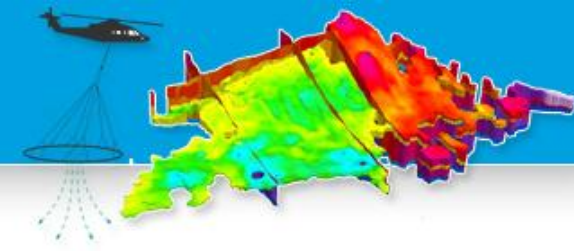


Hydrogeological applications of AEM data

Camilla Sorensen
Andrea Viezzoli
Tim Munday
Vincenzo Sapia

Aarhus Geophysics
Aarhus Geophysics
CSIRO
INGV

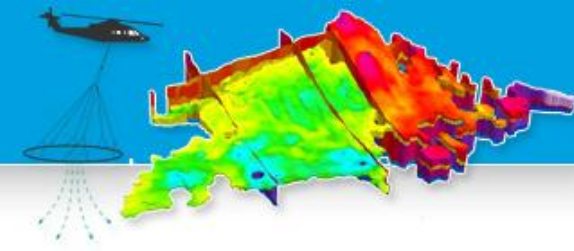
info@aarhusgeo.com



- Drivers

- Accurate definition of aquifer character, aquifer bounds and spatial variability
- Reliable determination of groundwater quality

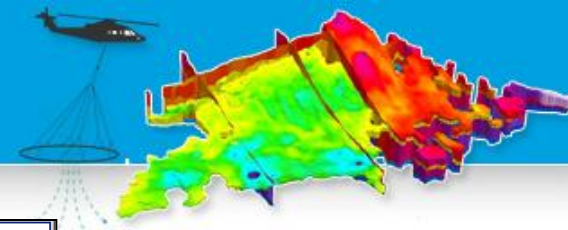




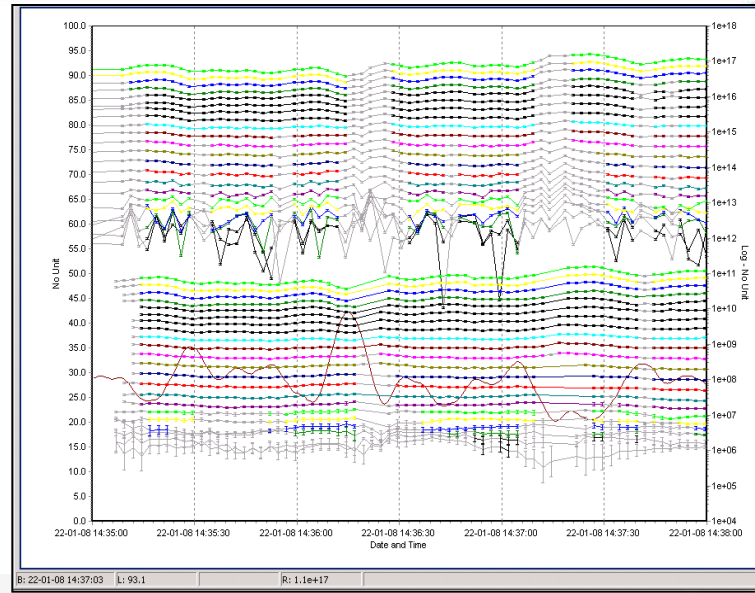
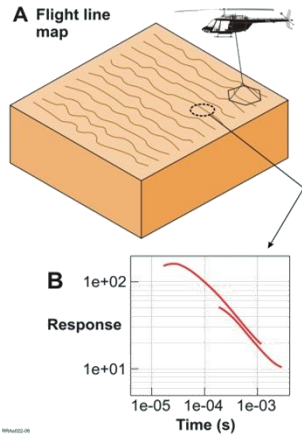
- Successful interpretation of AEM data requires
 - Good processing
 - Good inversion
 - Comparison with other data
- Examples
 - TEMPEST
 - SkyTEM
 - AeroTEM/VTEM



AEM for GW: Steps to success

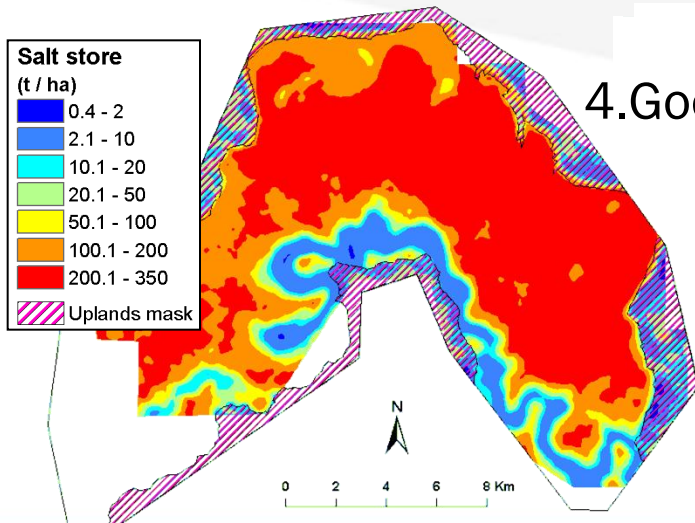


1. Good Source data

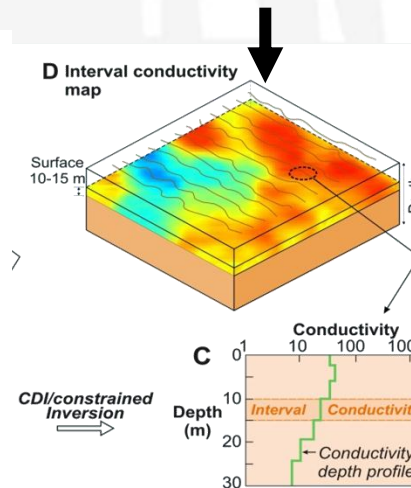


2. Good Processing

Prepare the best possible input for data inversion



4. Good derived products

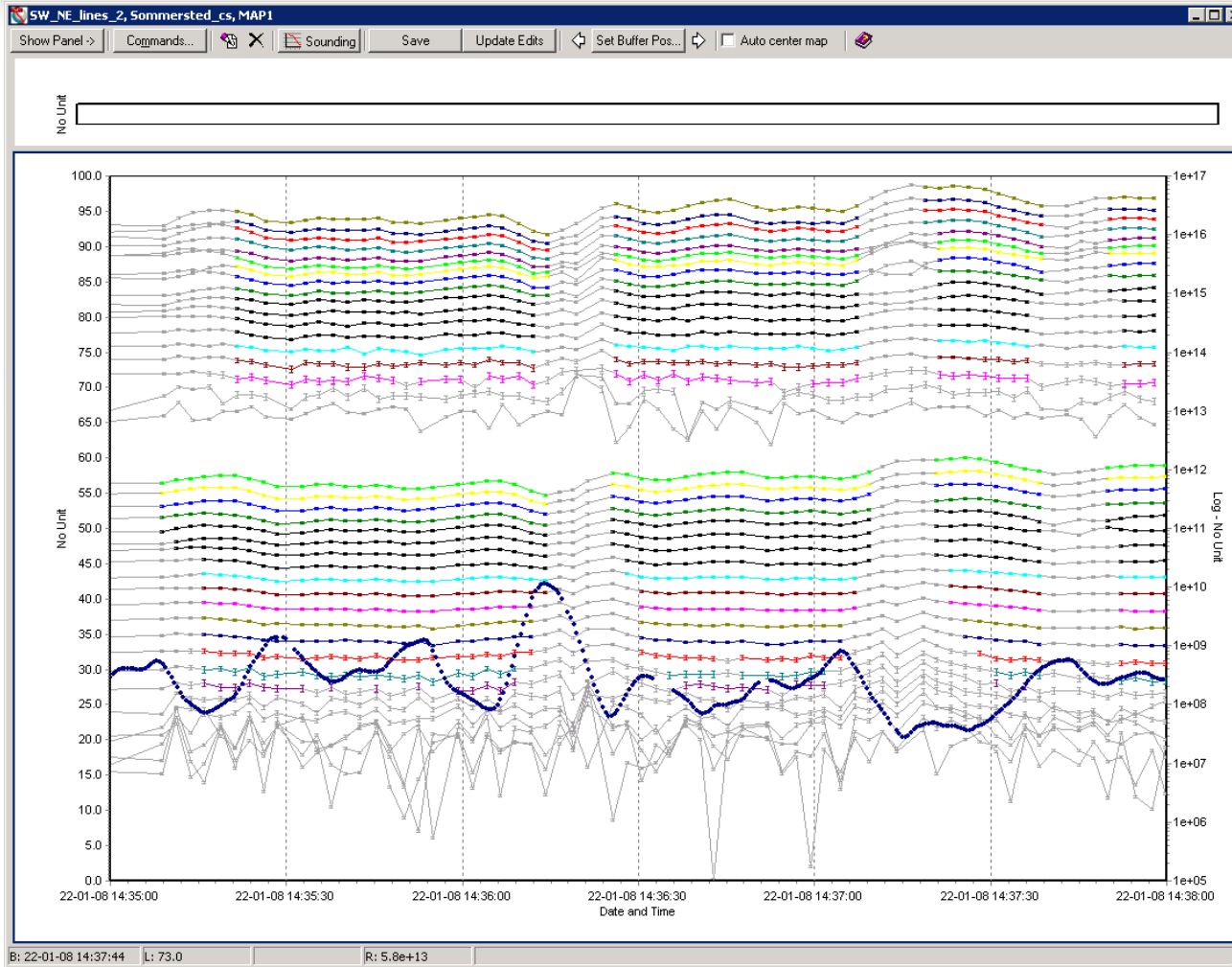
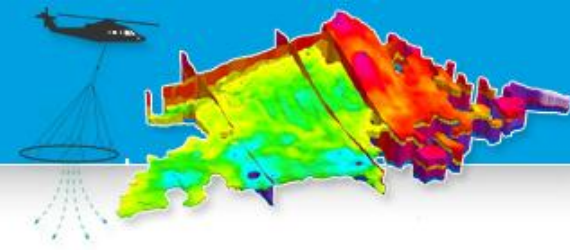


3. Good Inversion

Recover resistivity model consistent with ALL the data, both AEM and a-priori



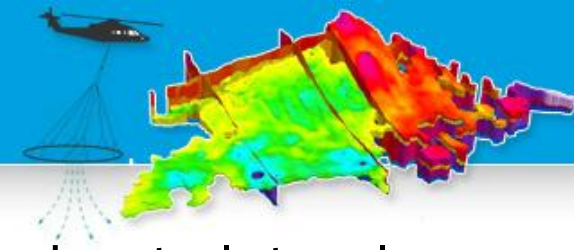
AEM data processing



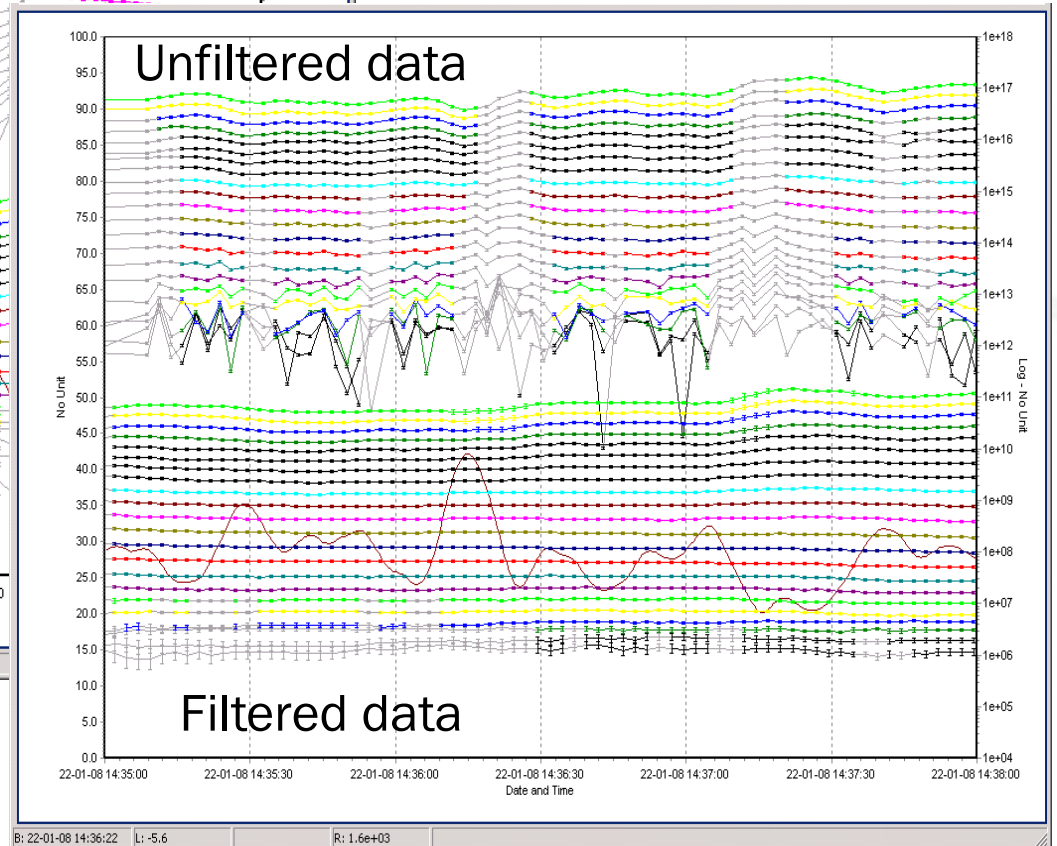
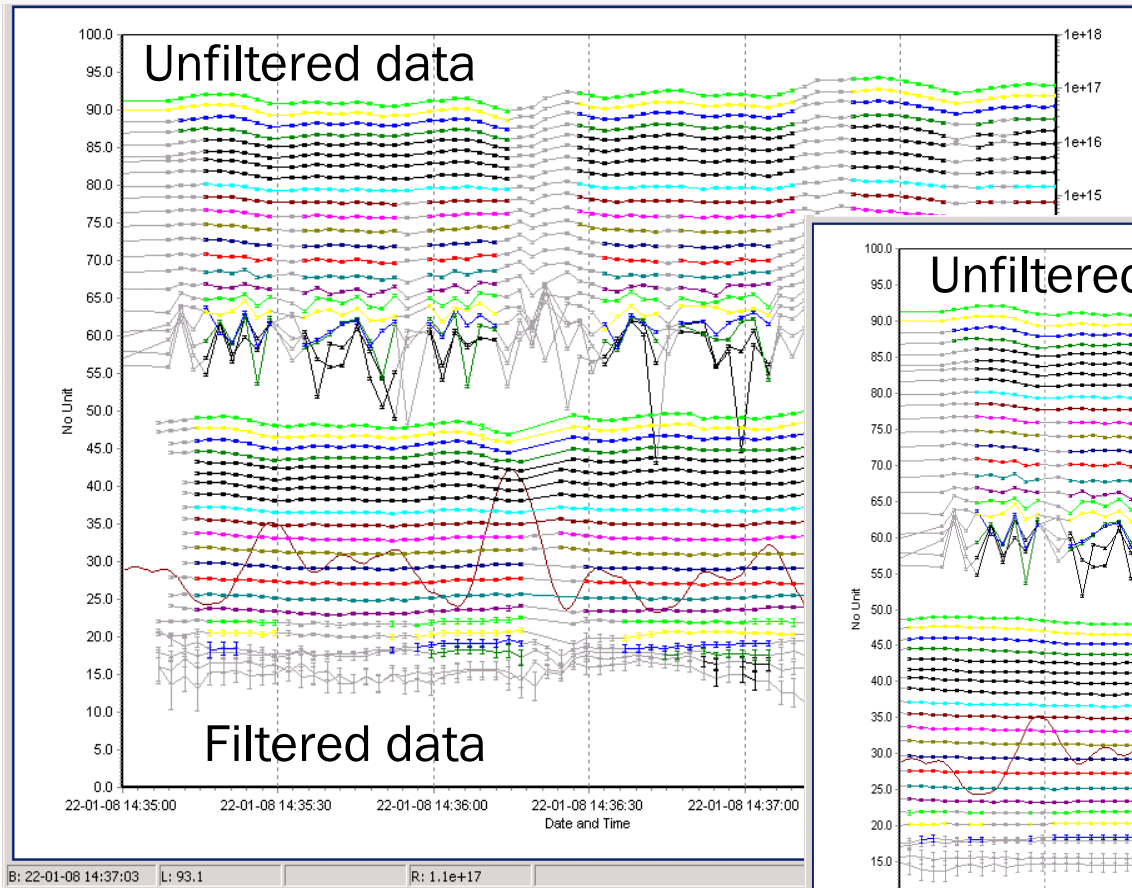
Decoupled
...and
noise removal



