Chloride Mapping on the Basis of Electromagnetic Log Data

By
Loren Metzger

Preliminary Findings

In cooperation with The Northeastern San Joaquin Groundwater Banking Authority and the California Department of Water Resources

USGS
science for a changing world

Scope of Presentation

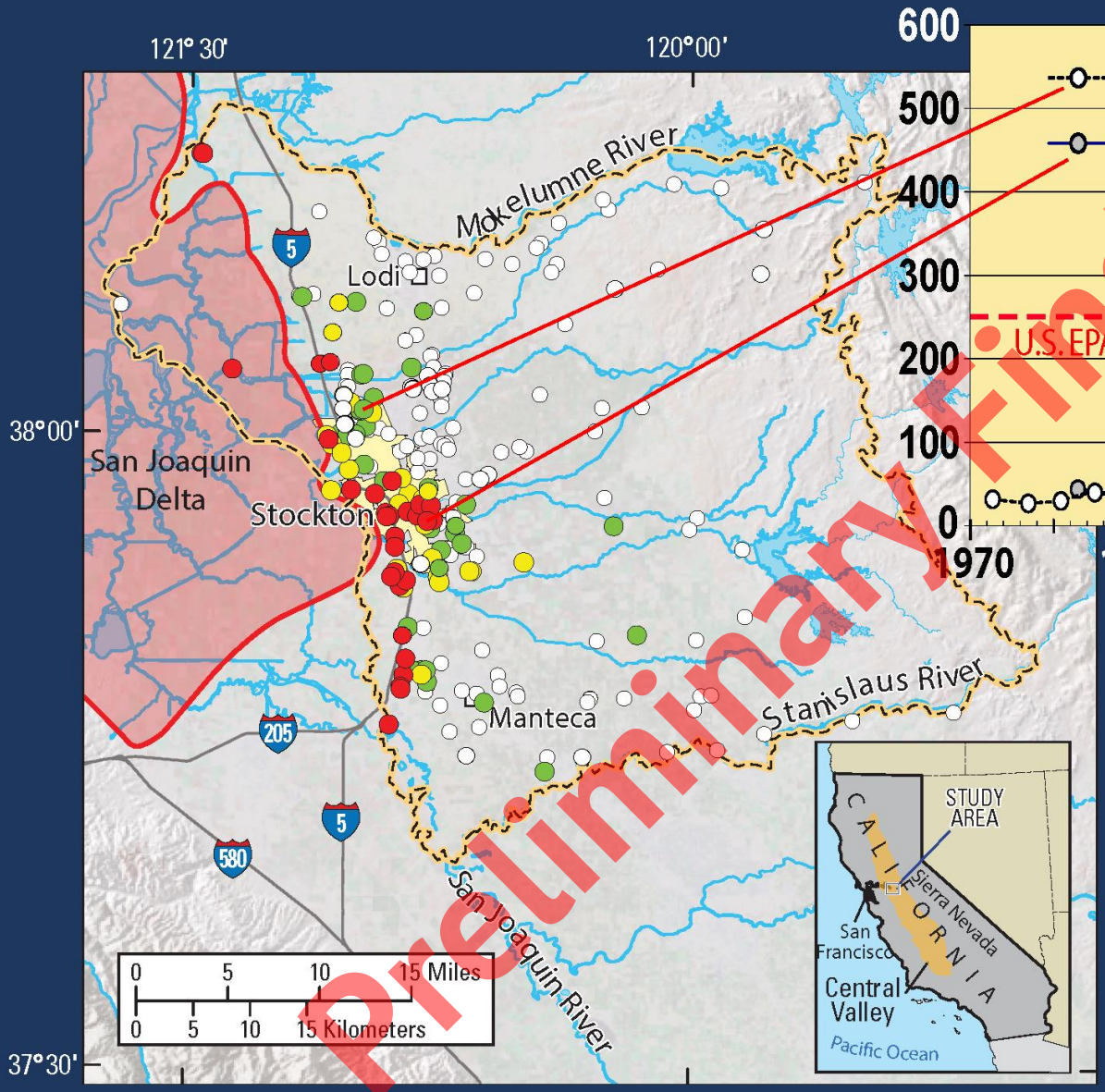
- Spatial distribution of chloride
- Description of EM Induction
- Results
- Correlation of EM resistivity & Cl
- 2-D chloride mapping
- Conclusions

