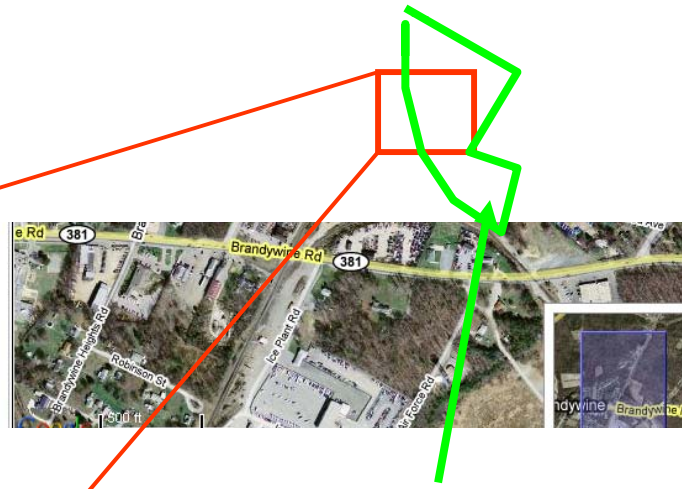
Site location

Remedial Action

- Amendment injections at ~1000 injection points
- Injection point spacing ~ 20 ft
- Dem/Val effort monitored two of the injections at edge of March/April 2008 treatment area

Dem/Val study area
(injections B6 & B7)





Brandywine DRMO
(green box)

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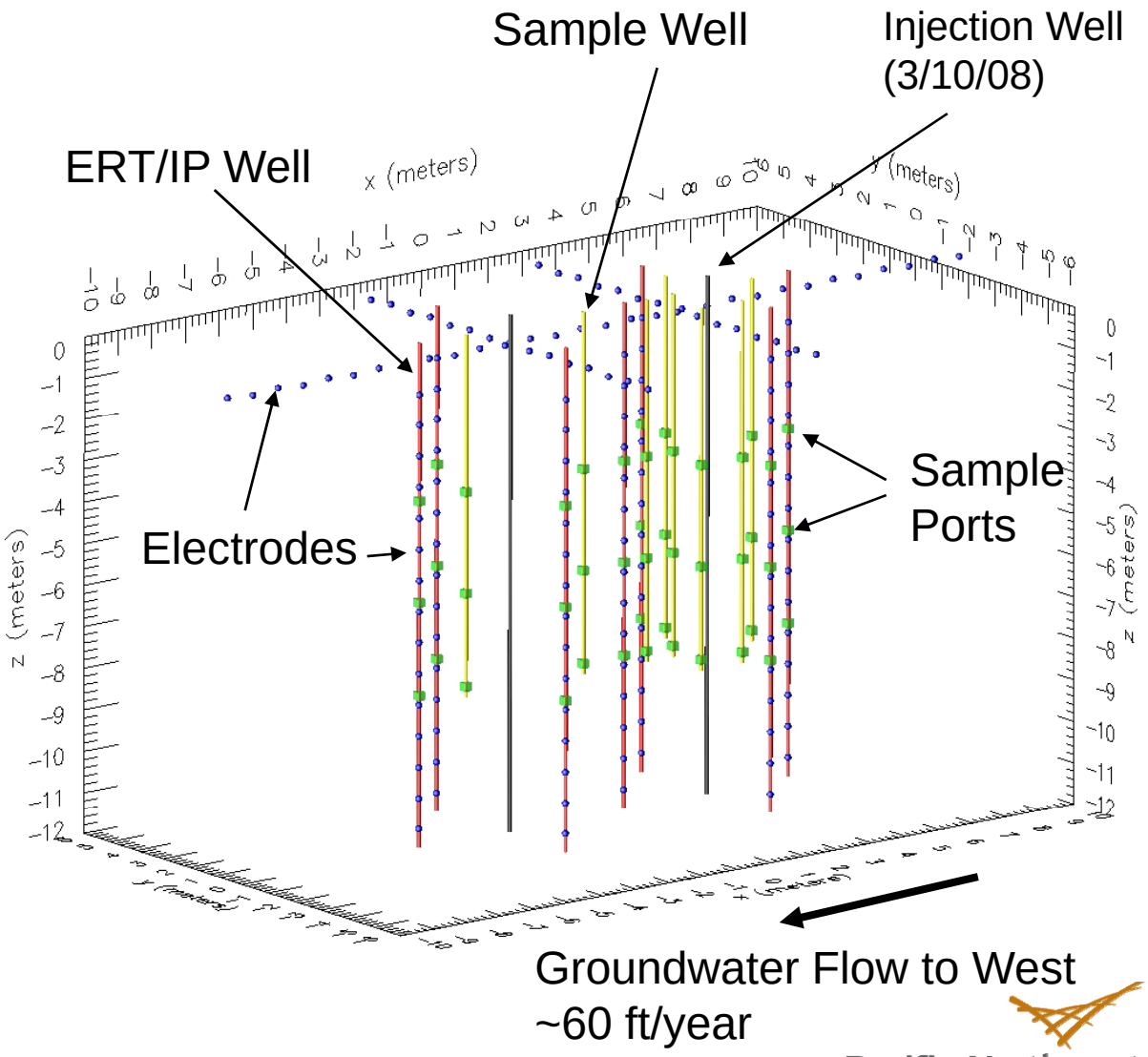
ERT/IP Monitoring Systems Details

