Looking Beneath a Saltwater Intrusion:
Geophysics for Improved Groundwater Management

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The Center for Groundwater Evaluation and Management
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<u>Goal:</u> To foster integration of new and emerging technologies into local, regional and statewide groundwater management practice.

<u>Approach:</u> Partnering with with groundwater management districts throughout the western US to demonstrate the value of these technologies.

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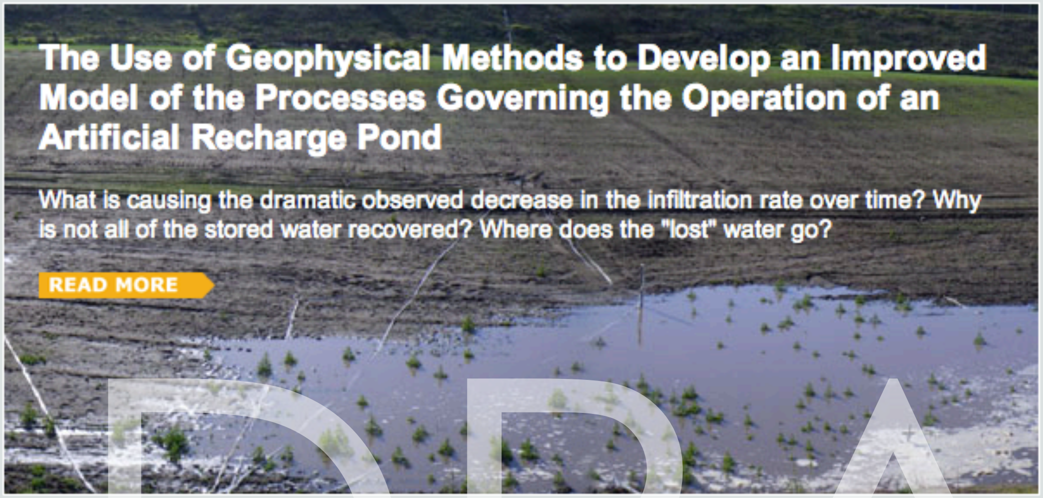

Modeling the operation of a recharge pond
What is causing the dramatic observed decrease in the...

NMR response of unconsolidated materials
What is the link between NMR relaxation times and...

InSAR data to monitor a confined aquifer
Can high quality InSAR data be acquired and used...

The GEM Center

The GEM Center is a research center that provides a multidisciplinary/crosscutting approach to groundwater evaluation and management. The focus of research is the integration of data, acquired across a wide range of spatial and temporal scales, to monitor and model subsurface hydrologic processes. The defining characteristic of the GEM Center is the use of geophysical data as an essential part of all aspects of groundwater evaluation and management. Central to our approach is the establishment of partnerships that allow the GEM Center to demonstrate state-of-the-science solutions to "real-world" problems. In this way, we hope to play a key role in encouraging the adoption of new approaches, and new technologies, for addressing the challenging problems we face in the evaluation and management of our groundwater resources.

Read full mission statement

News & Announcements

Success in a Nebraska Cornfield (video)
A collaborative effort involving researchers from Stanford, Schlumberger and the U.S. Geological Survey successfully drilled and logged a well in the Ogallala aquifer.

The GEM Center Web Site Launches
The Center for Groundwater Evaluation and Management launches a web site with information about research projects being conducted by Stanford faculty and students, affiliated faculty, and collaborators in the public and private sectors.

