Applications of Geophysical Methods at the DOE Field Research Center, Oak Ridge 2002-2004

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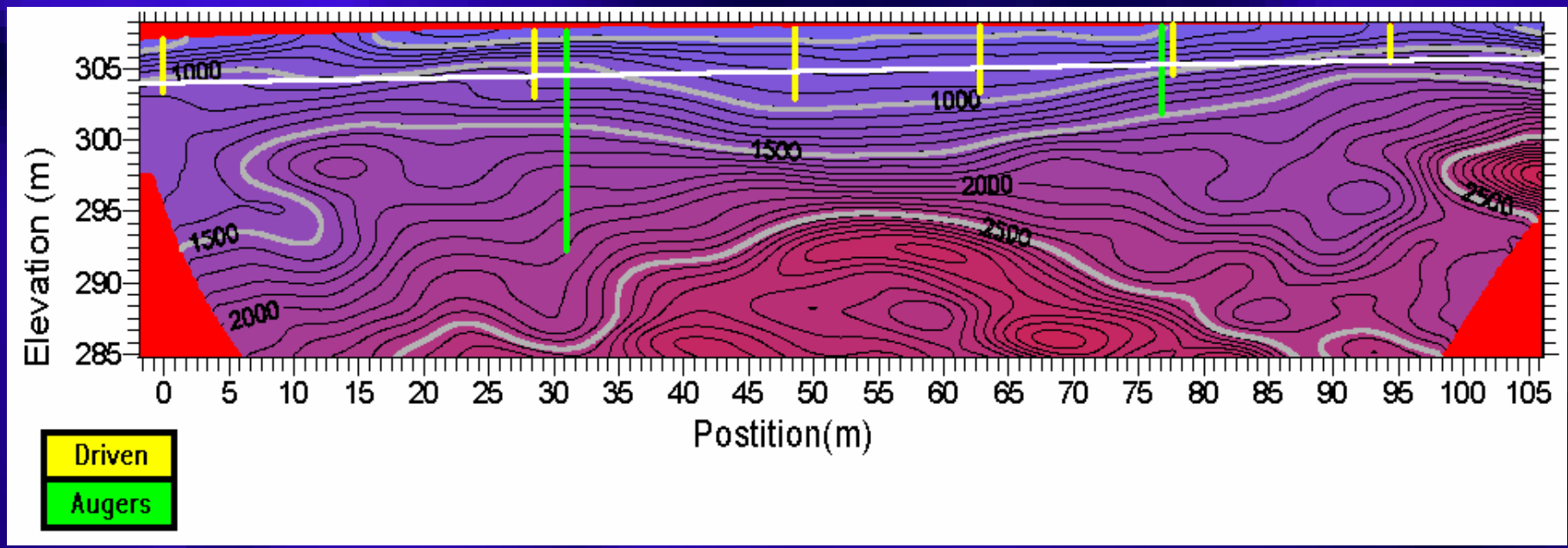
Methods Employed

- Multielectrode Resistivity
- Seismic Refraction Tomography
- Geophysical Logging
- Azimuthal Resistivity
- Crosshole Resistivity

Seismic refraction tomography data acquisition: Profiling geologic setting

- Bison EWG-1 accelerated weight-drop source, stacks of 4-8 shots
- Geometrics Strataview 48-channel seismograph, 1/8ms sample interval
- 1-2m receiver spacing
- 2-4m shot spacing

Seismic Refraction Tomography with well penetration (area 3)

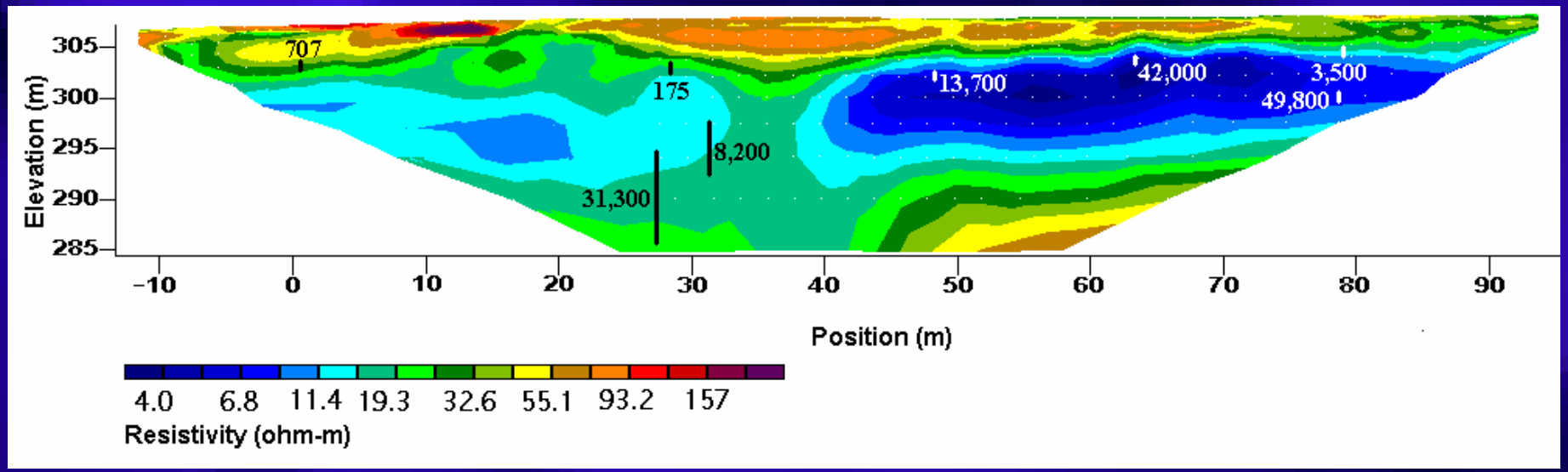


Multielectrode Resistivity: Used to profile geologic setting and contaminants

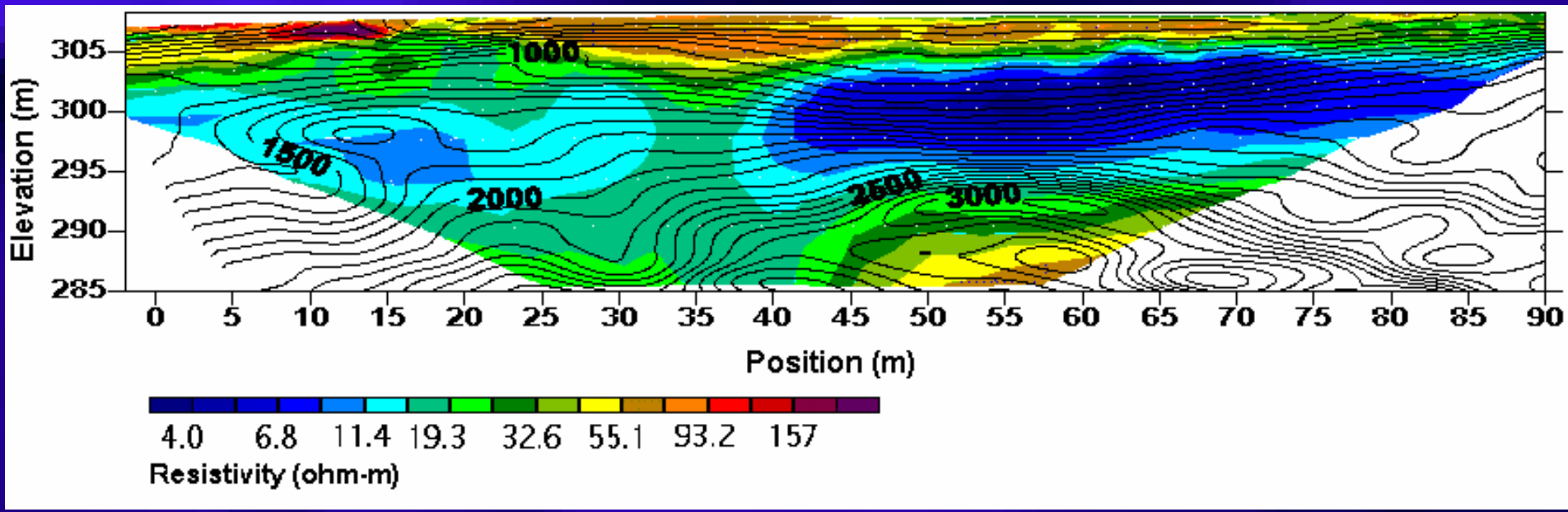
Multielectrode resistivity data collection

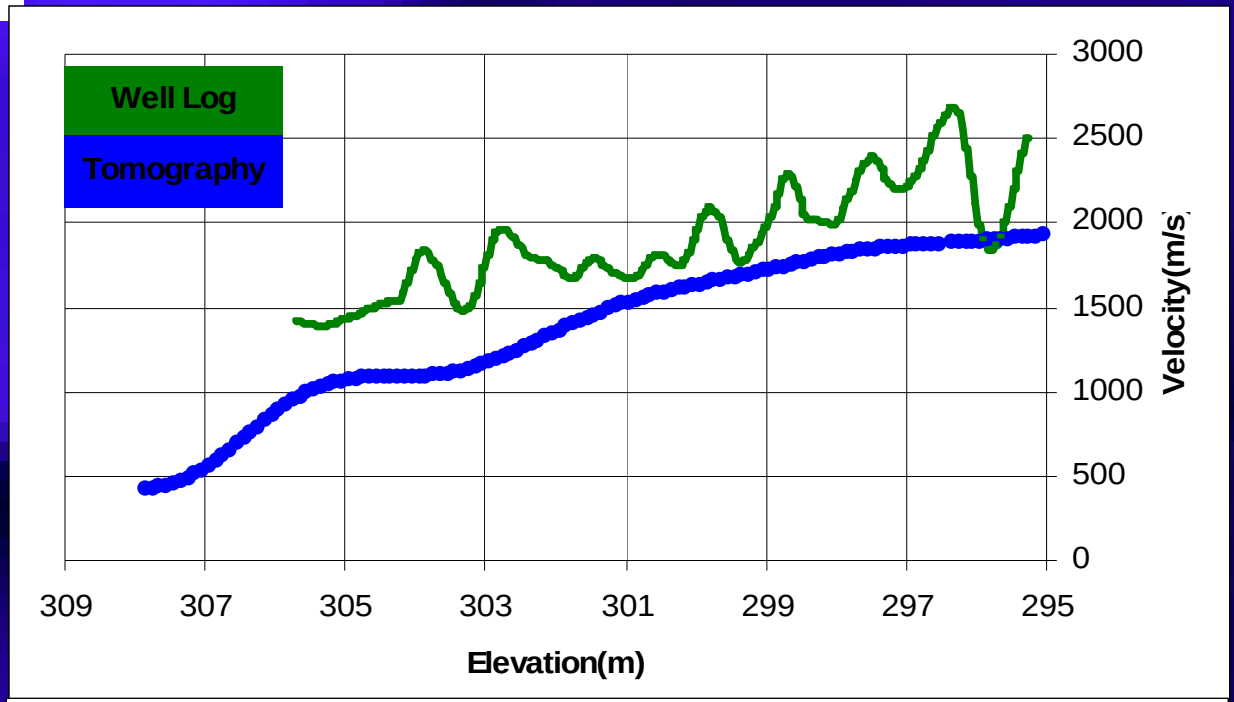
- 56-electrode Sting Swift system
- Data acquired on two lines, 7m apart
- On Line 1, acquired one long line at 2m electrode spacing and two lines at 1m electrode spacing
- Both dipole-dipole and Schlumberger configurations tested

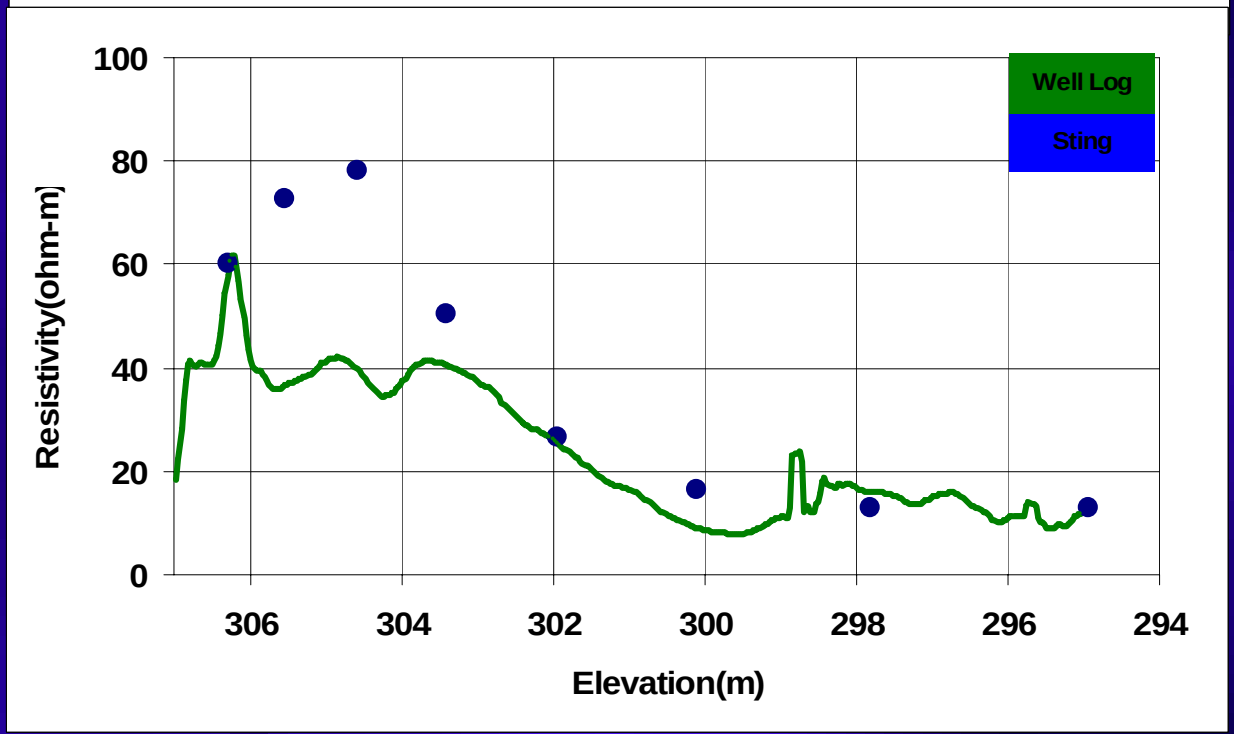
Resistivity with well nitrate concentrations (area 3)



Resistivity with velocity overlay







Borehole and Surface results compared (area 3)

FW-109

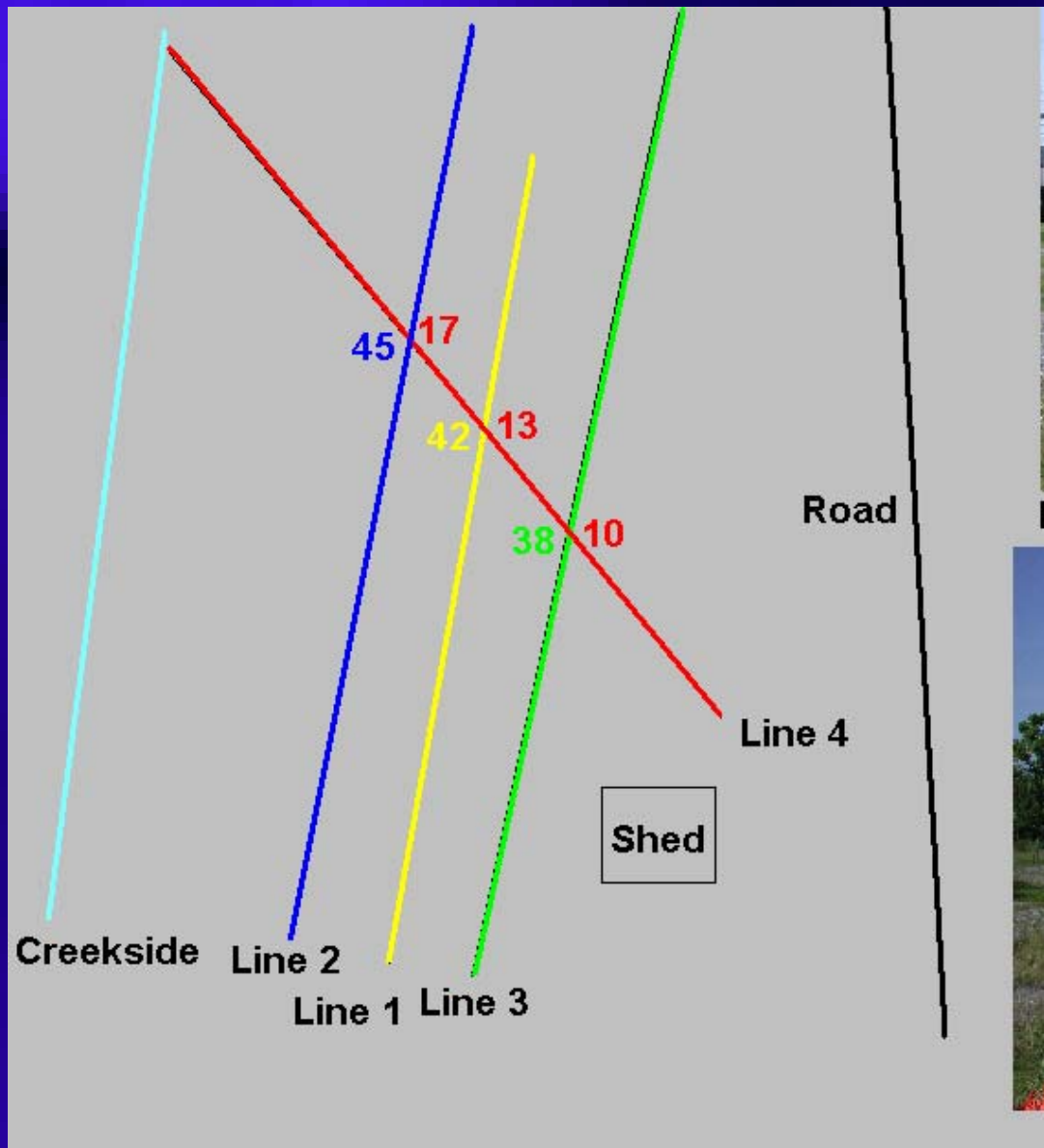
Relating Drilling information to tomography result

- Depth of refusal for driven probes correlates well with the 1,000 m/s velocity contour
- Based on augerholes, the bottom of the transition zone (top of bedrock) corresponds to somewhere between the 1,500 m/s and 2,000 m/s velocity contours.
- The cores taken during augering in the vicinity of position 25 m to 35 m confirmed that bedrock in this area is about 15 m deep as estimated from the velocity profile.
- Borehole velocity logs follow the same trend as tomographic results.

Relating borehole geophysics and ground water sampling to resistivity results

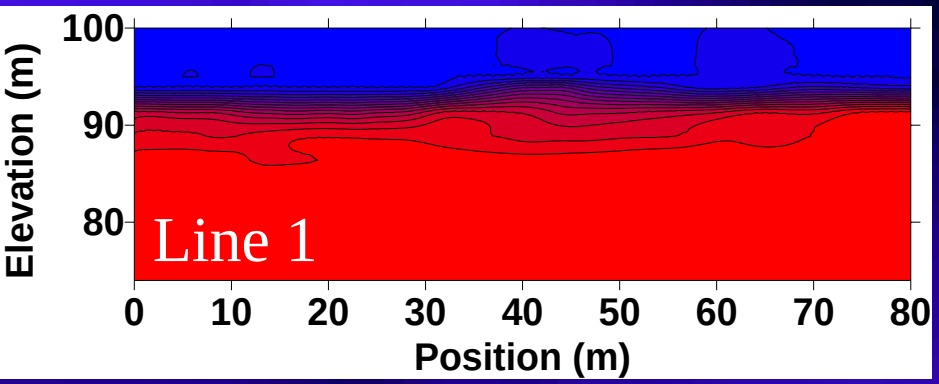
- Borehole resistivity logs show the same resistivity trends as surface resistivity results
- Ground water nitrate concentrations correlate well with the surface resistivity results