- 8 Chem sample wells
- 7 ERT/Chem wells

- ERT wells: 15 electrodes @ 2 feet spacing. 2 inch Sampling ports at 11,19 and 26 feet

-Sampling wells: sampling ports at 11 and 19 feet. Well screen at bottom (26 feet)
-45 total sampling ports

-ERT data acquisition: repeat 3D survey with 35000 measurements



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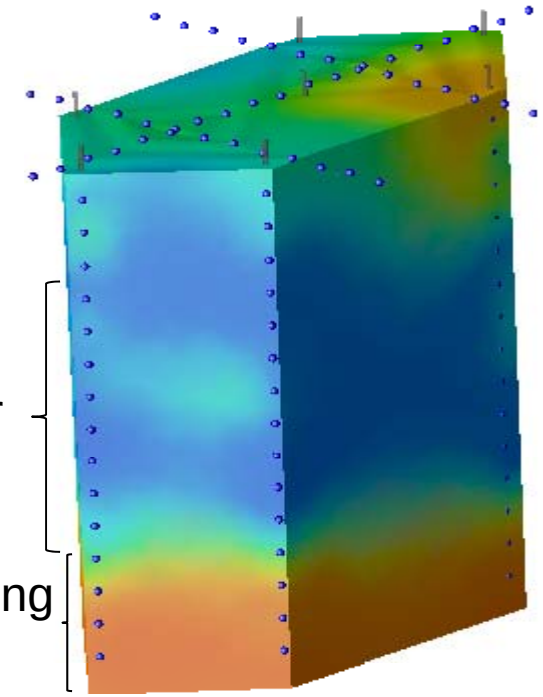
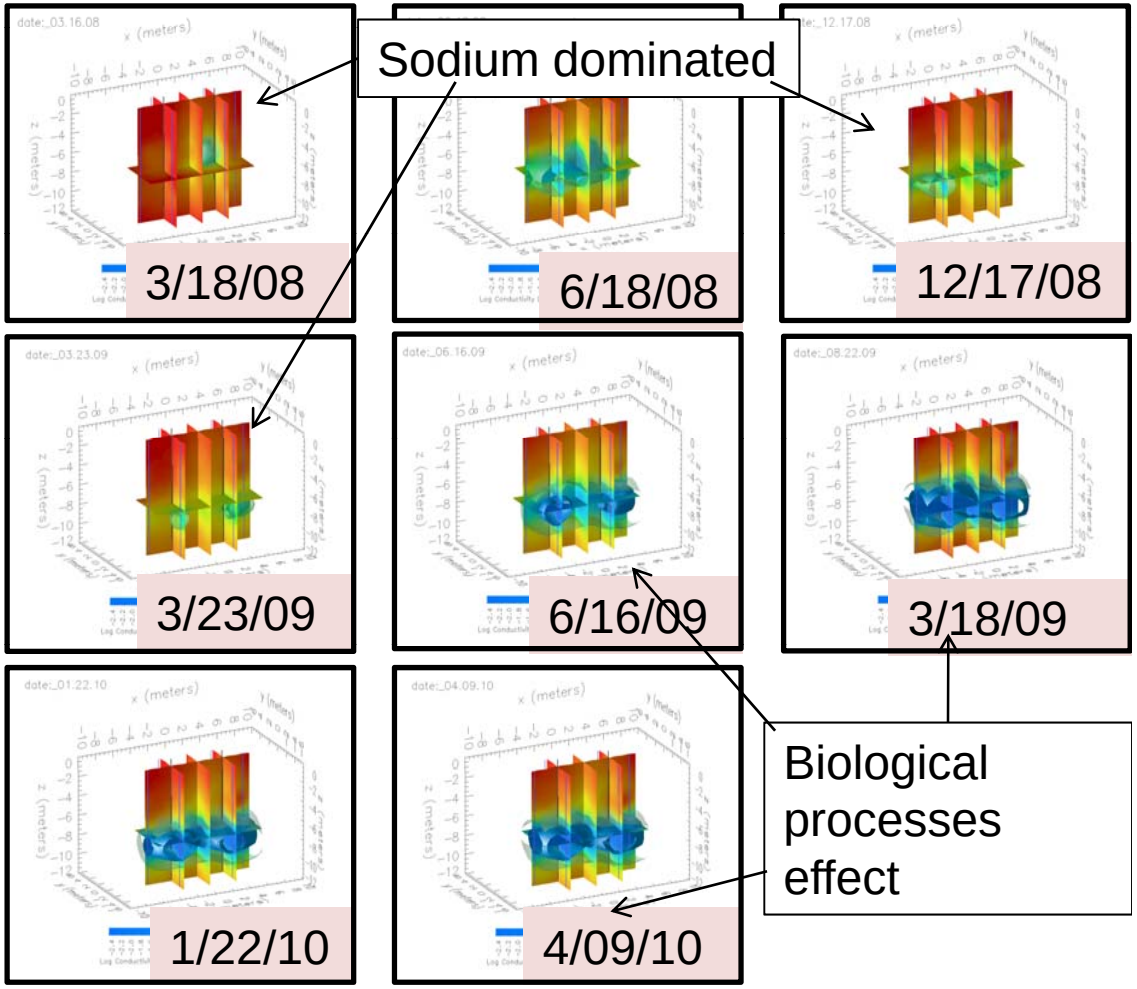
Time-lapse ERT imaging results