MORE NEWS

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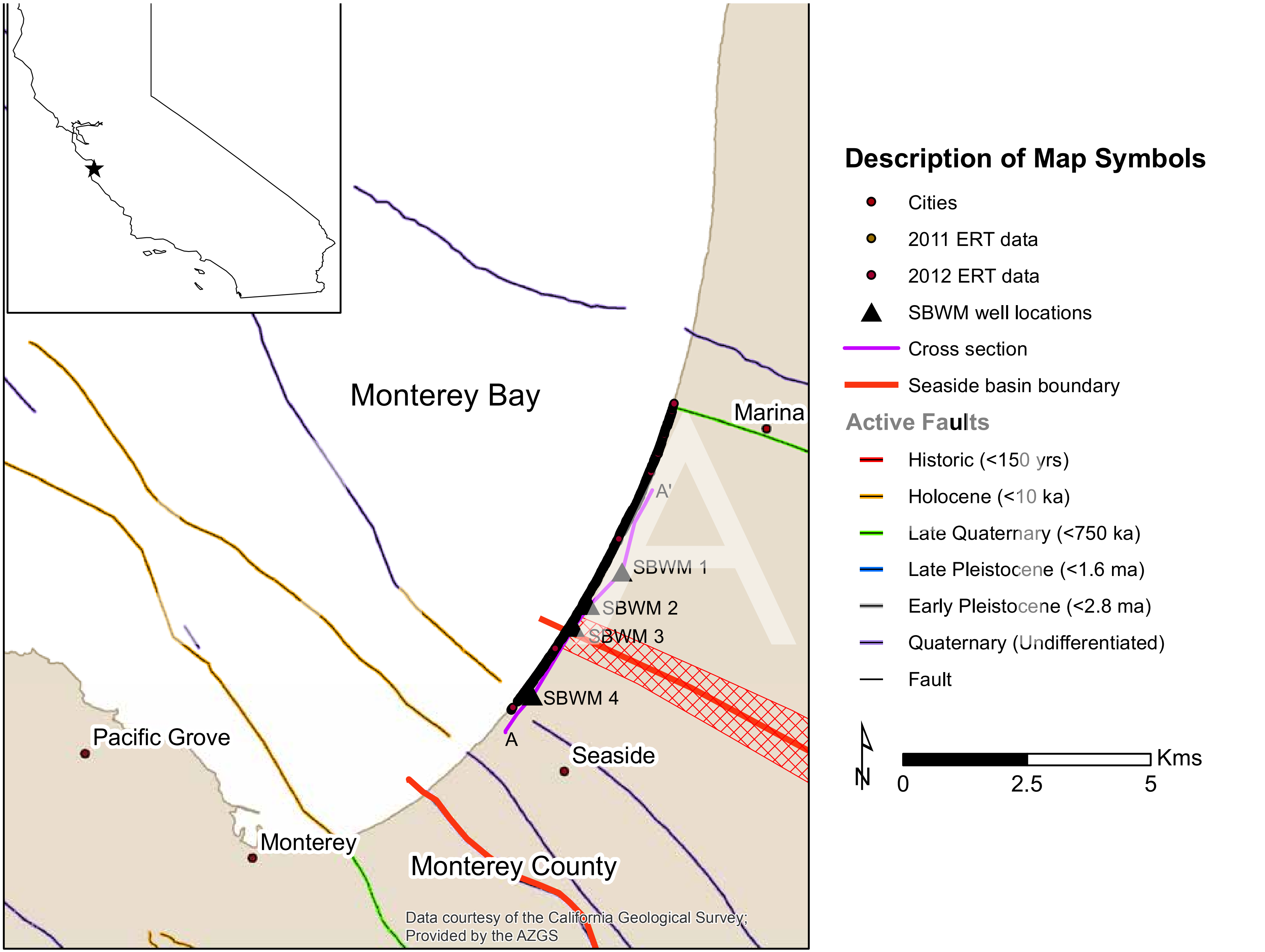
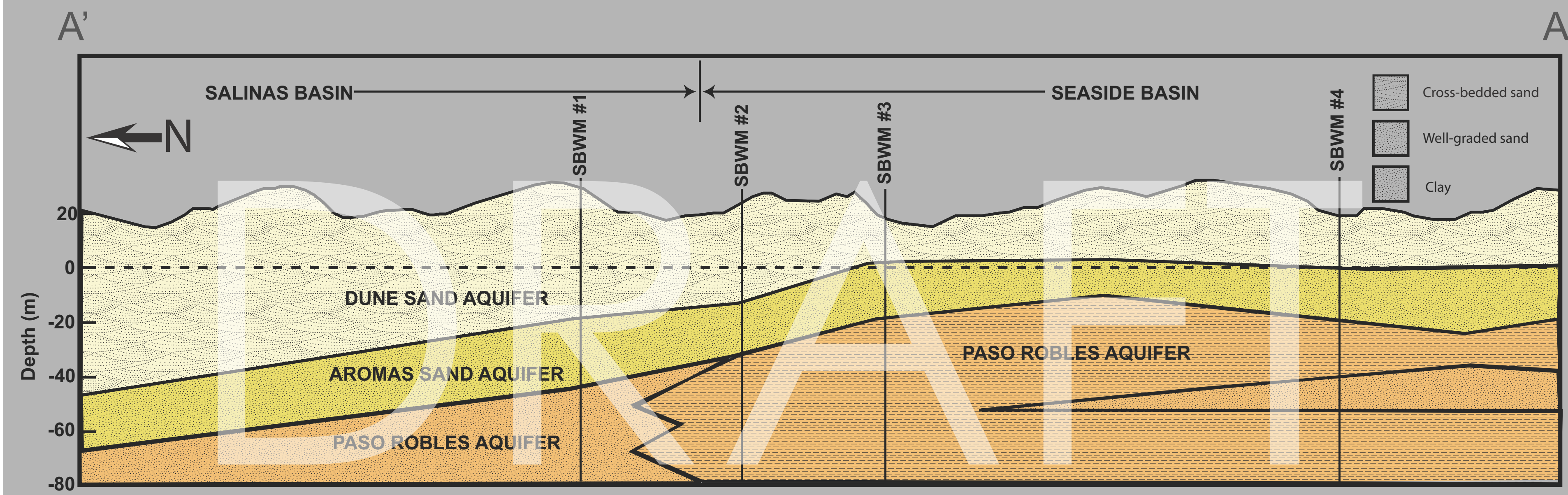

Monterey Bay
Marina
A'
SBWM 1
SBWM 2
SBWM 3
SBWM 4
A
Pacific Grove
Seaside
Monterey
Monterey County
Data courtesy of the California Geological Survey;
Provided by the AZGS
Description of Map Symbols
Cities
2011 ERT data
2012 ERT data
SBWM well locations
Cross section
Seaside basin boundary
Active Faults
Historic (<150 yrs)
Holocene (<10 ka)
Late Quaternary (<750 ka)
Late Pleistocene (<1.6 ma)
Early Pleistocene (<2.8 ma)
Quaternary (Undifferentiated)
Fault
N
Kms
0
2.5
5

Borehole based monitoring for Saltwater intrusion

- Sentinel Wells 2007
- 4 monitoring wells drilled to facilitate time-lapse logging of the aquifer to identify saltwater intrusion zones
- Wells drilled to ~ 300-400m
- Logged seasonally using resistivity logging –WHY?
- Not really early warning! Once we see it in the well it is there.



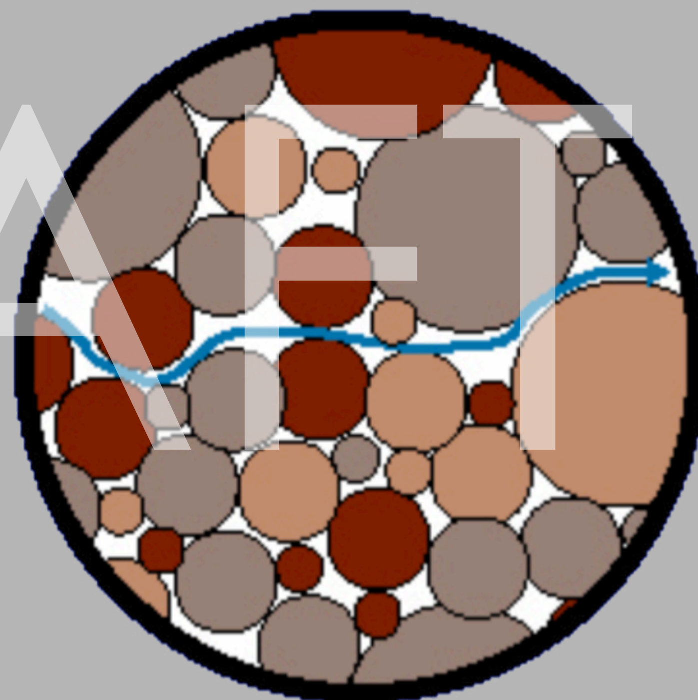
modified after Feeney 2009

Why resistivity?