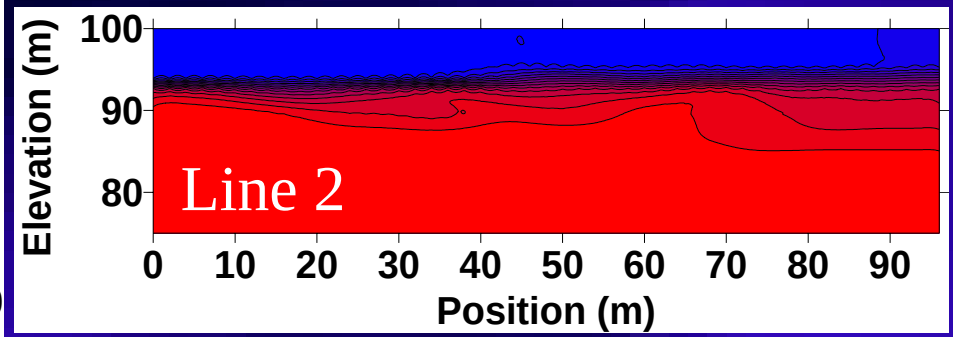
Area 2 Seismic

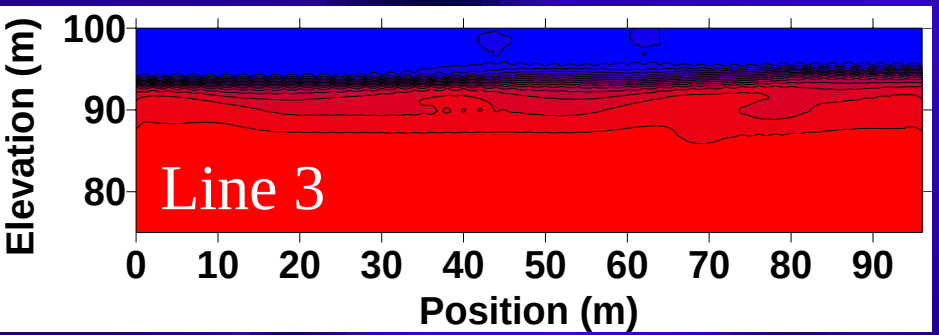


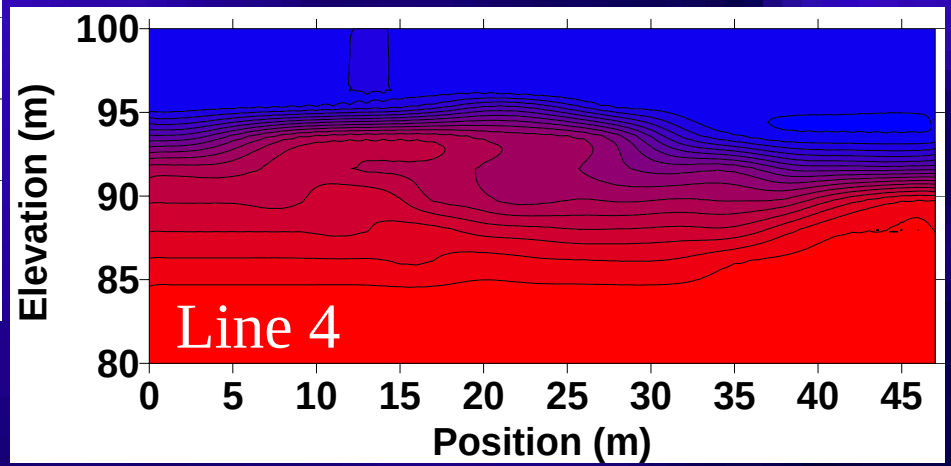
Photos showing position of Line 1

Area 2 Seismic

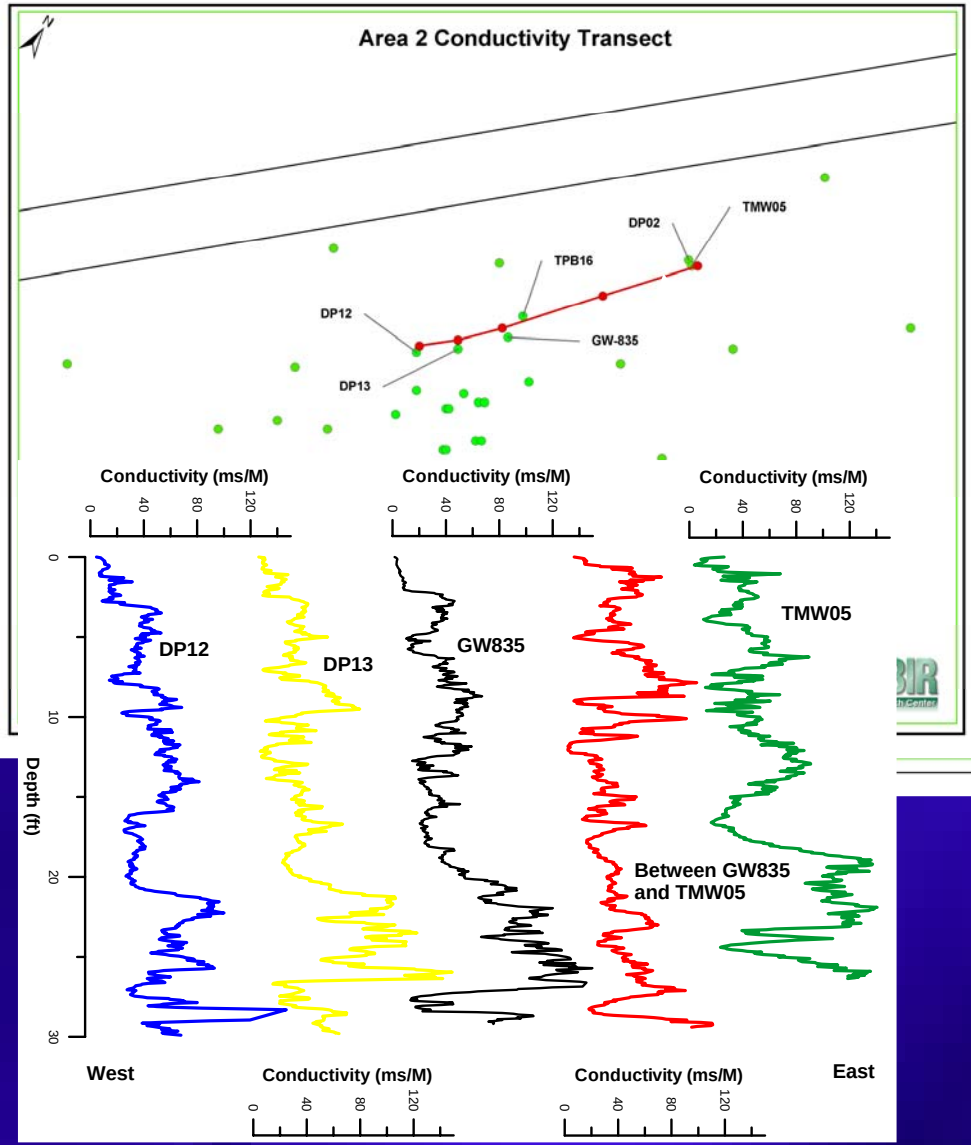


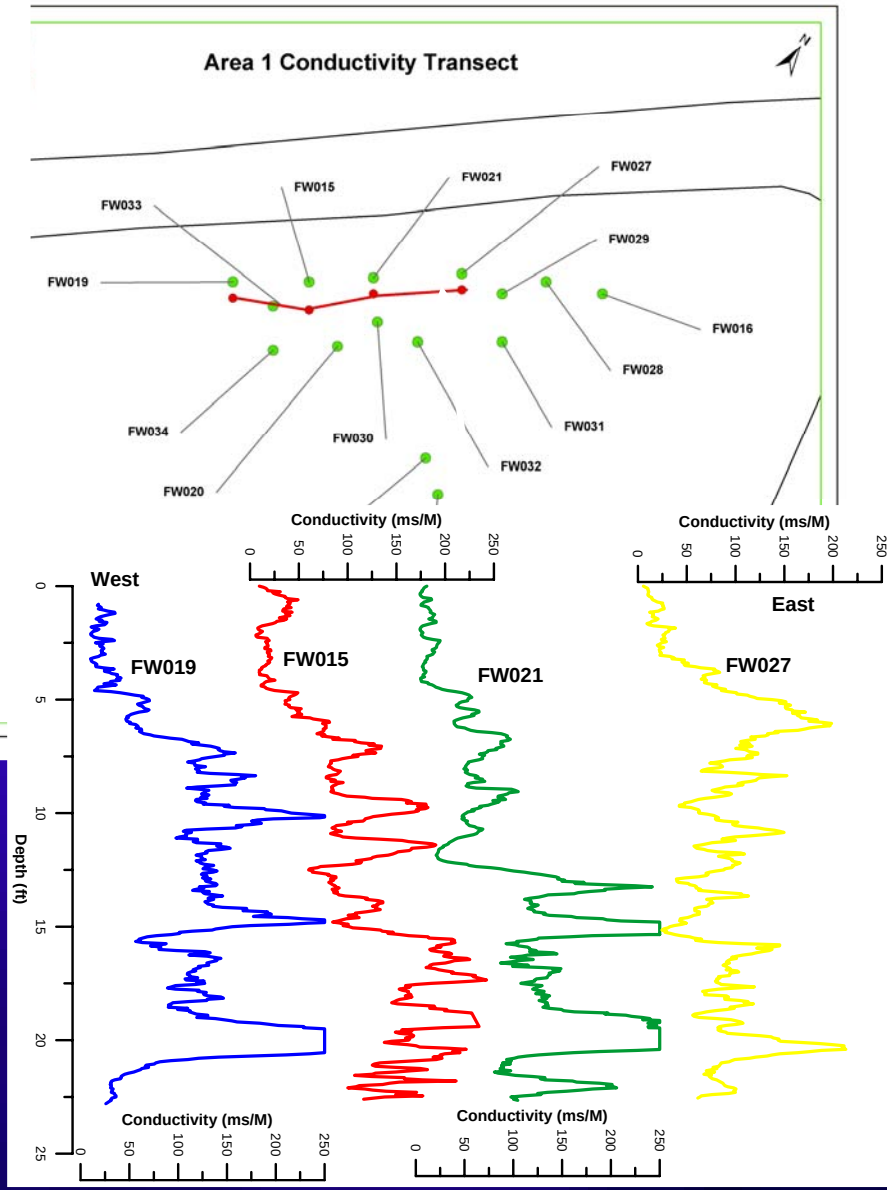






Electrical conductivity Profiling



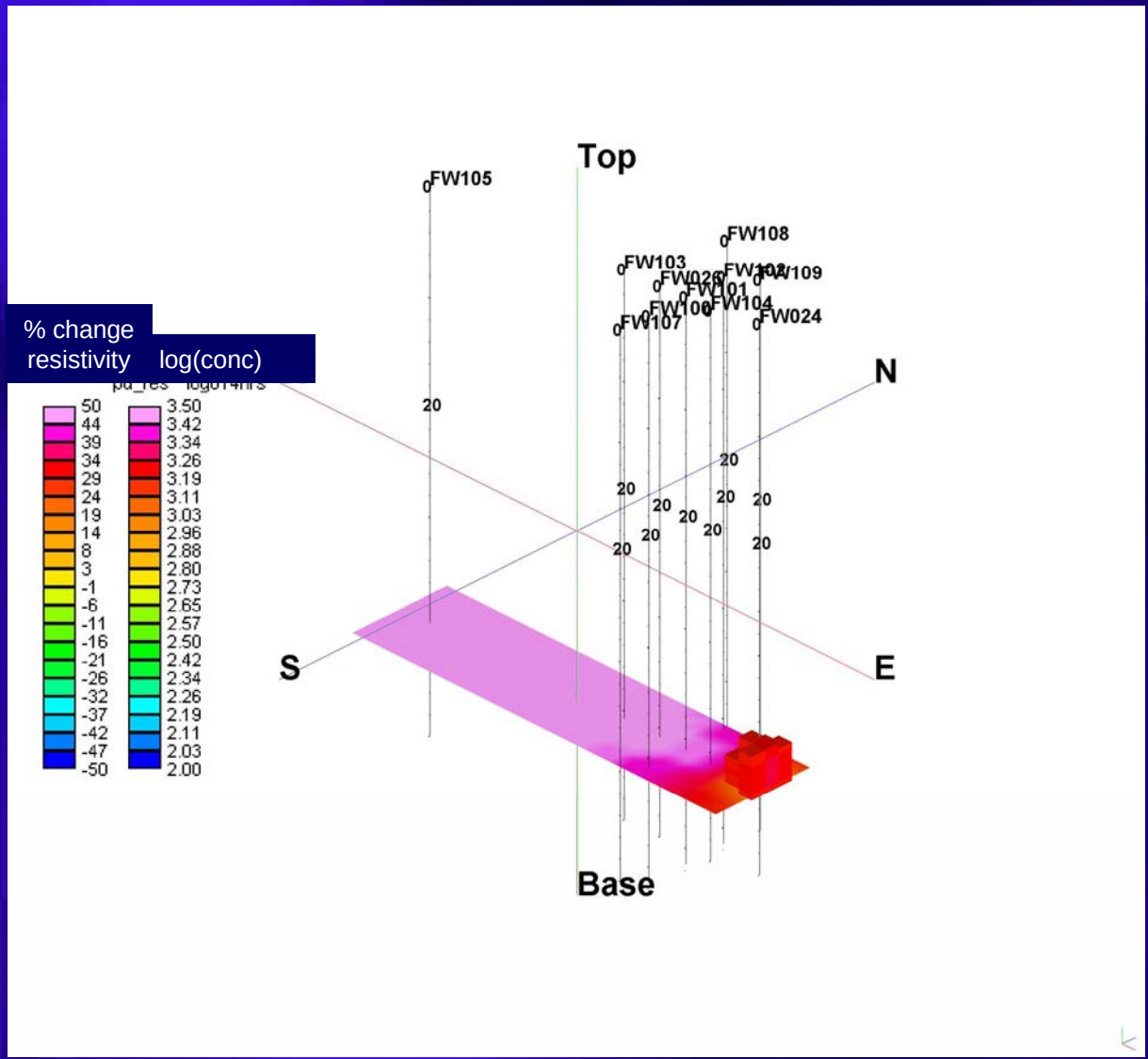


Data acquired by Geophex Ltd.

Area 3:
EM Logging During Flow Test

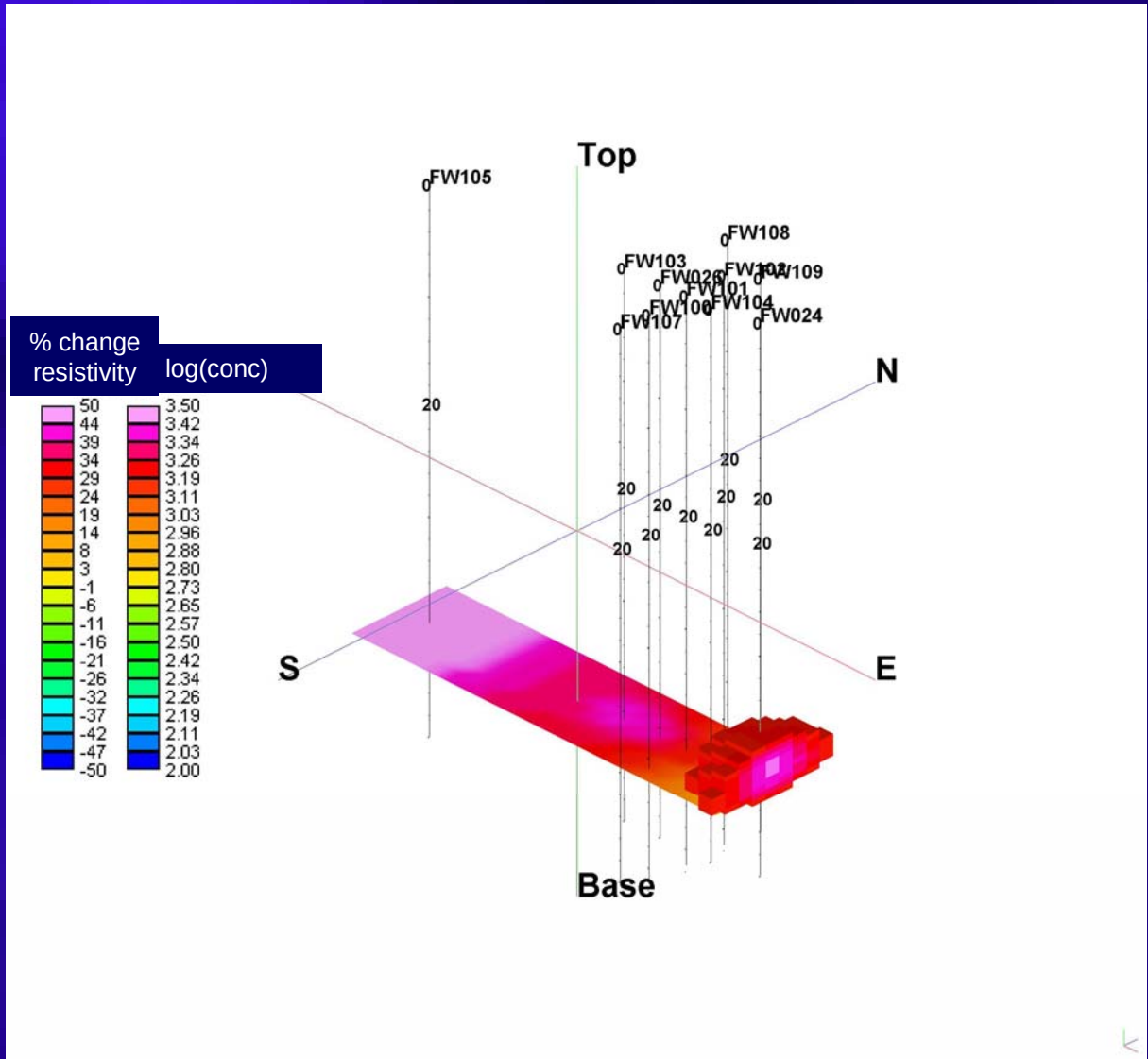
- 10 wells logged repetitively over a 1-week period with EM-39 borehole conductivity logger
- A dilute KCL solution was injected in well 24 and displaced highly conductive nitrate-rich fluids.

3D: +30% change in resistivity
2D: log(NO_3 concentration) in mg/l



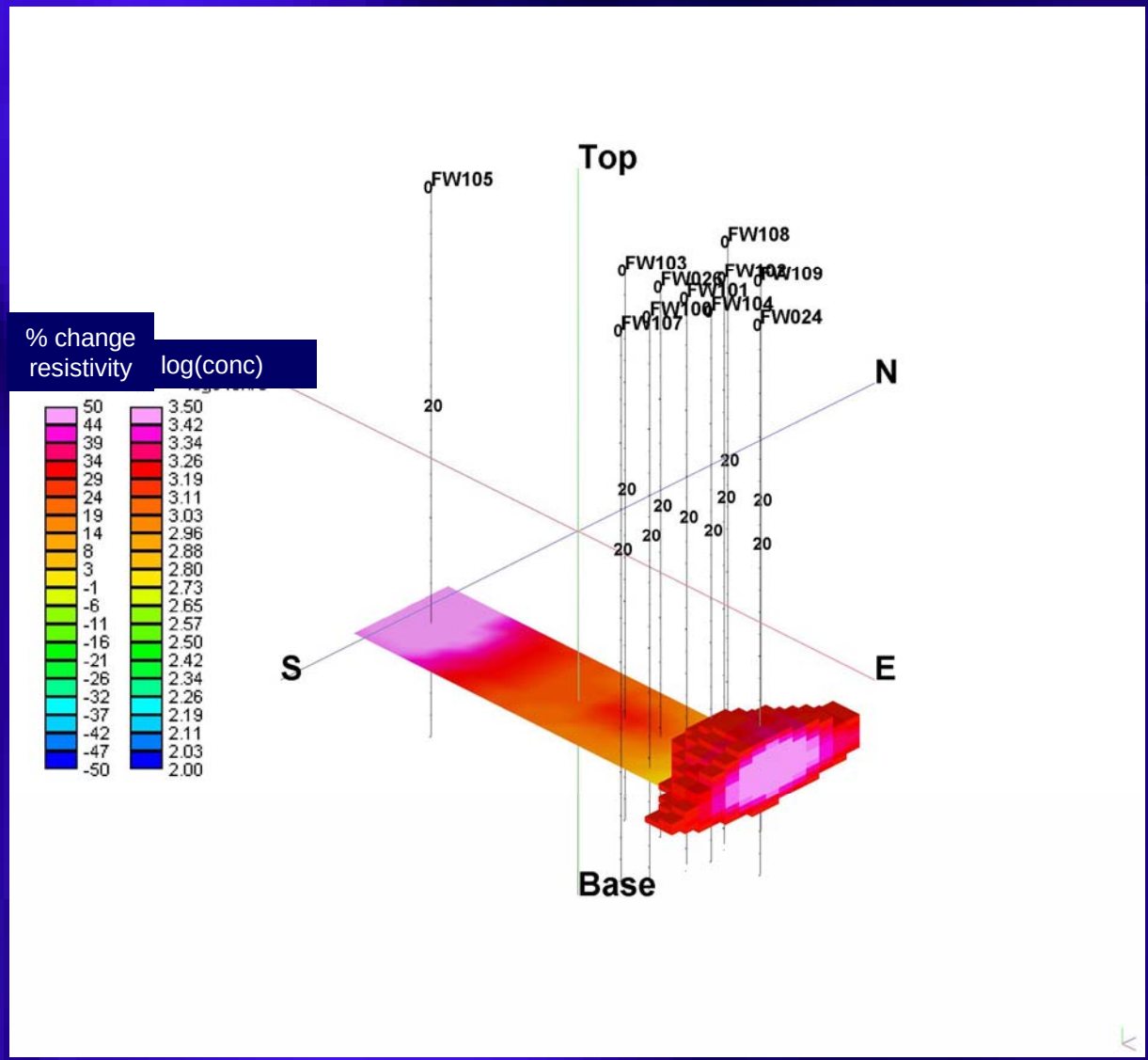
Time 014 hrs

3D: +30% change in resistivity
2D: log(NO_3 concentration) in mg/l



Time 028 hrs

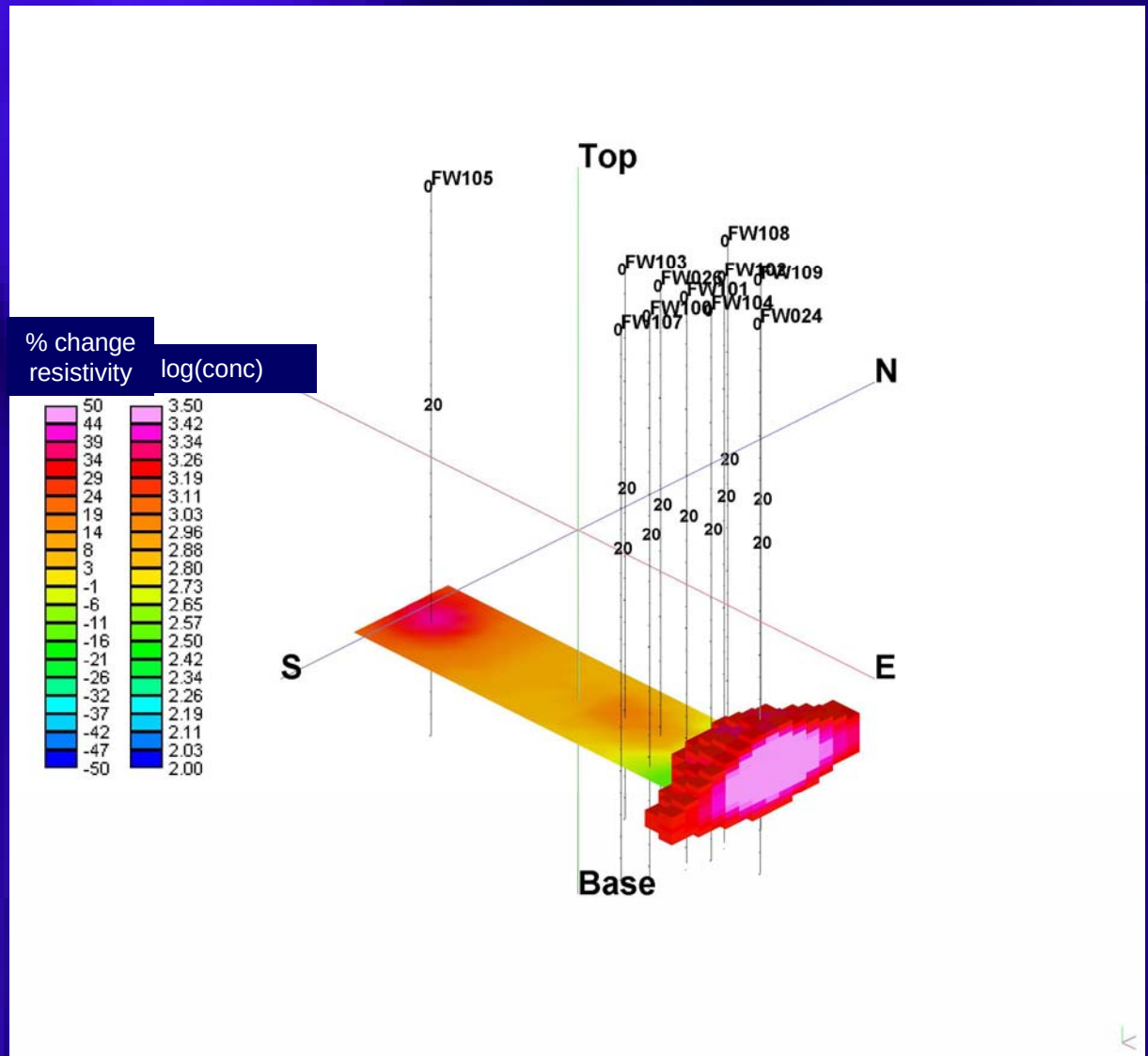
3D: +30% change in resistivity
2D: log(NO_3 concentration) in mg/l