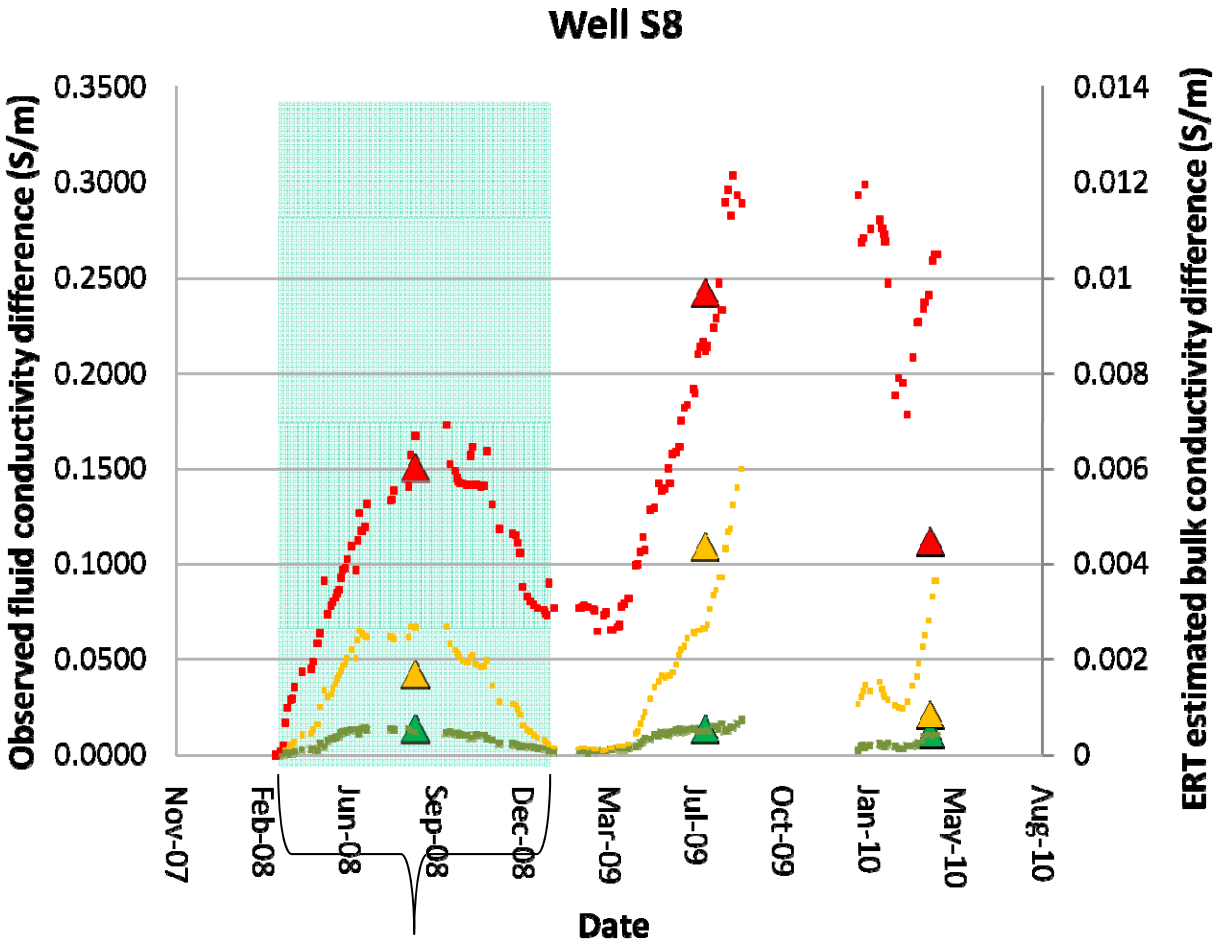
Baseline Characterization





Simplified description: initially “conservative tracer” (first year) (signal results from changes in fluid conductivity) followed by changes