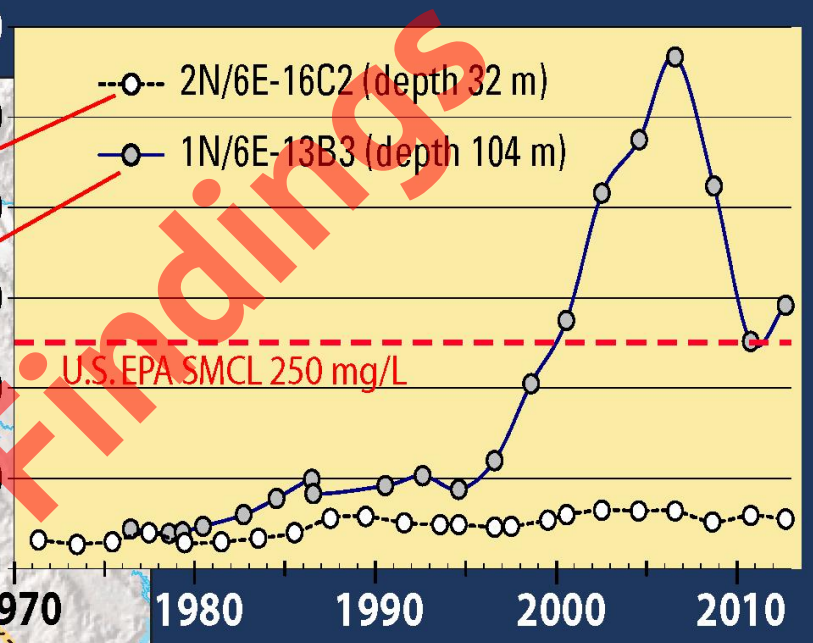
EM Induction logging at Victory Park

Related reference: *Metzger, L.F. and Izbicki, J.A. (2013), Electromagnetic-induction logging to monitor changing chloride concentrations. Ground Water, Vol. 51, no. 1, pp. 108-121. Doi: 10.1111/j.1745-6584.2012.00944.x*

USGS science for a changing world

Chloride concentrations in water from wells





Preliminary Findings

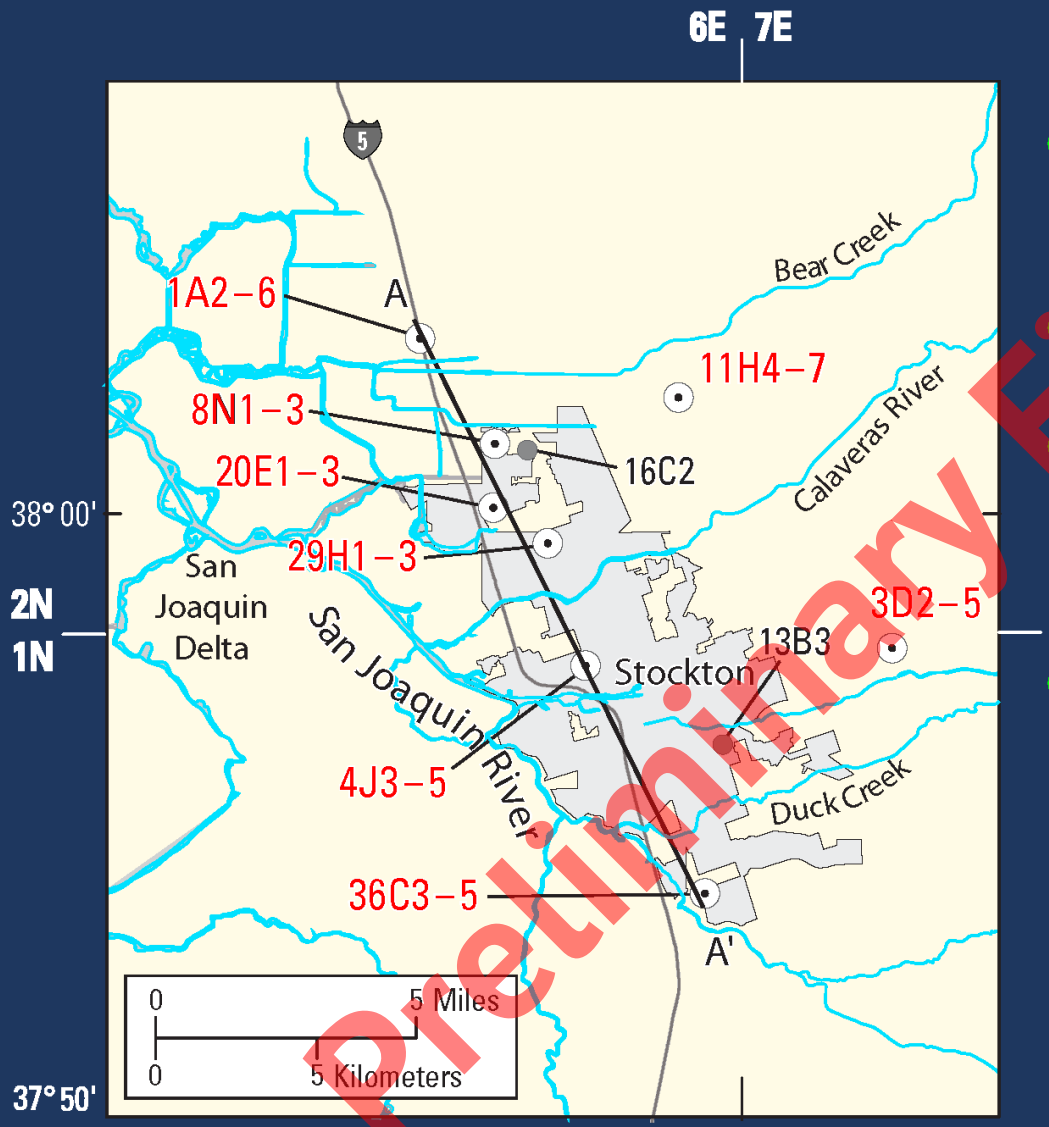
1984-2012: *Modified from USGS Open File Report 2006-1309*