Time 046 hrs

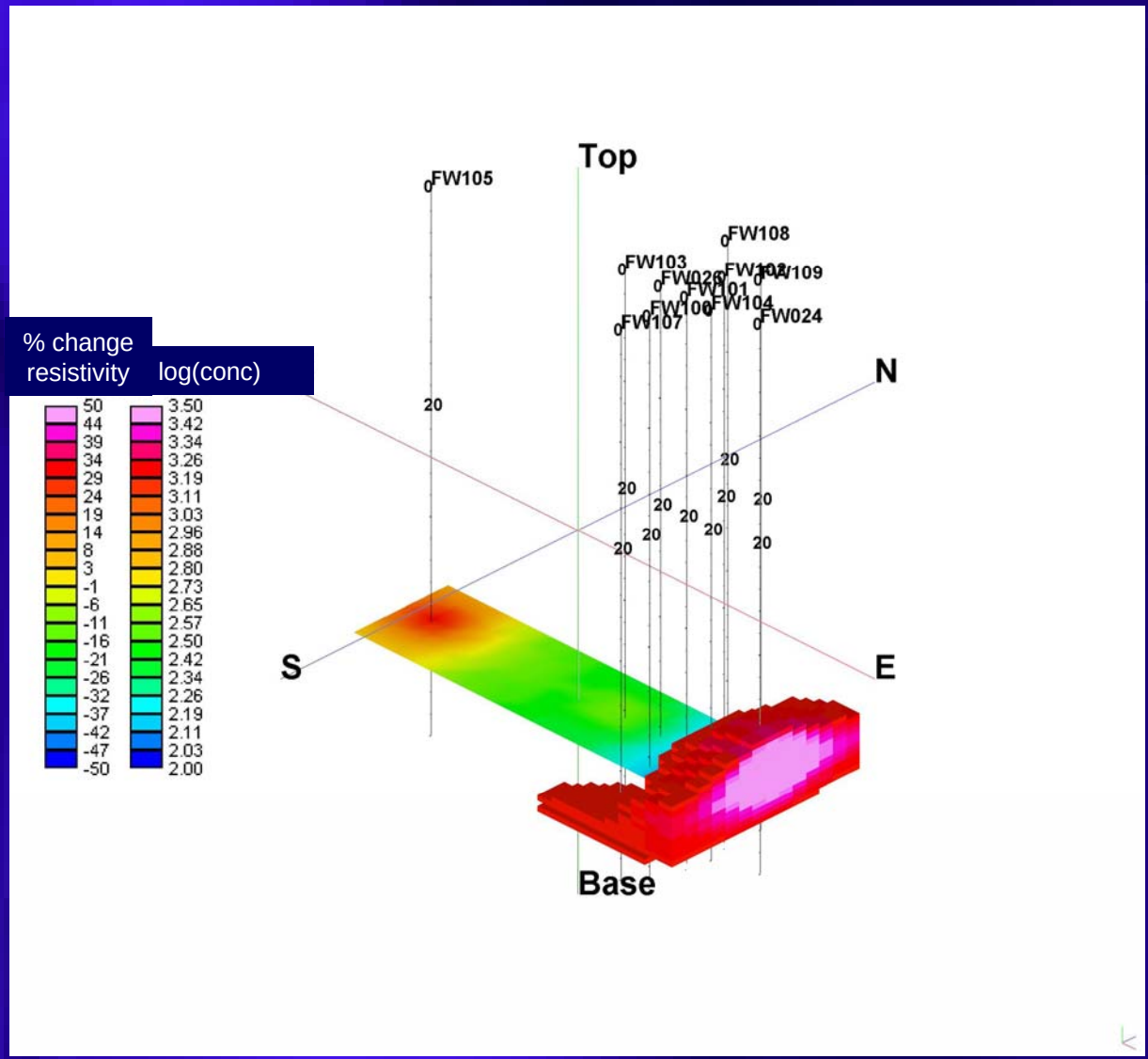
3D: +30% change in resistivity

2D: log(NO_3 concentration) in mg/l



Time 062 hrs

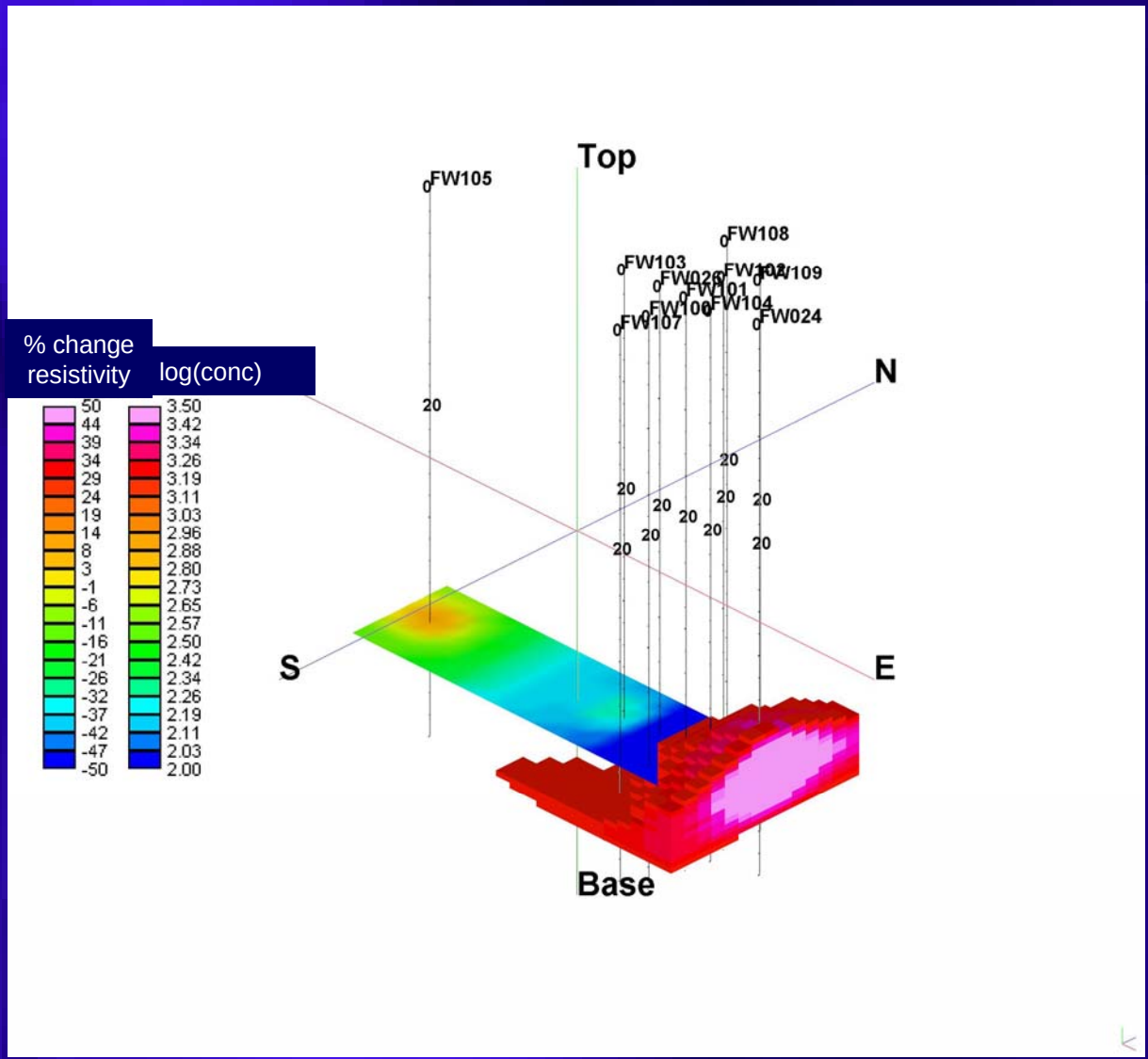
3D: +30% change in resistivity
2D: log(NO_3 concentration) in mg/l



Time 078 hrs

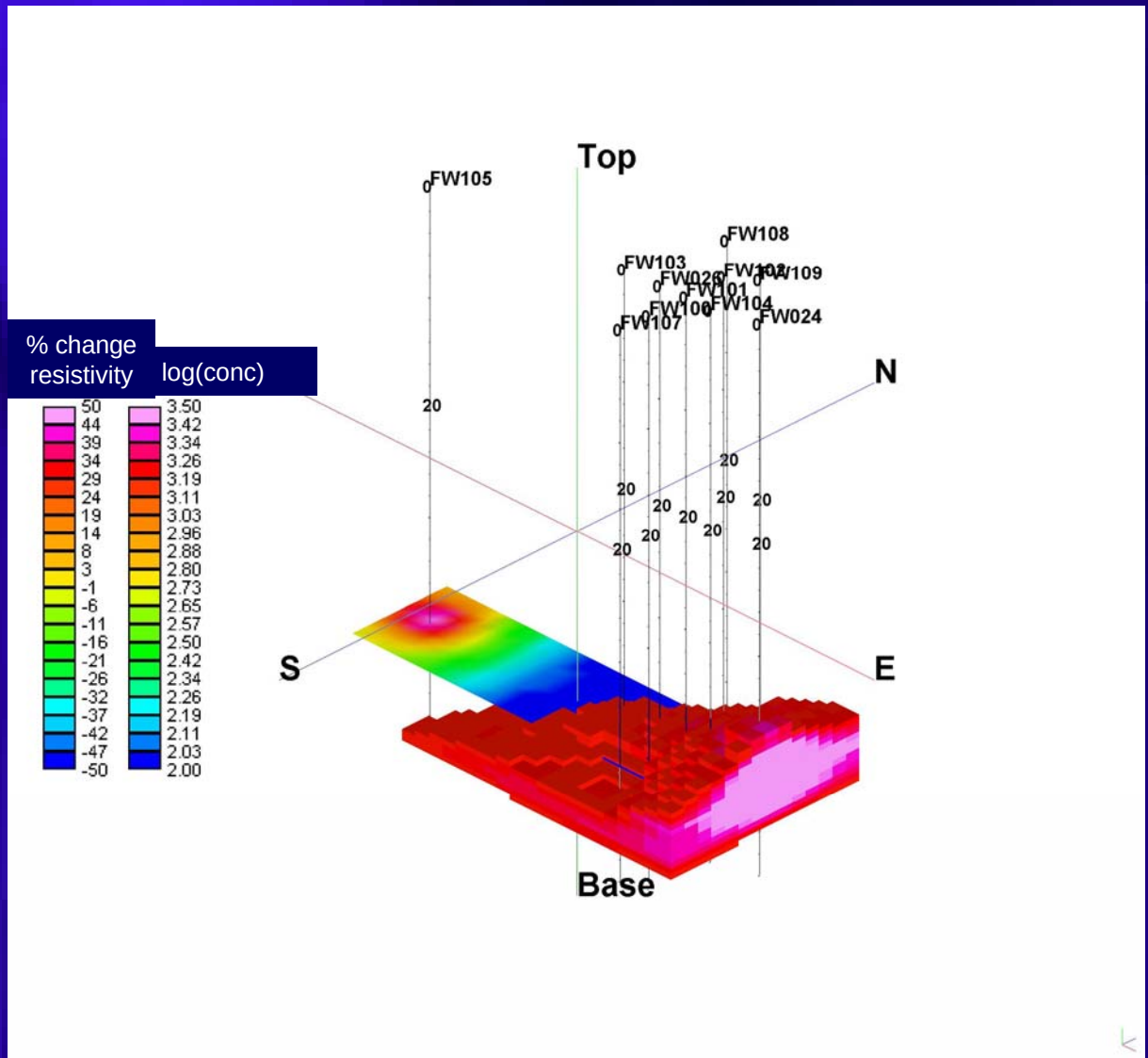
3D: +30% change in resistivity

2D: log(NO_3 concentration) in mg/l



Time 095 hrs

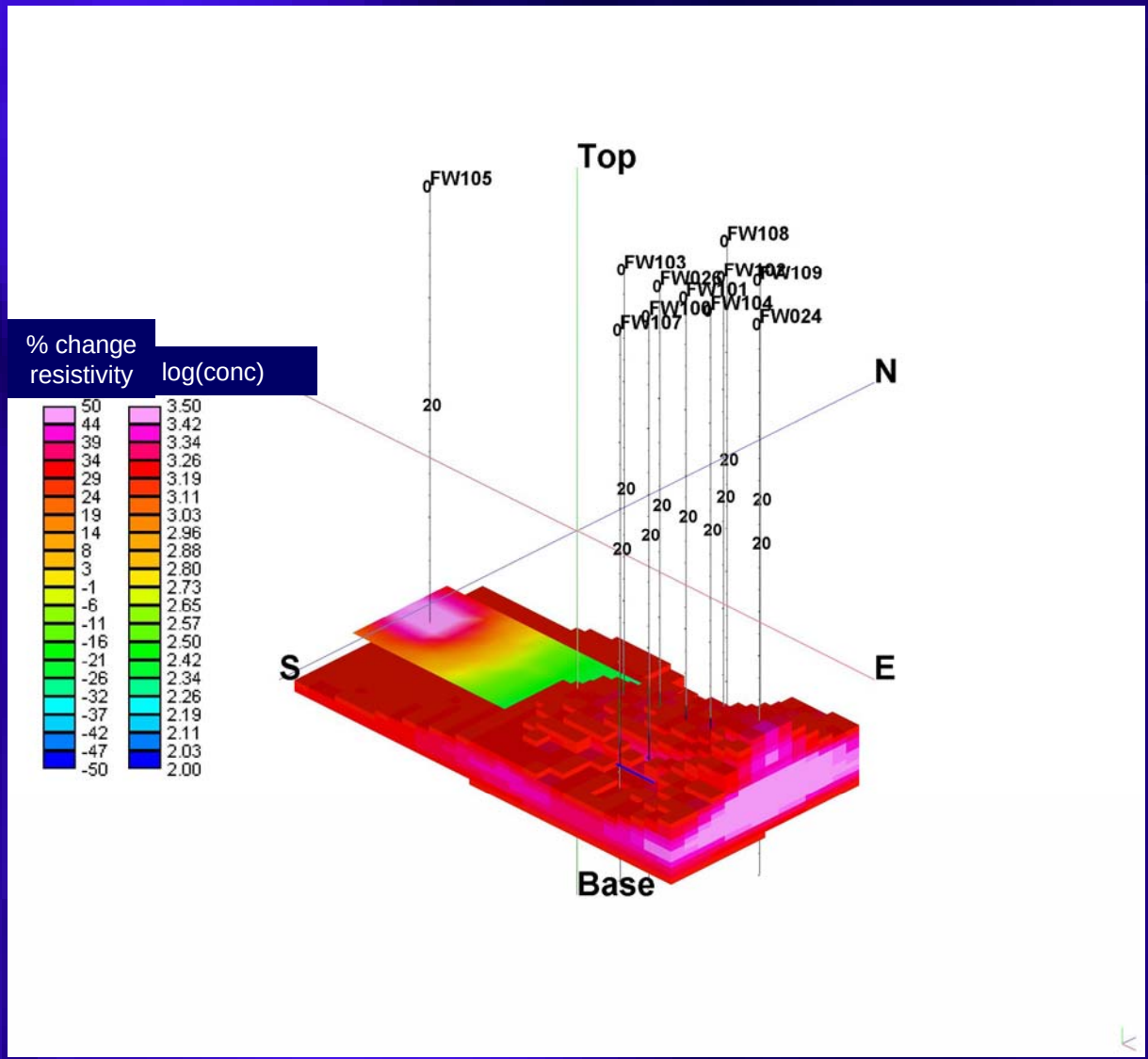
3D: +30% change in resistivity
2D: log(NO_3 concentration) in mg/l



Time 119 hrs

3D: +30% change in resistivity

2D: log(NO_3 concentration) in mg/l

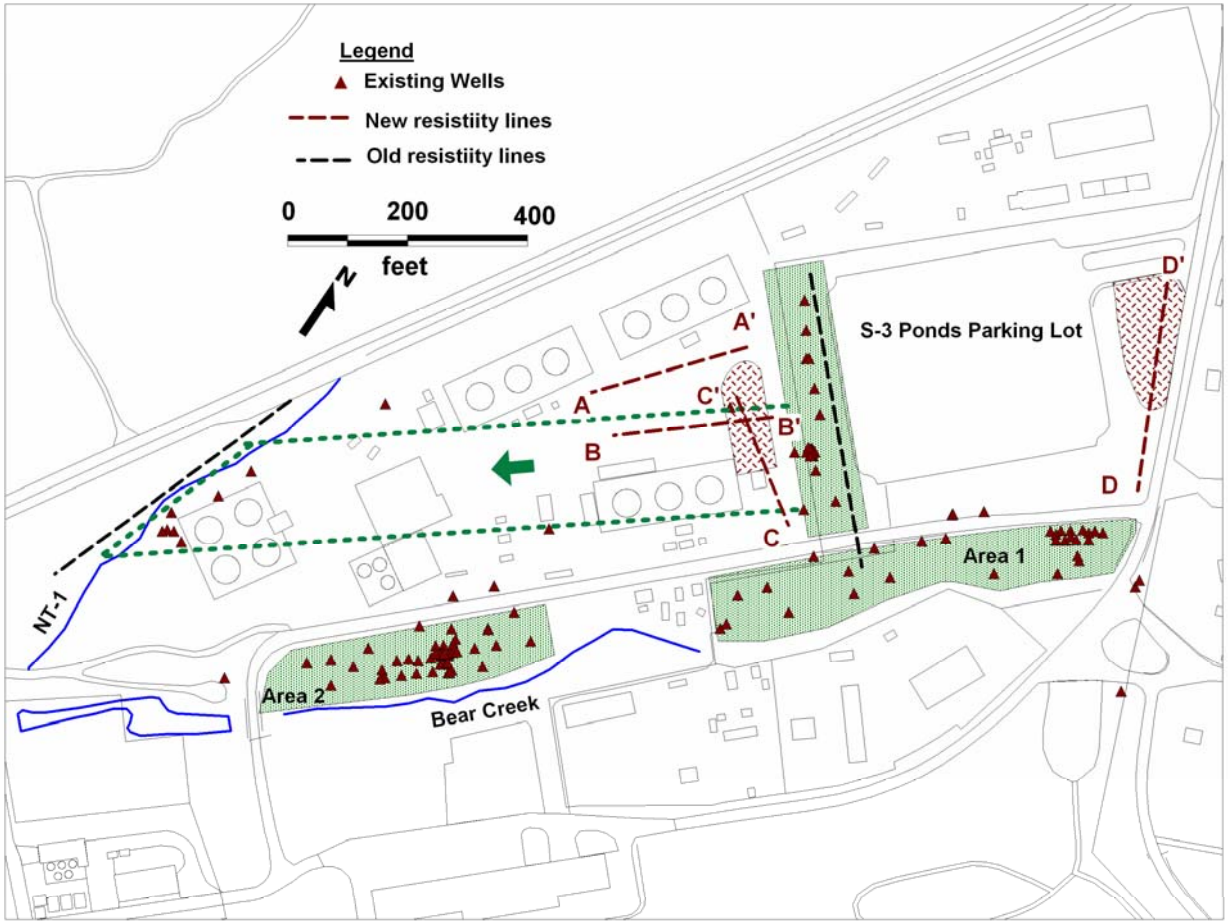


Time 143 hrs

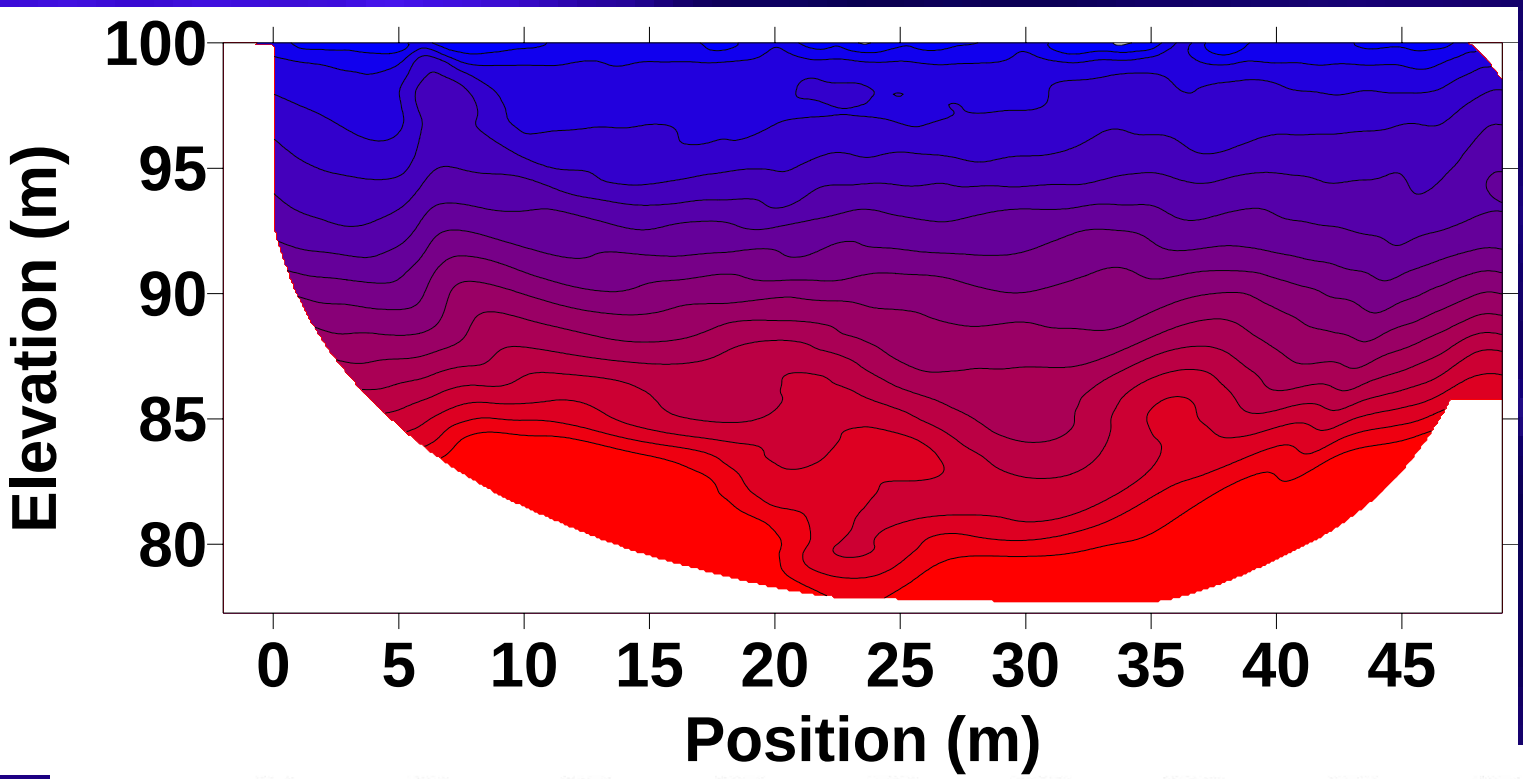
Time-lapse logging

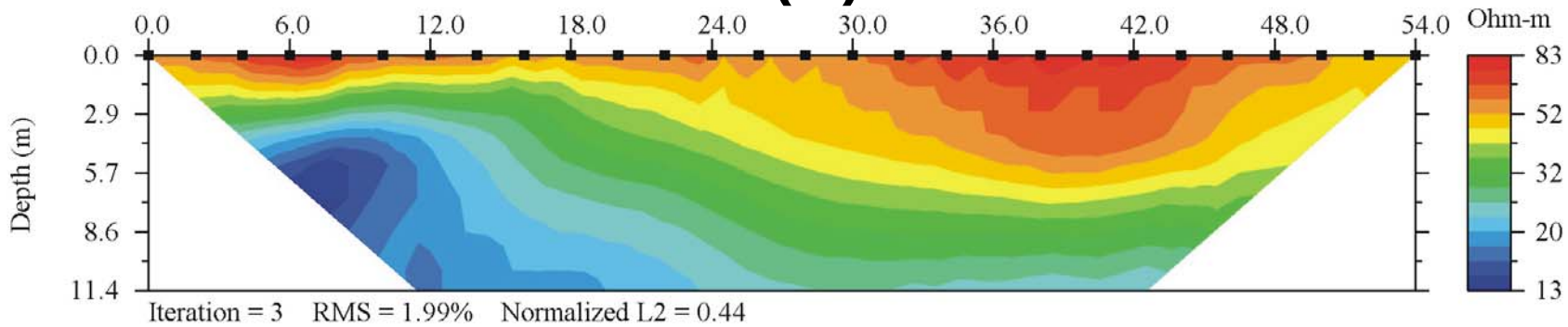
- Time lapse EM logs showed a steady increase in the zone of increased resistivity as conductive fluids were displaced near the injection well.
- The resistivity pattern agreed with the flow direction and dip of the geological strata.