AEM data processing



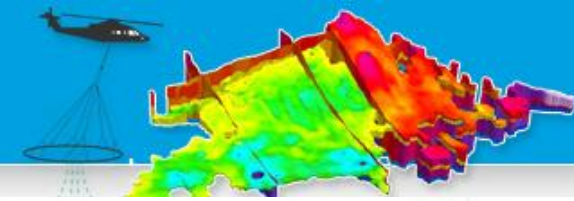
Moderate lateral averaging



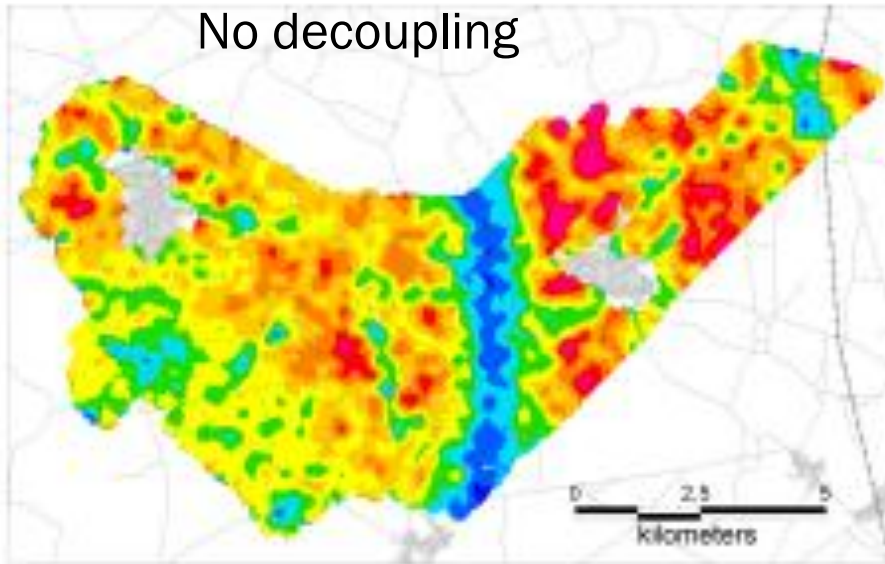
Excessive lateral averaging



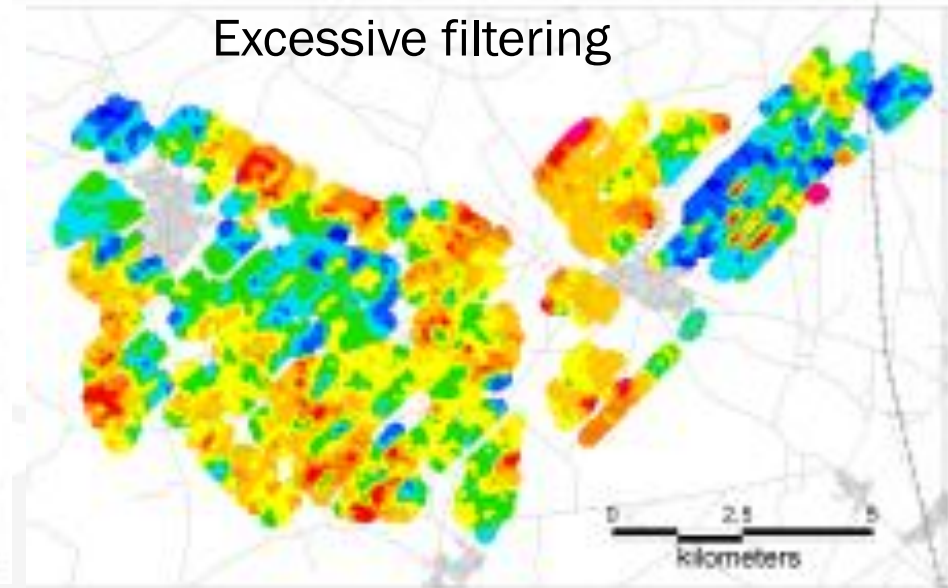
Consequences for derived products



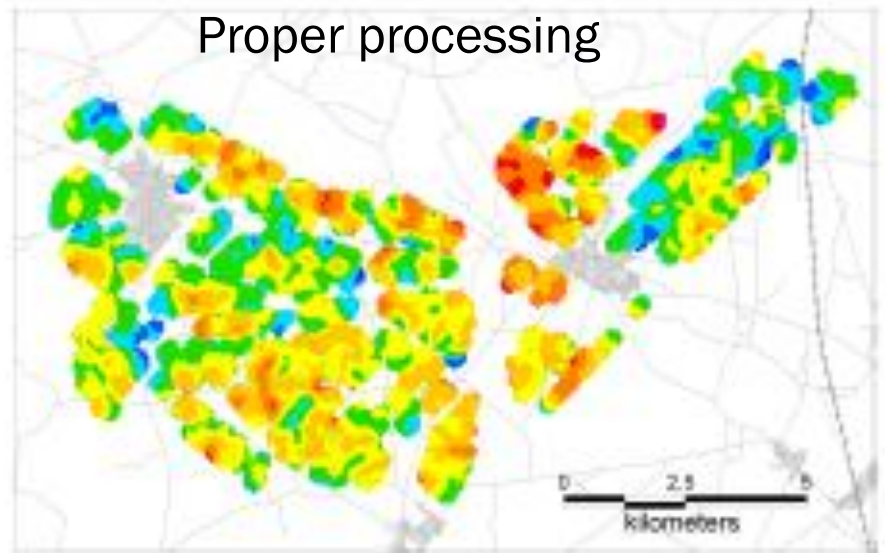
No decoupling



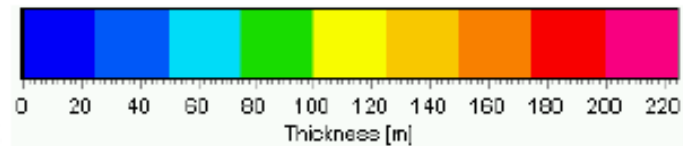
Excessive filtering



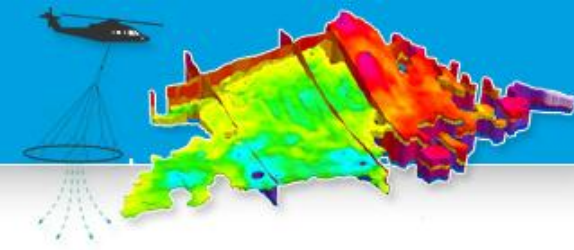
Proper processing



ACQUIFER THICKNESS



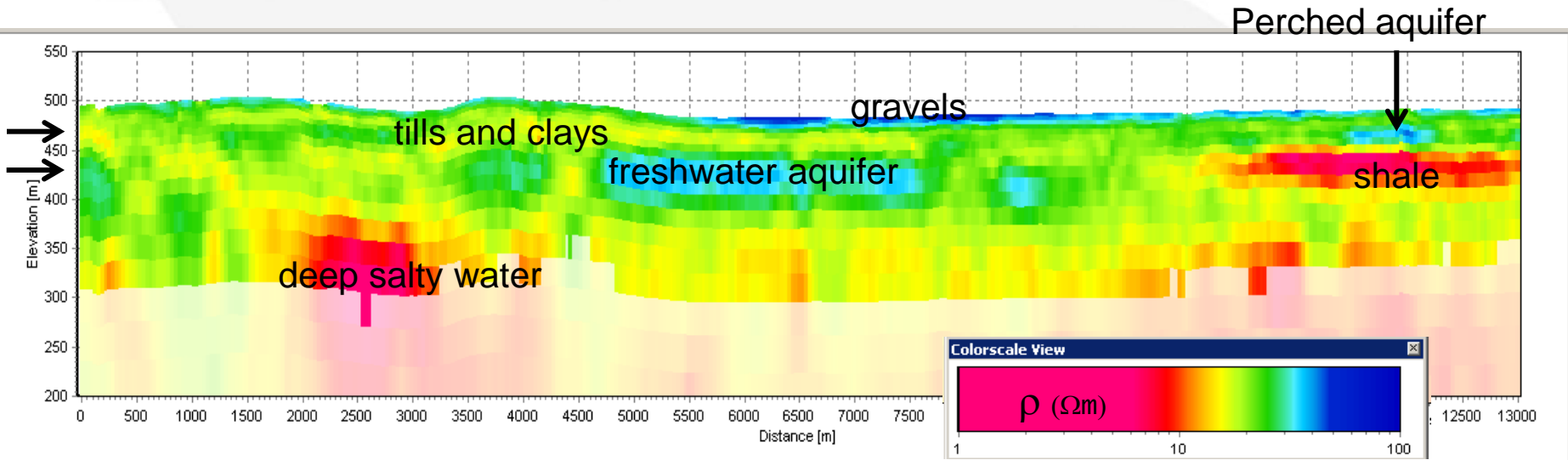
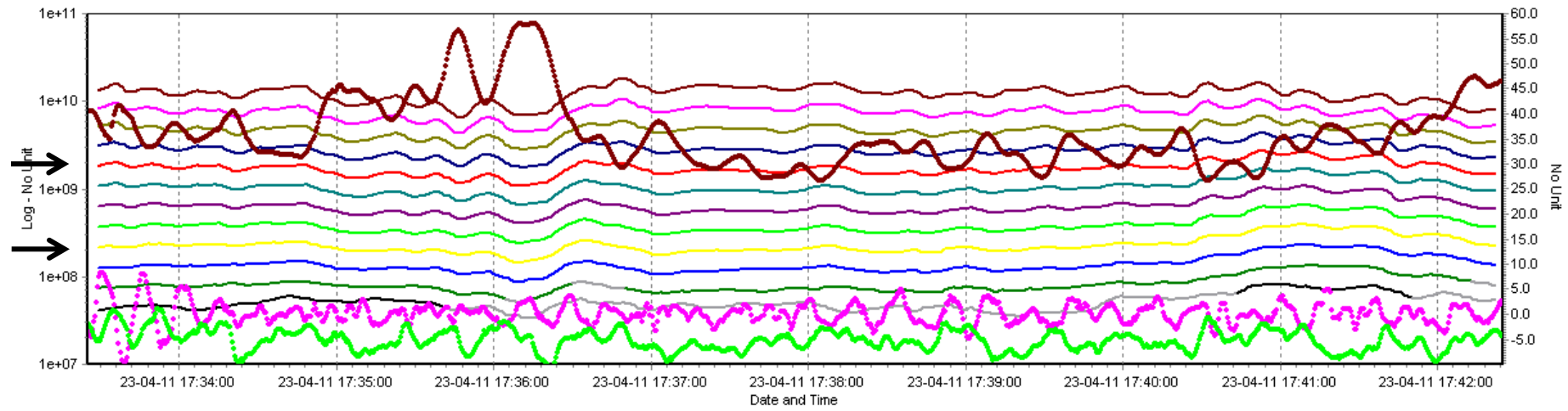
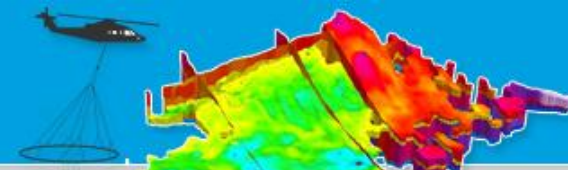
Inversion for hydrogeology



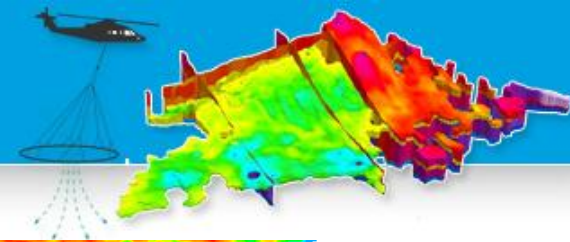
- Forward response accuracy
 - INVERSIONS can produce *accurate, quantitative* output
 - Approximate methods (Emflow/ITEM) produce faster, first pass(?), *qualitative* output
 - Data interpretation requires caution – eg need to know depth of investigation
- Dimensionality
 - 1D (quasi 3D) adequate in majority cases – most aquifers are flat (ish)
 - 3D might be needed in true 3D cases (still to be demonstrated in hydrogeological example)
- But....Inversion is one part of the workflow
 - Inaccurate raw data or processing → bad inversion output



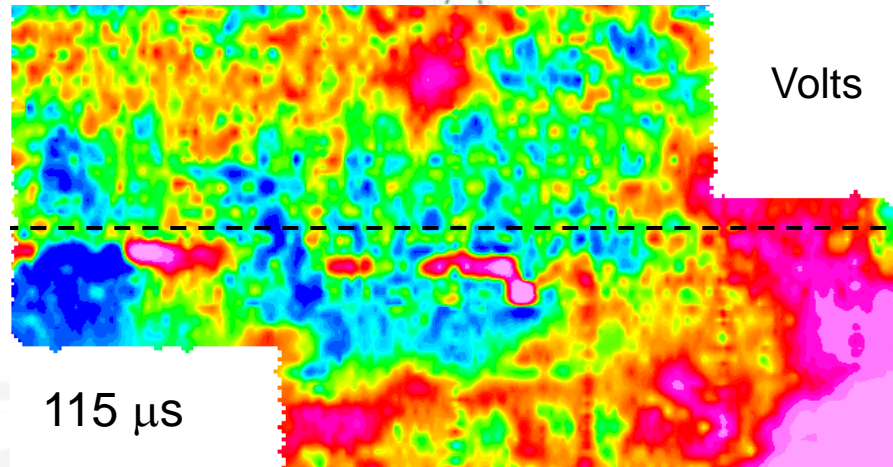
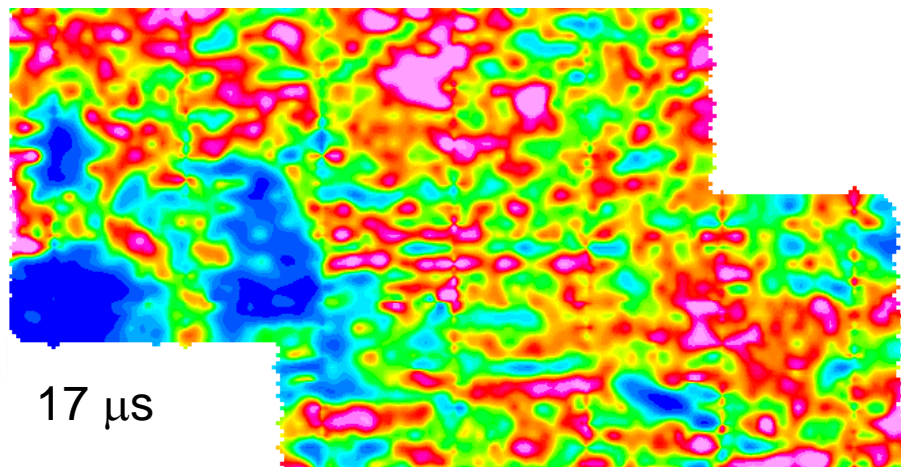
Inversion of AEM data