Chloride, in mg/L

- Less than 50
- 50 to 100
- 100 to 250
- Greater than 250

1931 extent of chloride greater than 1,000 mg/L in Delta surface water (Piper and others, 1939)

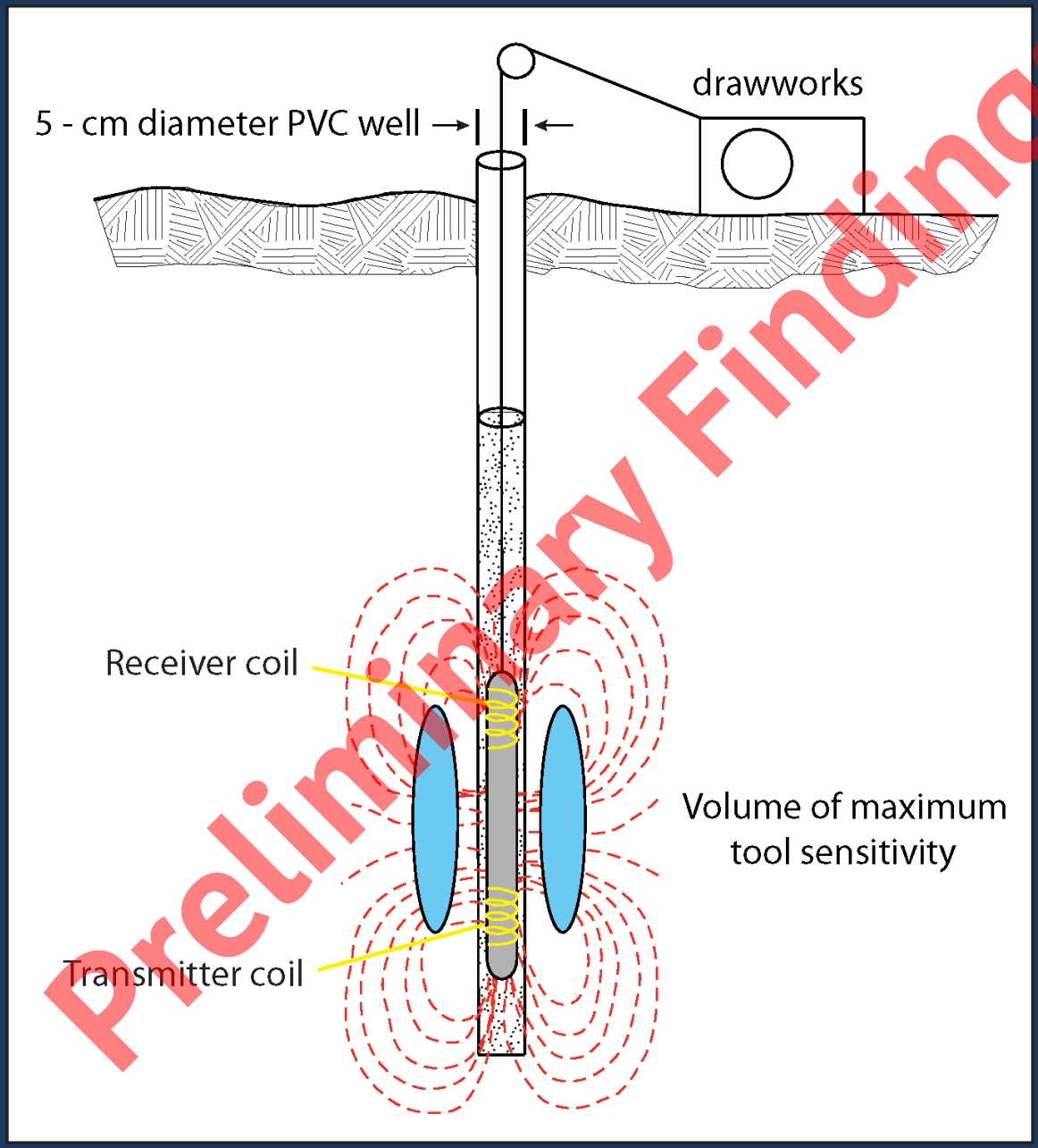
Wells EM logged and sampled for chloride



- 8 multiple-well sites (28 individual wells)
- 39 EM logs (2004 - 2012)
- ~1,460 m logged well depth versus 29 screened intervals w/combined length of 165 m
- Chloride: 88 water samples (range 4 to 2,050 mg/L) and 8 core material samples (range 28 to 3,590 mg/L)