New Seismic and Resistivity Lines

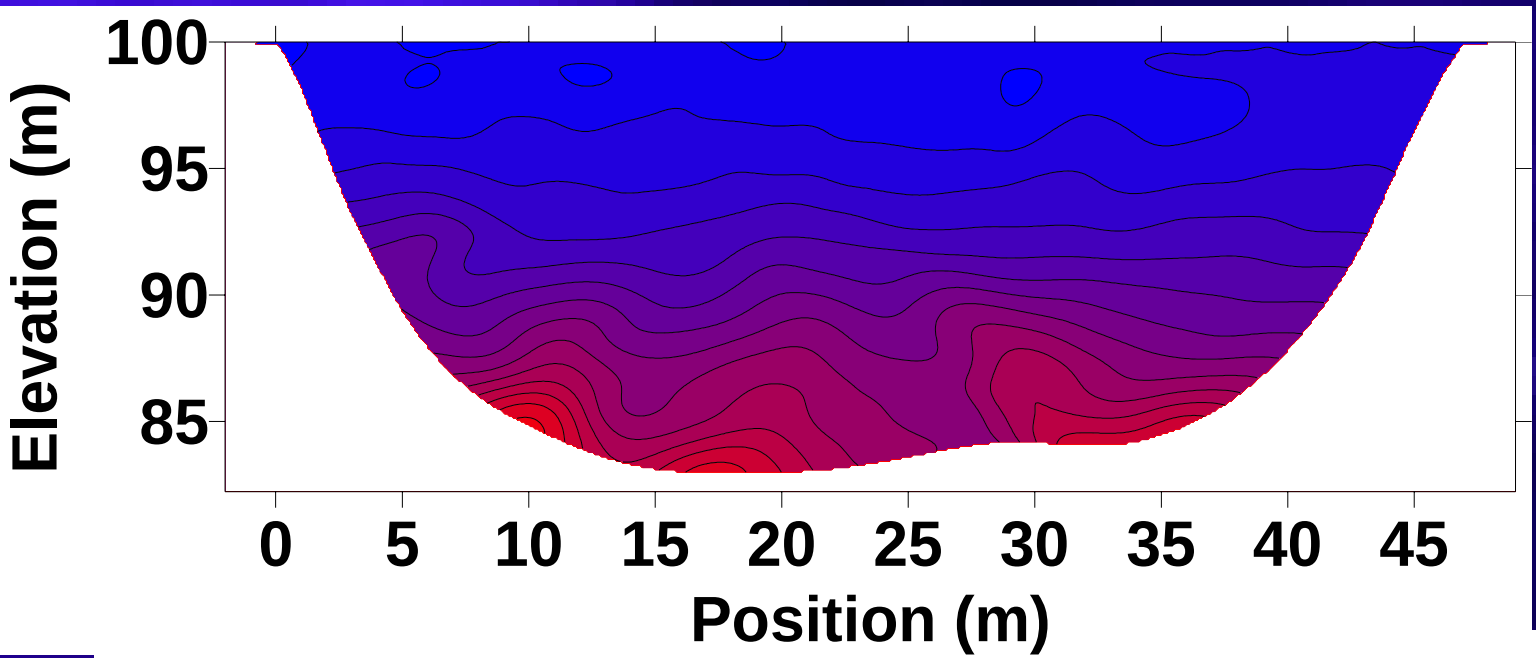


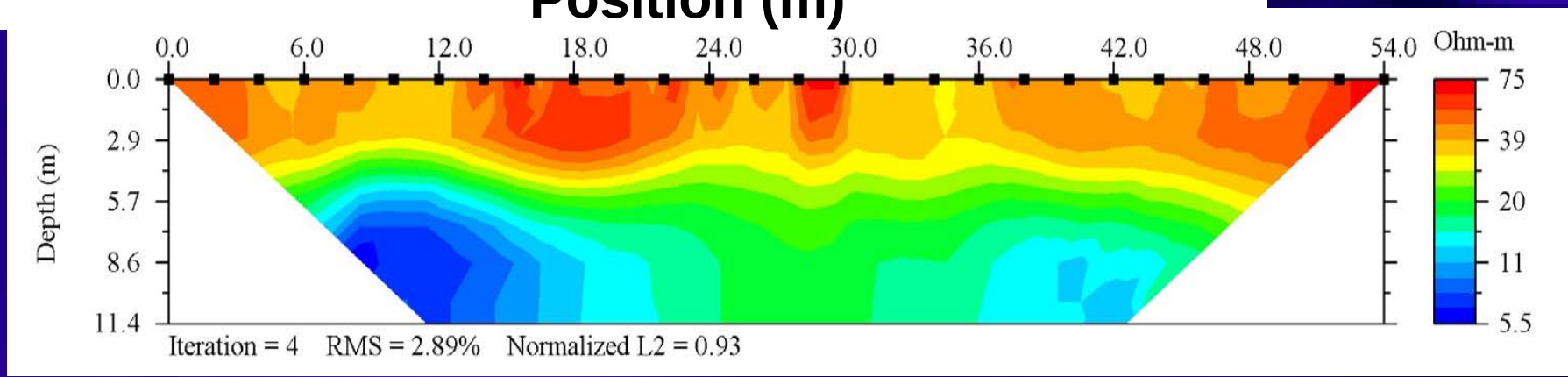
Line A’-A: along south side of bio-oxidation tanks (F4, F5, F6)



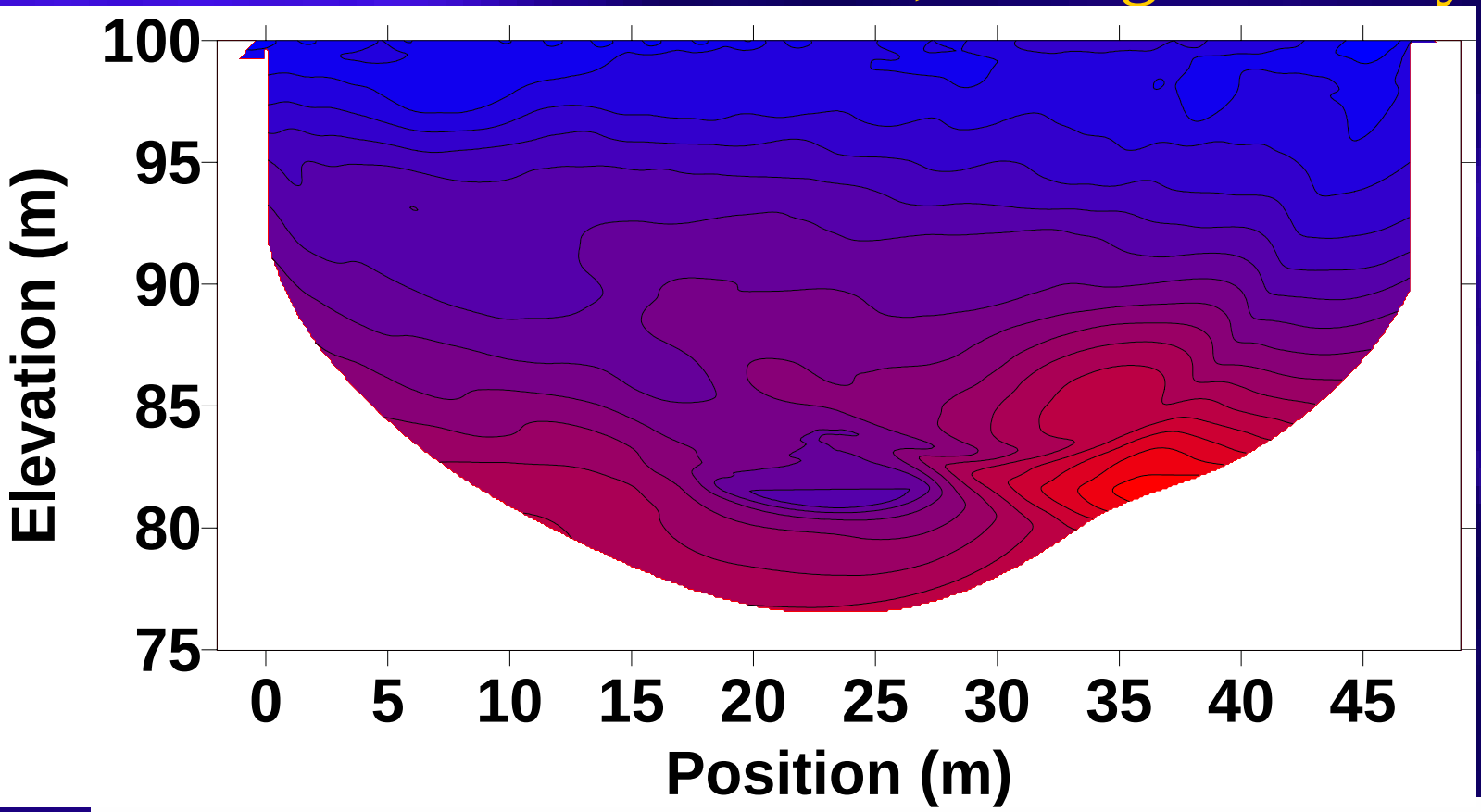


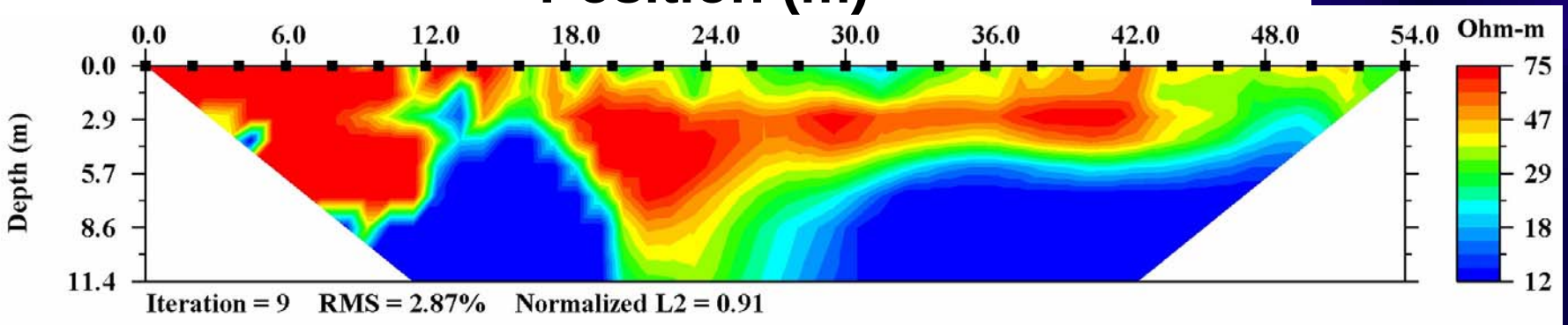
Line B'-B, along north side of bio-denitrification tanks (F1, F2, F3)



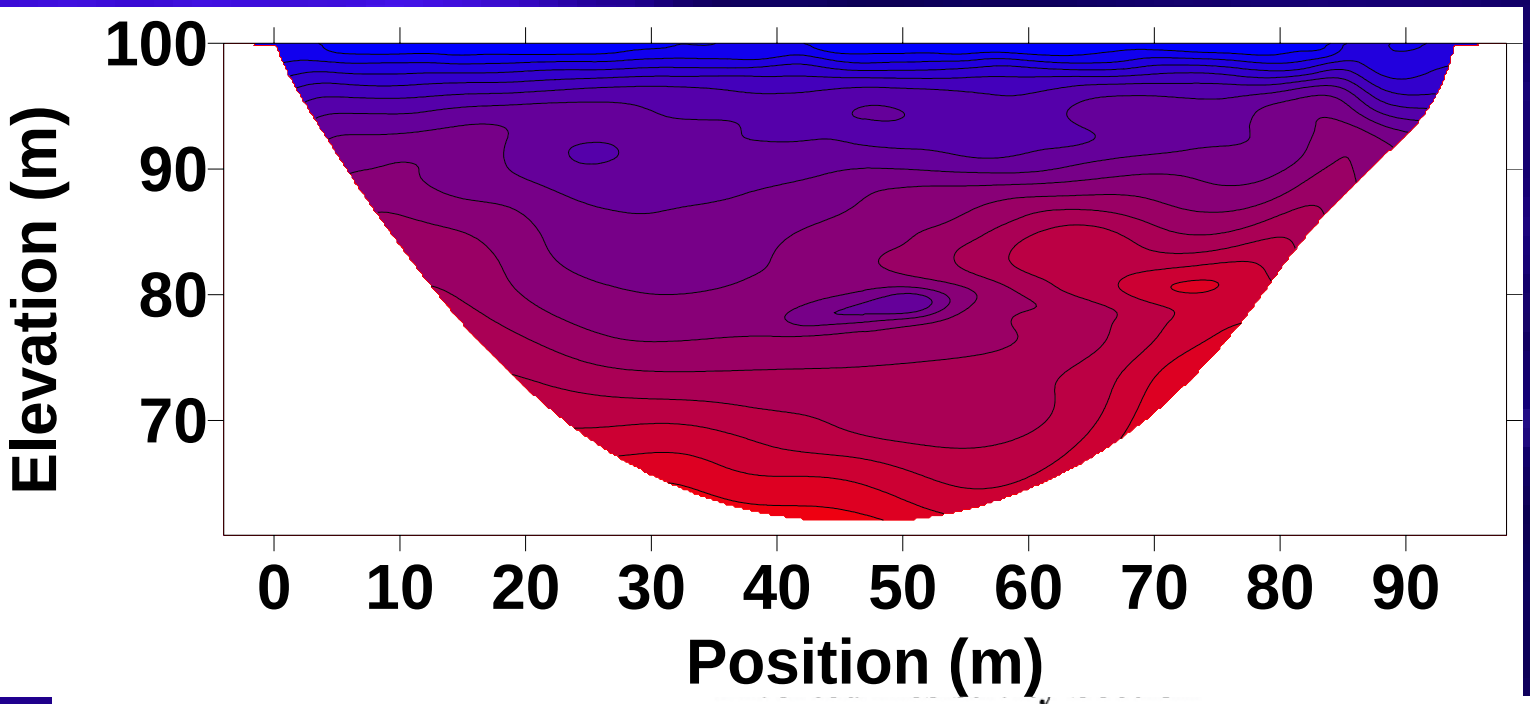


Line C-C': along east side of bio-denitrification tank F3, through tanker yard

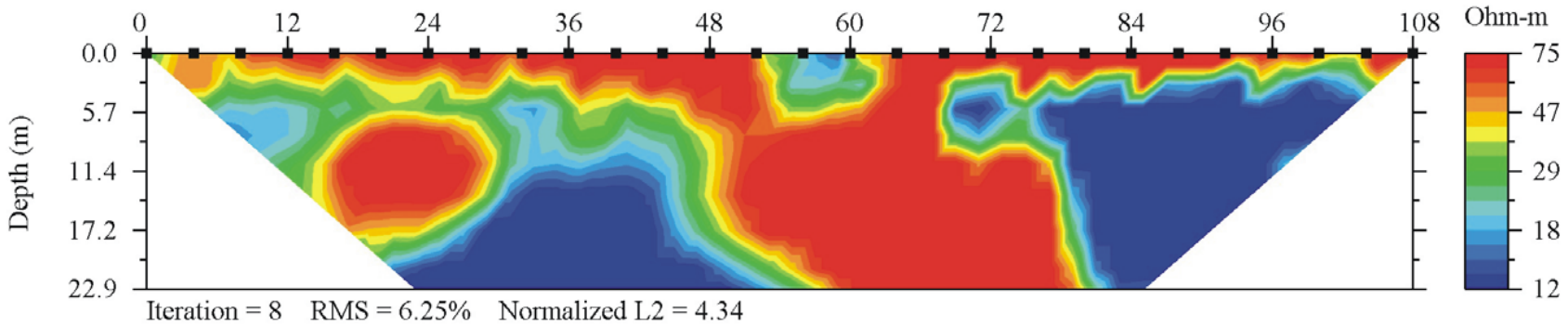




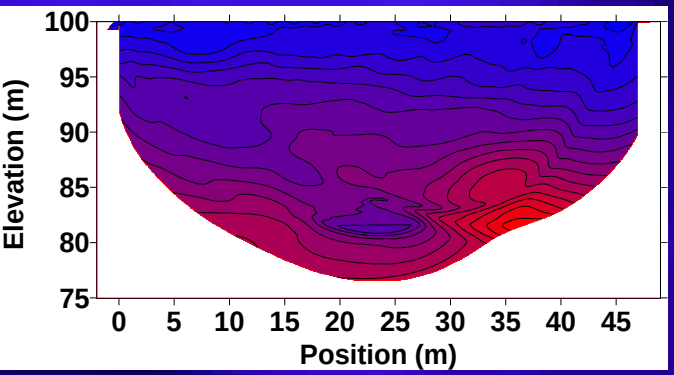
Line D-D’: along east side of S-3 ponds parking lot

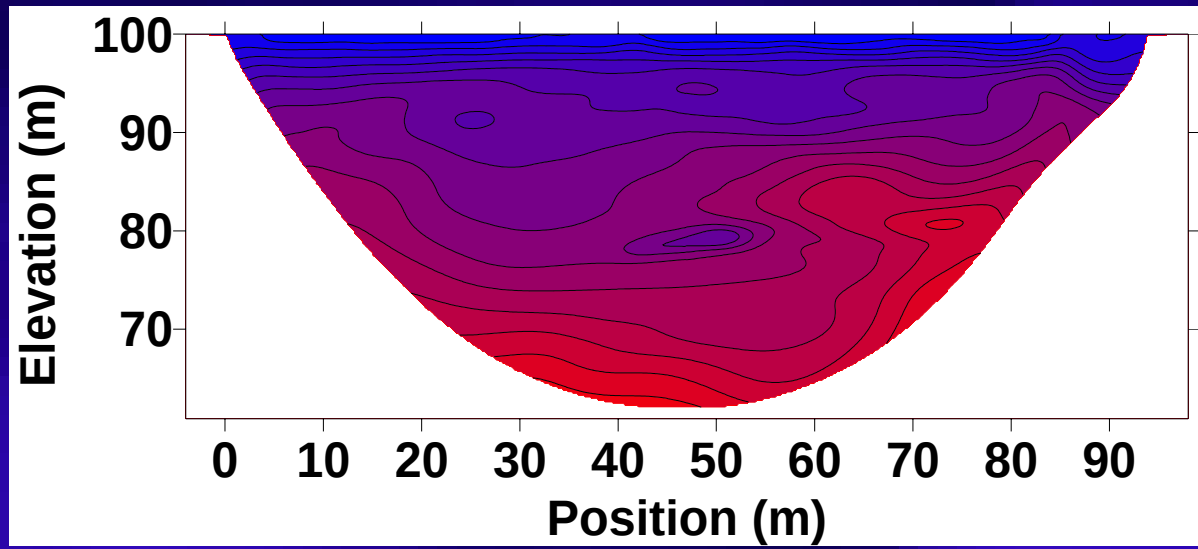


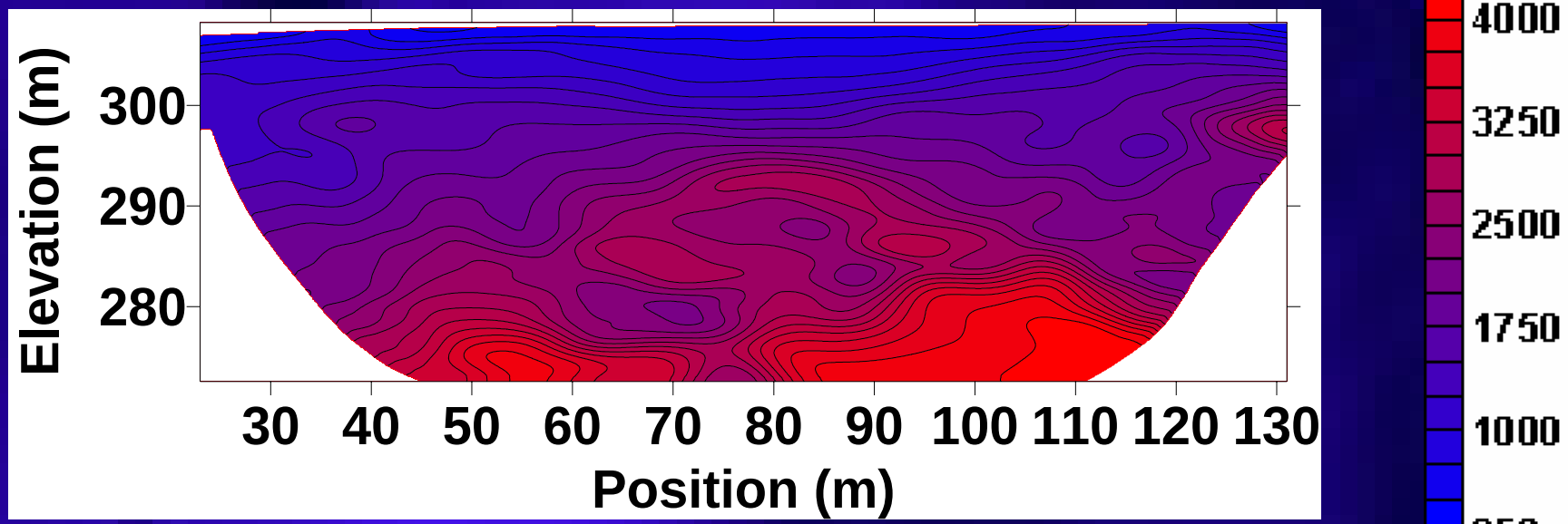
D’

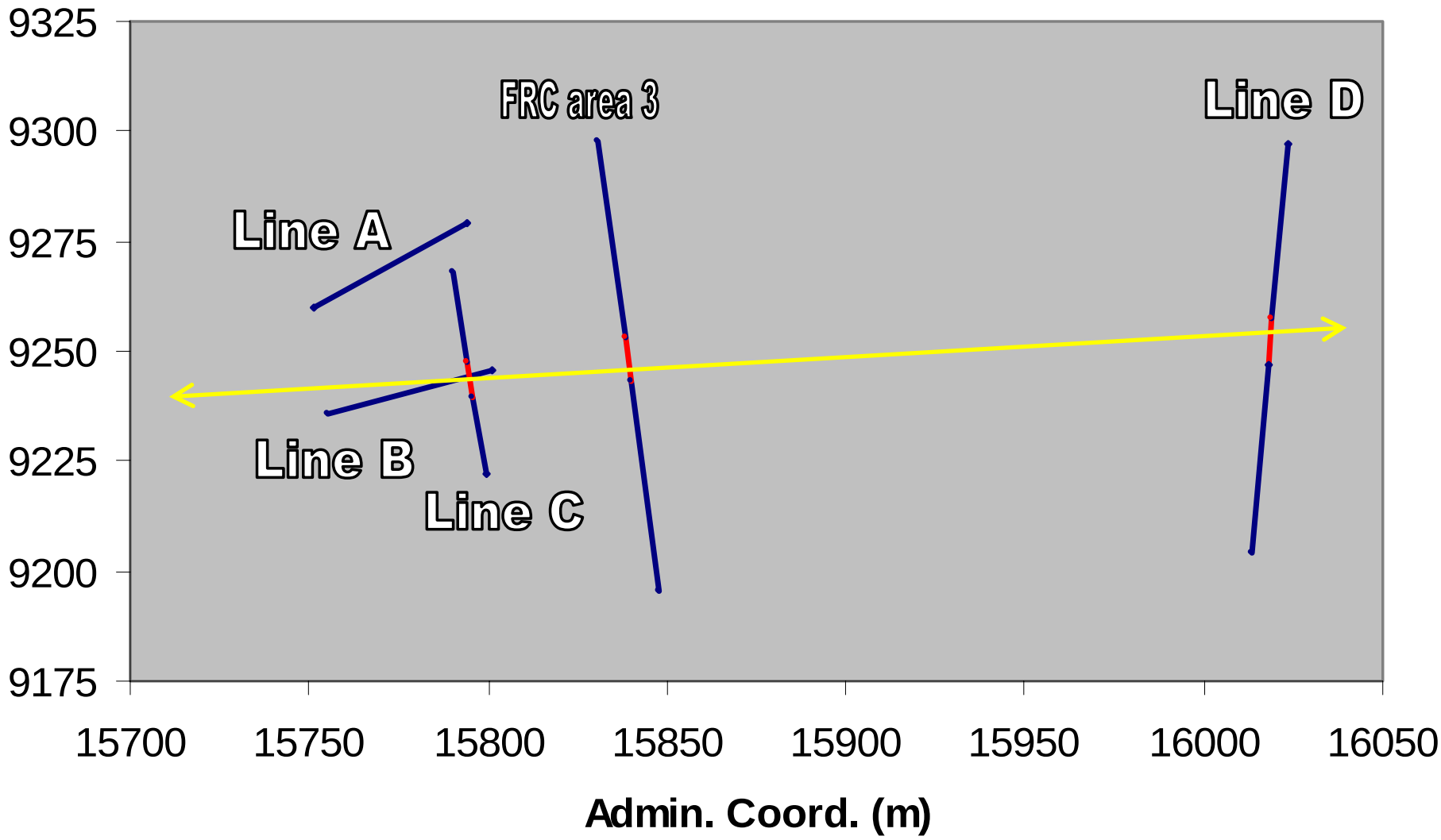


Low-velocity feature across thee lines

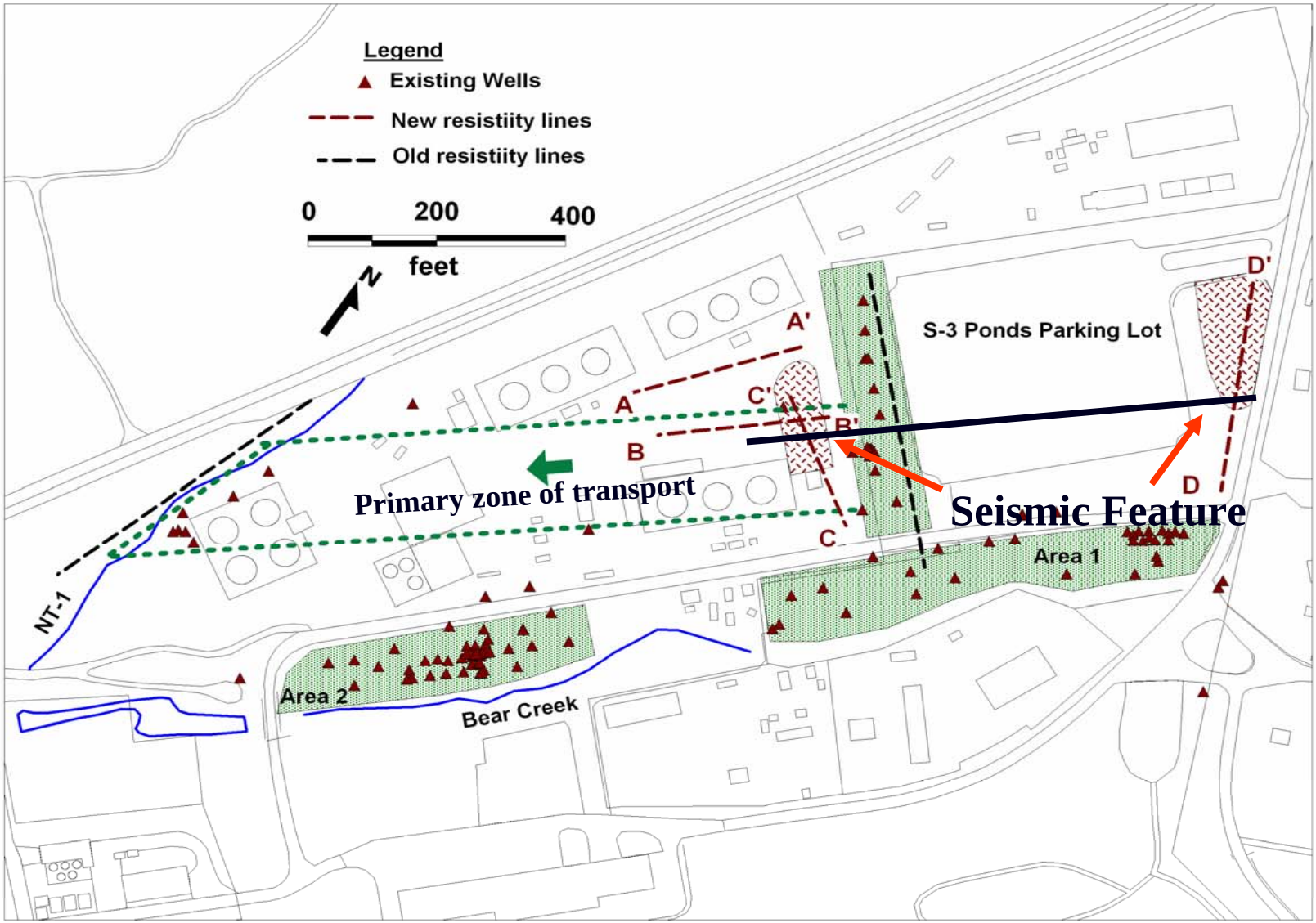








Red areas on the lines are approximate locations of the low velocity (hole) feature with the yellow line showing the trend.