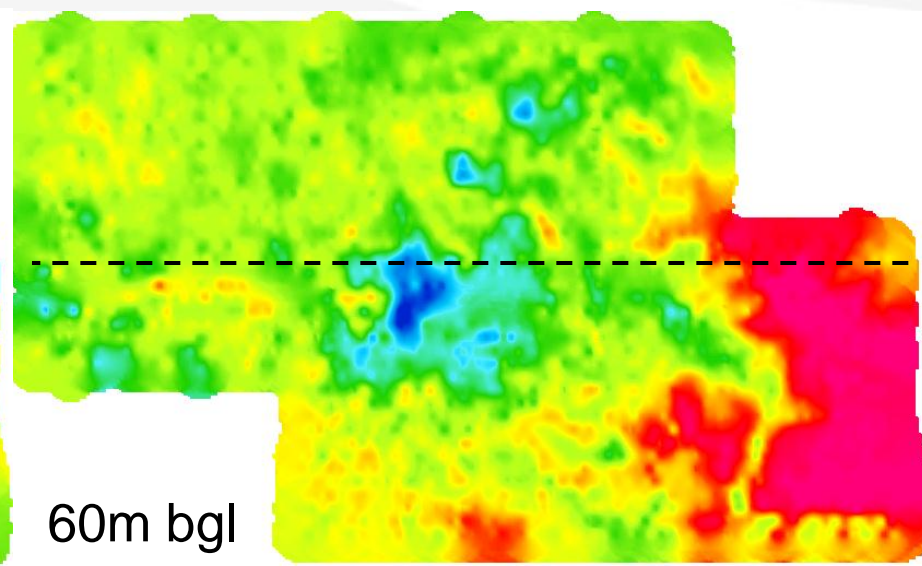
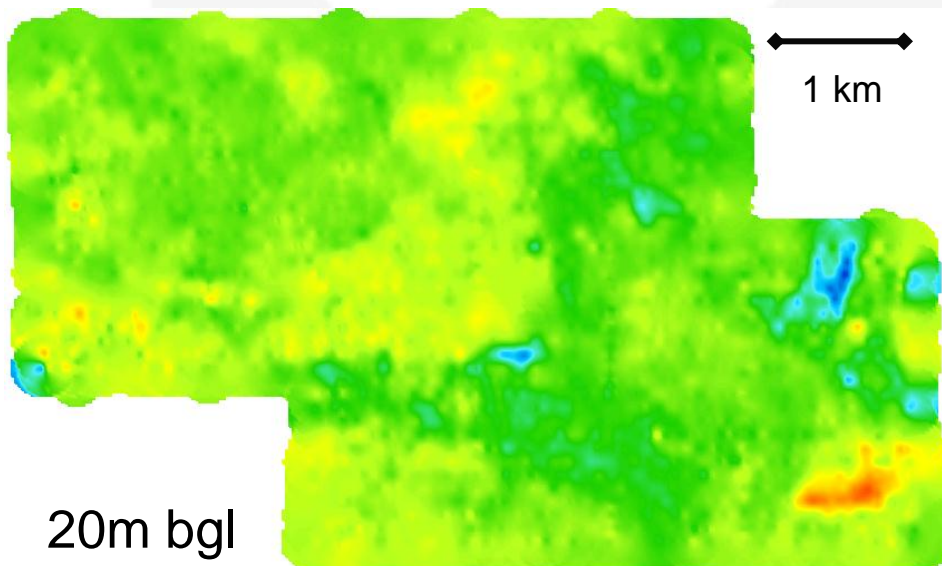
Data Space vs Model Space



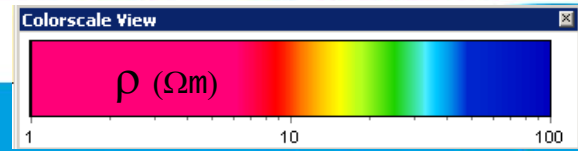
Data space



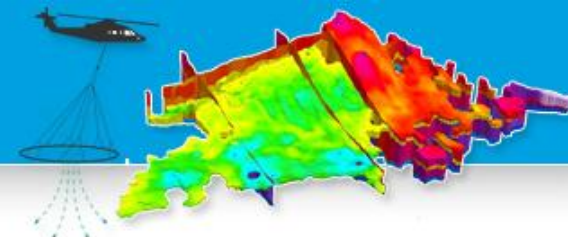
Volts



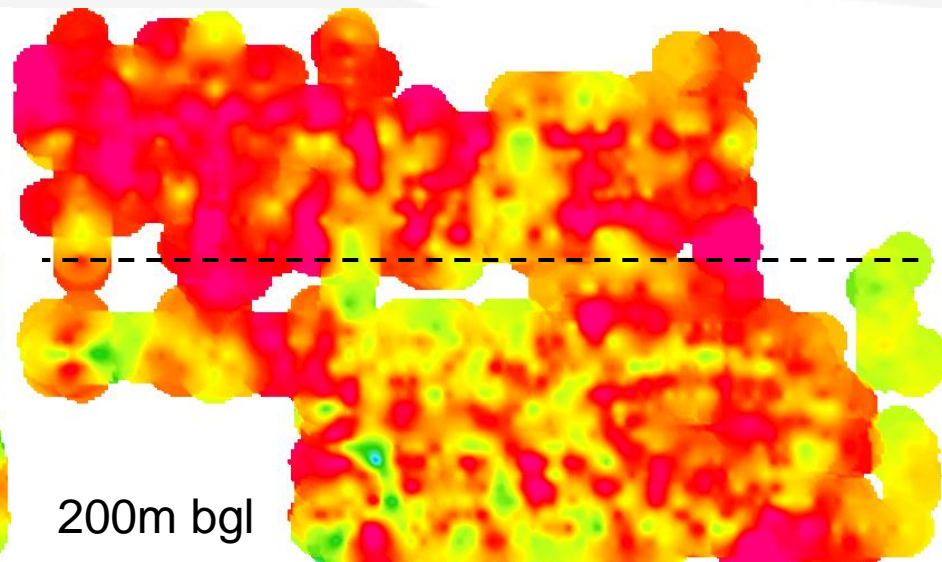
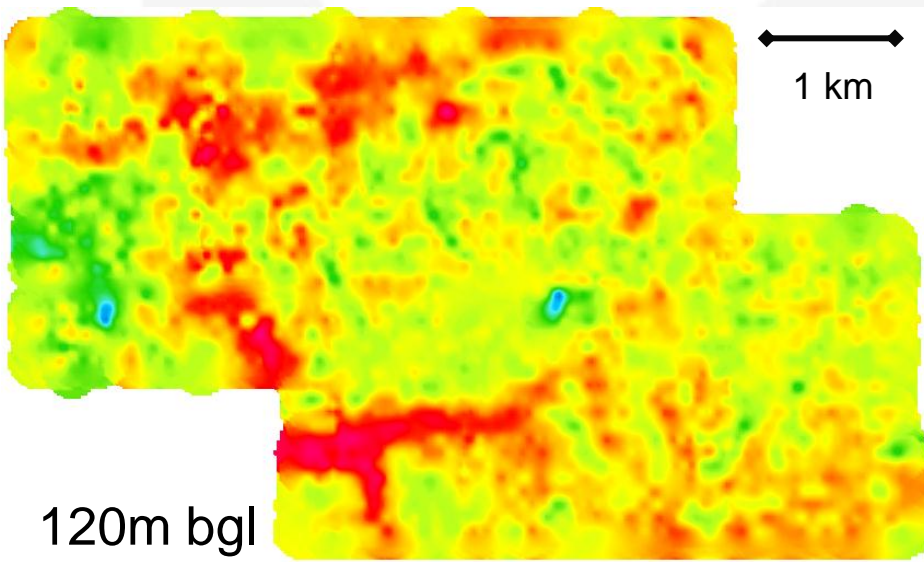
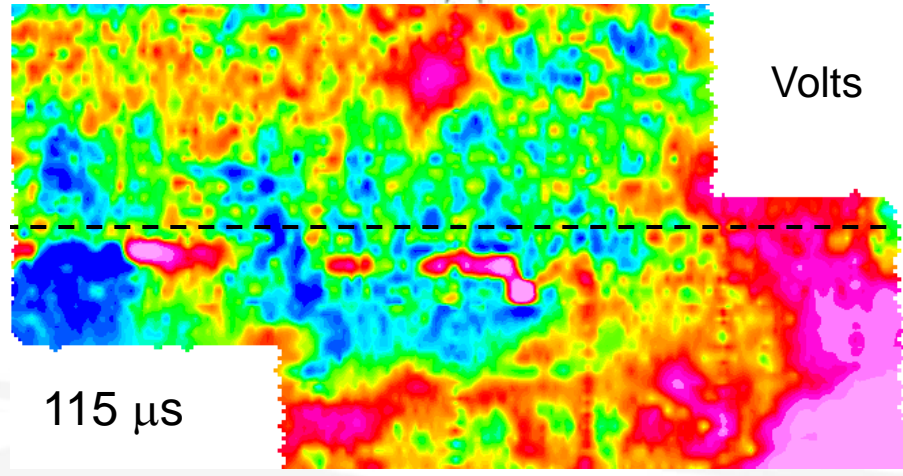
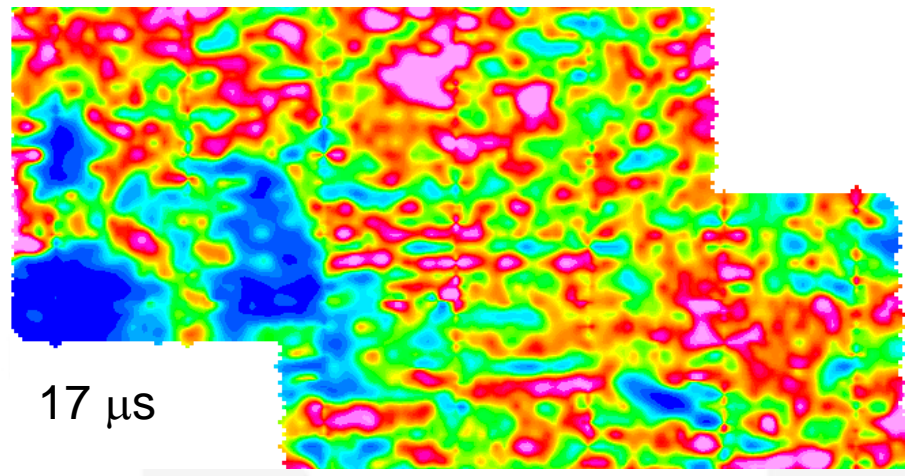
Model space