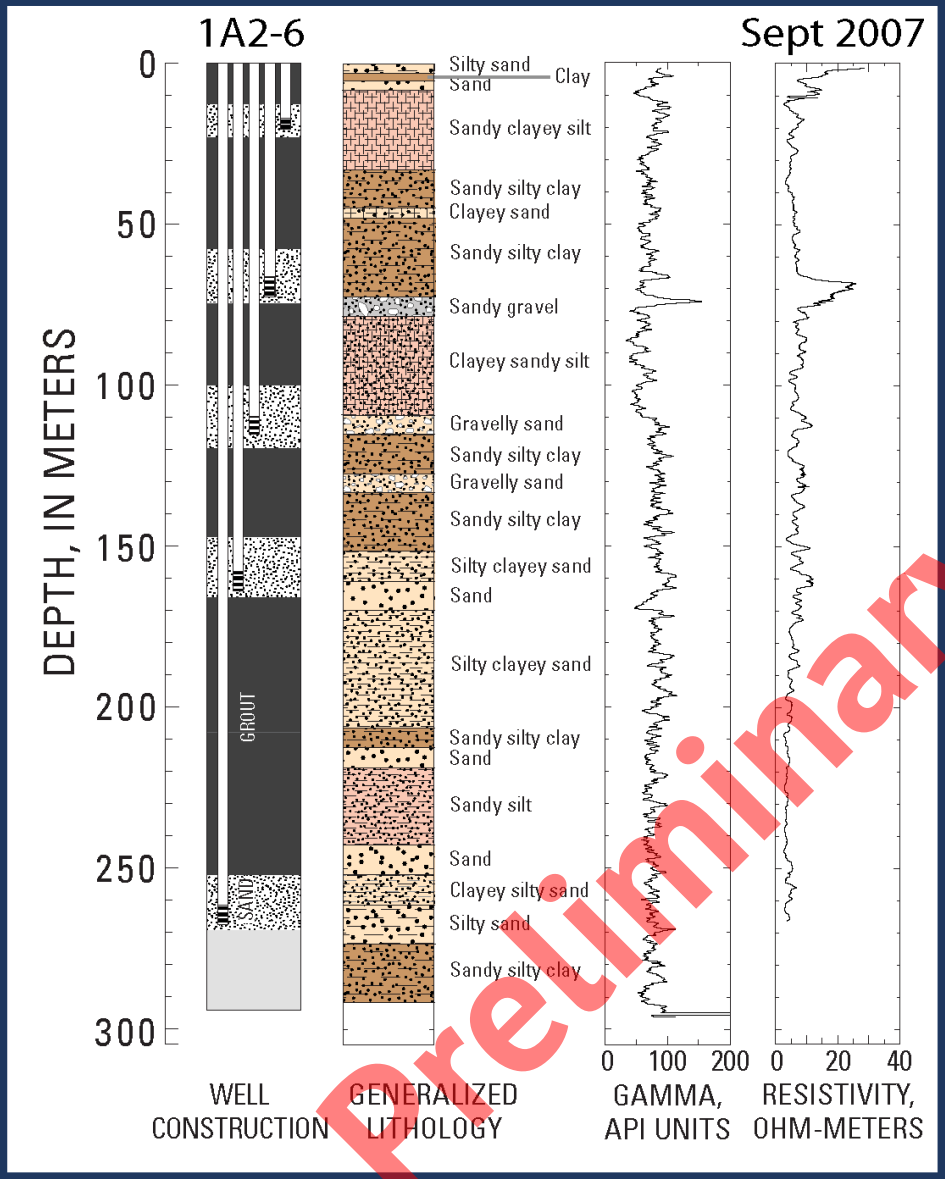
USGS
science for a changing world

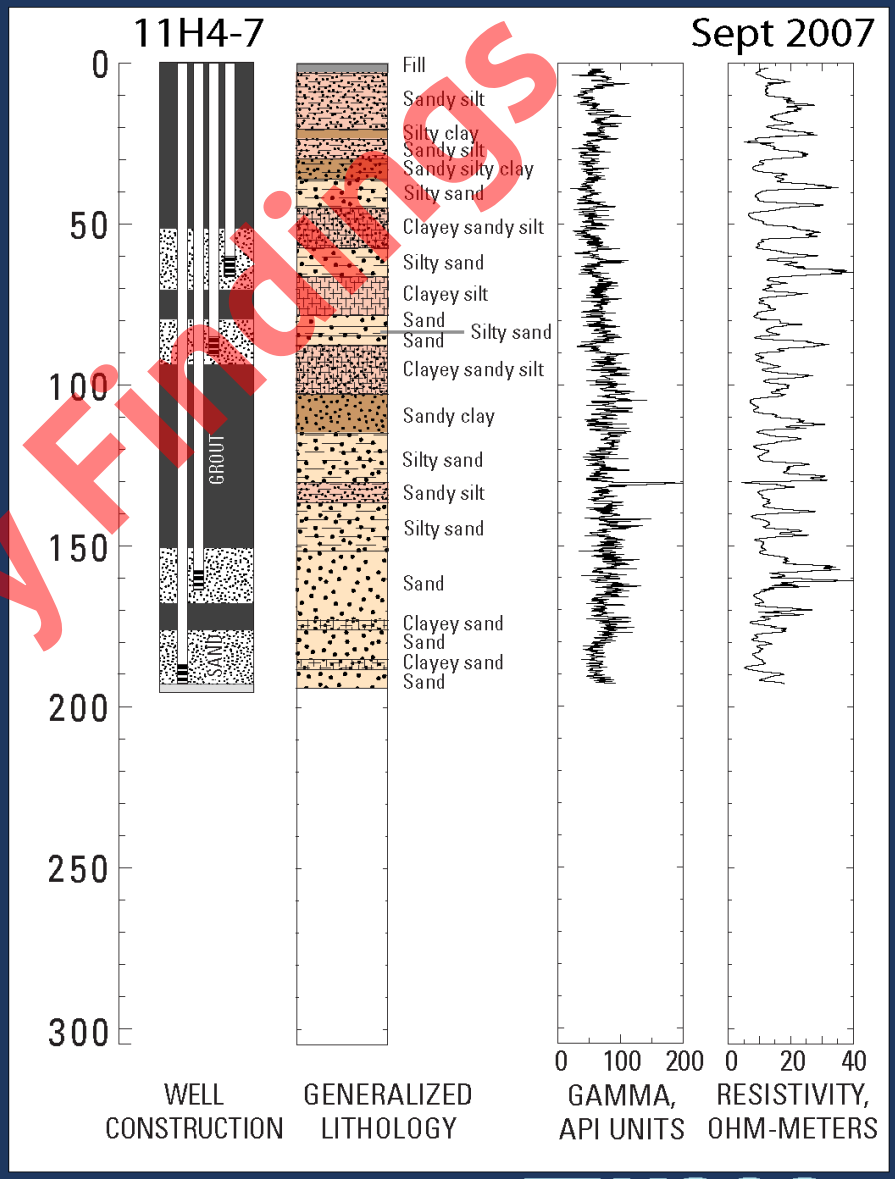
Electromagnetic Induction Logging