Location of Seismic Feature

Area 3: 2004 Seismic Refraction Tomography and Resistivity

- Resistivity shows bedrock interface, but no surprises
- Seismic data indicate a possible conduit, oriented along geologic strike, intersecting three profiles at similar depth

Azimuthal Resistivity, FRC Area 2

- To define the preferential flow direction, resistivity was measured repeatedly over a 5-day period during a flow test
- Bromide was injected at ~400 mg/L.
- Injection rate: 0.5 L/min for 24 hours followed by 24h at 3 L/min
- Two significant flow directions became apparent

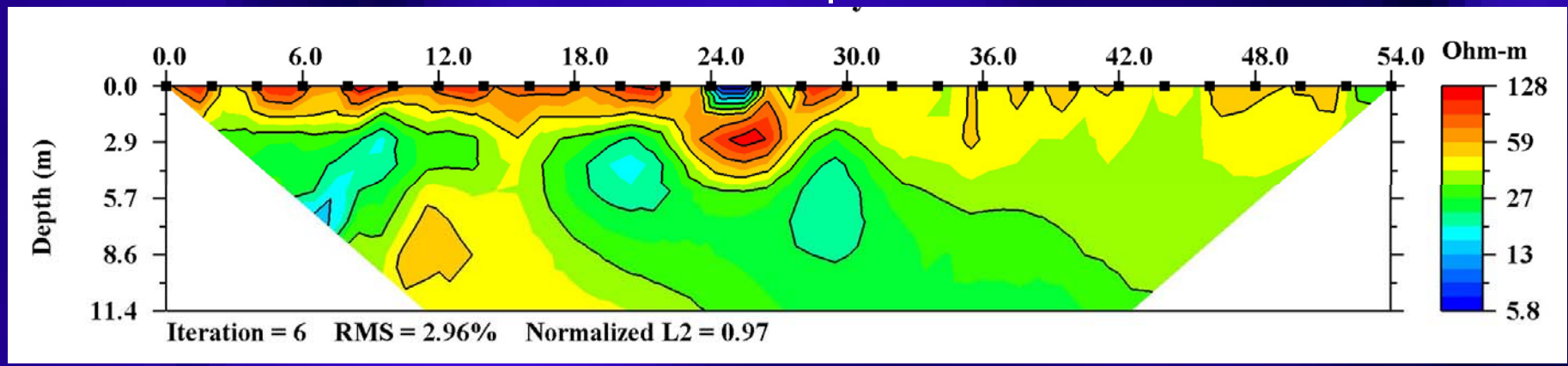
Surface Resistivity, FRC Area 2

Schlumberger/Wenner inverted resistivity section across proposed bio-remediation test cell

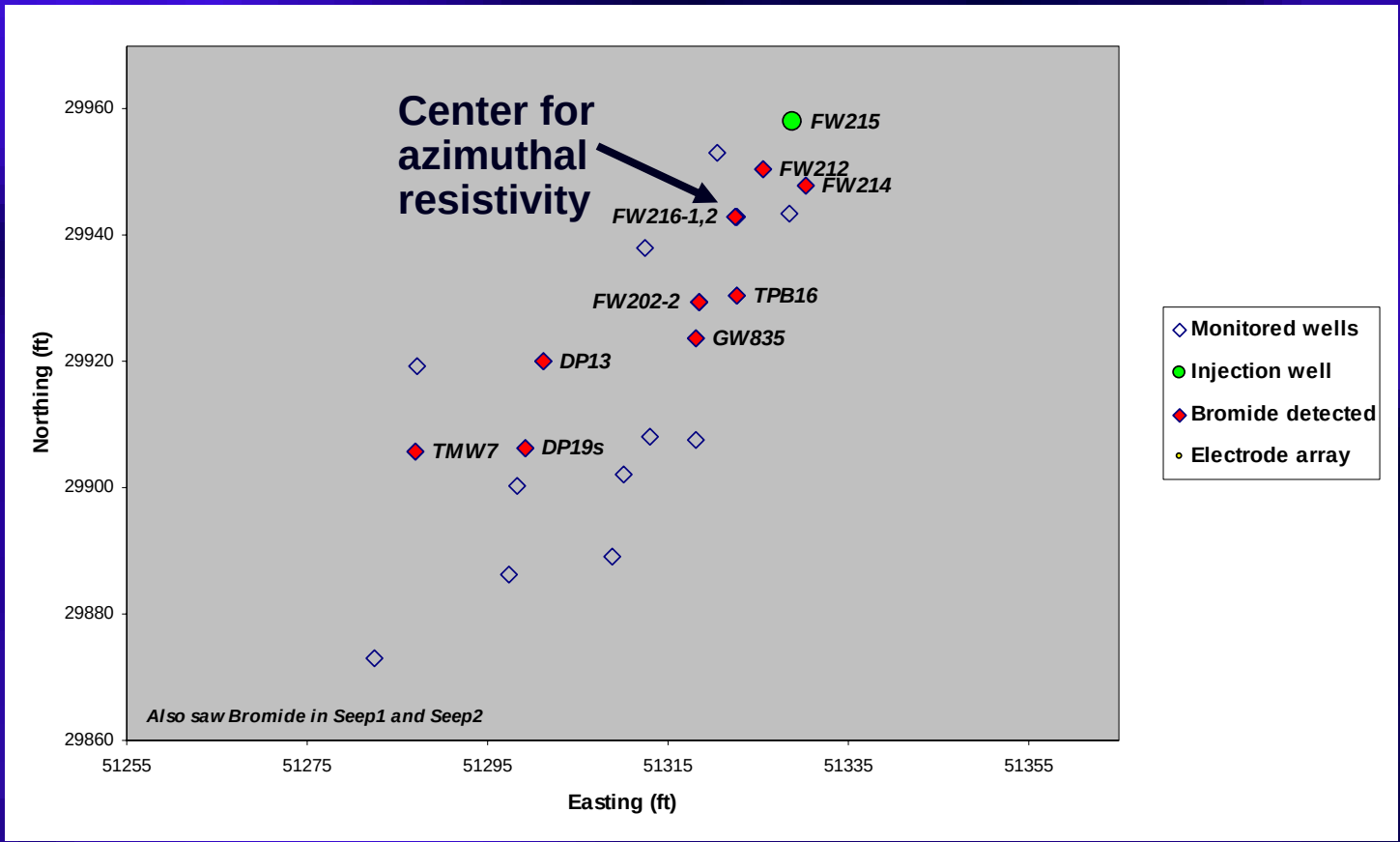
| bio cell |

E **W**

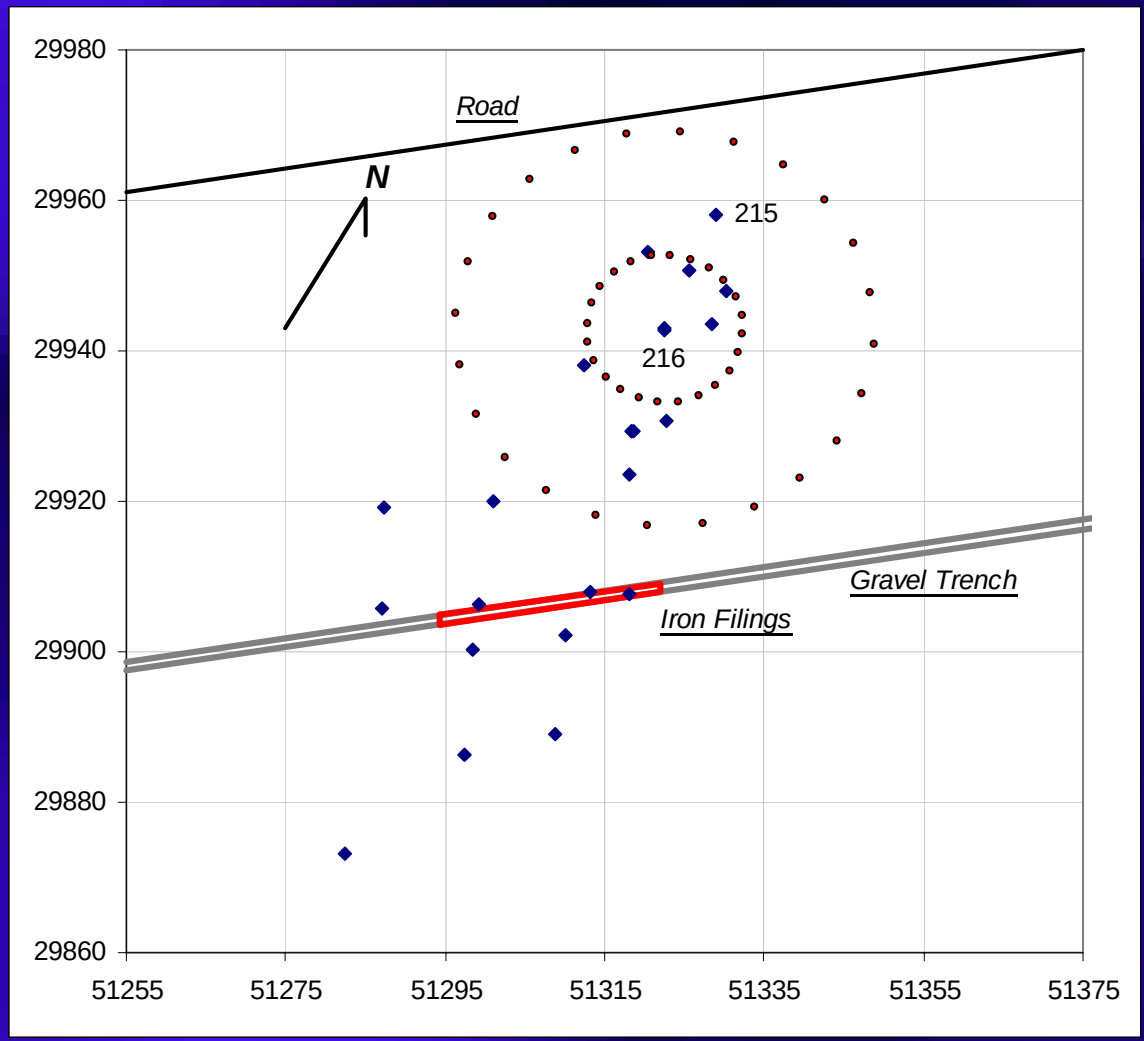
| FW 216



Azimuthal Resistivity, FRC Area 2

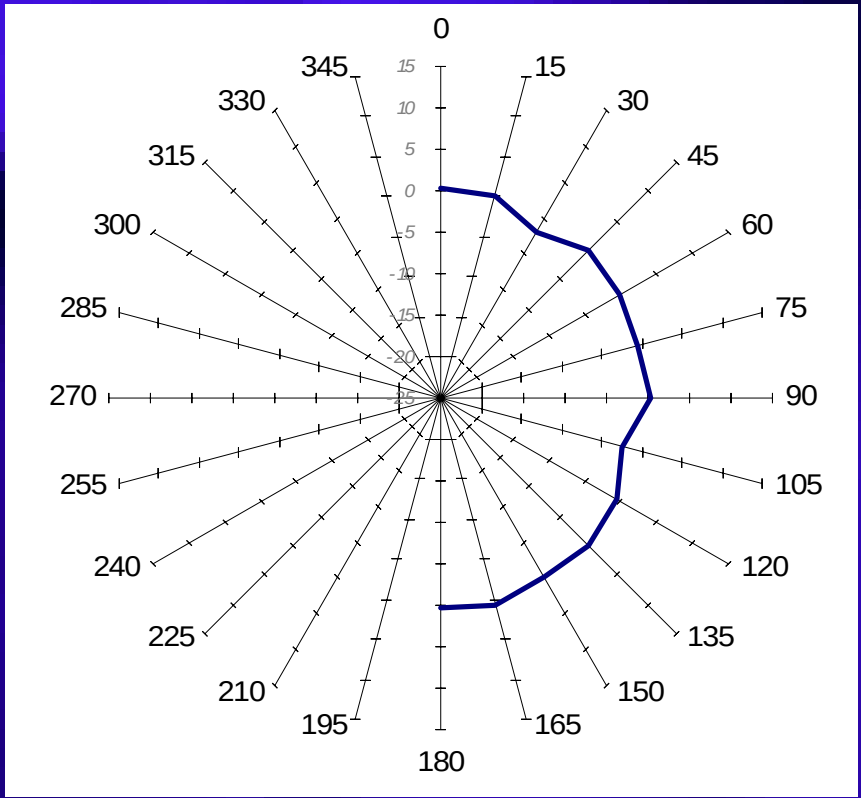


Azimuthal Resistivity, FRC Area 2 electrode locations

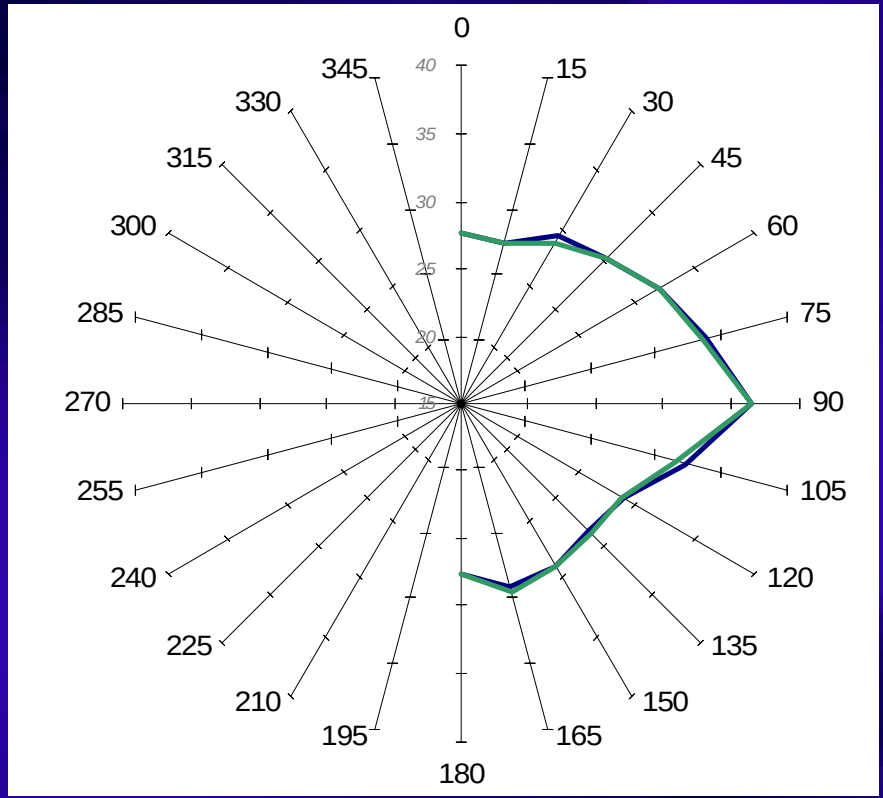


Azimuthal Resistivity, FRC Area 2

% diff



Resistivity



Hour 4

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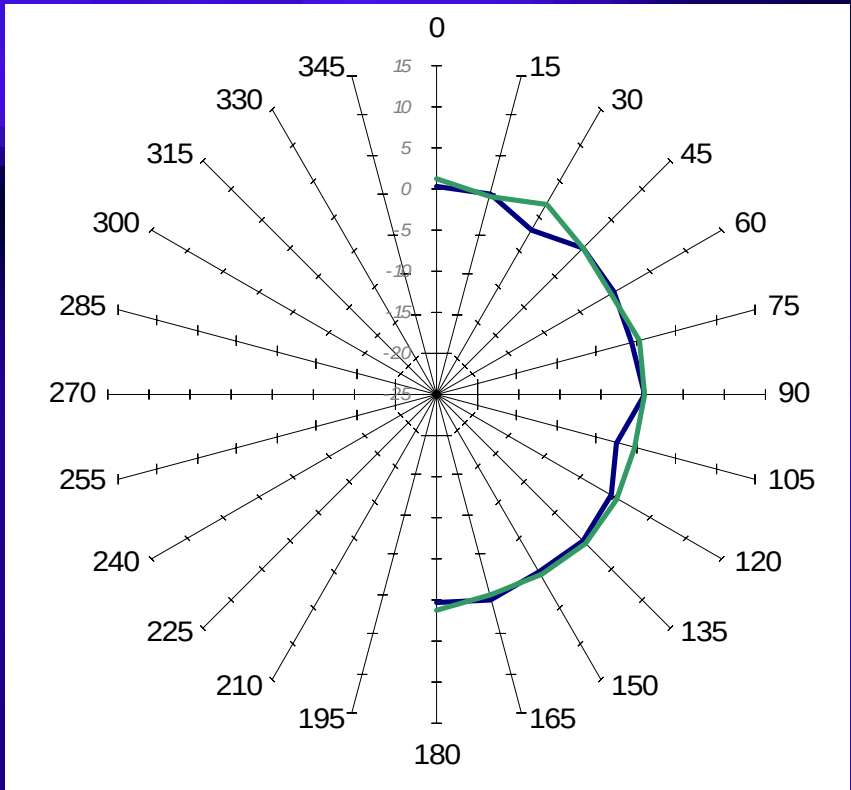
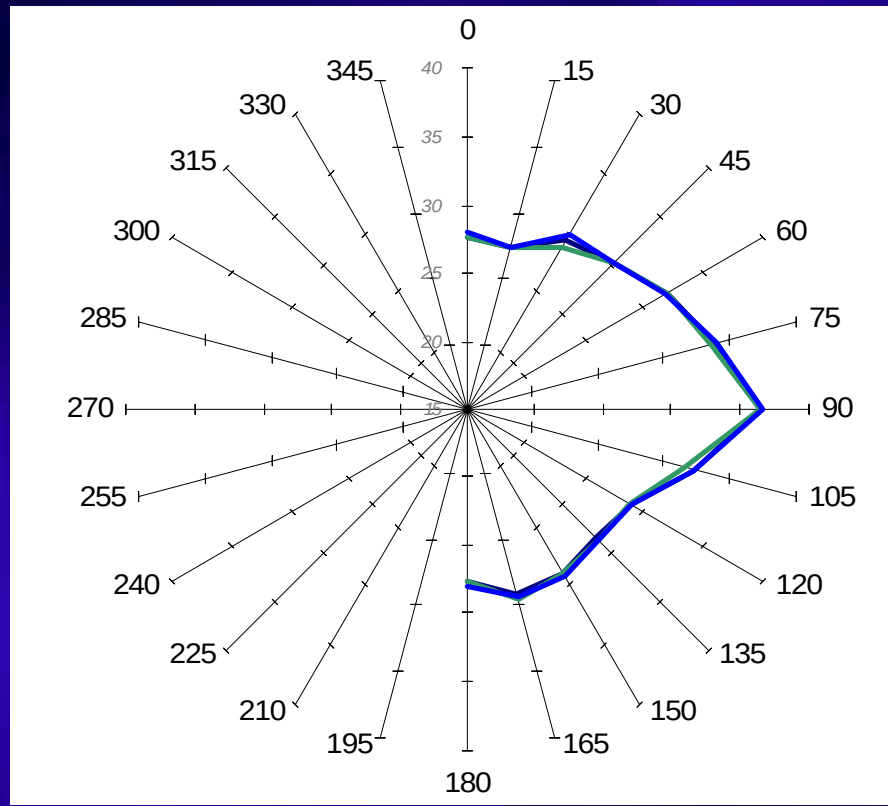