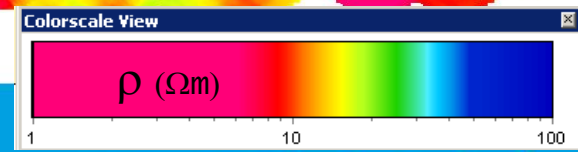
Data Space vs Model Space



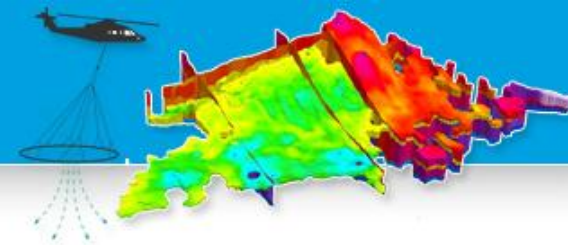
Data space



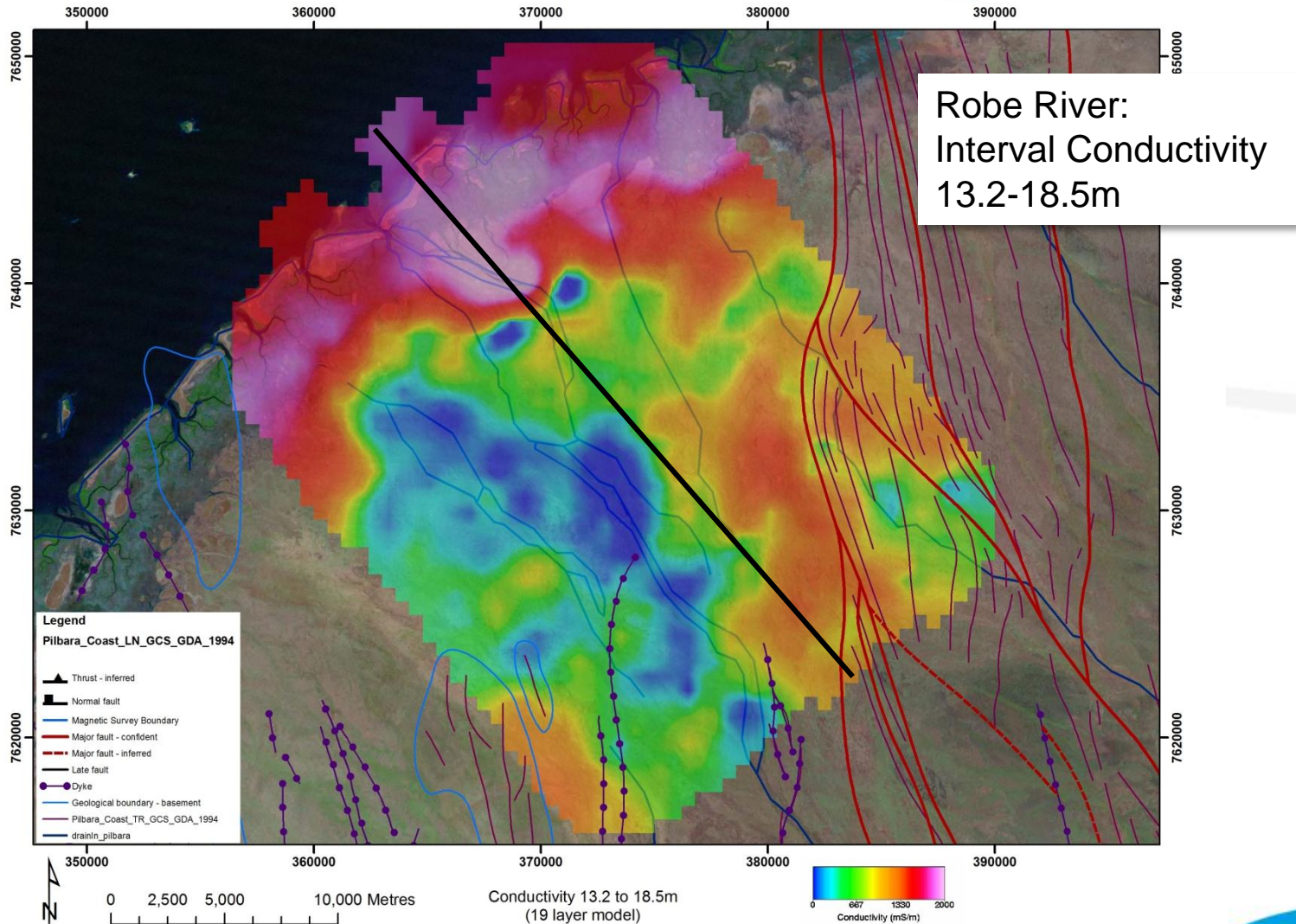
Model space



Pilbara GW Studies - TEMPEST



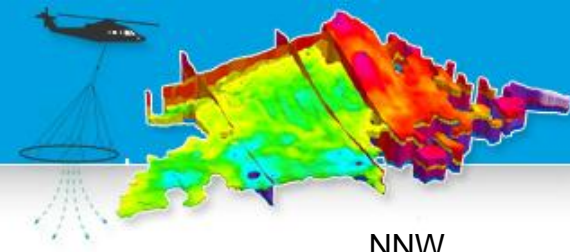
Groundwater resources for Fe mining



Source:
Koomberi



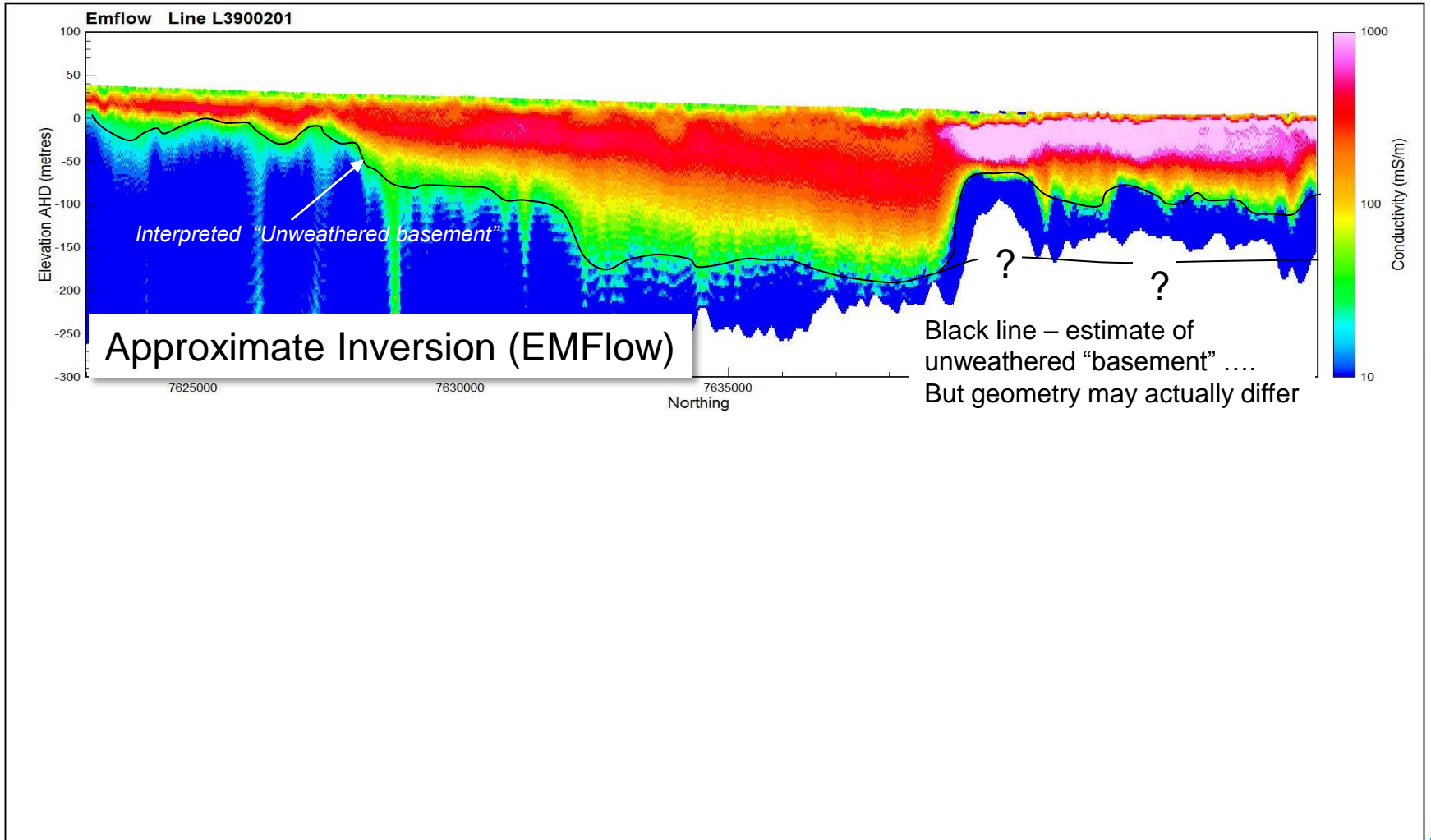
Depth of Investigation



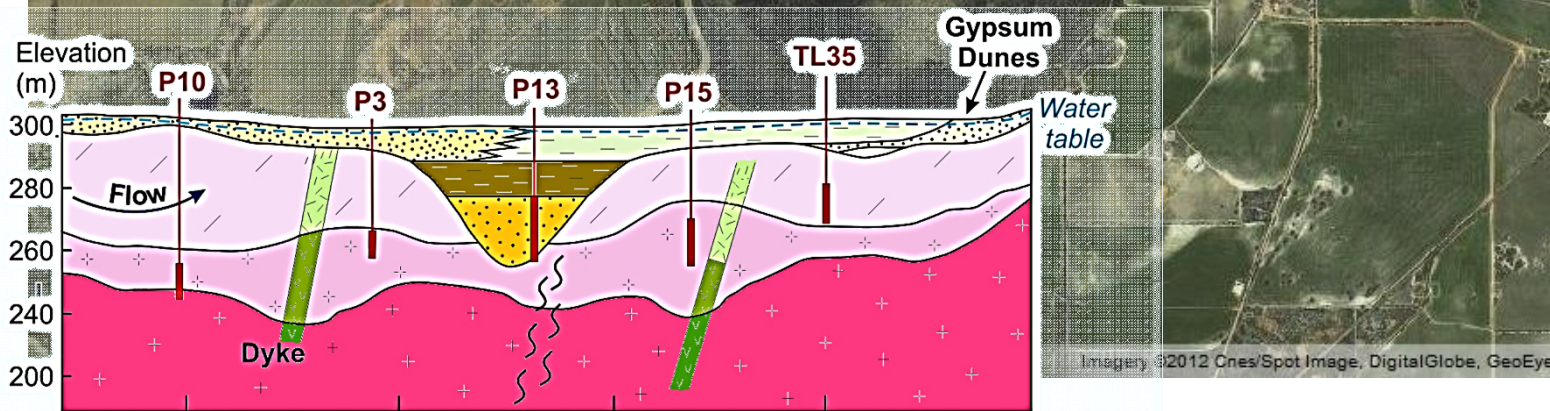
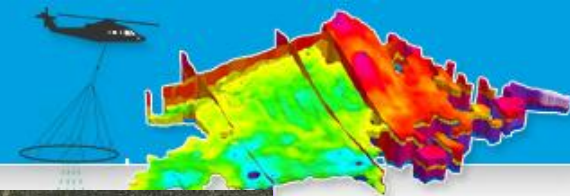
Conductivity-Depth Section

SSE

NNW



Toolibin, WA - SkyTEM



Fine lacustrine sediments
 Intensely-weathered bedrock
 Saprock

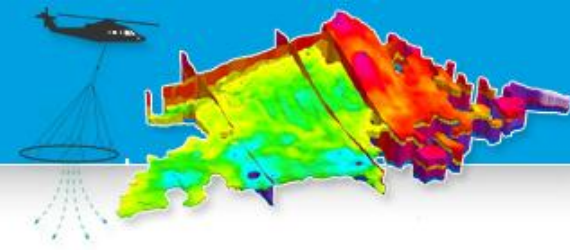
Fine alluvial sediments

Coarse alluvial sediments

Granites

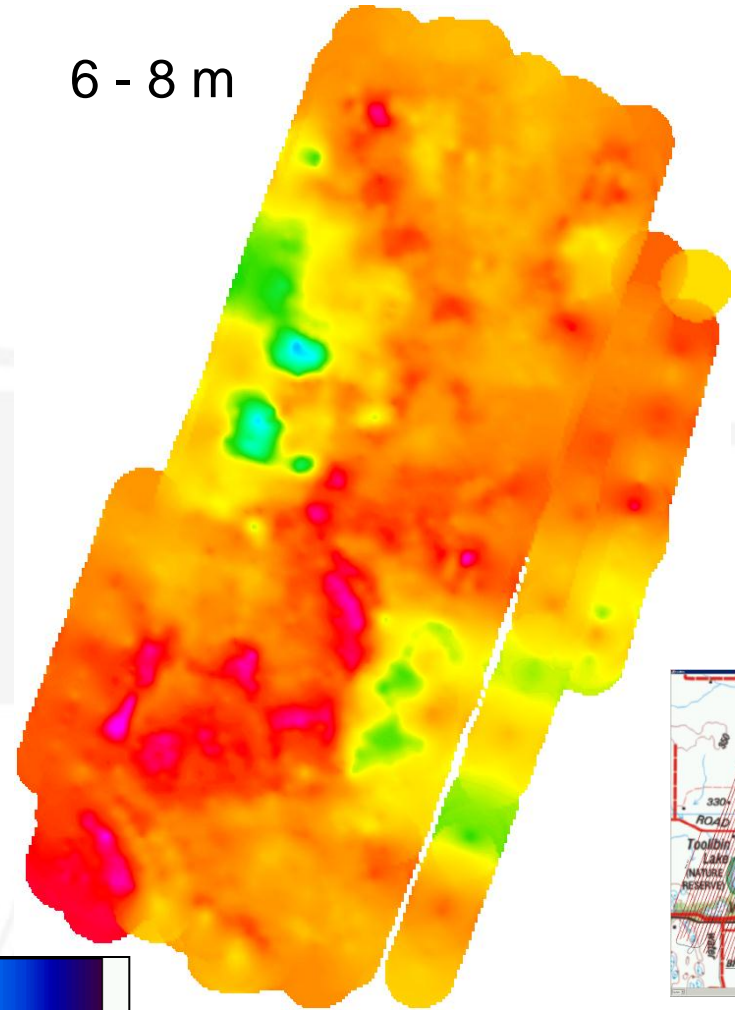
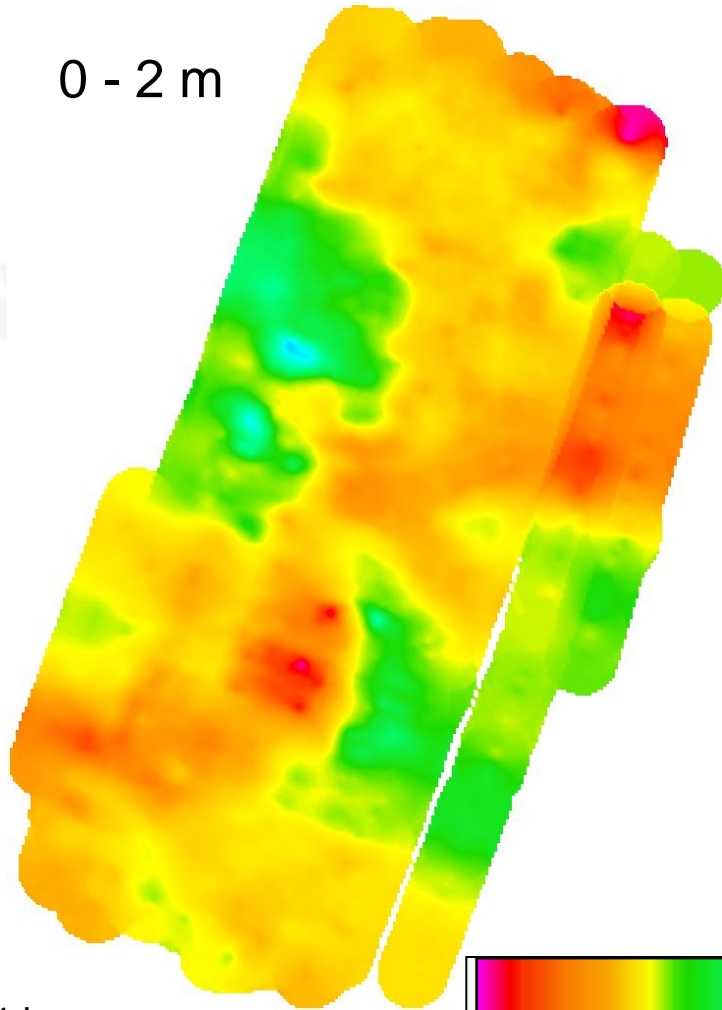


Average resistivity (depth)

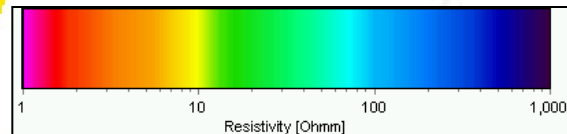


0 - 2 m

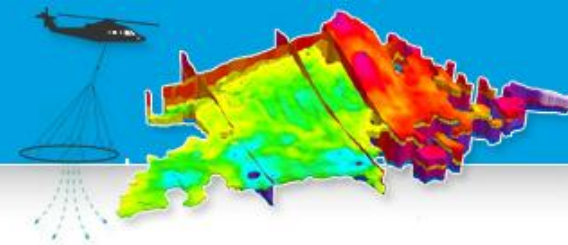
6 - 8 m



1 km



Average resistivity (depth)