USGS
science for a changing world

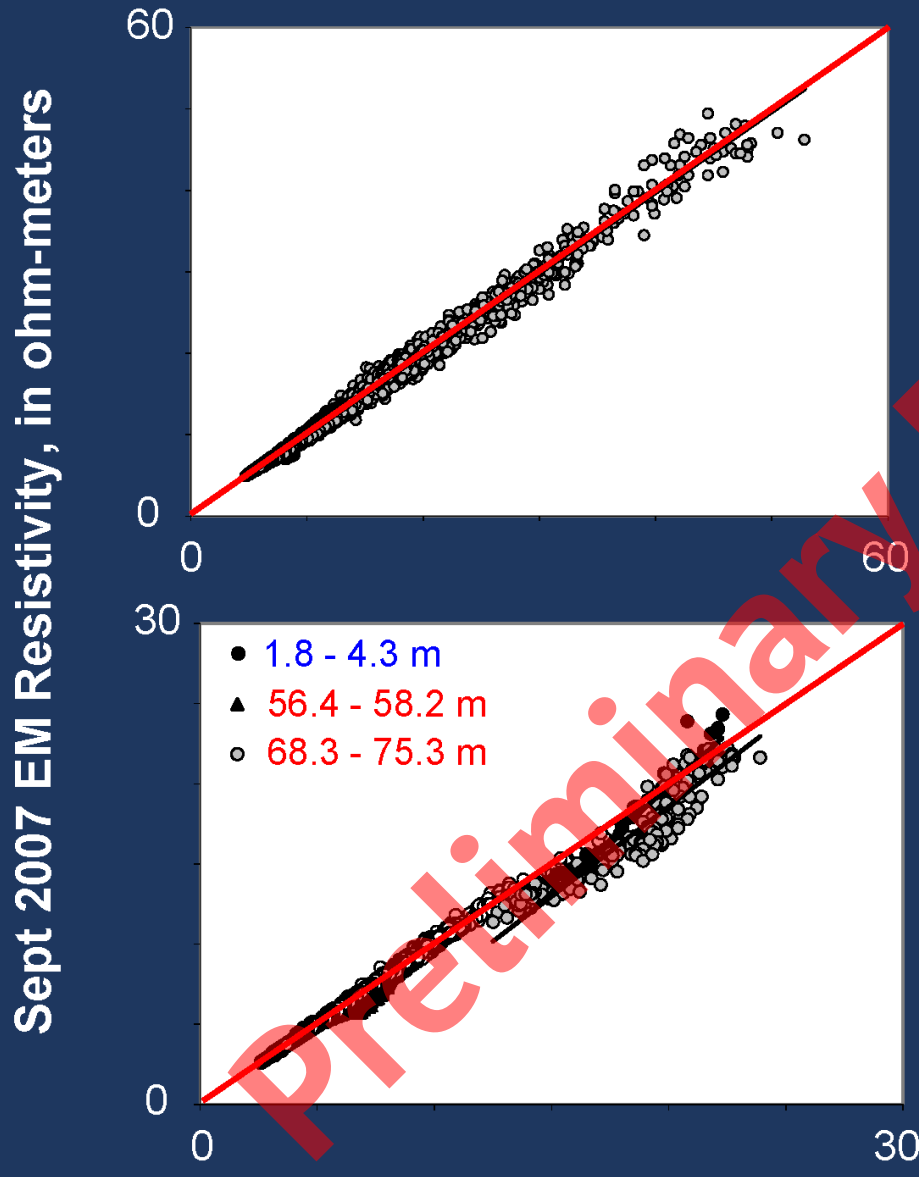
Electromagnetic (EM) Resistivity Results