- Electrical Resistivity Tomography (ERT)
- Well documented for small-scale water resource applications
- Currently used in petroleum applications – this has lead to advancement in field systems and processing approaches
- Non-invasive, fast deployment, continuous data
- 2D, 3D, and 4D imaging is possible

What You're Measuring: Resistivity (Ohm-m)

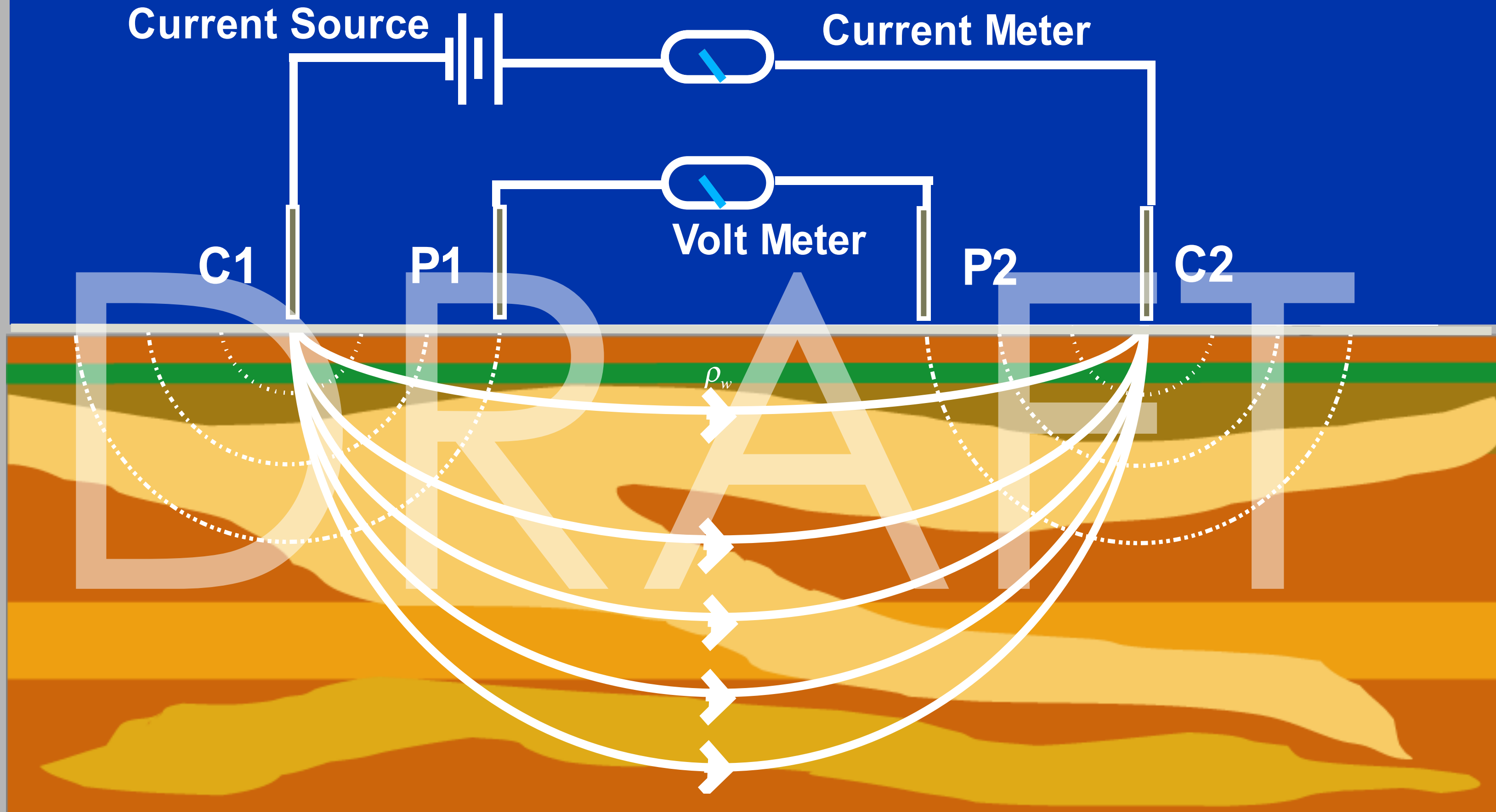
- Resistivity is a function of the bulk electrical properties and is sensitive to:
  - porosity
  - connectivity of pore fluid
  - pore fluid chemistry
  - lithology