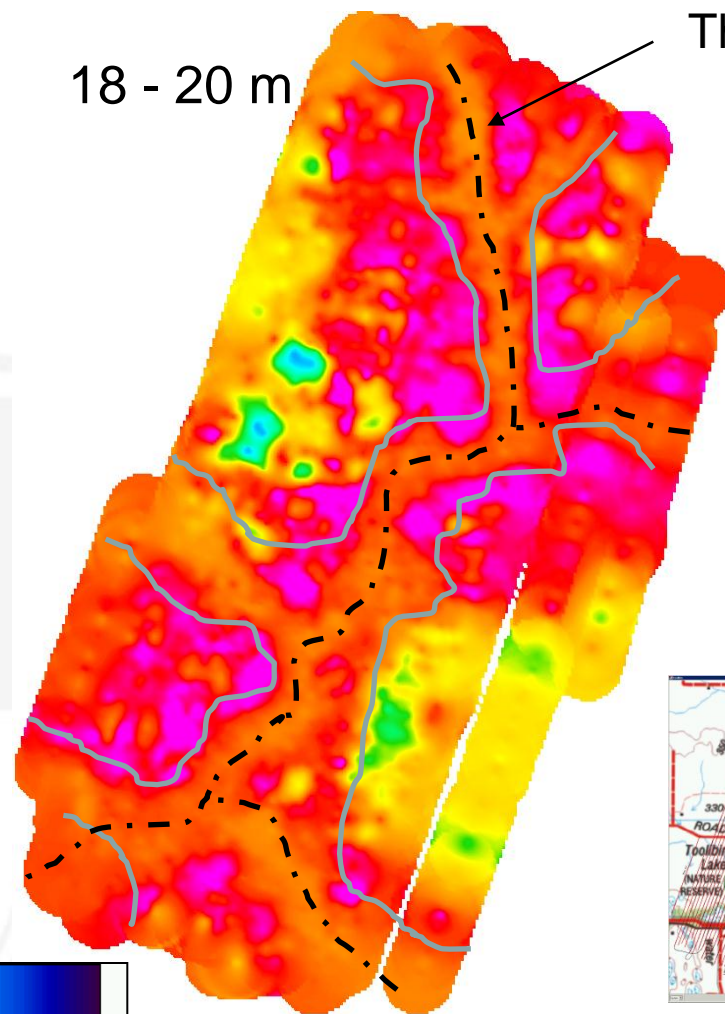
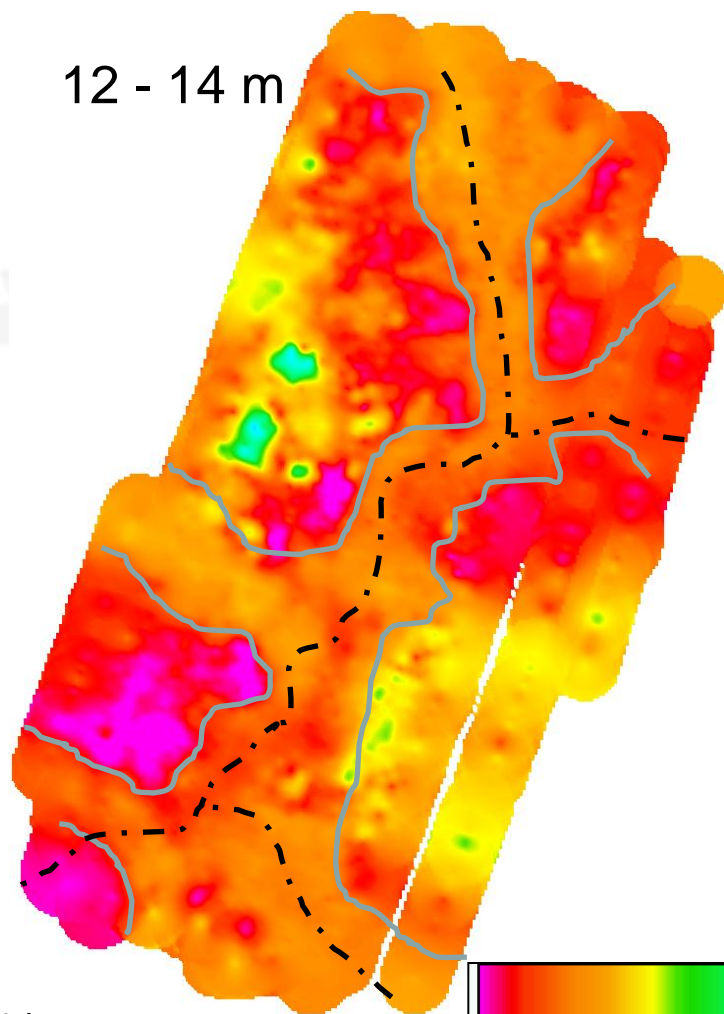


Extent of palaeovalley sediments

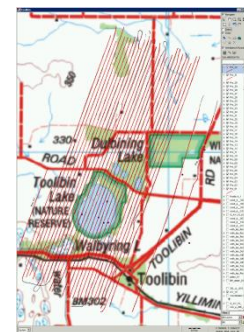
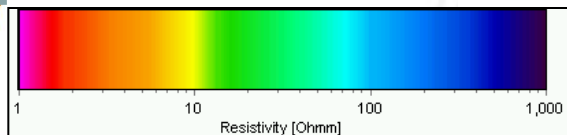
12 - 14 m

18 - 20 m

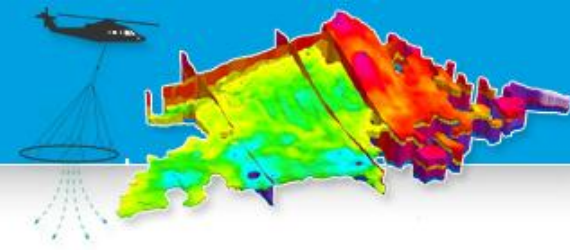
Thalweg



1 km

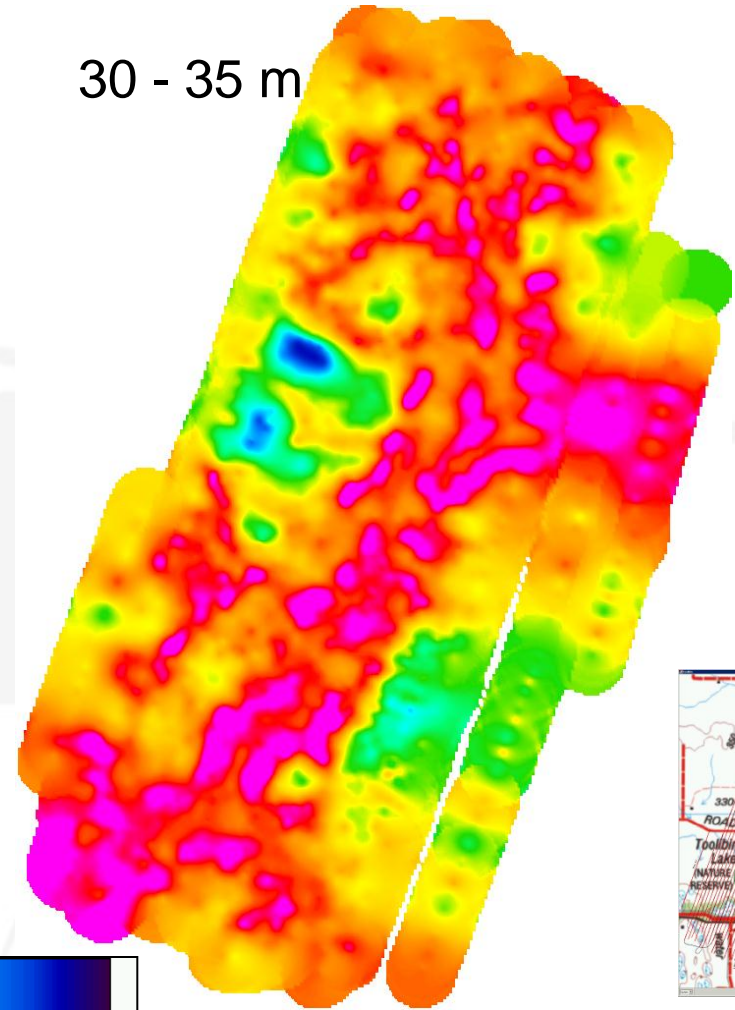
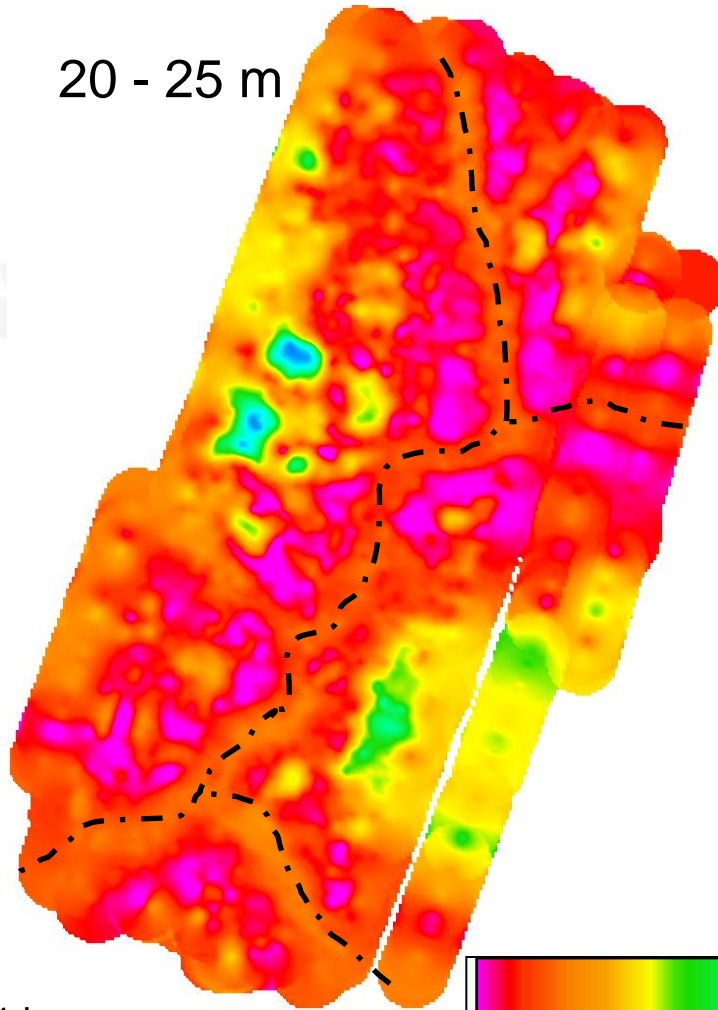


Average resistivity (depth)

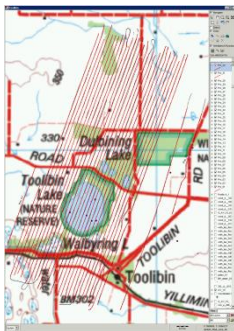
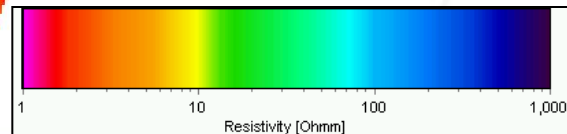


20 - 25 m

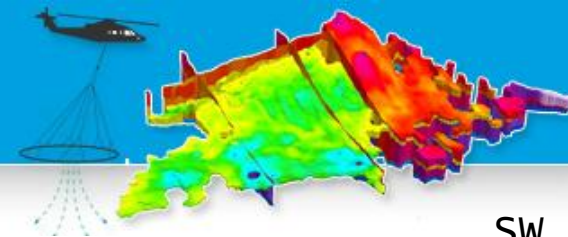
30 - 35 m



1 km

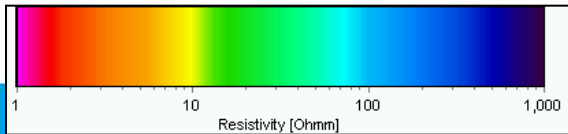
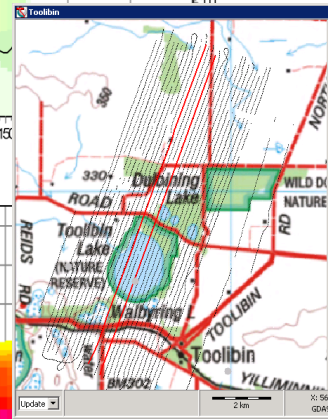
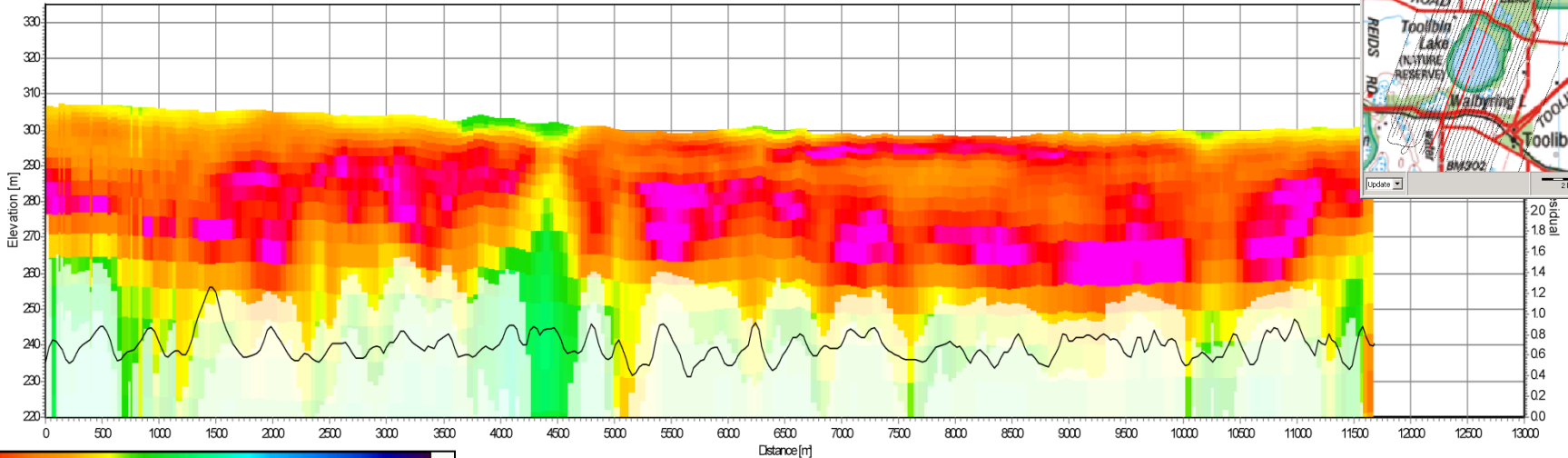
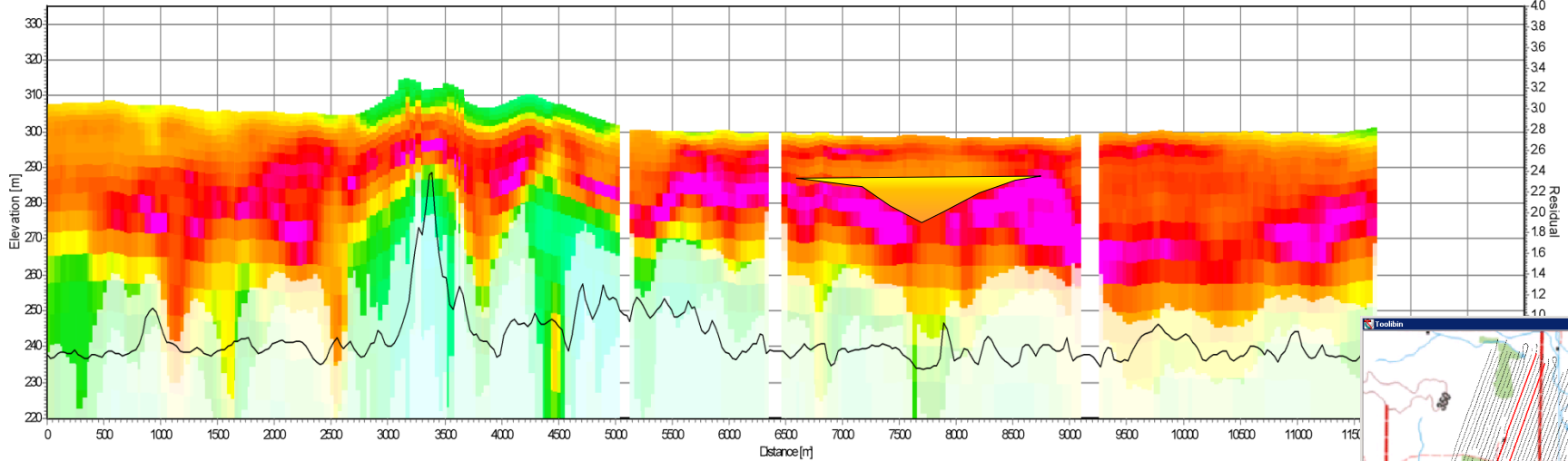