USGS
science for a changing world

Comparative Electromagnetic (EM) Logs



Multiple-Well Site 29H1-3

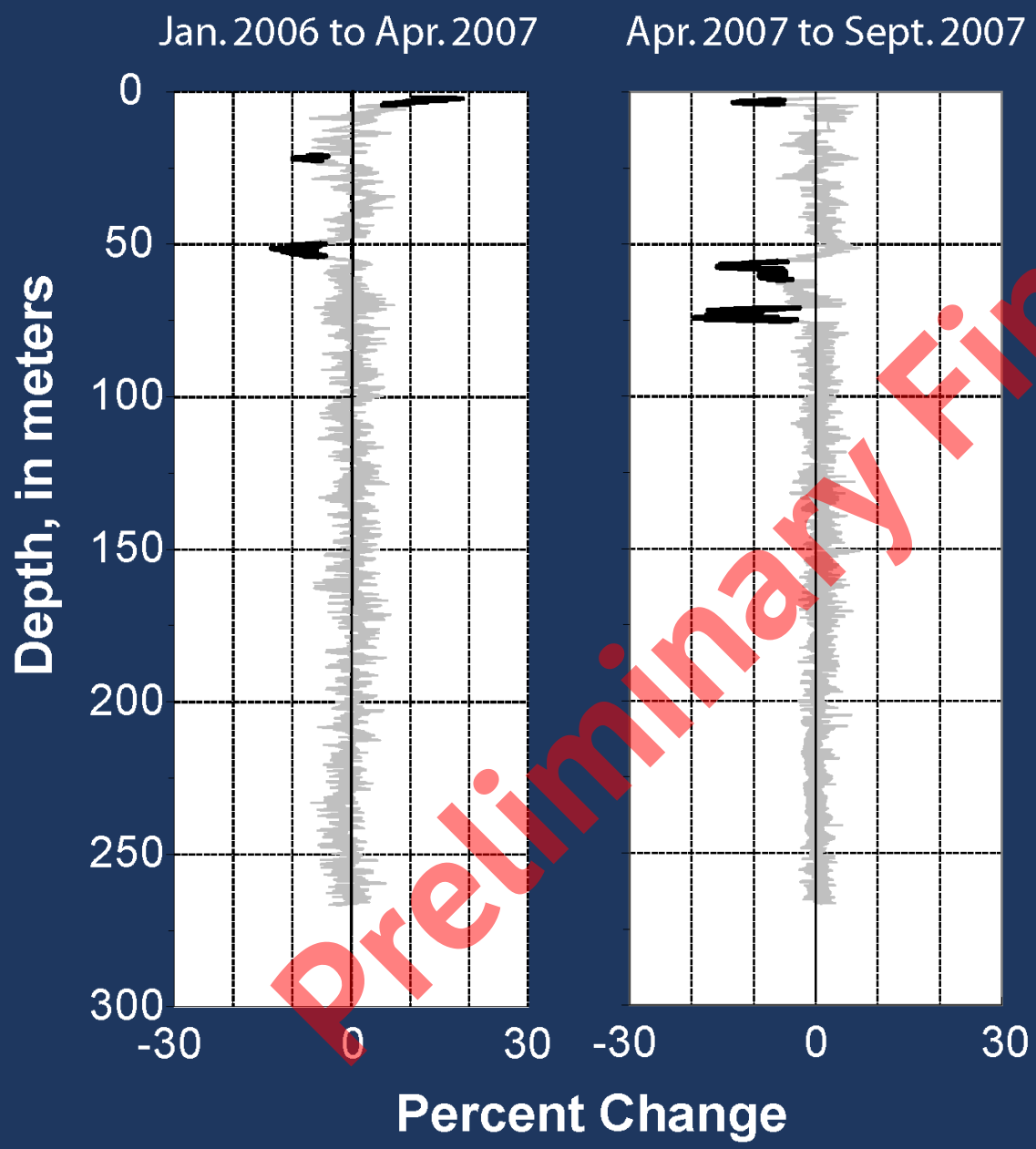
- Stable with little change in electromagnetic resistivity or chloride concentrations