in solid phase conductivity resulting from precipitation

Relating changes in bulk conductivity to changes in geochemistry



~3.5 m bgs

~6.0 m bgs

~8.5 m bgs

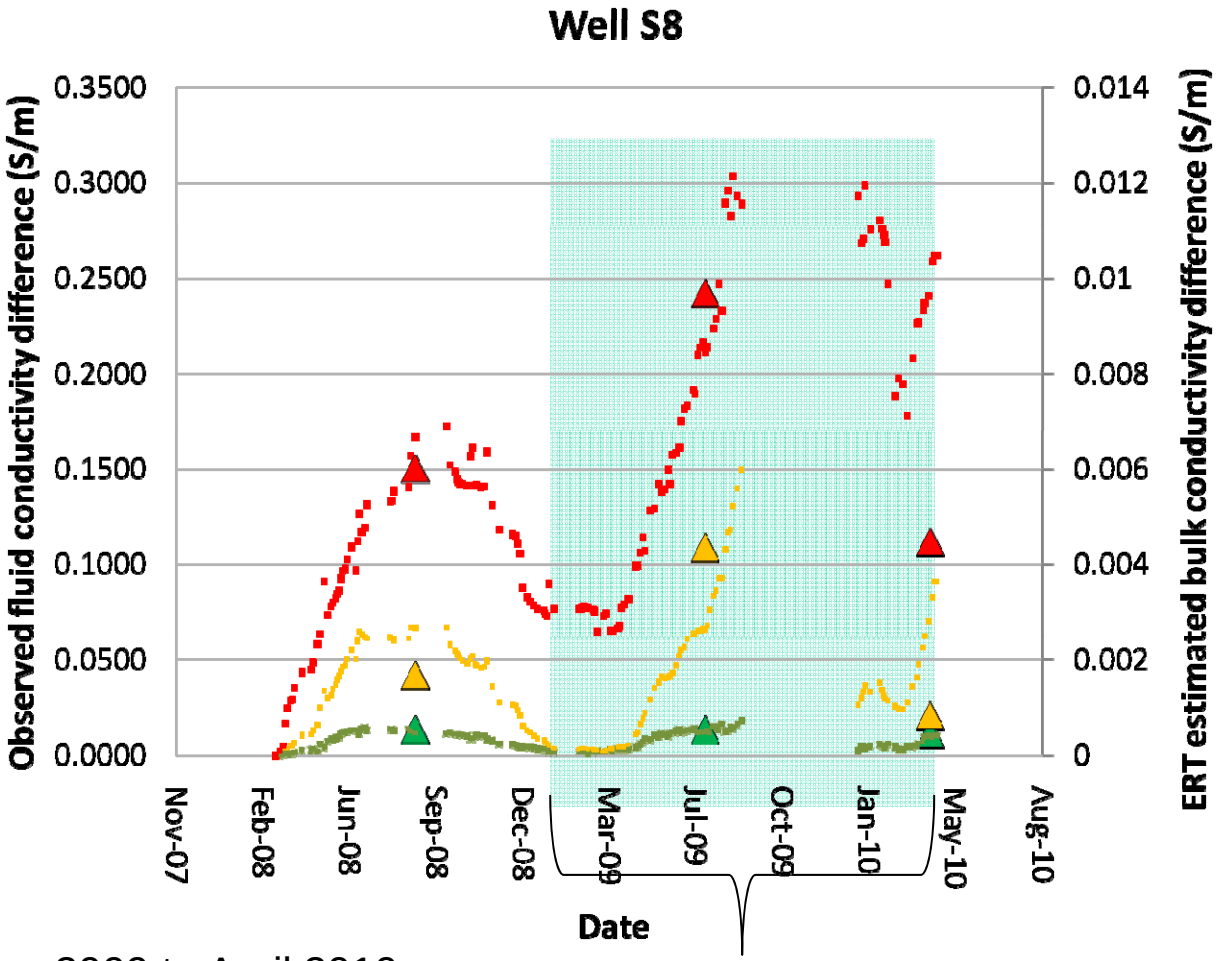
Note:

- Dots are ERT inversion results at sample ports.
- Triangles are fluid conductivity measurements taken at sample ports

March 2008 to Jan. 2009 summary:

- Little microbial activity
- Rise and fall in bulk conductivity due primarily to sodium transport and subsequent dilution.

Relating changes in bulk conductivity to changes in geochemistry



~3.5 m bgs

~6.0 m bgs

~8.5 m bgs

Note:

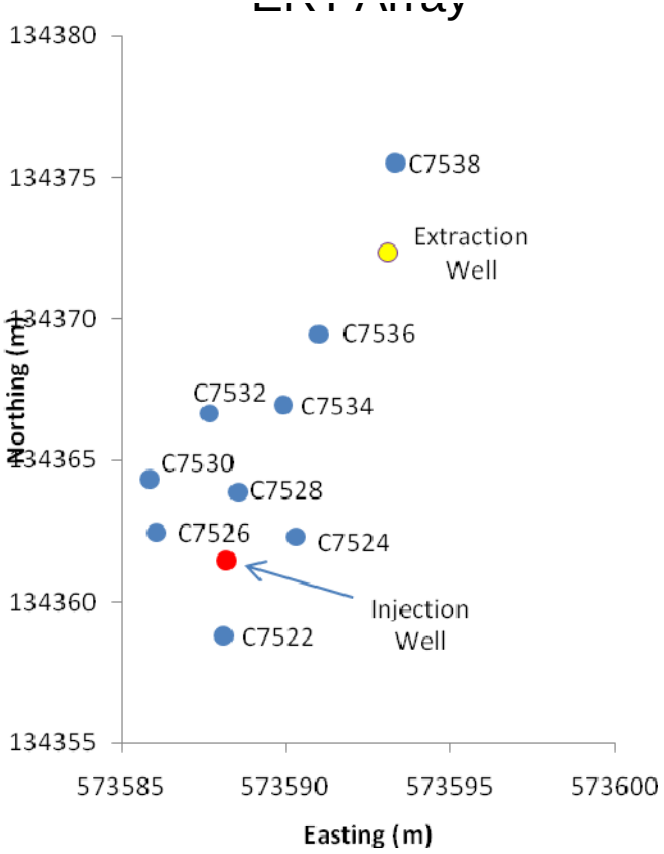
- Dots are ERT inversion results at sample ports.
- Triangles are fluid conductivity measurements taken at sample ports