Profile 14 and 17

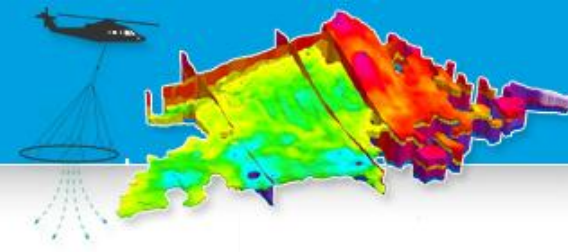


NE

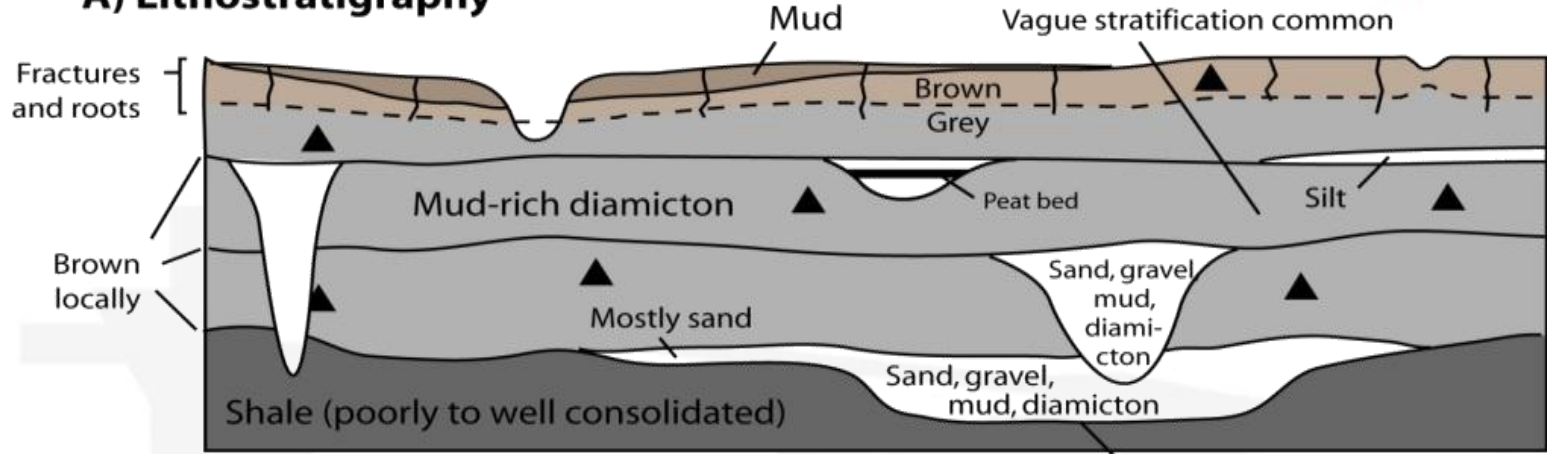
SW



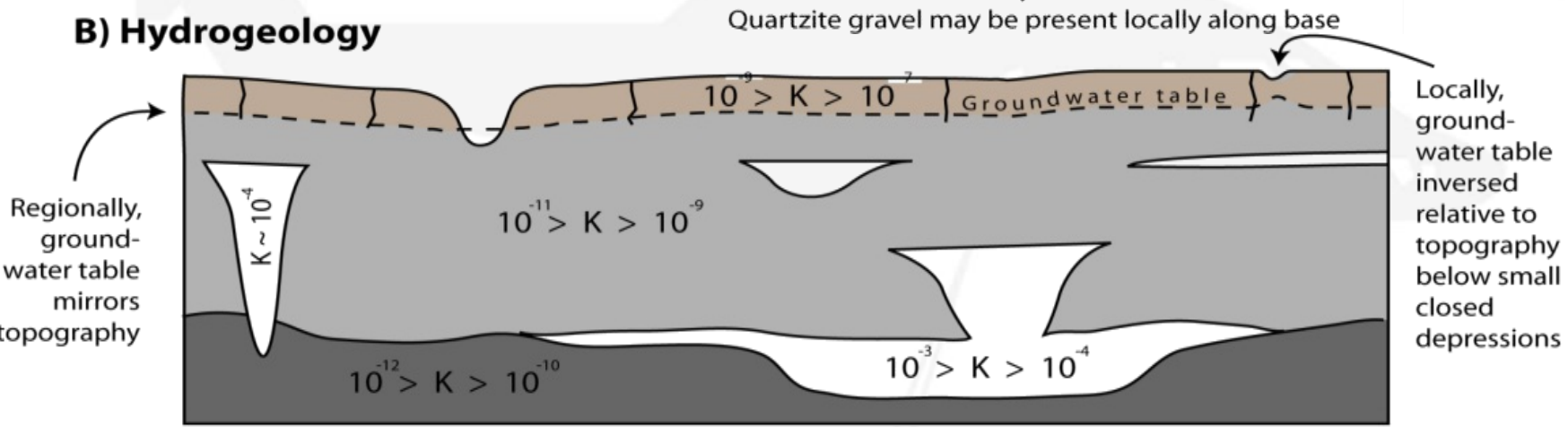
Conceptual hydrogeological model for buried-valley incision



A) Lithostratigraphy



B) Hydrogeology



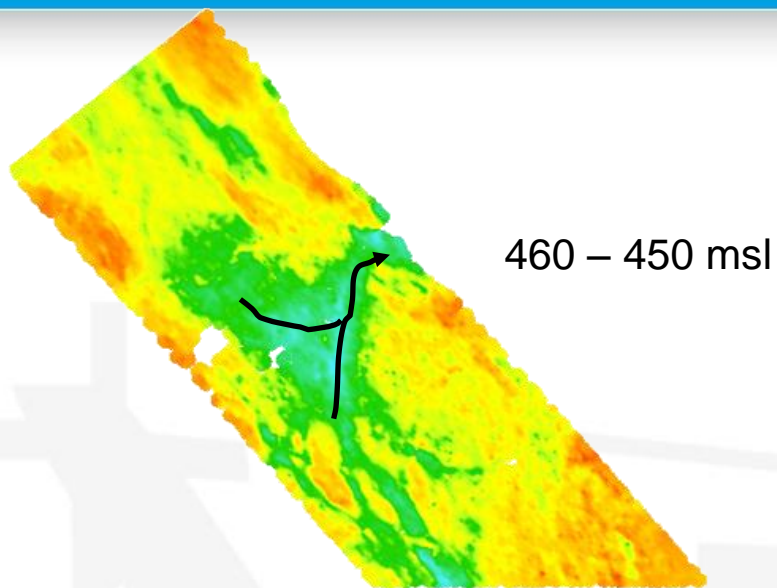
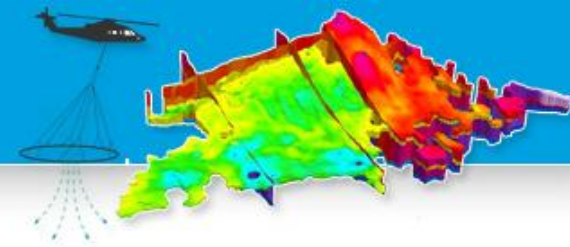
Gravel and sand at the bottom of the BVs

$K = \text{hydraulic conductivity in m/s}$

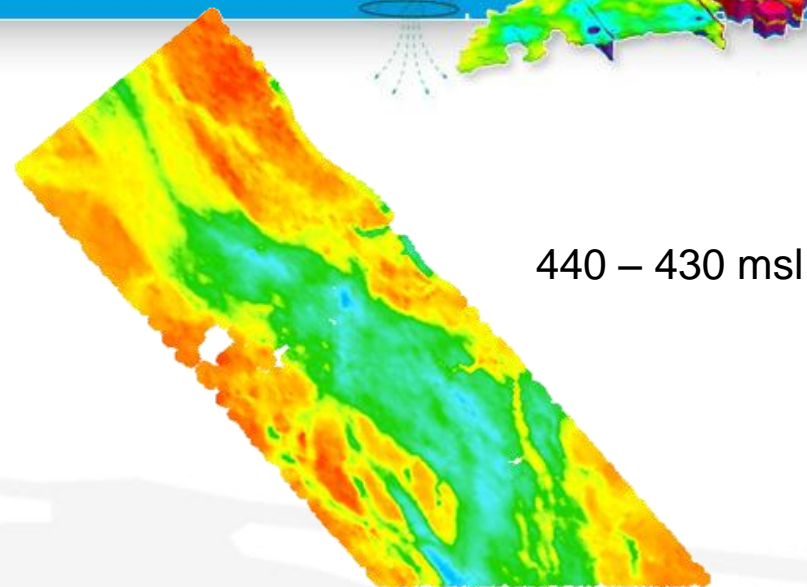
Cummings et al., 2012



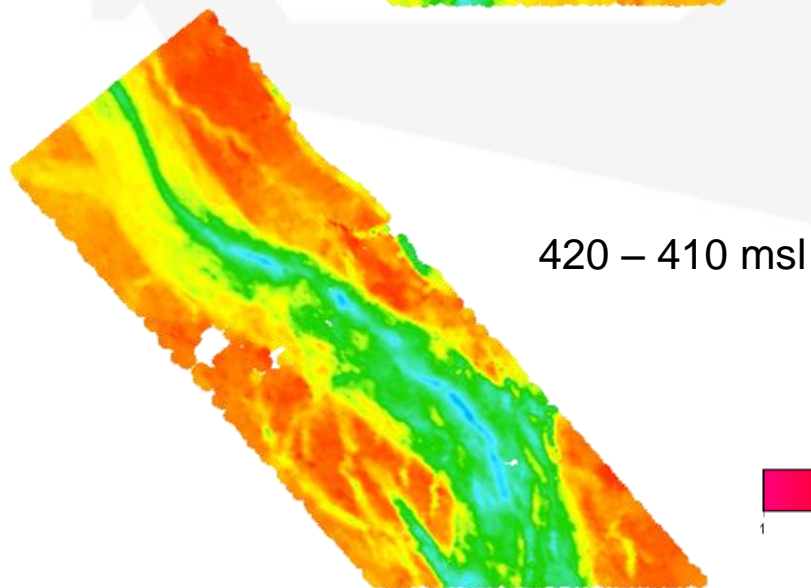
Interval Resistivity Images



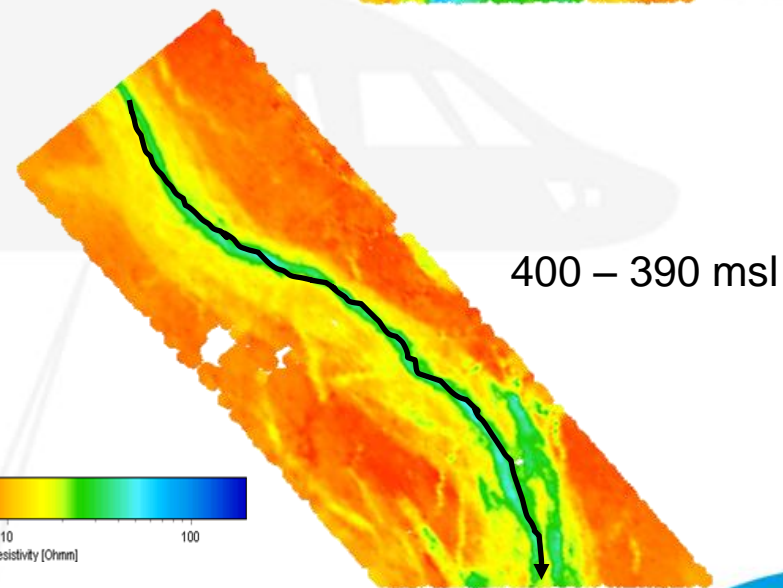
460 – 450 msl



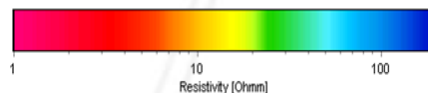
440 – 430 msl



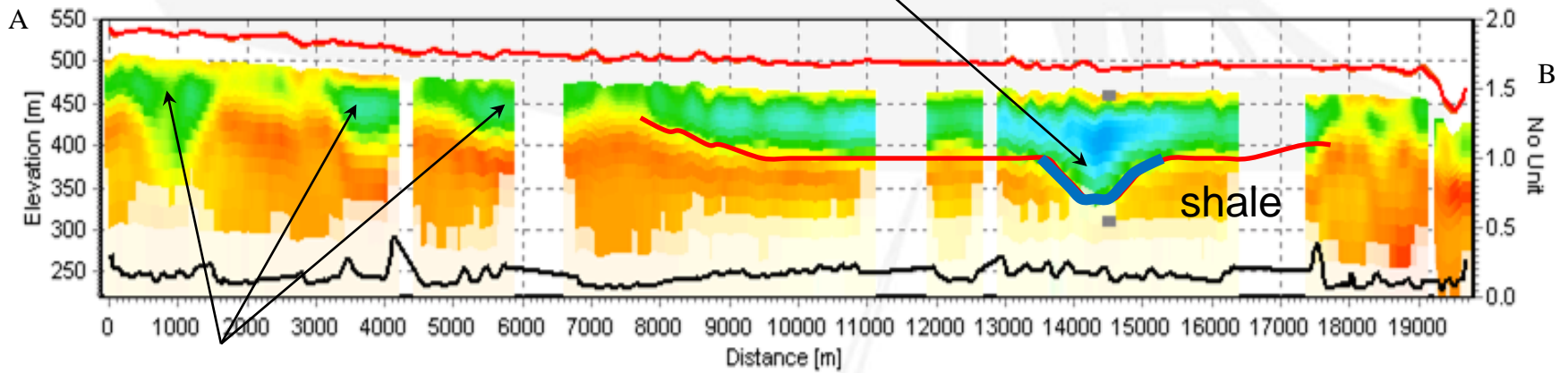
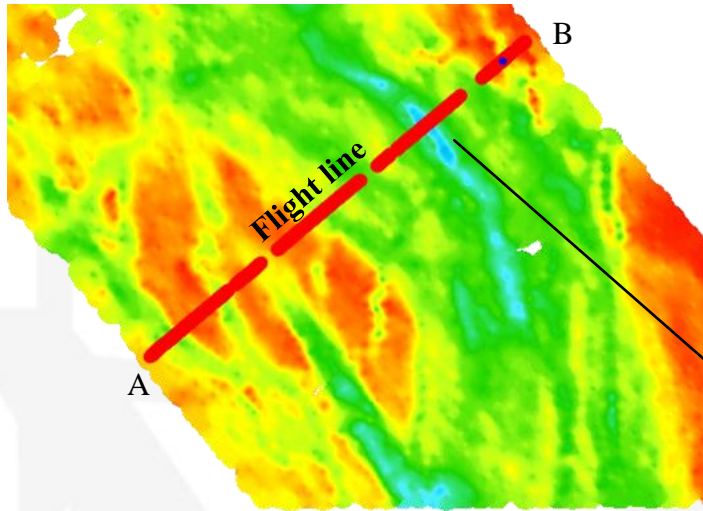
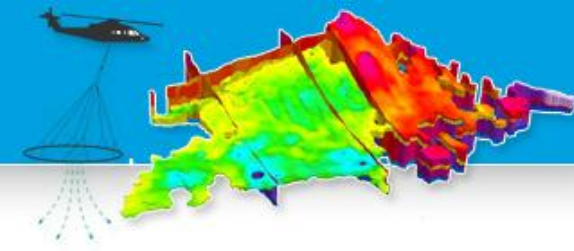
420 – 410 msl