Resistivity



Hour 8

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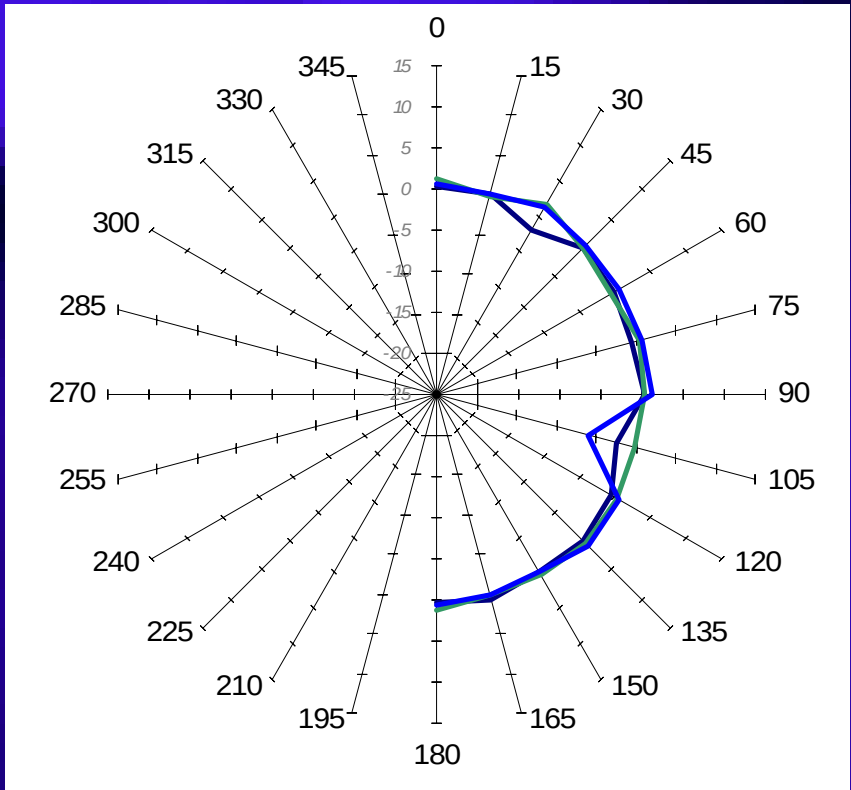
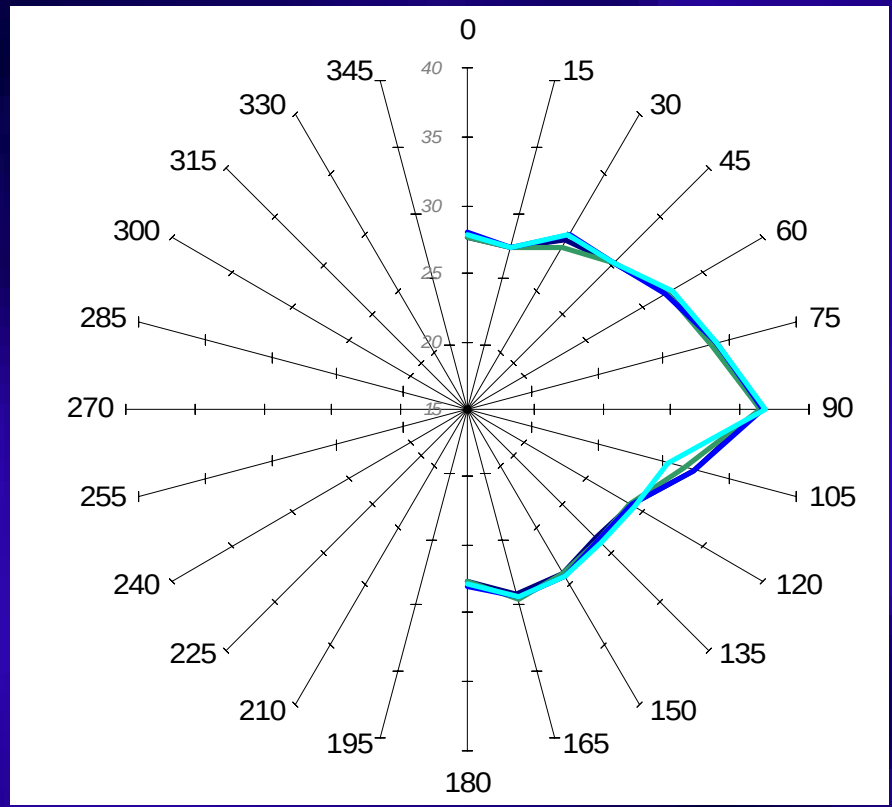


Resistivity



Hour 12

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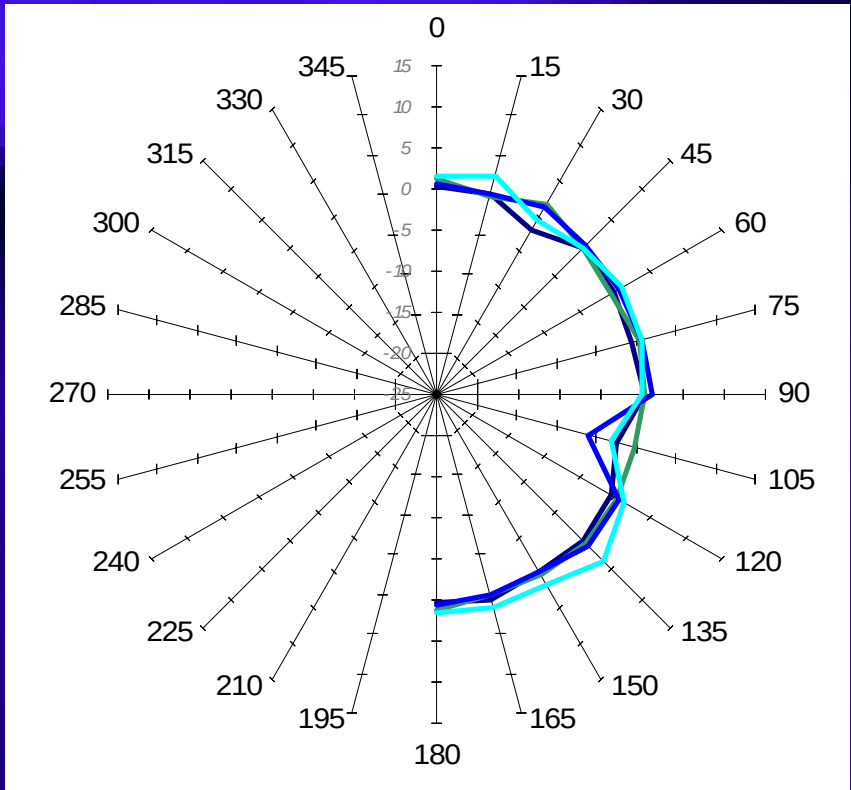
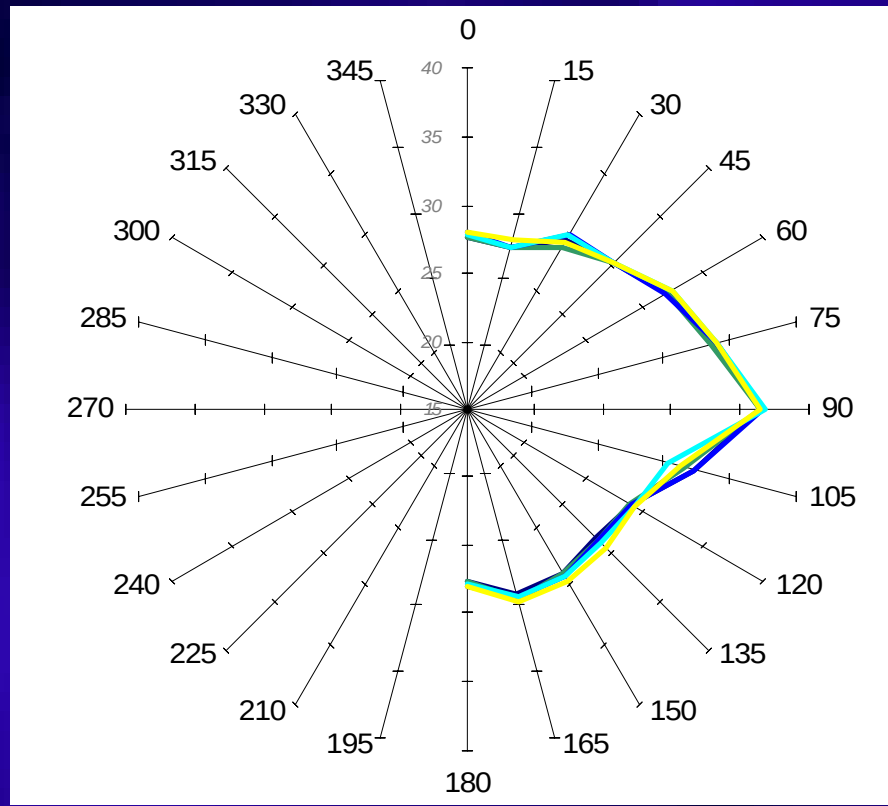


Resistivity



Hour 16

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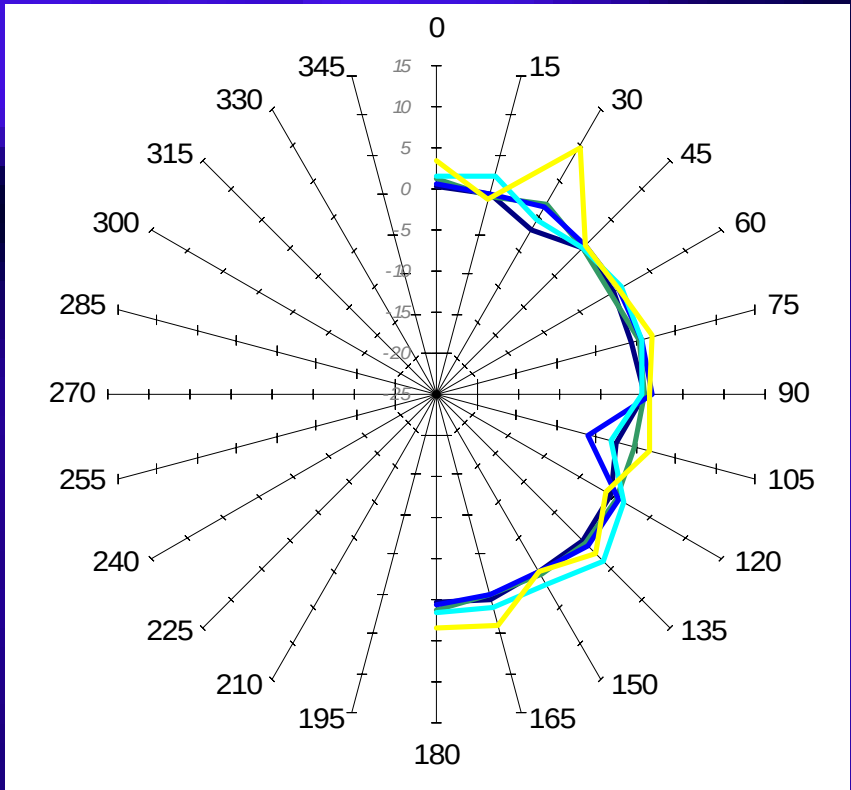
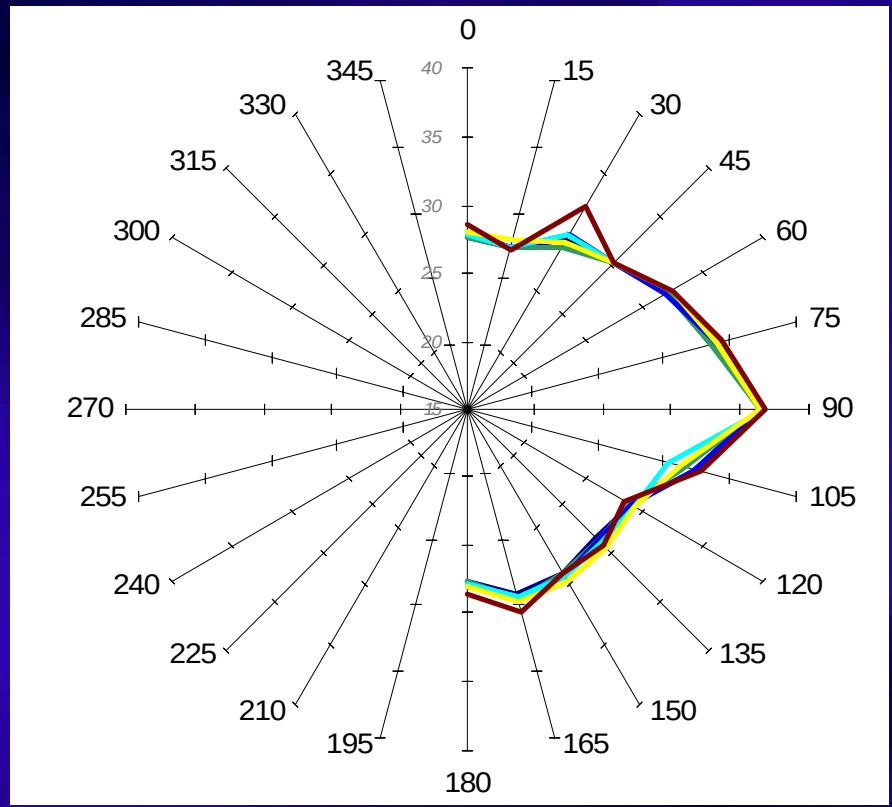


Resistivity



Hour 20

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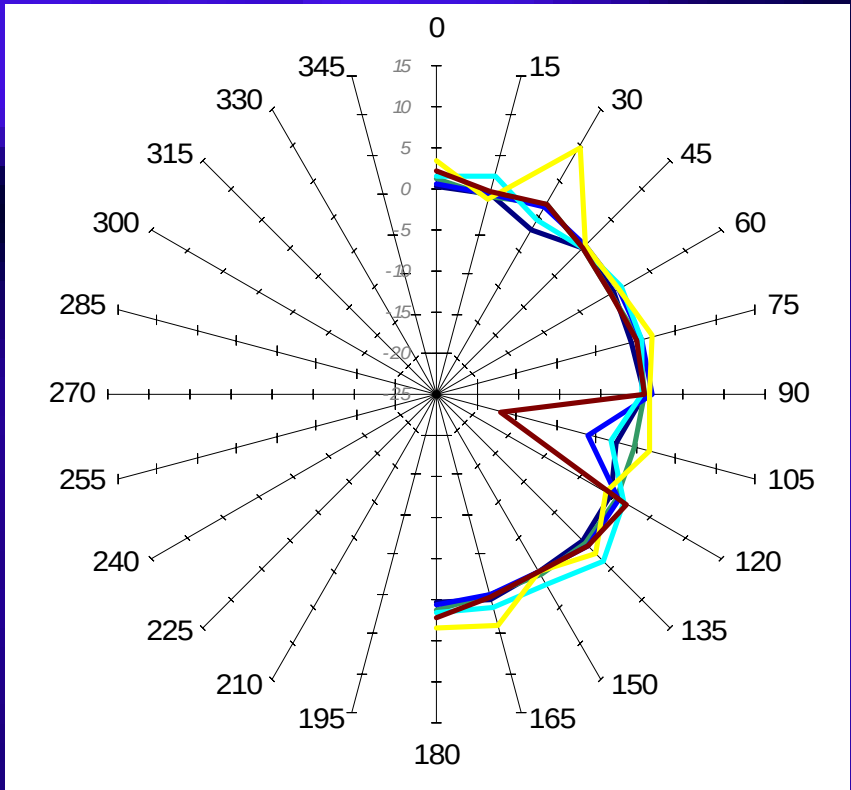
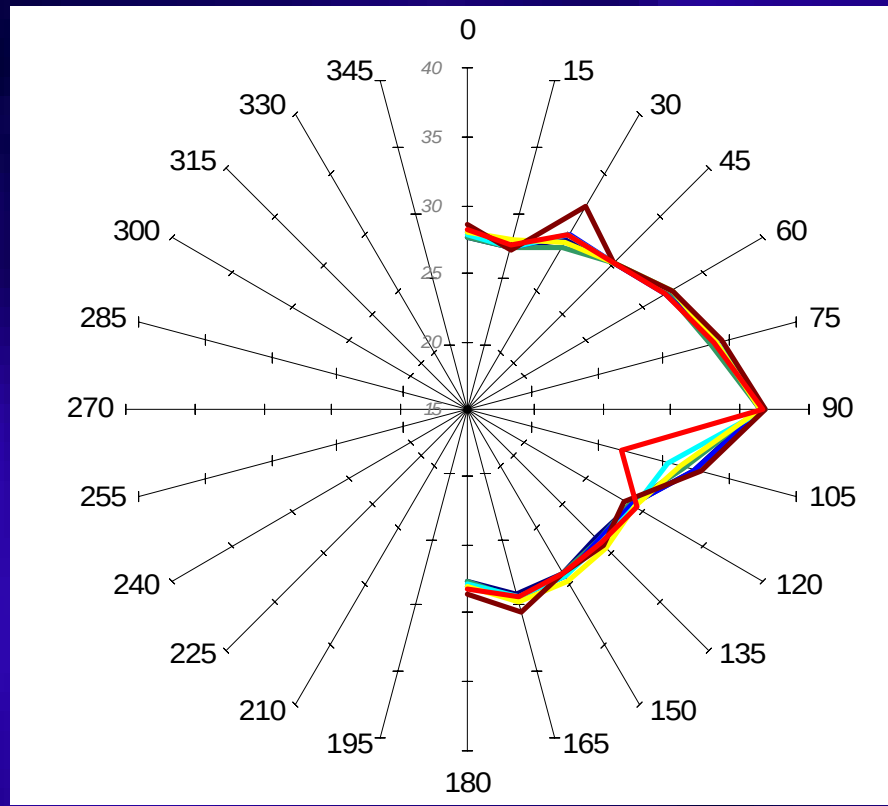


Resistivity



Hour 24

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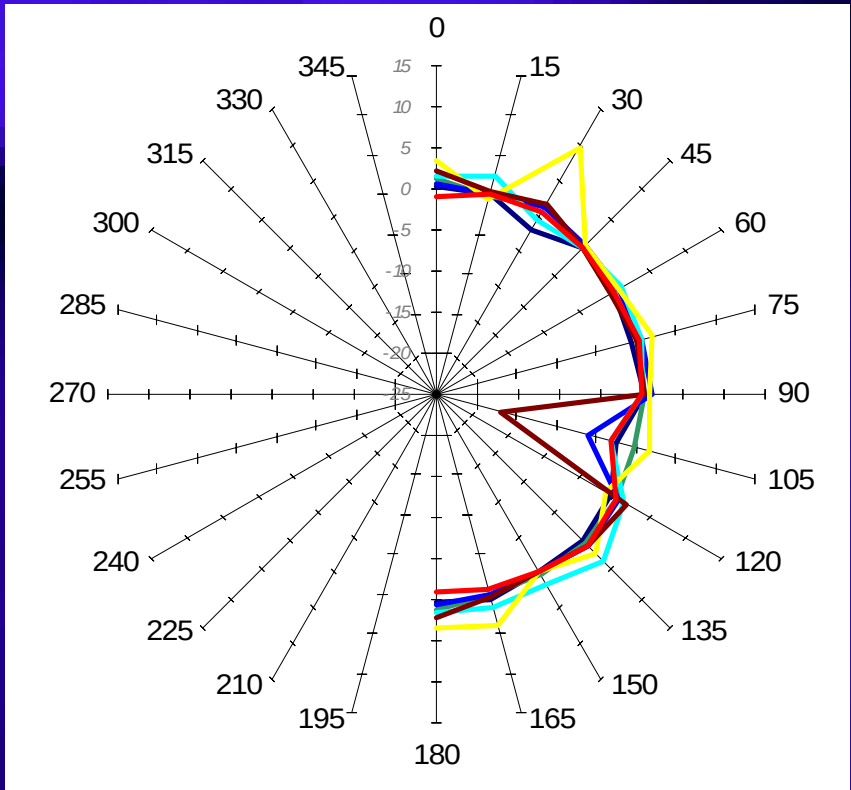
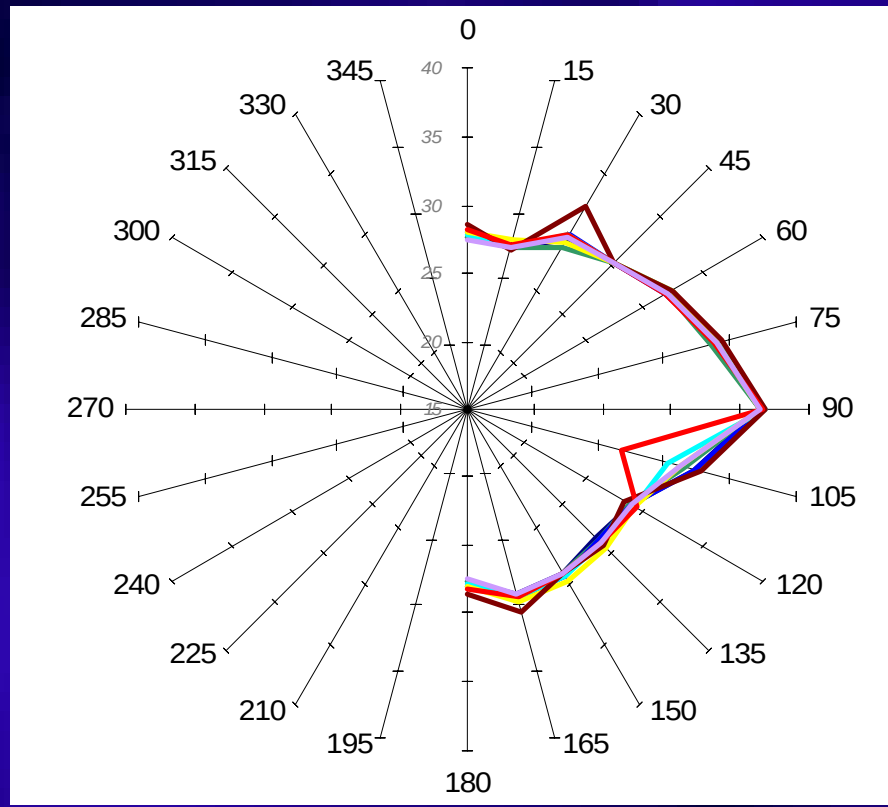


Resistivity



Hour 28

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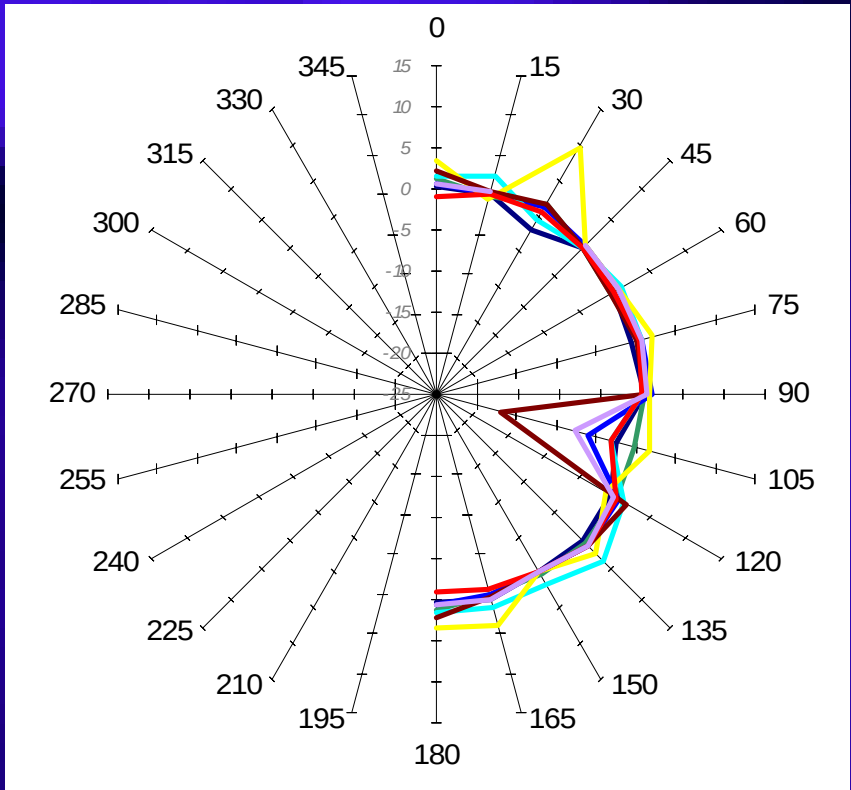
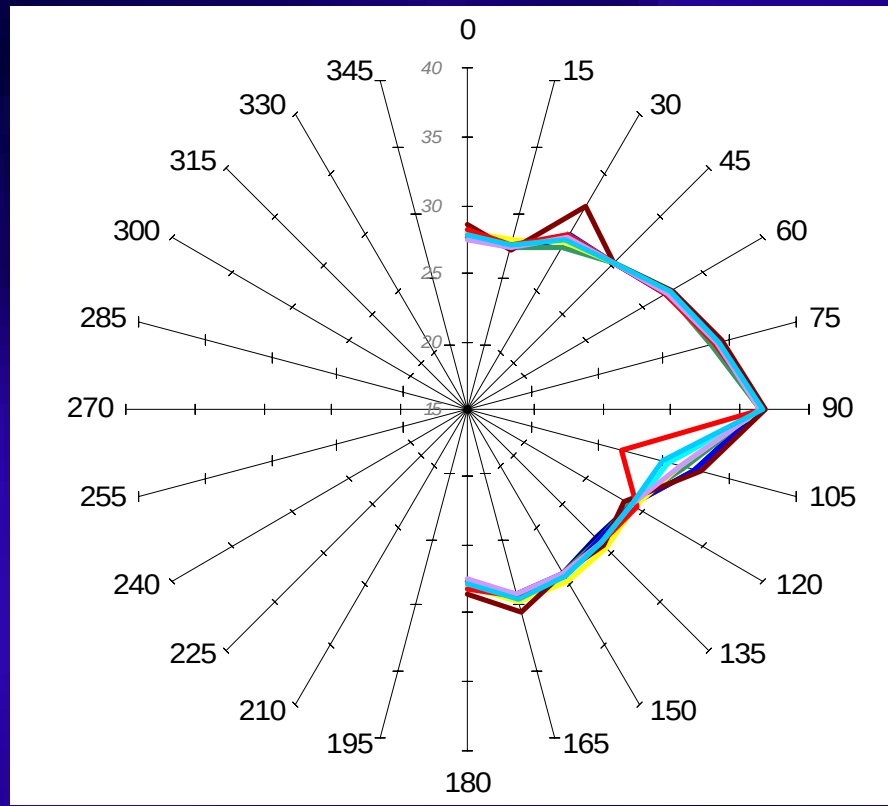