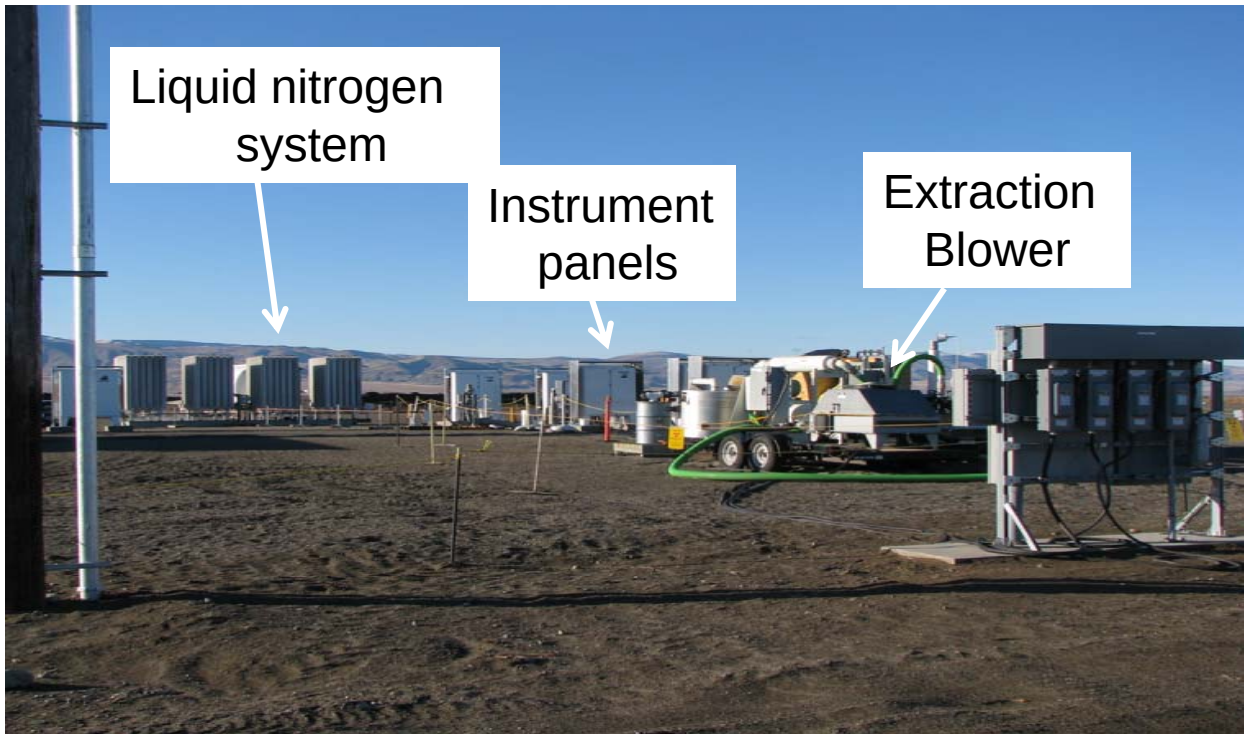
Jan 2009 to April 2010 summary

- Geochemical data suggest vigorous microbial activity
- Fluid conductivity decreases, bulk conductivity increases suggesting increase in interfacial conductivity (iron-sulfide precipitation)

Hanford BC Cribs Desiccation Treatability Test

Historical liquid waste crib.
Primary vadose zone contaminants
Nitrate, Tc^{99}, Uranium





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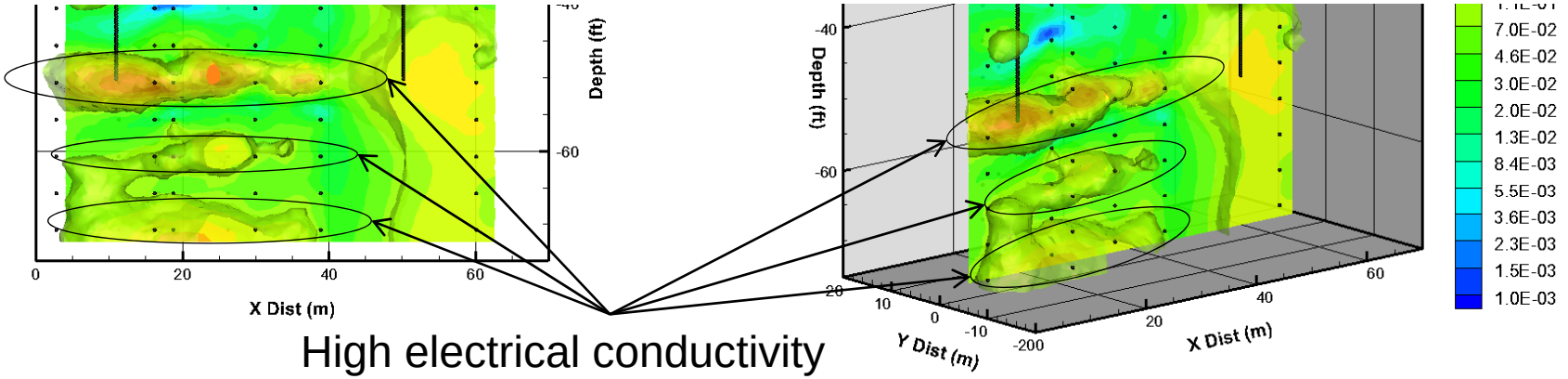
Background ERT Characterization

Section View

Oblique View



High electrical conductivity contaminated zones

- high sat. and/or ionic strength
- low permeability (fine)