Multiple-Well Site 1A2-6

- Changing electromagnetic resistivity and chloride concentrations

USGS science for a changing world

Comparative Electromagnetic (EM) Logs

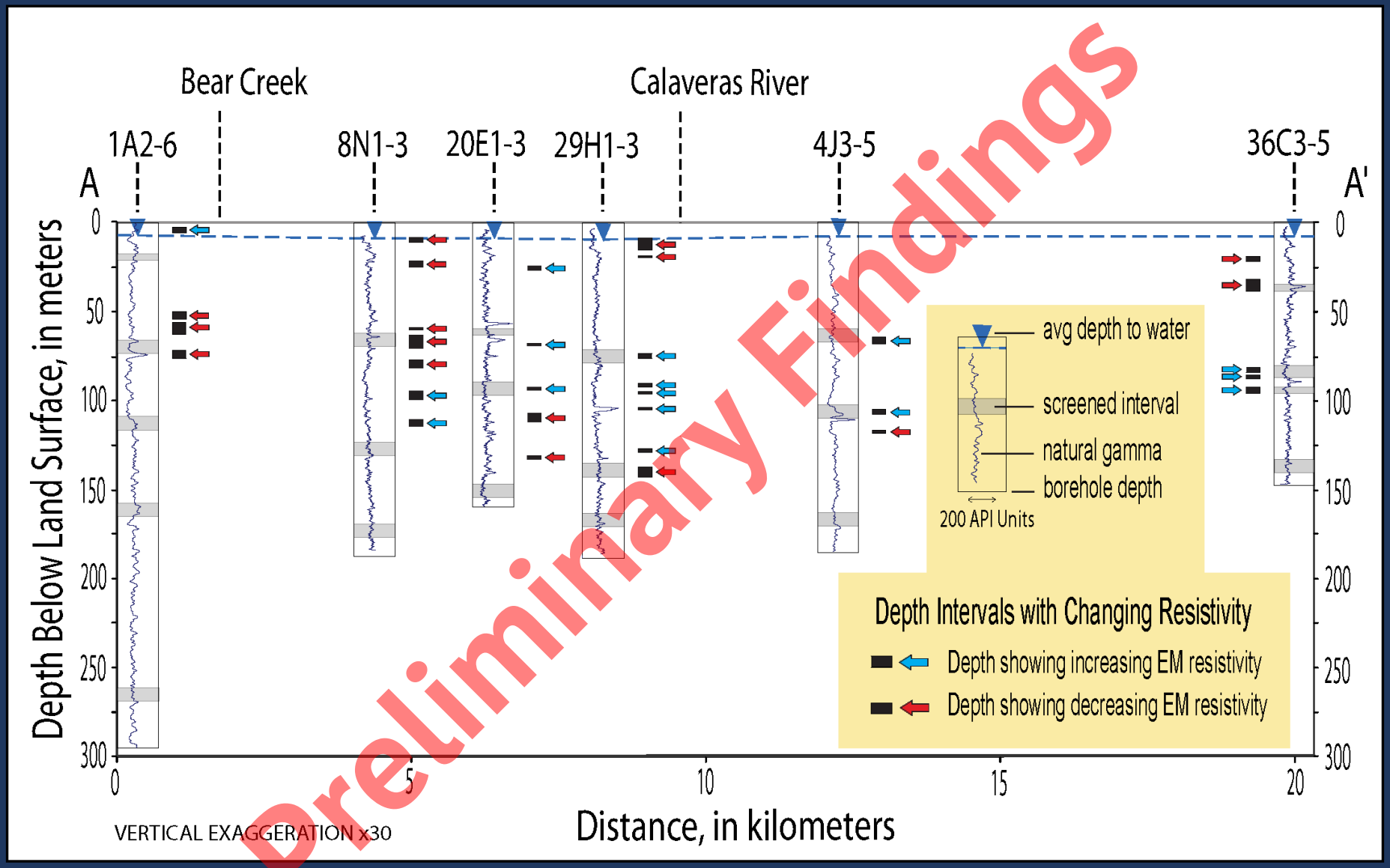


Multiple-Well Site 1A2-6

- Highlighted depth intervals show change greater than 1 standard deviation
- '+' percent change is increase in EM resistivity i.e. improving water quality
- '-' percent change is decrease in EM resistivity i.e. poorer water quality