Resistivity



Hour 32

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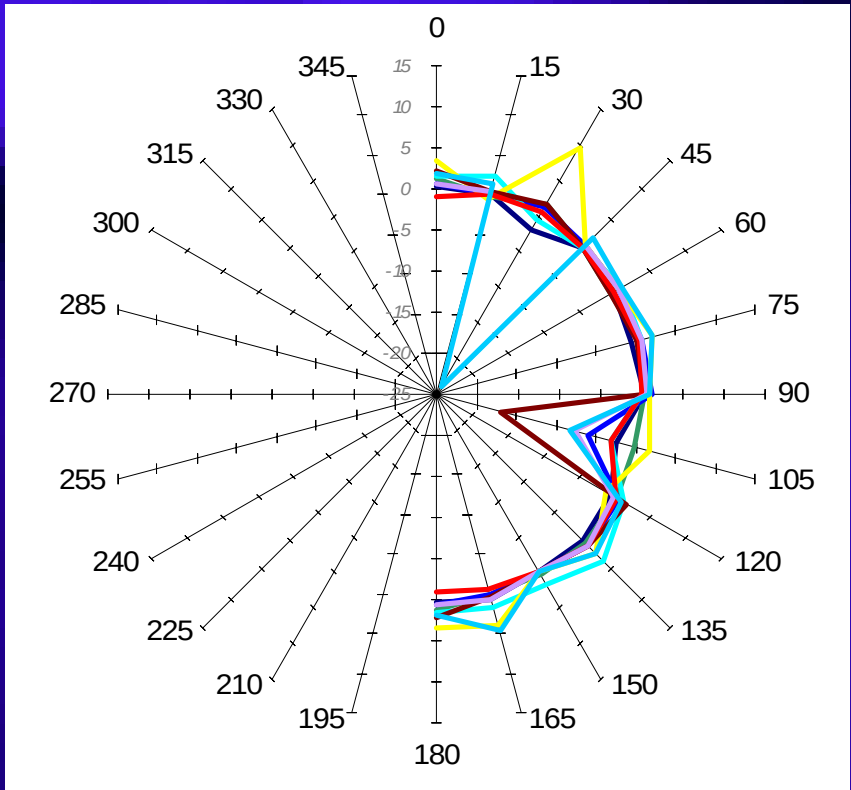
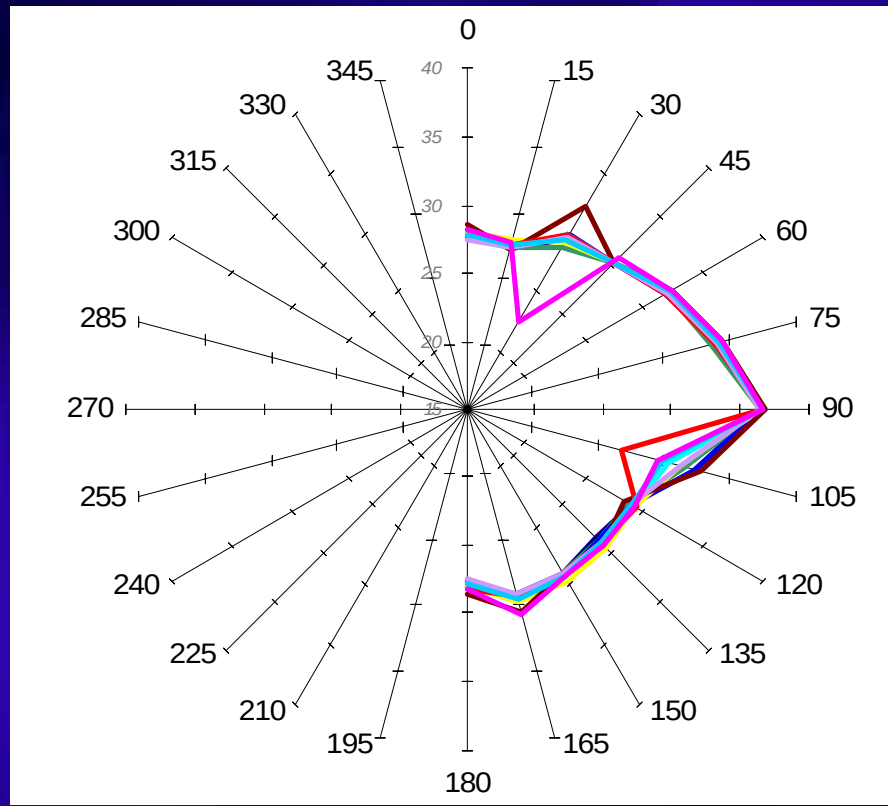


Resistivity



Hour 36

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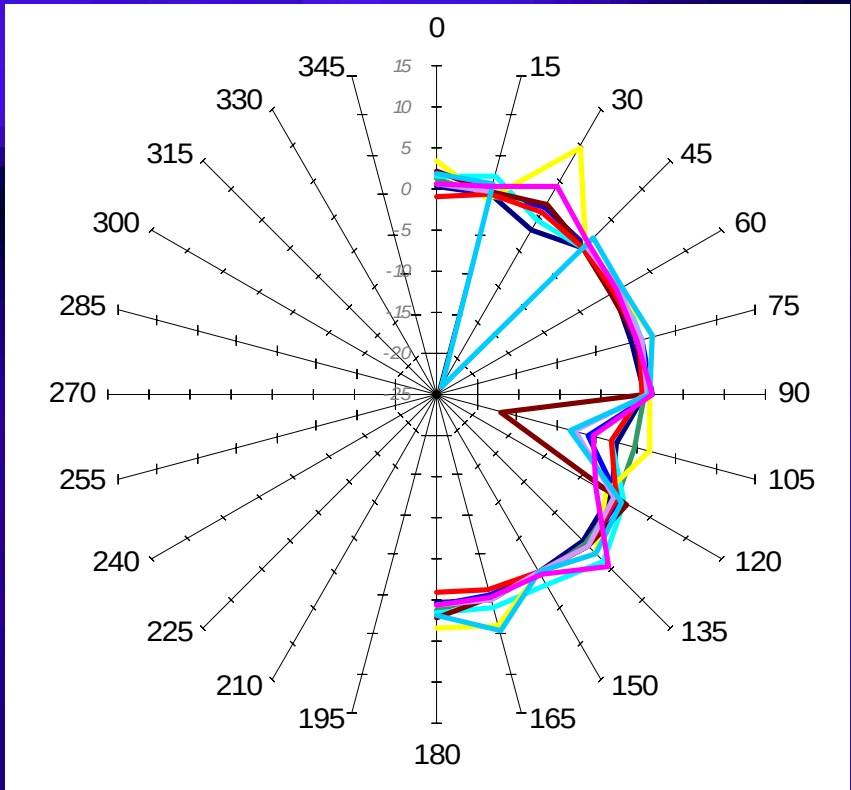
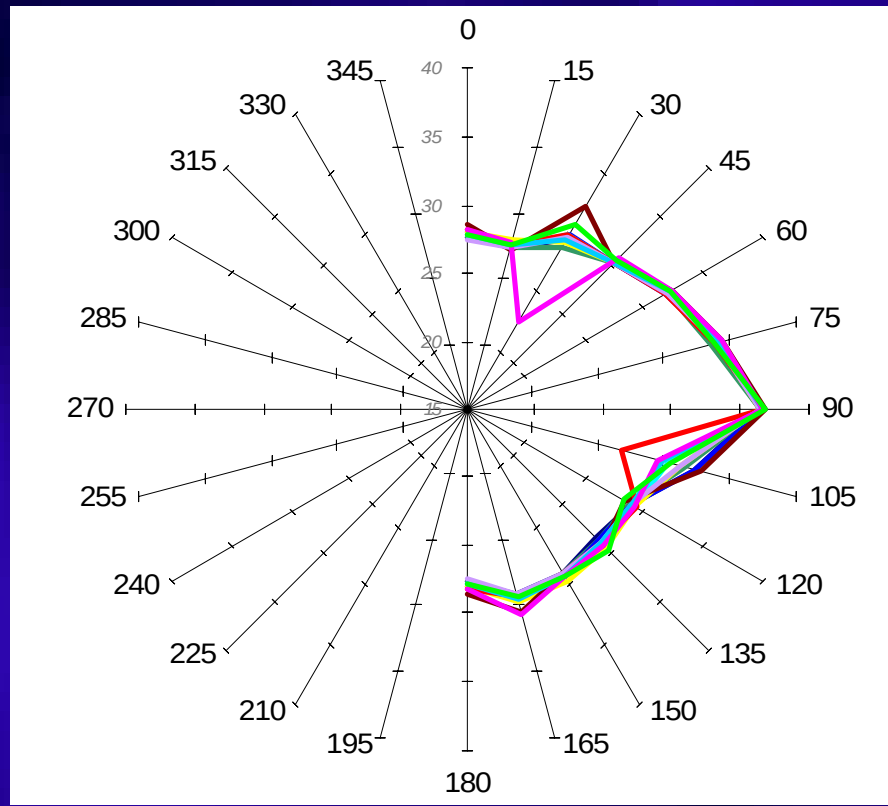


Resistivity



Hour 40.5

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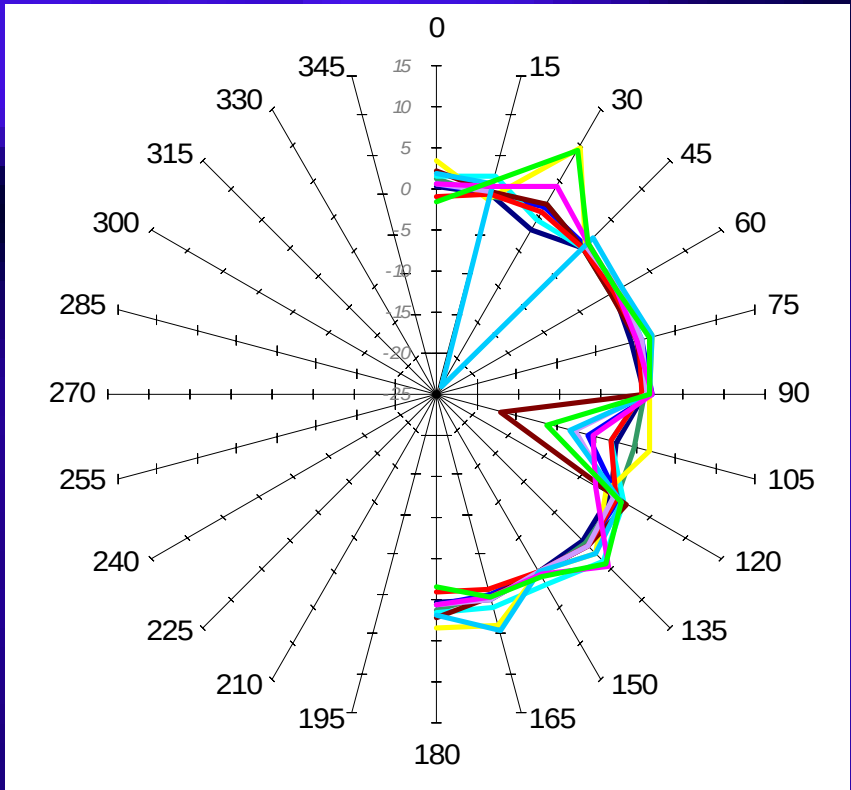

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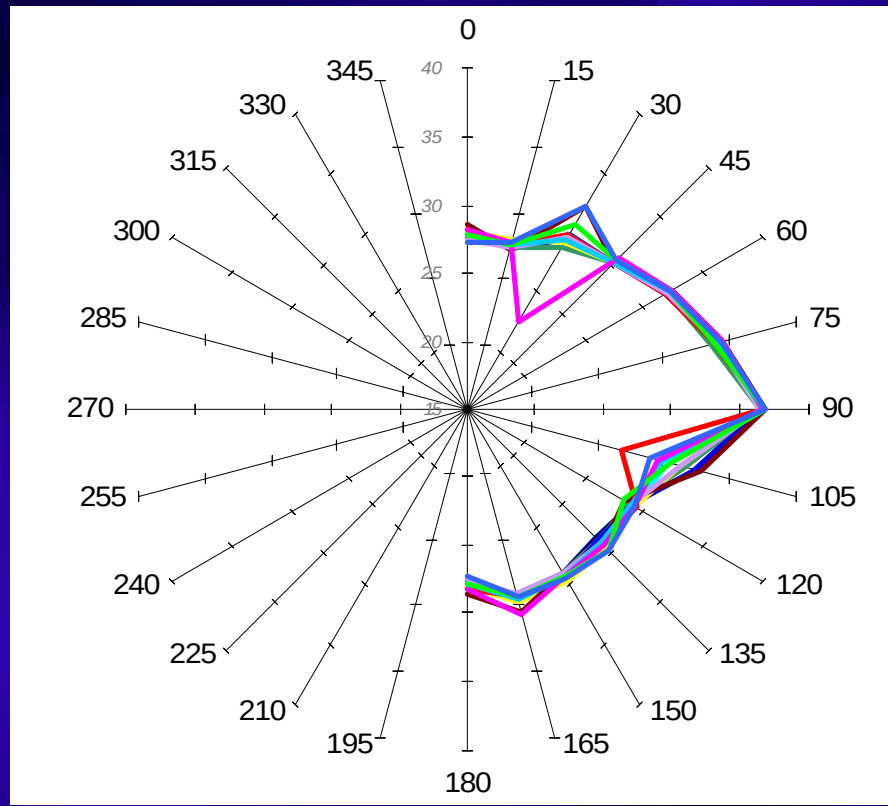

Hour 45

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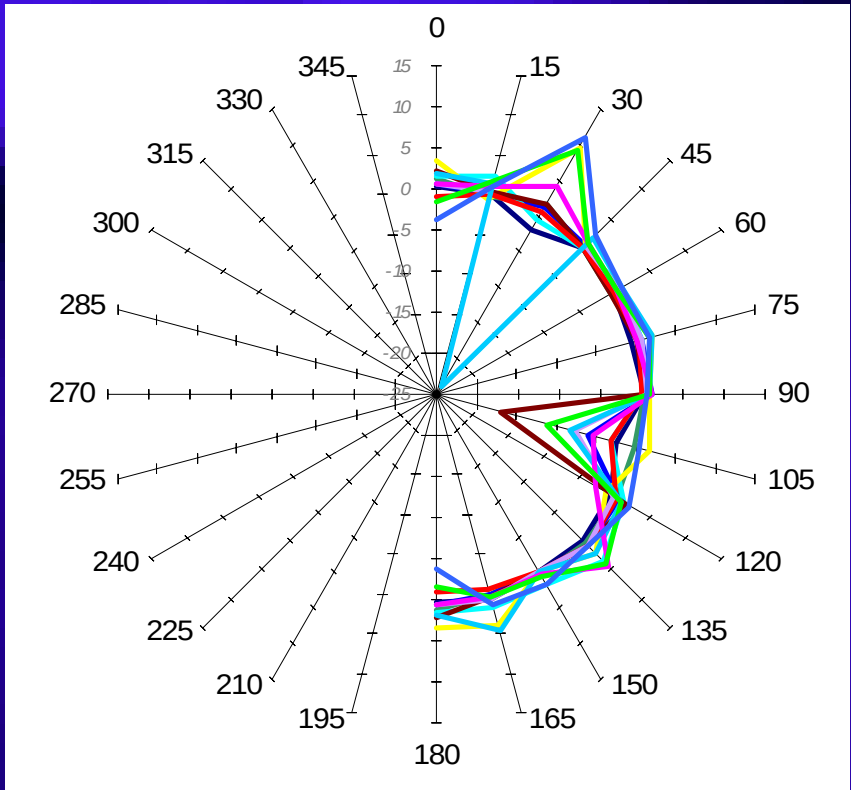

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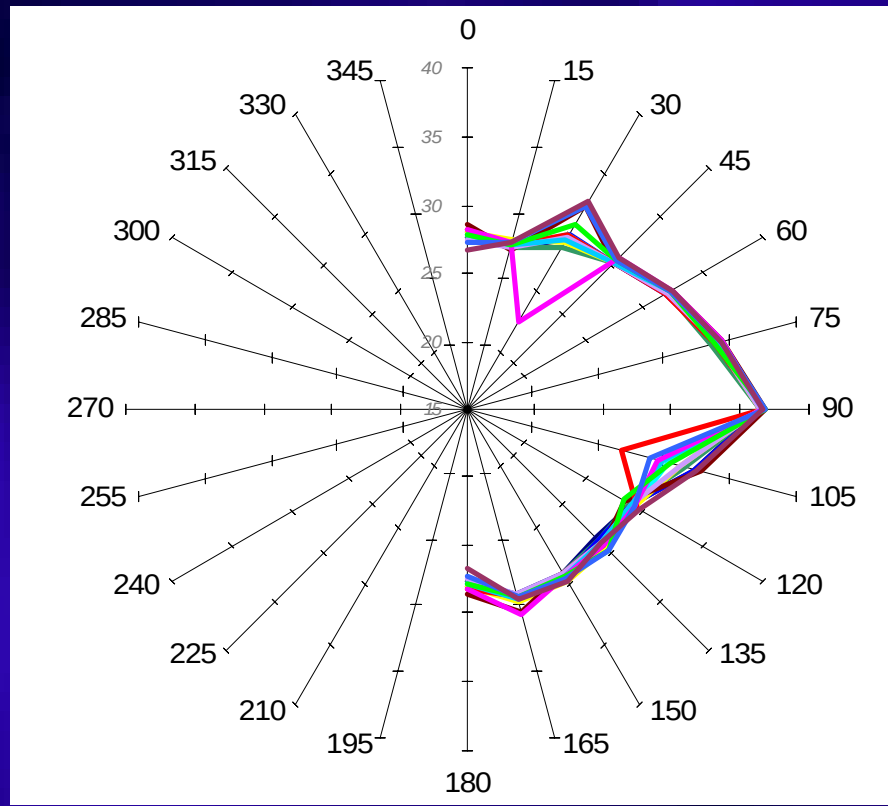

Hour 48.5

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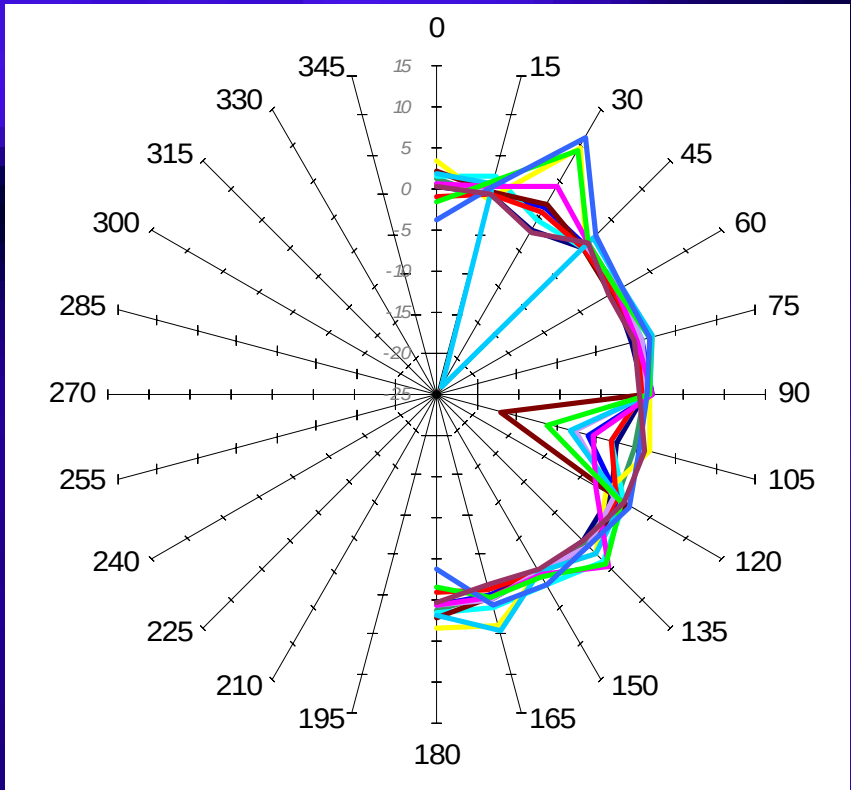

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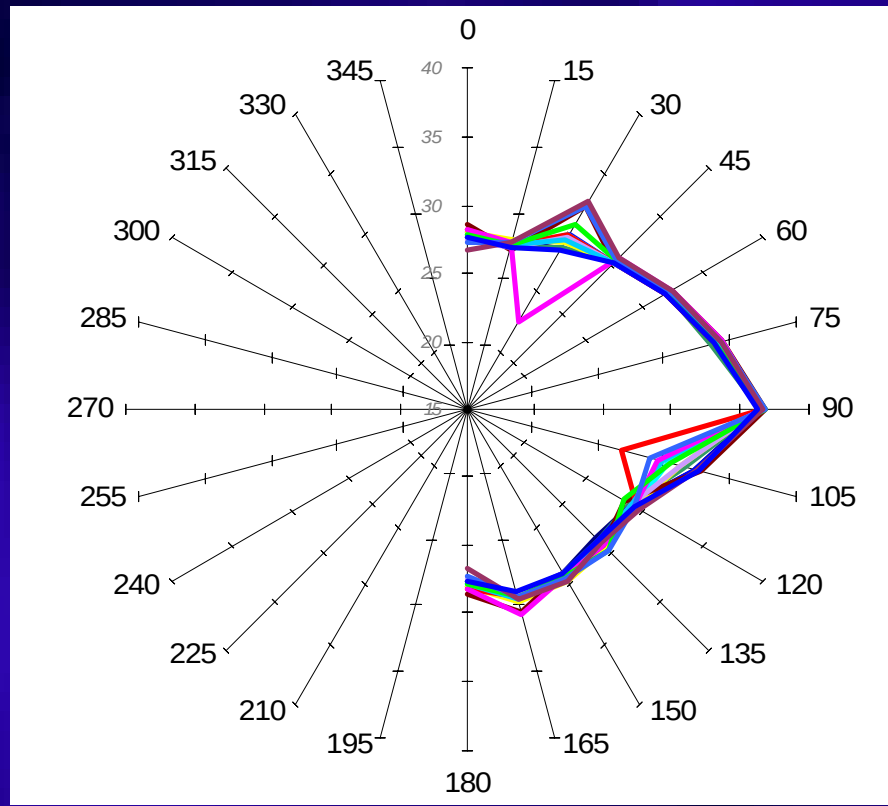