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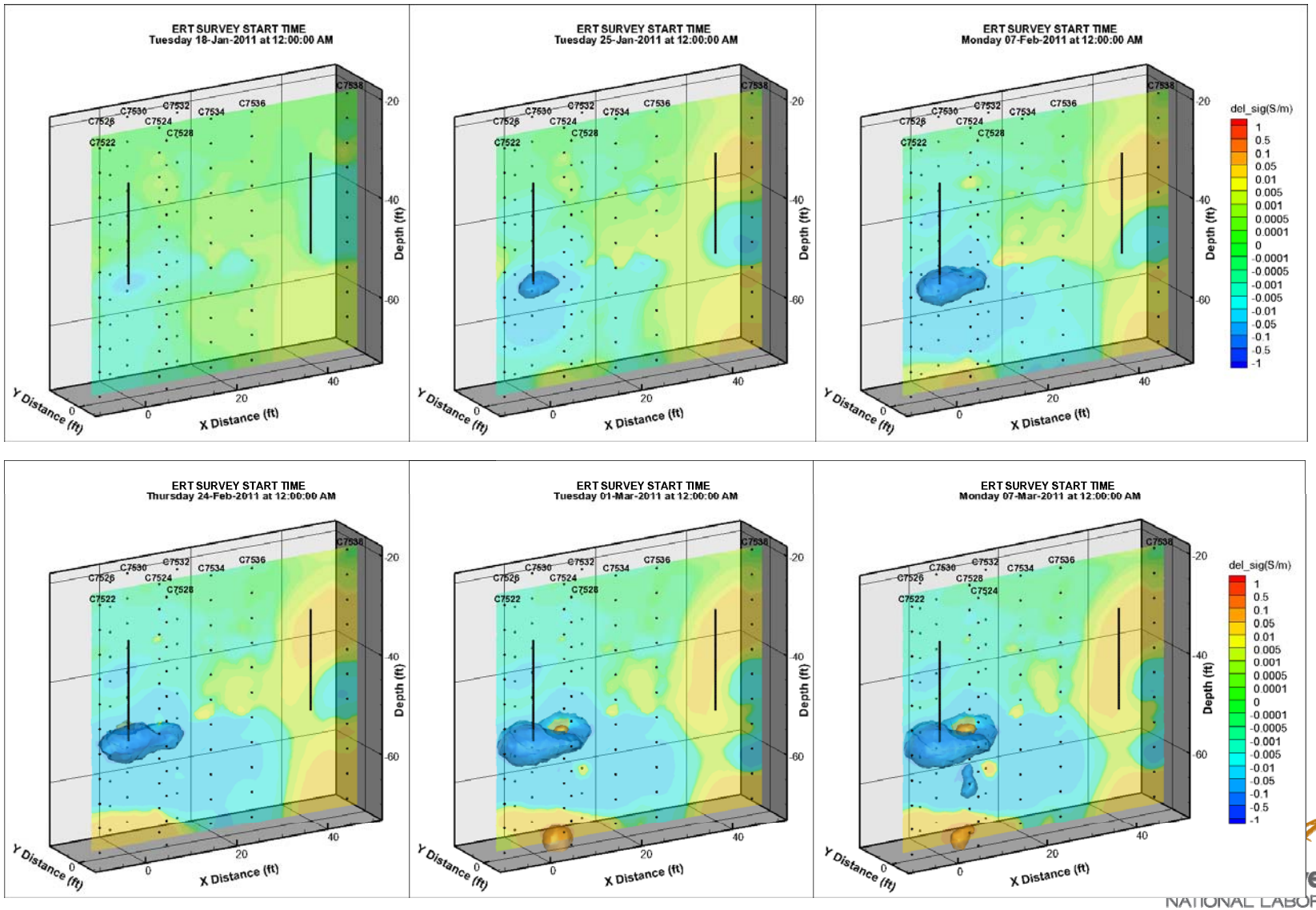
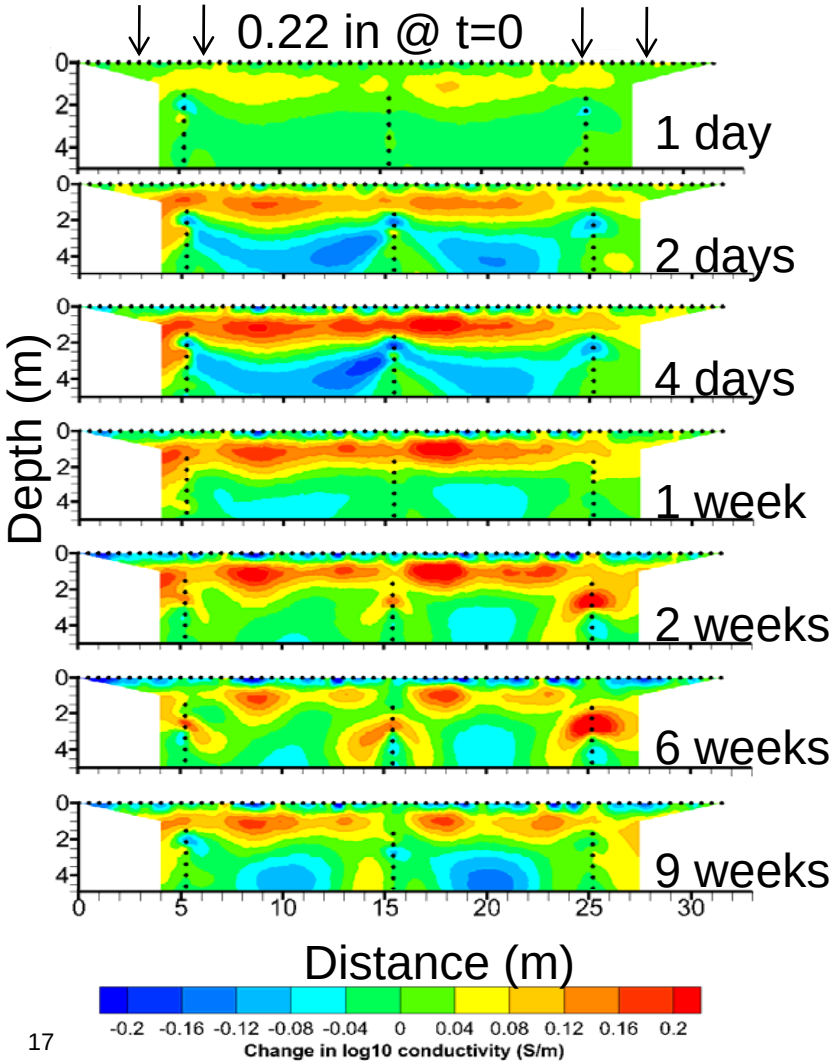
4D desiccation induced changes in bulk conductivity