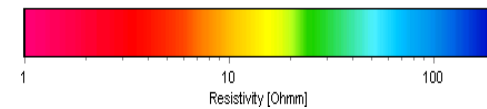
400 – 390 msl



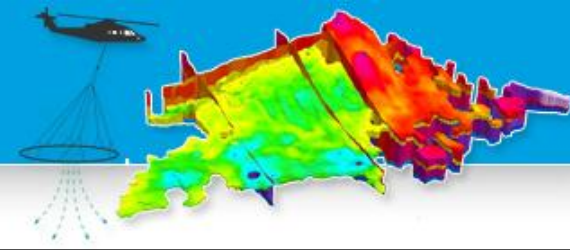
Aquifer Geometry



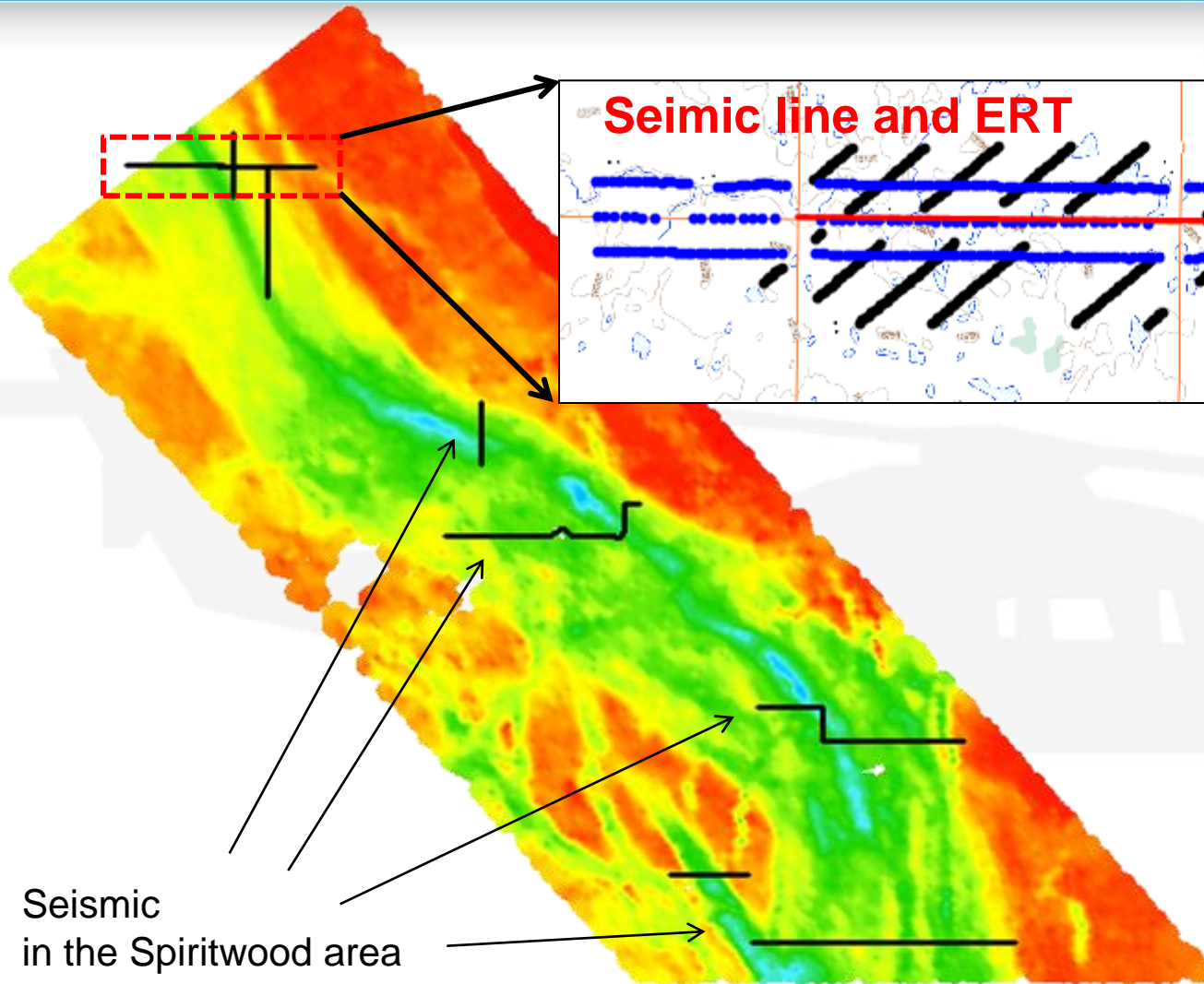
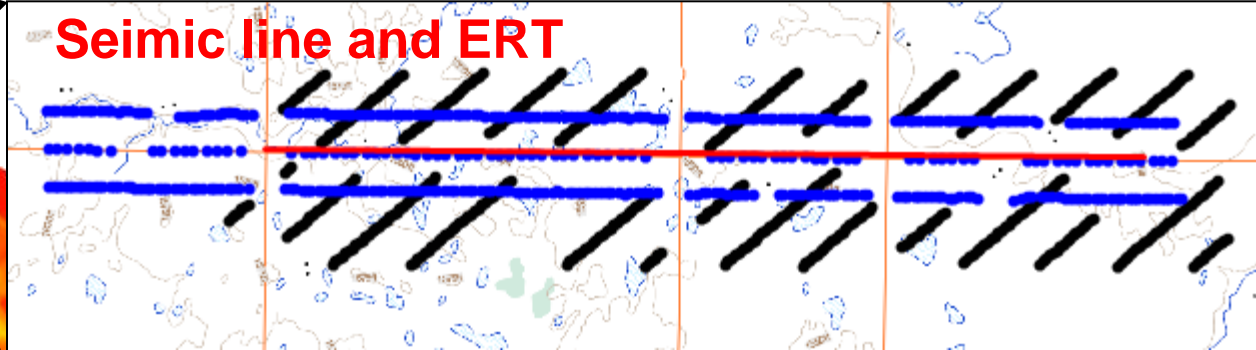
In addition to the main incised valleys, multiple valley-like features outside of the main valley are observed.



System Comparison + Constraint



Seismic line and ERT



VTEM
dataset

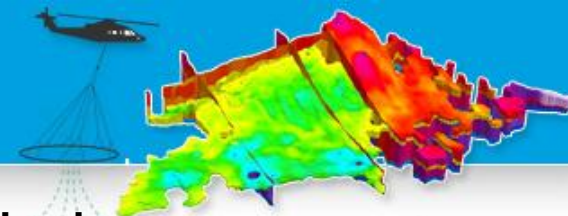
AeroTEM
dataset

Seismic
in the Spiritwood area

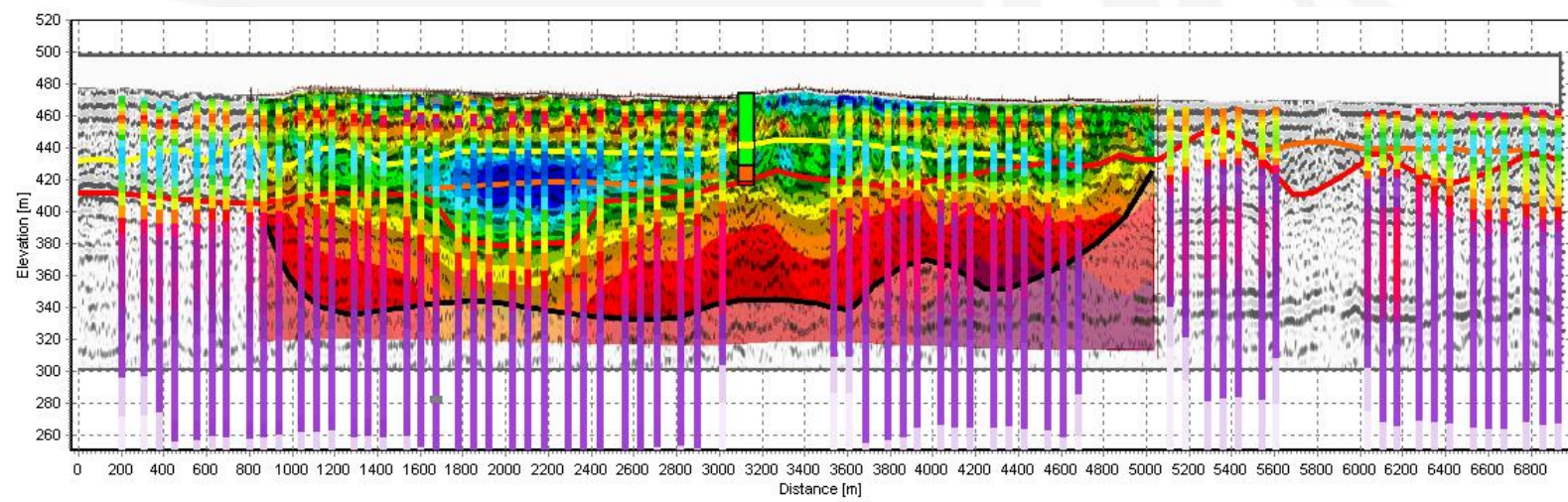
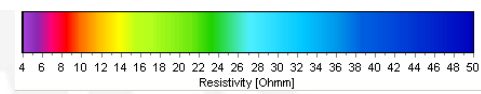
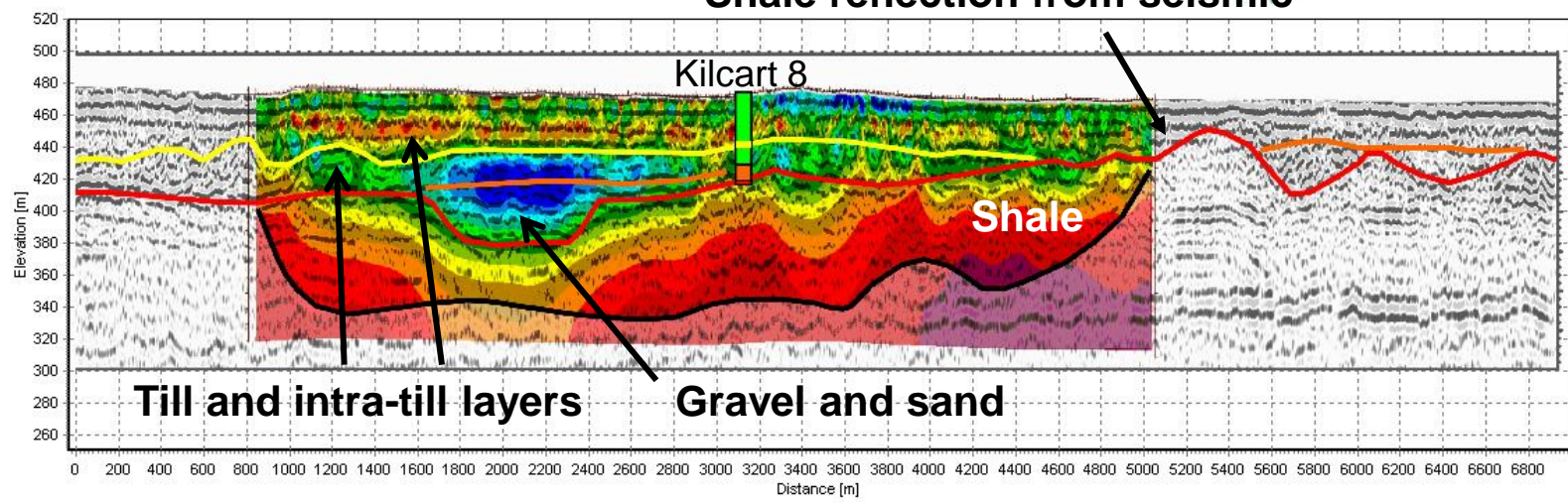
5 km