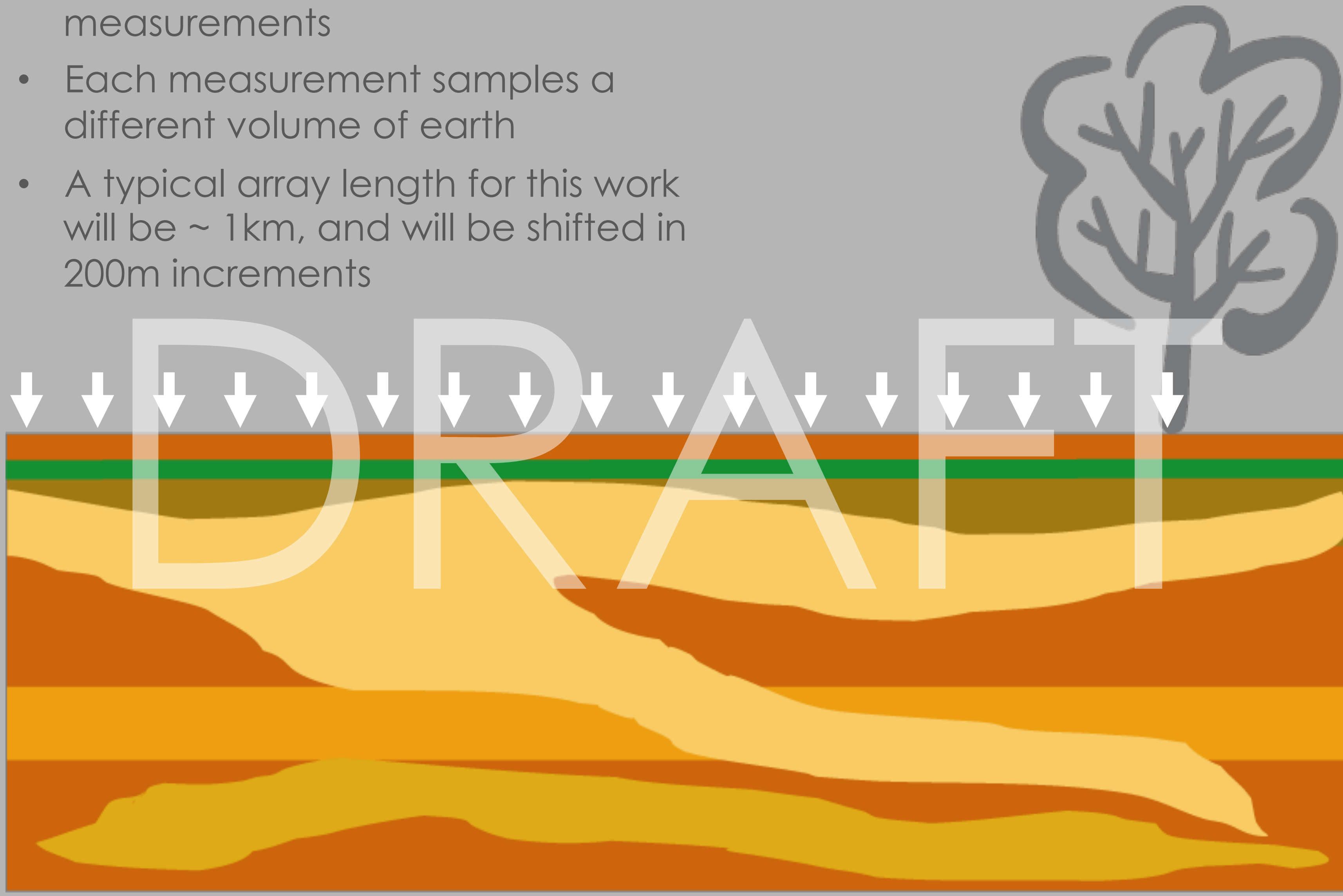
Pore fluid chemistry: Salinity

	Concentration (g/L)	Conductivity (S/m)	Resistivity (Ohm-m)
Freshwater	0.03	0.006	156
	0.1	0.02	48
	0.3	0.06	16
	1	0.2	5
	3	0.6	2
Saltwater	10	1.8	1

Concept of Operation

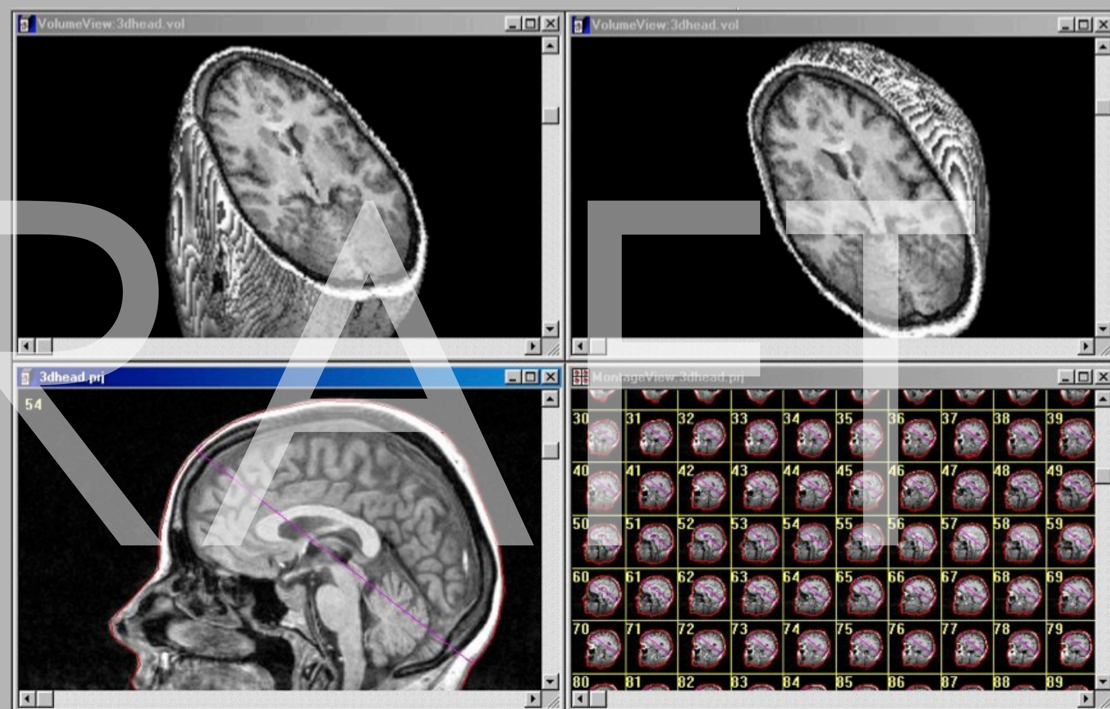


- We use multiple sensors (electrodes) to make 10's of thousands measurements
- Each measurement samples a different volume of earth
- A typical array length for this work will be ~ 1km, and will be shifted in 200m increments