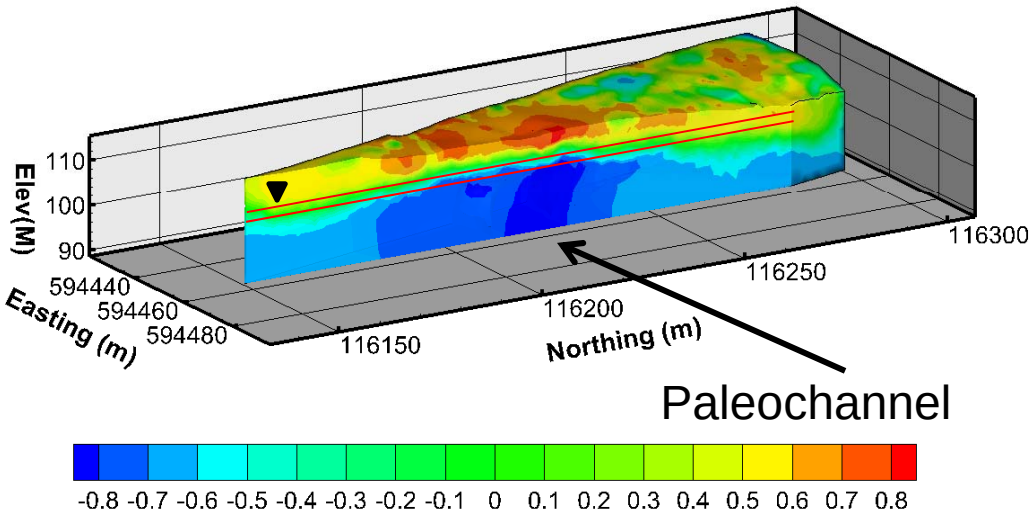


Other example applications

Vadose zone infiltration monitoring



Hyporheic exchange monitoring at Hanford along the Columbia River



Conclusions

- Changes in subsurface electrical conductivity obtained from ERT inversions coupled with sparse supporting data from sampling can be interpreted with high confidence in terms of spatiotemporal information on remedial processes.
- Capability to 'see' in 4D
- Petrophysics are important
- Automation for long term monitoring is feasible