Hour 55

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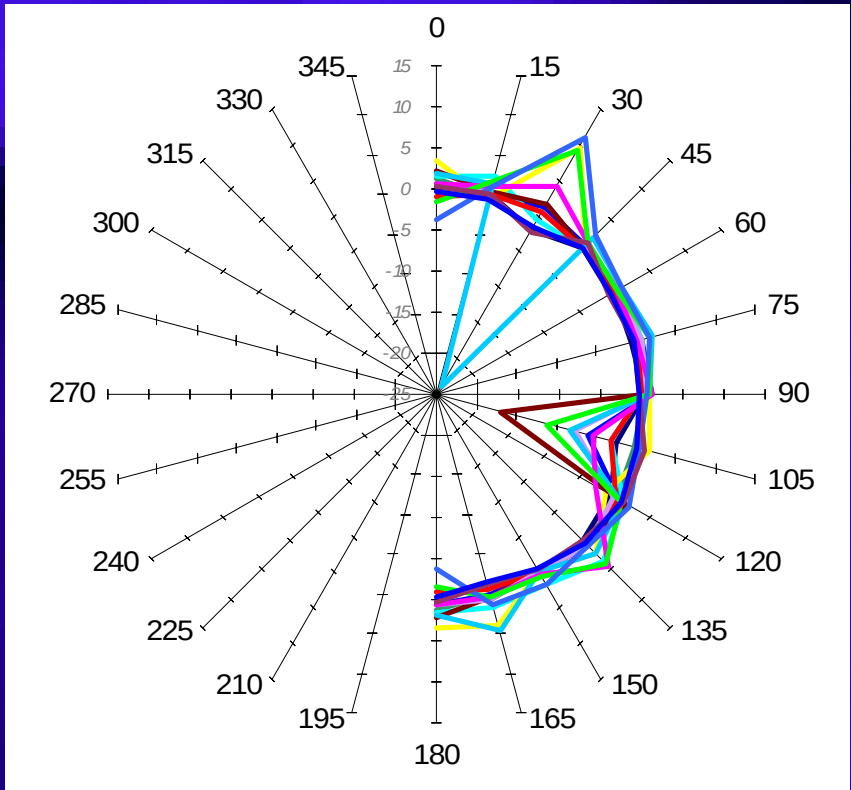
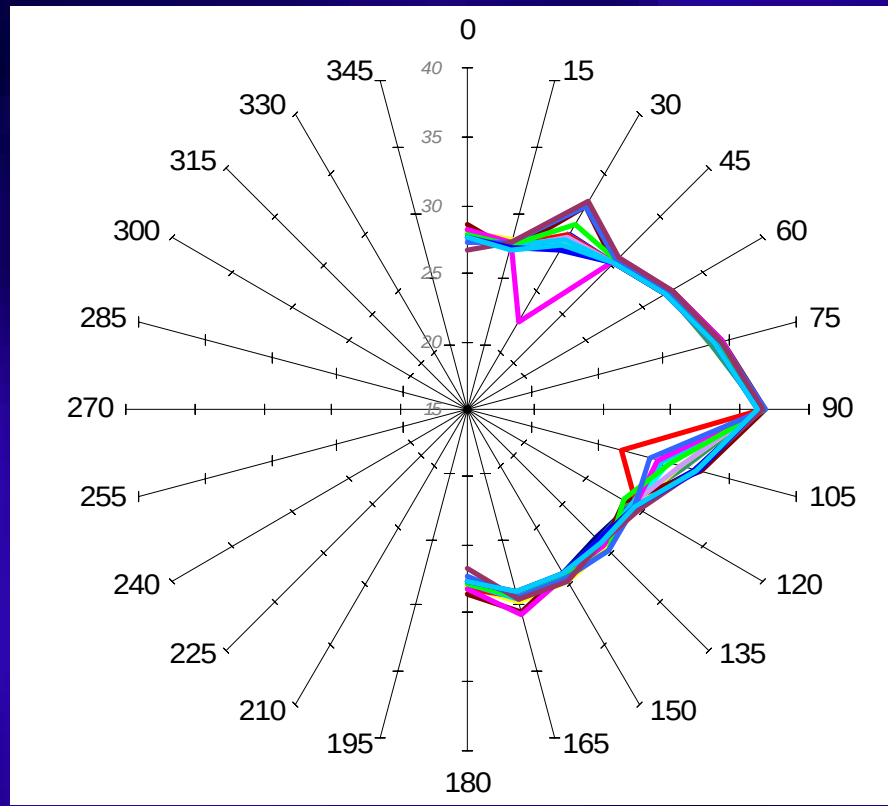


Resistivity



Hour 73

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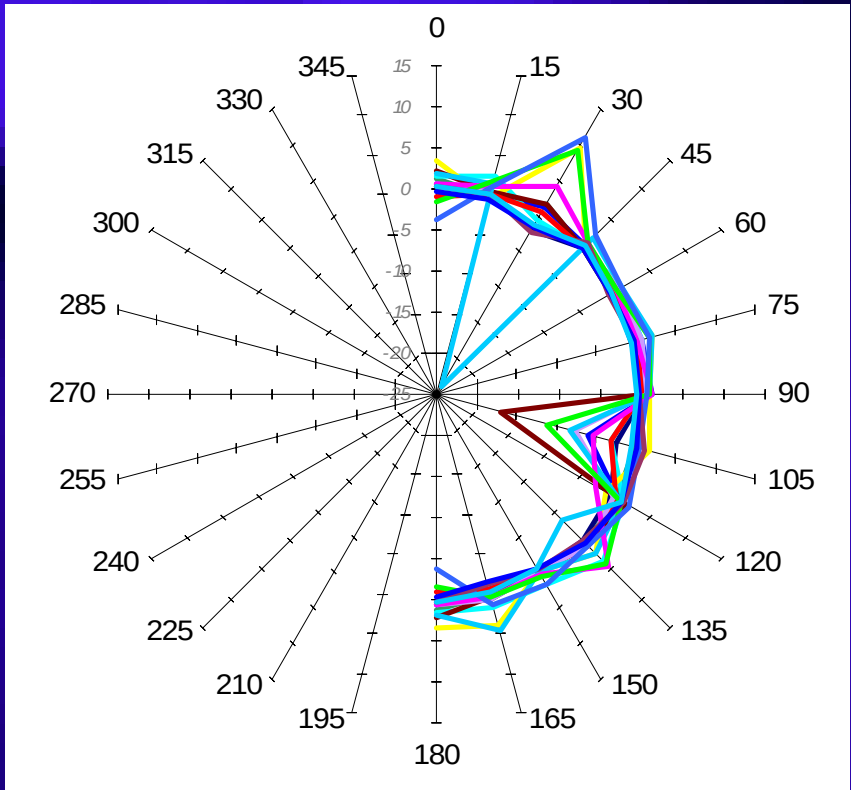
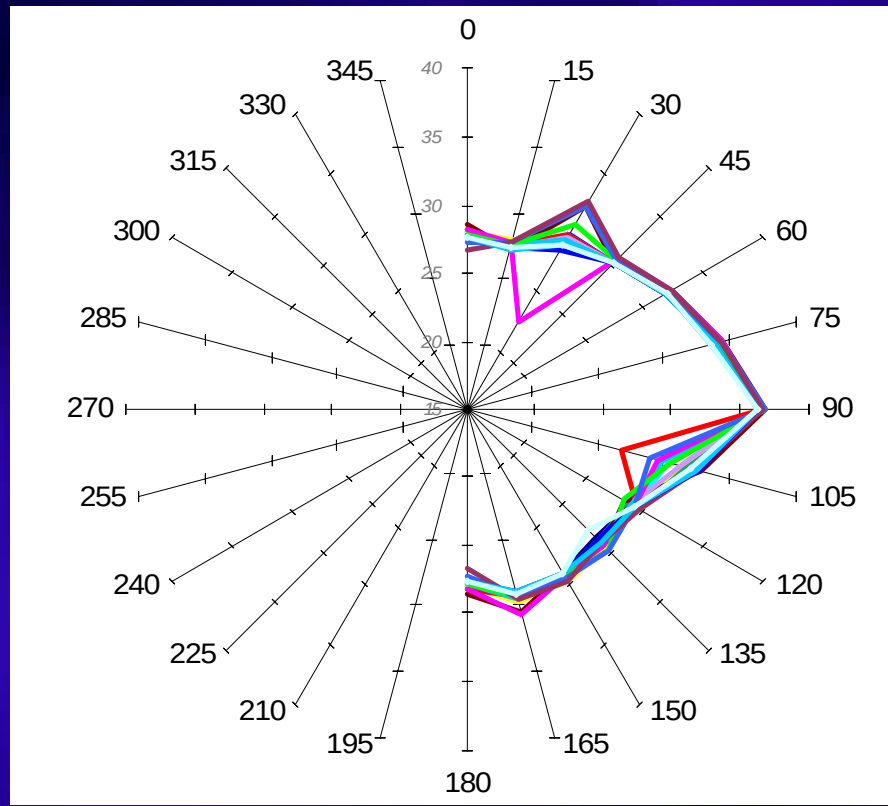


Resistivity



Hour 98

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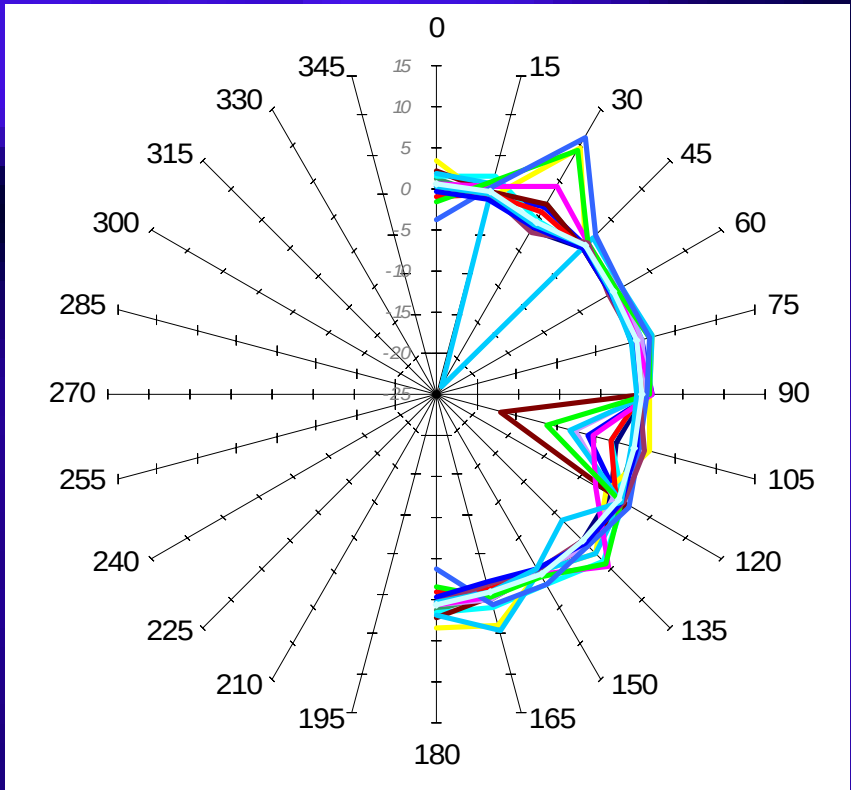
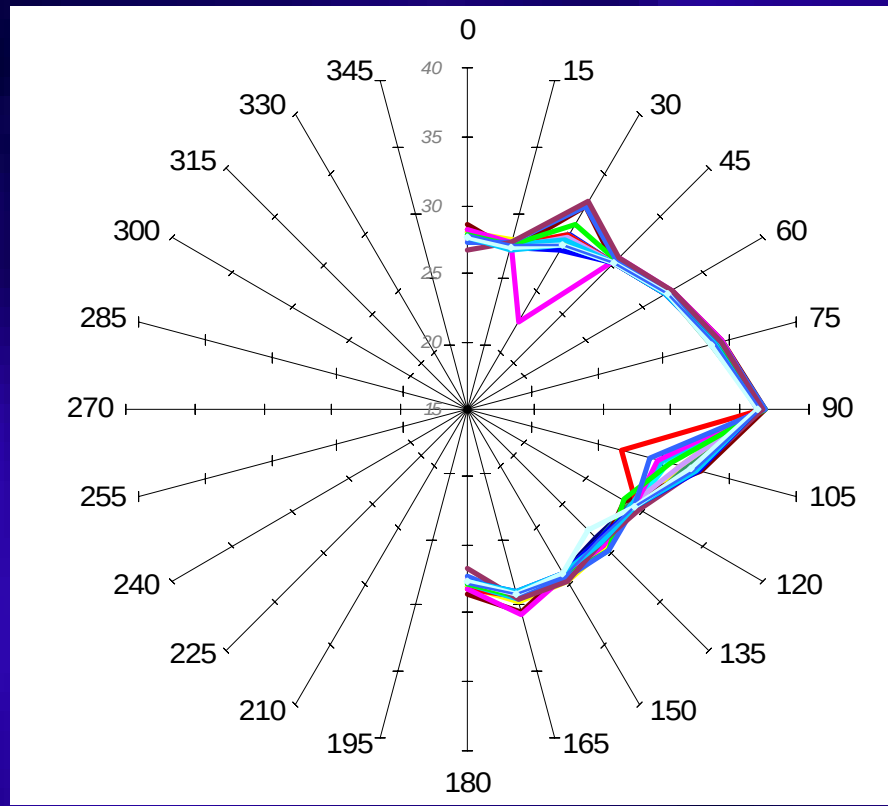


Resistivity



Hour 123

Azimuthal Resistivity Summary

- Two directions showed most change in azimuthal resistivity: N30E, N105E
- These directions align roughly parallel with and orthogonal to the bromide solution flow direction.

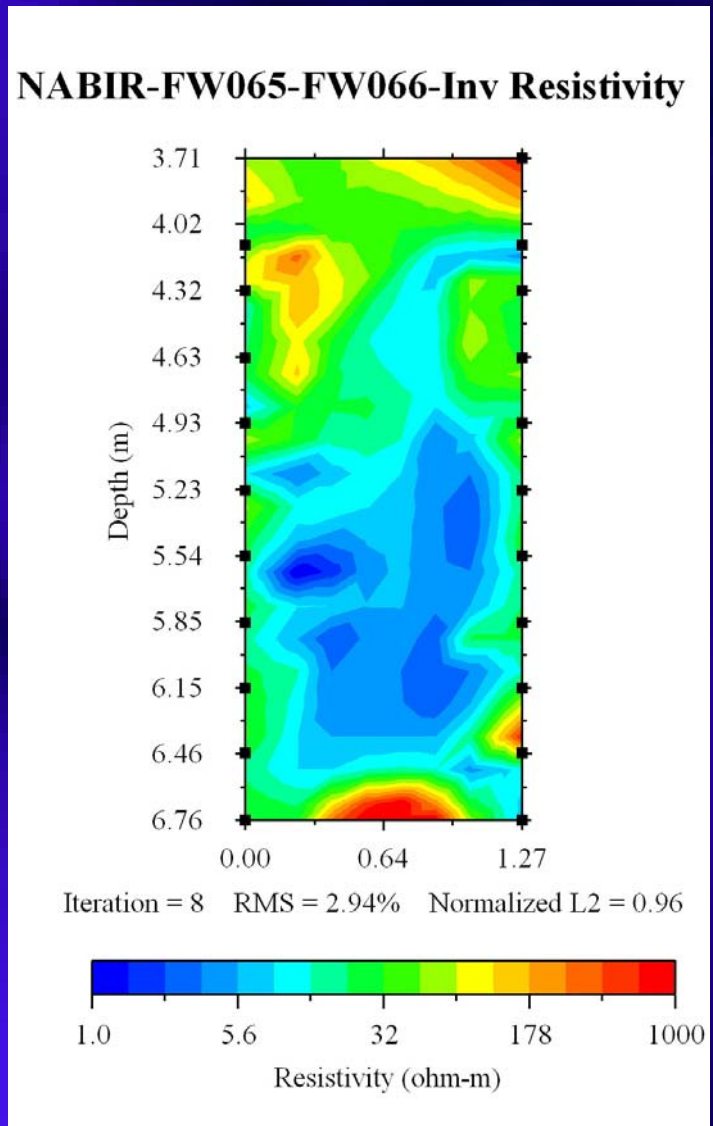
Crosshole Resistivity

- Purpose: To test cross-borehole equipment and software preliminary to use at Area 2 bio-remediation test site.
- Data collected August 19-20, 2004
- Area 2, between wells 228 and 229

  Area 1, between wells 065 and 066

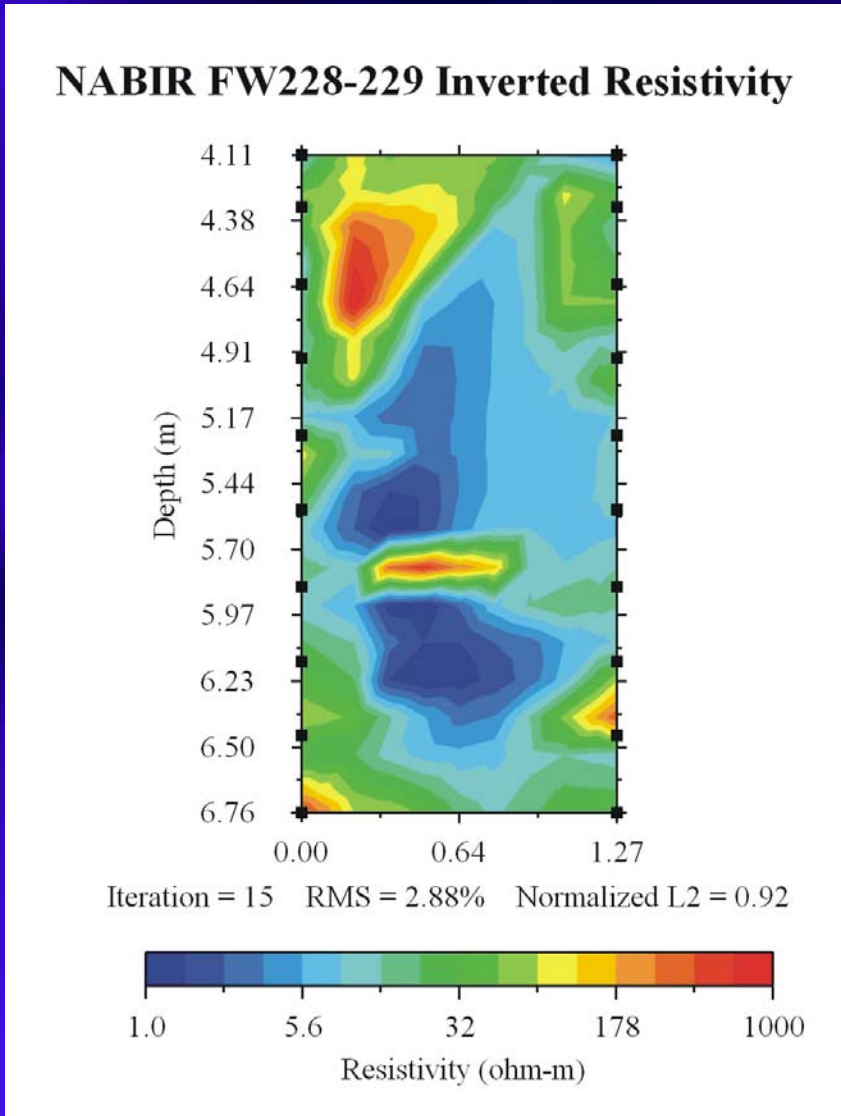
Cross-borehole resistivity

Area 1



Cross-borehole resistivity

Area 2



Cross-borehole Results

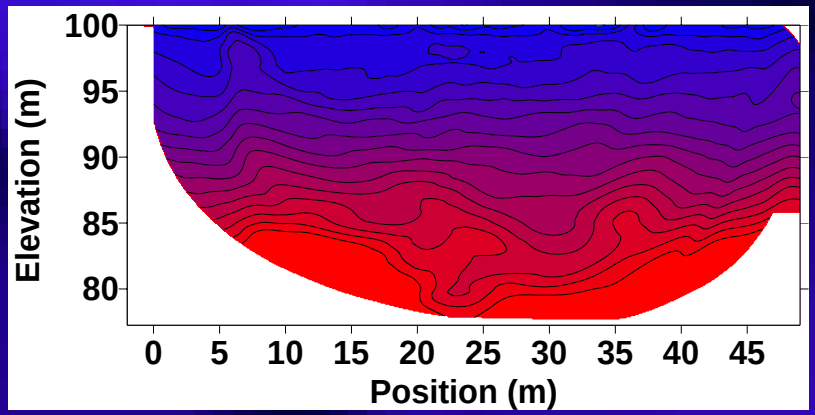
- Inverted crosshole resistivities are reasonable for the geological conditions and groundwater geochemistry.
- Lower resistivities starting at ~5 m depth in Area 1 are most likely the beginning of higher nitrate concentrations.
- The localized high-resistivity feature in the FW 228-229 line is likely a rock or other aquatard, such as clay.

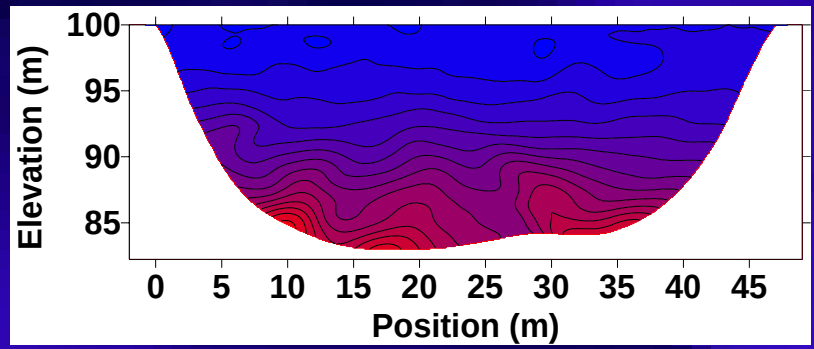
Conclusions

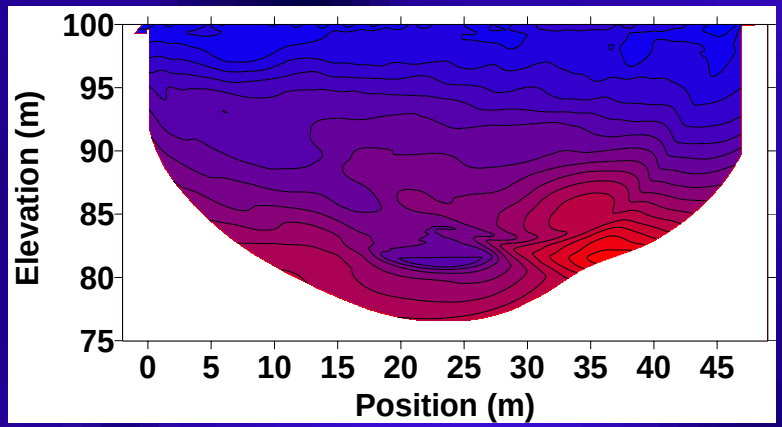
- Multielectrode resistivity was effective in imaging the ionic contamination plume
- Refraction tomography successfully mapped the transition zone between saprolite and bedrock that shows a significant influence on contaminant transport
- The geophysical results were used to help select the location and depth of investigation at Area 3 for field research
- Drilling, borehole geophysics, and ground water sampling verified the geophysical results

Conclusions

- Repeated EM conductivity logging during Area 3 flow test provided documentation for propagation of the injected fluid through time
- Azimuthal resistivity data acquired during flow tests (Area 2) indicates preferential pathways
- Crosshole resistivity sections in Areas 1 and 2 are in general agreement with known geology


Elevation (m)
100
95
90
85
80
0 5 10 15 20 25 30 35 40 45
Position (m)


Elevation (m)
100
95
90
85
0 5 10 15 20 25 30 35 40 45
Position (m)


Elevation (m)
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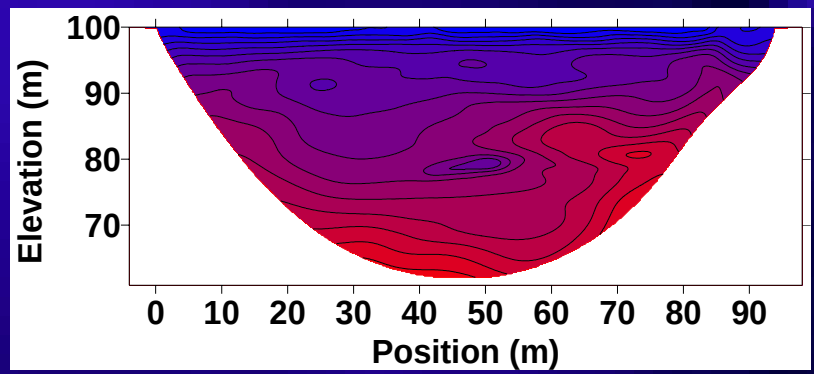
95
90
85
80
75
0 5 10 15 20 25 30 35 40 45
Position (m)


Elevation (m)
100
90
80
70
0 10 20 30 40 50 60 70 80 90
Position (m)