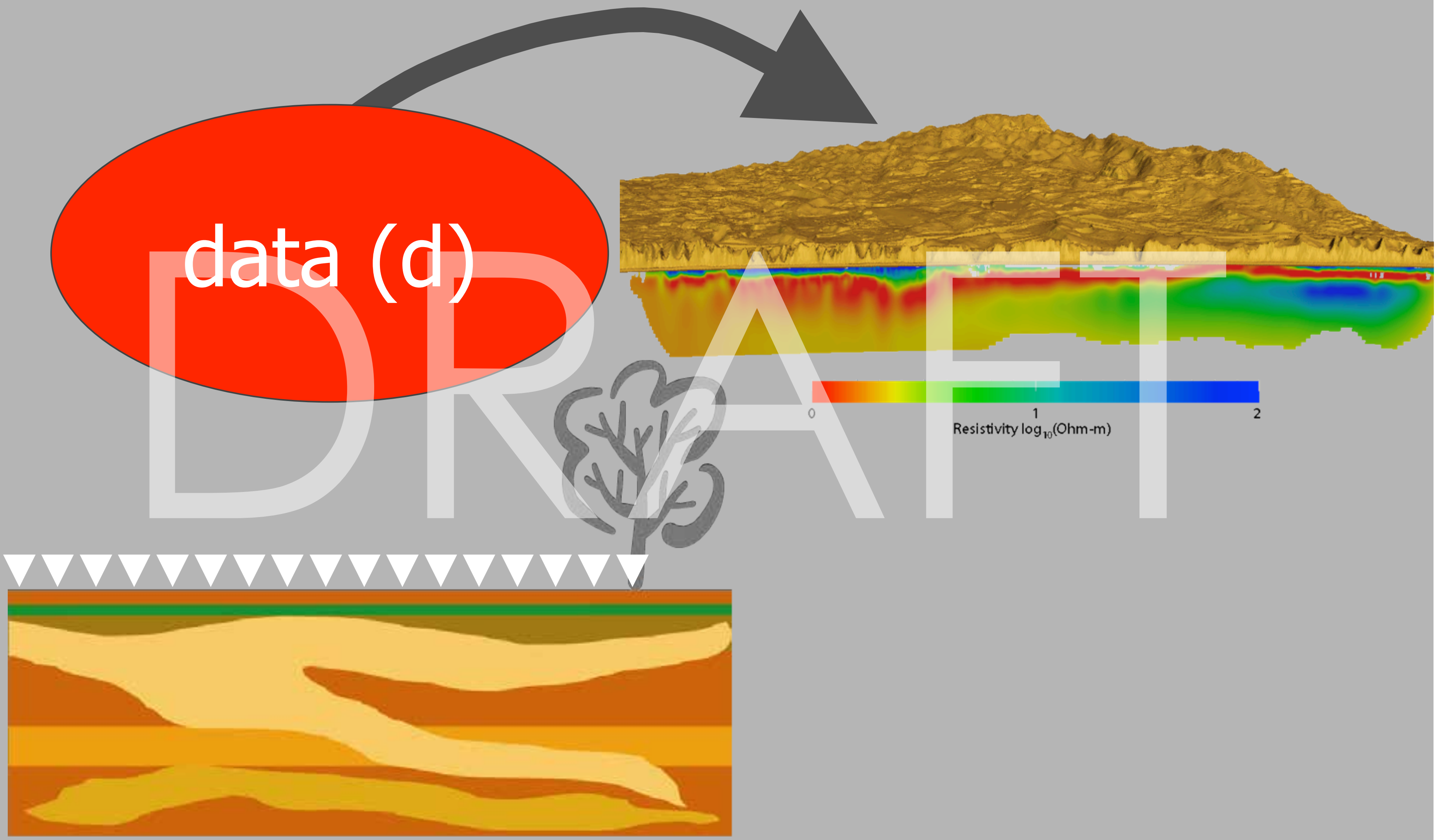
Geophysical Tomography

Like medical tomography, but with much poorer resolution



http://www.ablesw.com

Geophysical Tomography



Data acquisition/ Processing

Two field campaigns:

- July 2011
- October 2012
- Total field days ~10

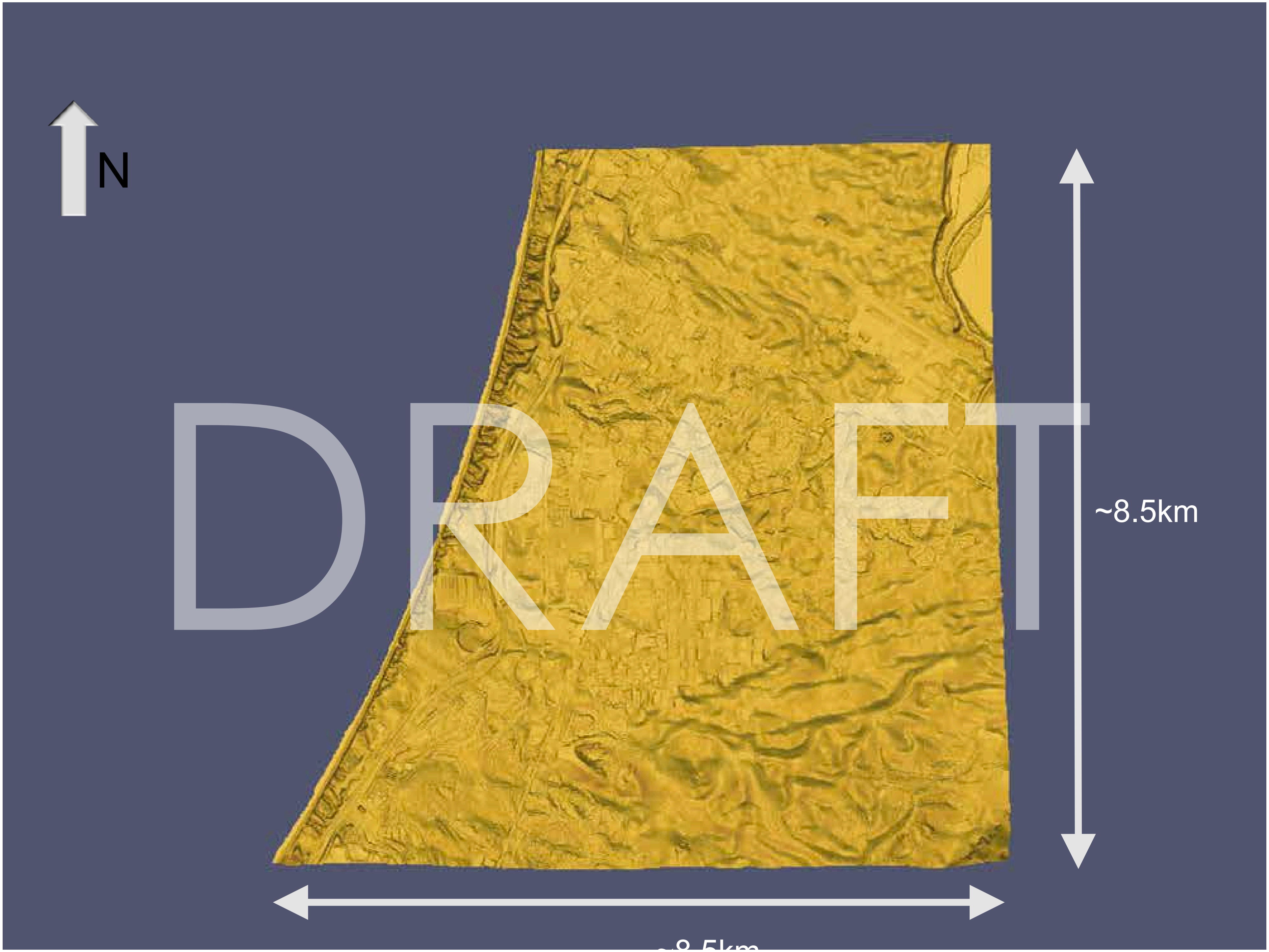
Total survey length: 6.8km

Total number of data acquired: 130,000

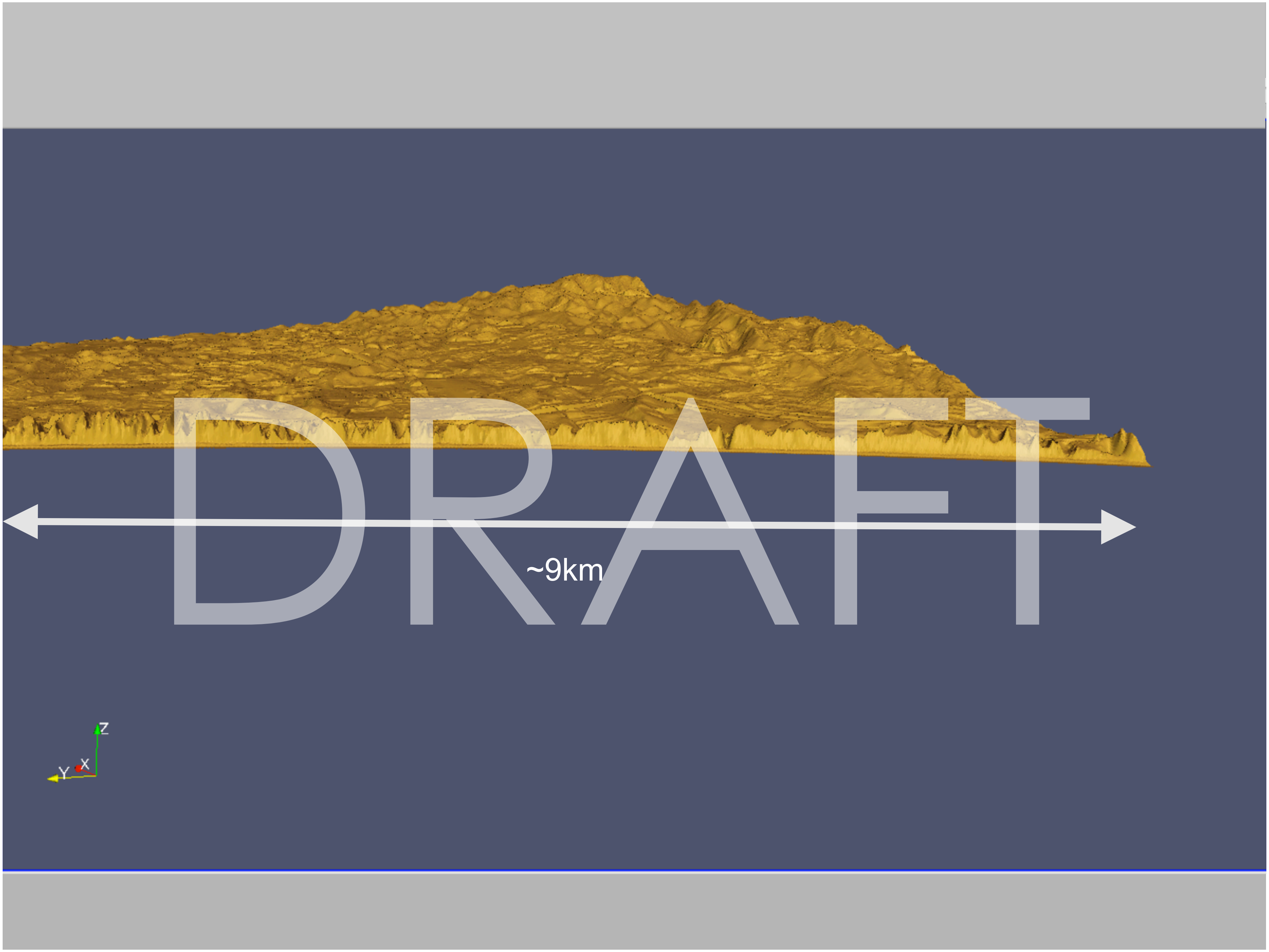
Spatial resolution of inversion mesh: x: 10m, z: 5→10m