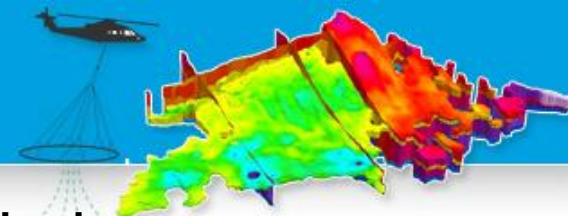
DC and seismic vs VTEM



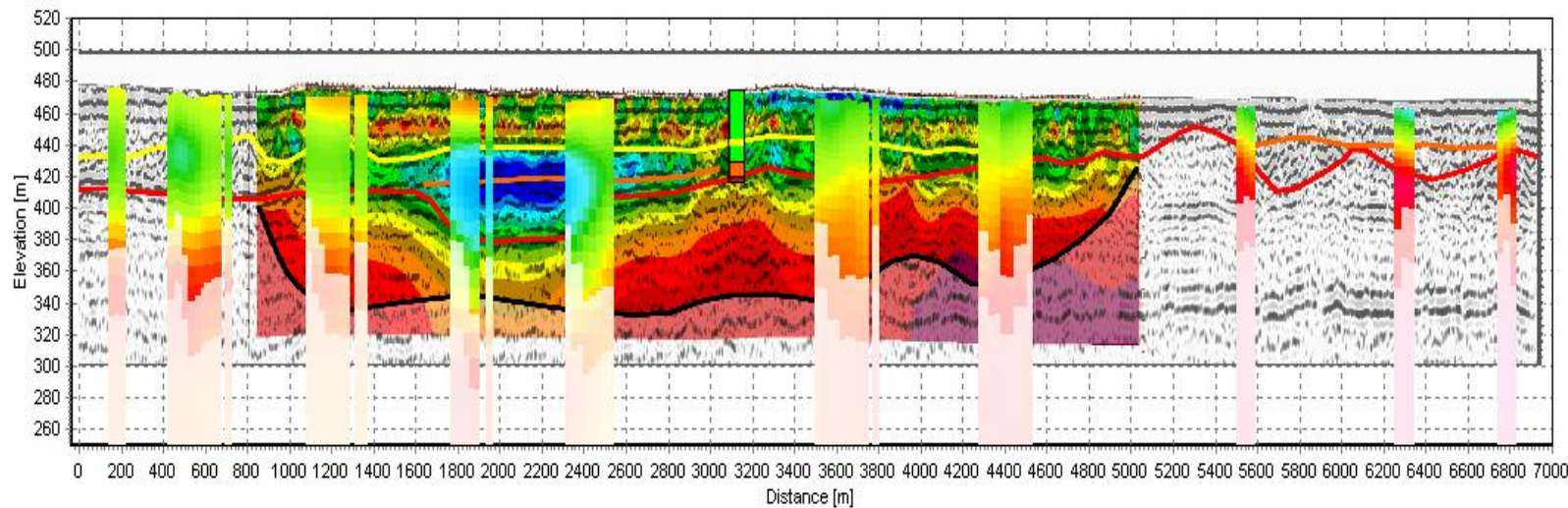
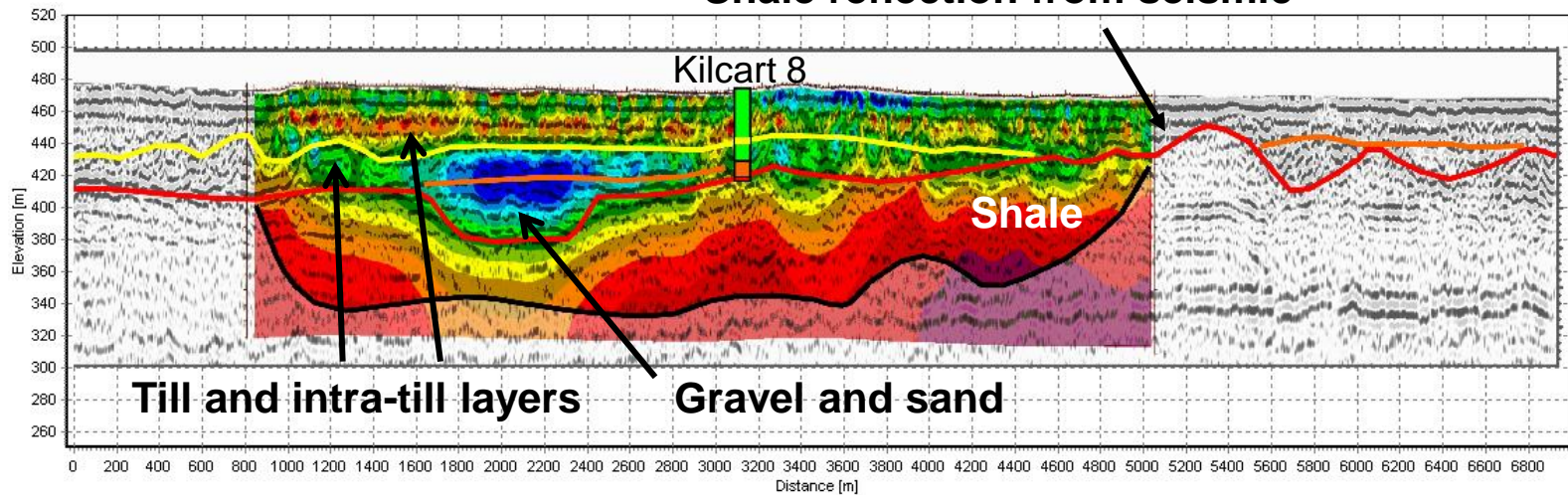
Shale reflection from seismic



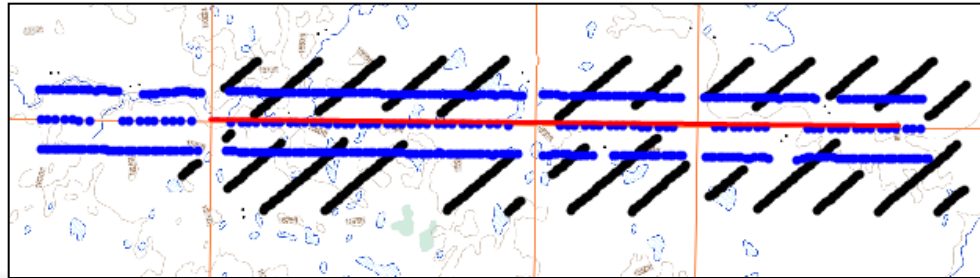
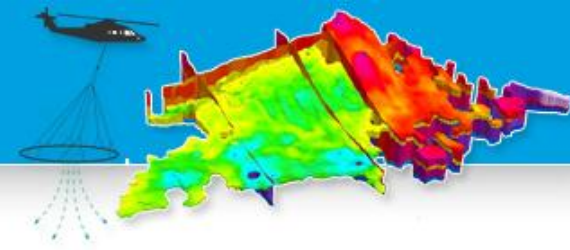
DC and seismic vs AeroTEM



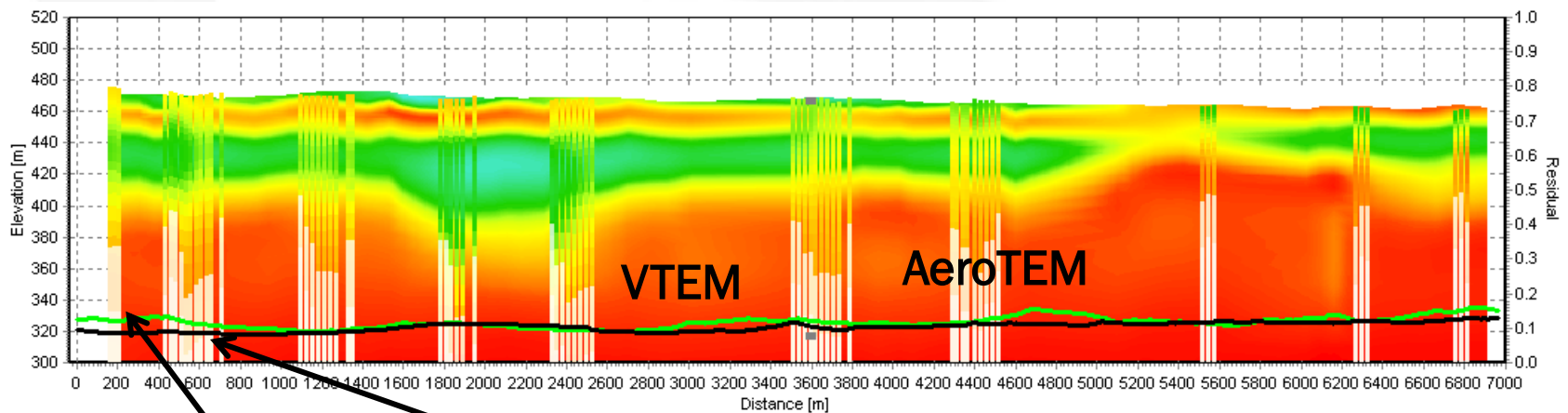
Shale reflection from seismic



AeroTEM VS VTEM



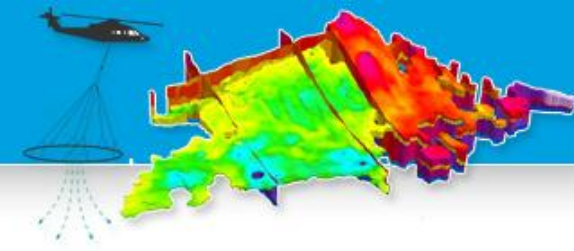
VTEM
dataset
AeroTEM
dataset



Data Residual
VITEM

Data Residual
AeroTEM





- Adding prior information to inversion
 - Boreholes
 - Geological models
 - Other geophysical data
- Goals
 - Better resolve parameters with low sensitivity
 - Achieve a better match to other data which may aid integration of derived products
 - Possible "recalibration" of AEM datasets



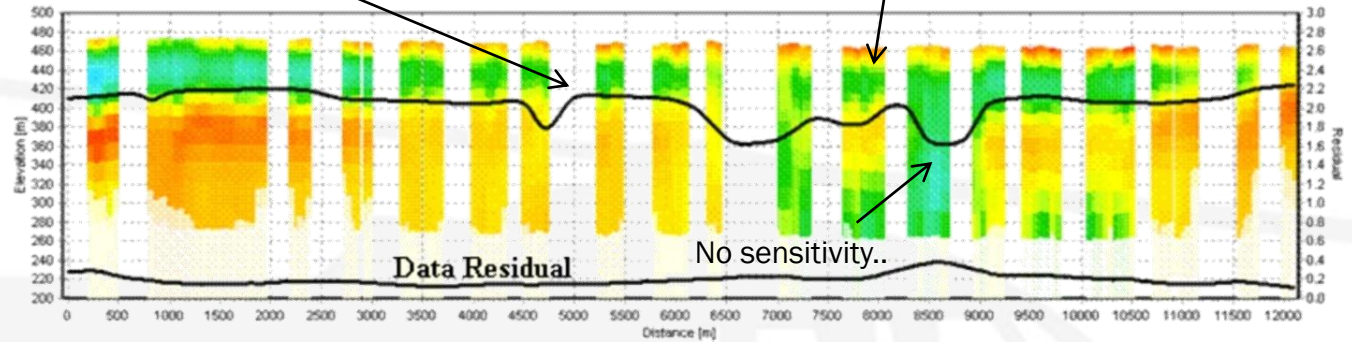
A-priori added to inversion



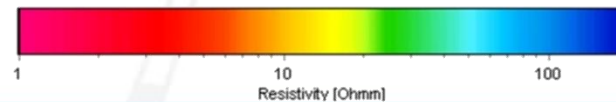
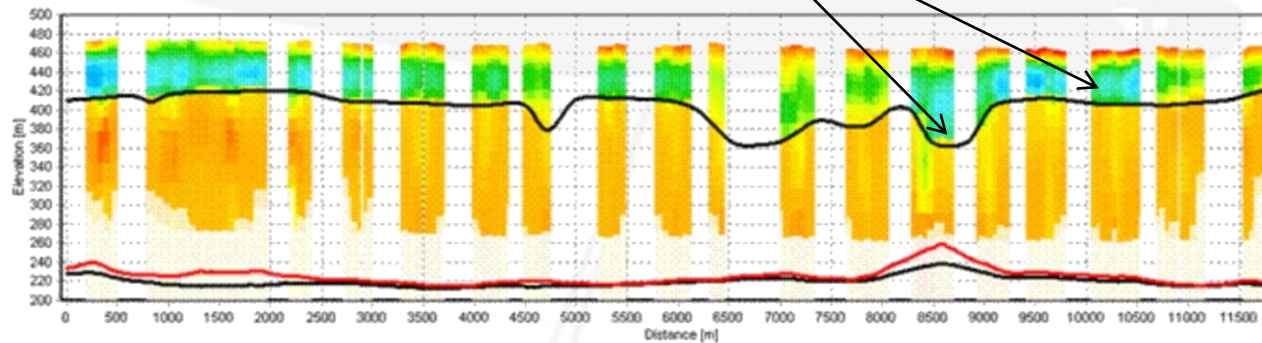
Re-inversion of the AEM data with the seismic data as “tight” (low STD) a-priori constraints and a 10 Ωm bedrock res.

Shale boundary from Seismic

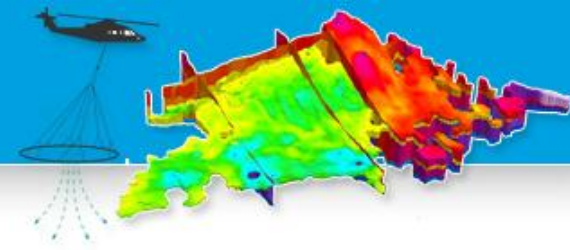
AeroTEM inversion no a-priori



Shale boundary changes according to a-priori



Summary

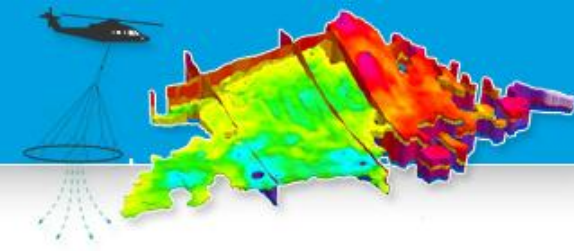


- Accurate aquifer characterisation requires
 - Good processing
 - Good inversion
 - Comparison or integration with other data

- Otherwise

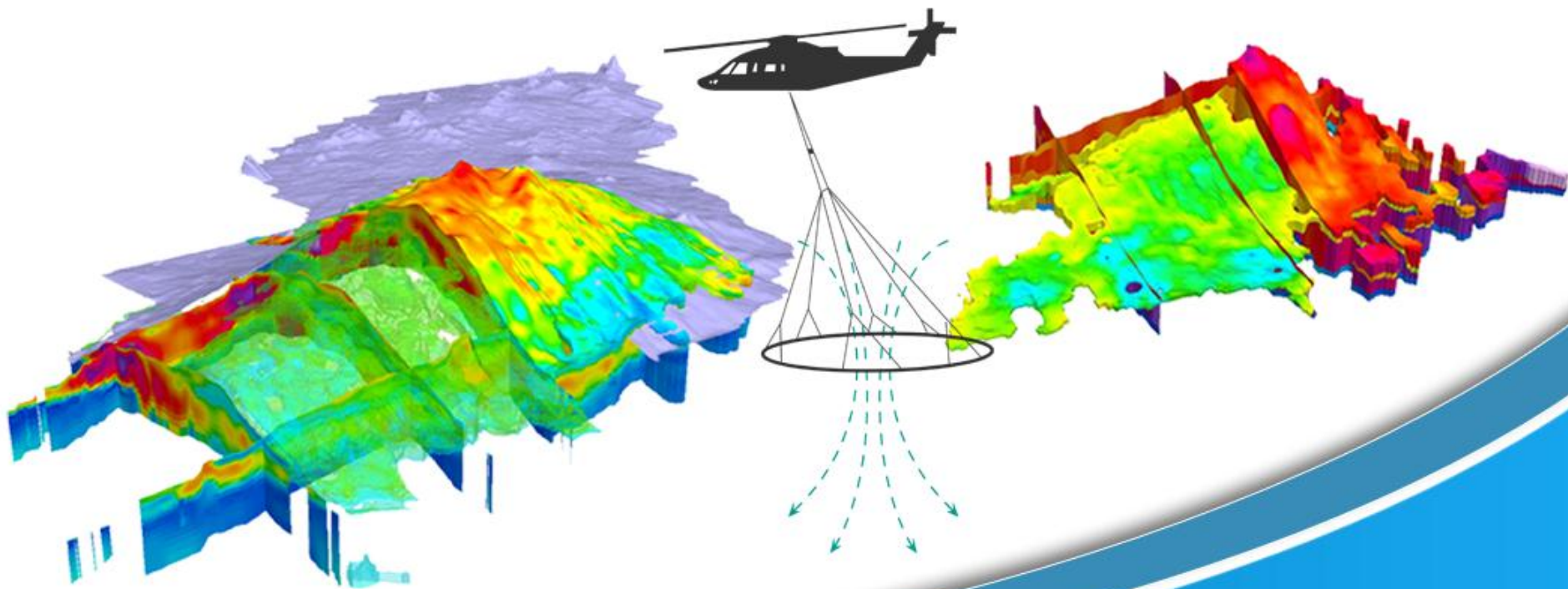


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From data to knowledge

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