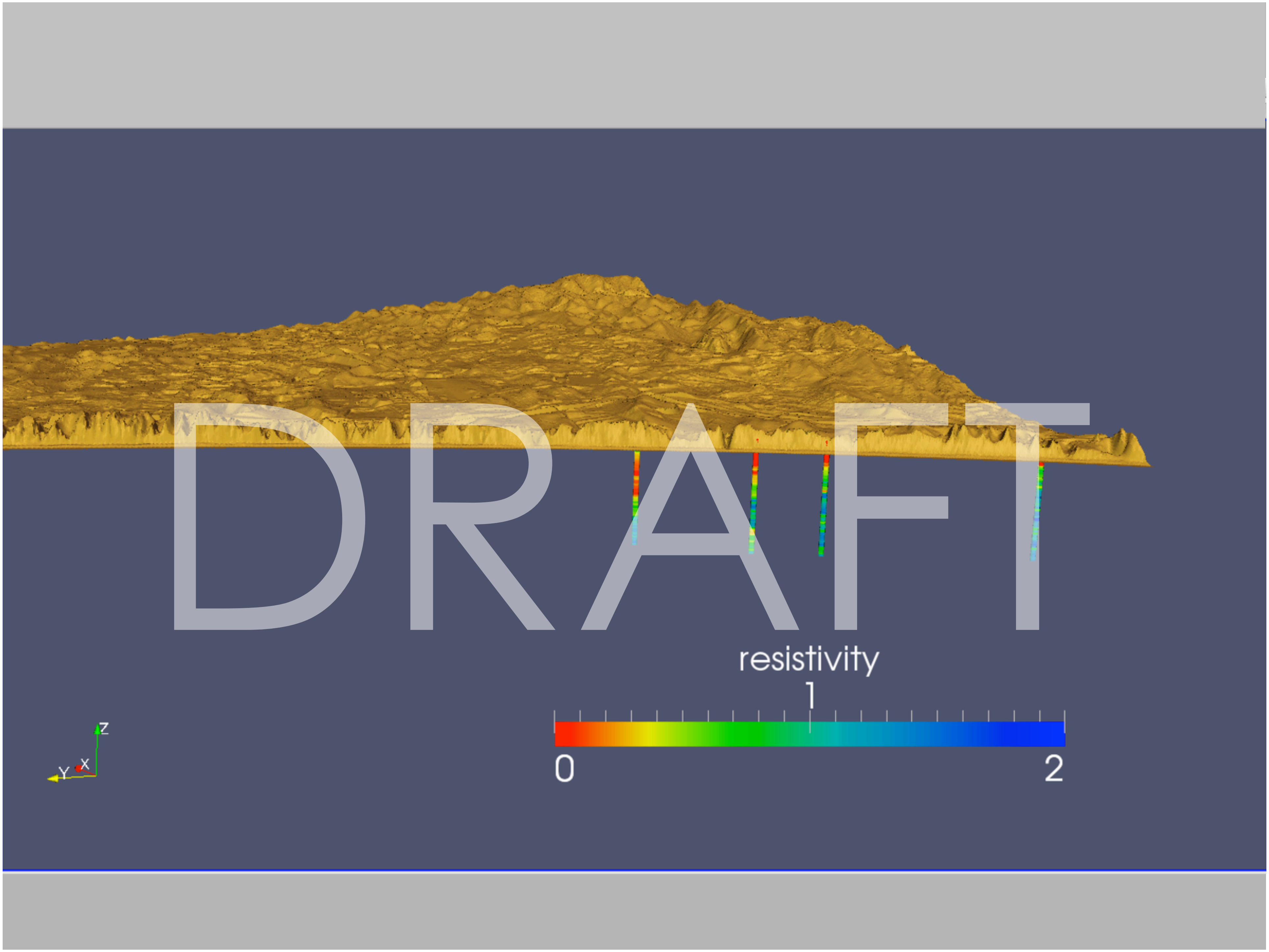
Acquisition Cost: $60,000

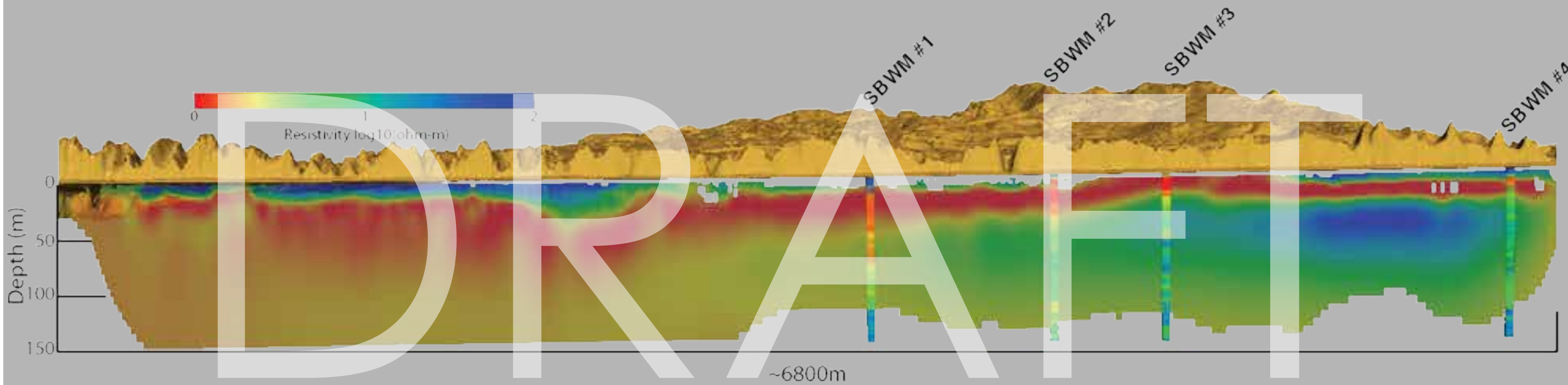

DRAFT



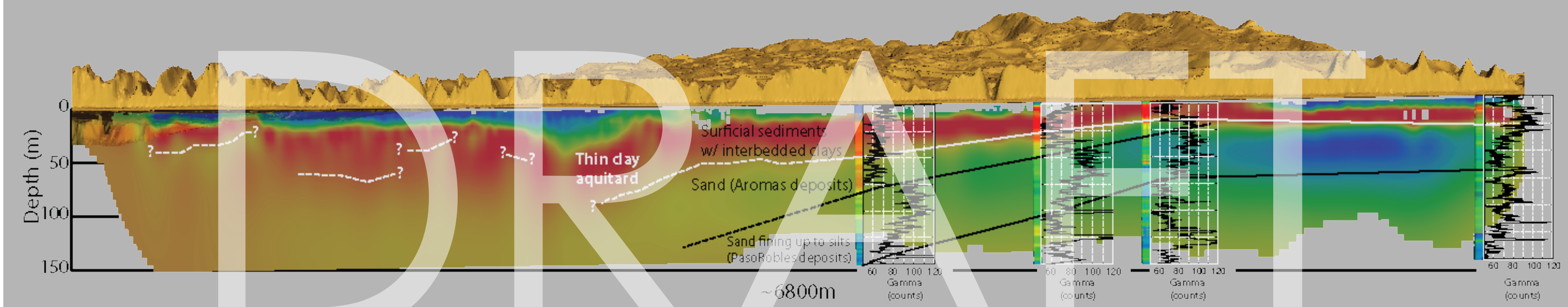
N
~8.5km
~8.5km
DRAFT

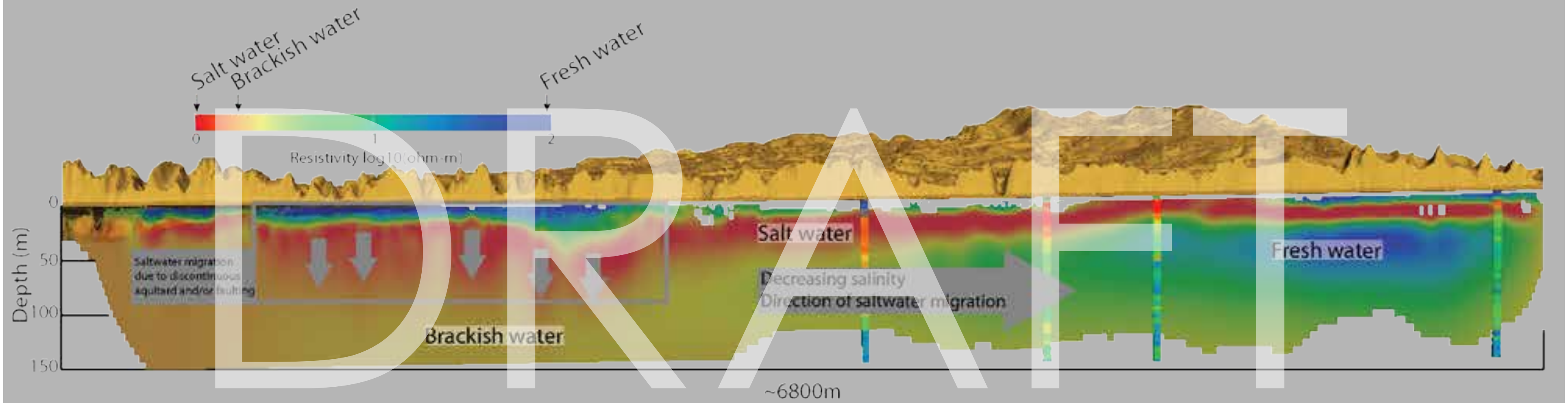

DRAFT
~9km
Z
Y
X


DRAFT
resistivity
1
0
2
Z
Y
X



SBWM #1
SBWM #2
SBWM #3
SBWM #4
0
1
2
Resistivity log10(ohm-m)
Depth (m)
0
50
100
150
~6800m


Depth (m)
0
50
100
150
Surficial sediments w/ interbedded clays
Thin day aquitard
Sand (Aromas deposits)
Sand fining up to silts (PasoRobles deposits)
~6800m
60 80 100 120
Gamma (counts)
60 80 100 120
Gamma (counts)
60 80 100 120
Gamma (counts)
60 80 100 120
Gamma (counts)



Salt water
Brackish water
Fresh water
0
1
2
Resistivity log10(ohm-m)
Depth (m)
0
50
100
150
Saltwater migration
due to discontinuous
aquitard and/or faulting
Salt water
Fresh water
Decreasing salinity
Direction of saltwater migration
Brackish water
~6800m
DRAFT

Conclusions

- Effective non-invasive subsurface imaging
- Improved large-scale understanding of aquifers
- Improved operational modeling
- Optimized remediation or interventions
- Lower cost and environmental impact
- Potential for long-term, spatially exhaustive monitoring

Acknowledgments

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