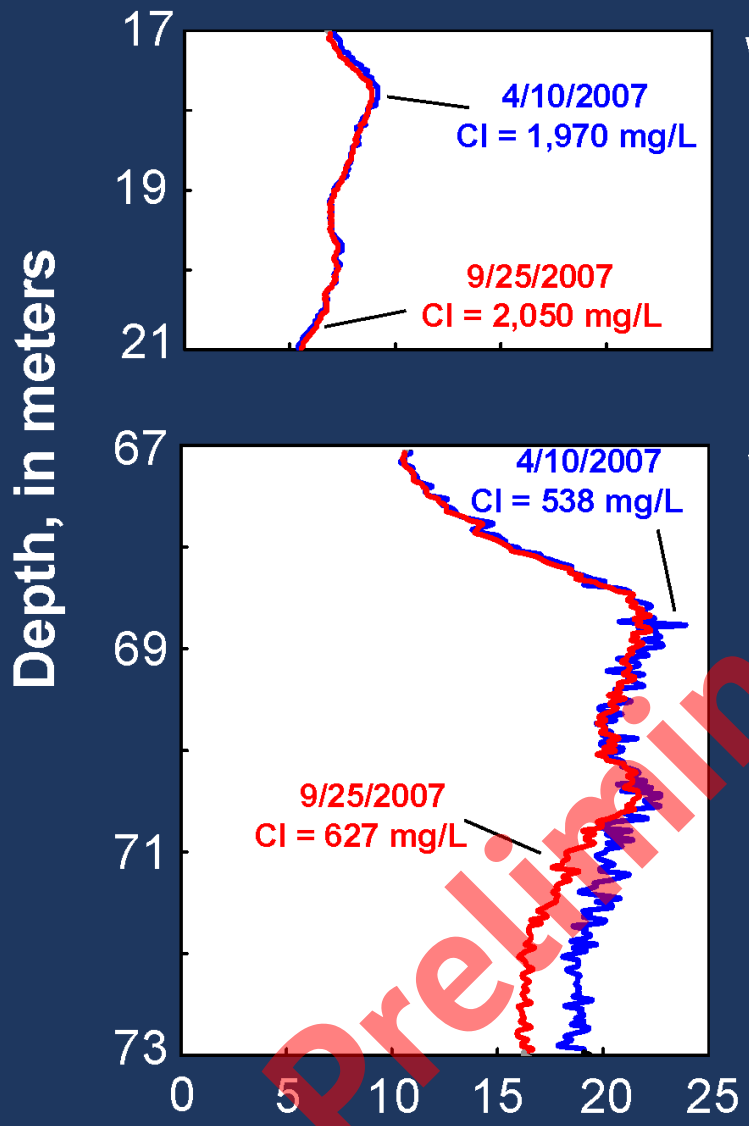
USGS
science for a changing world

Depth intervals with changing EM resistivity



USGS
science for a changing world

Comparative Electromagnetic (EM) Logs



Well 1A6 (17 - 21 m depth)

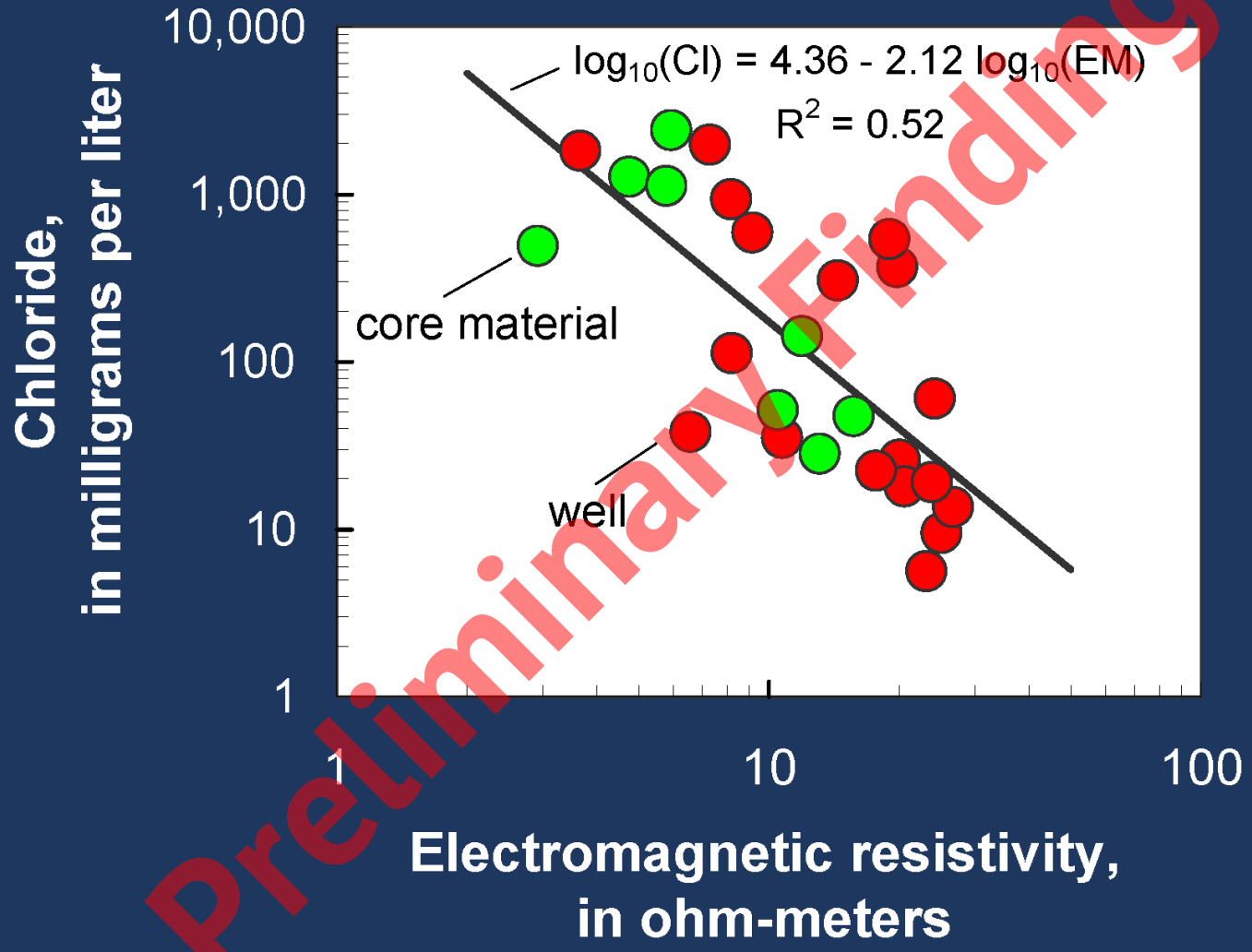
- Stable with little change in electro-magnetic resistivity or chloride concentrations

Well 1A5 (67 - 73 m depth)

- Changing electromagnetic resistivity and chloride concentrations

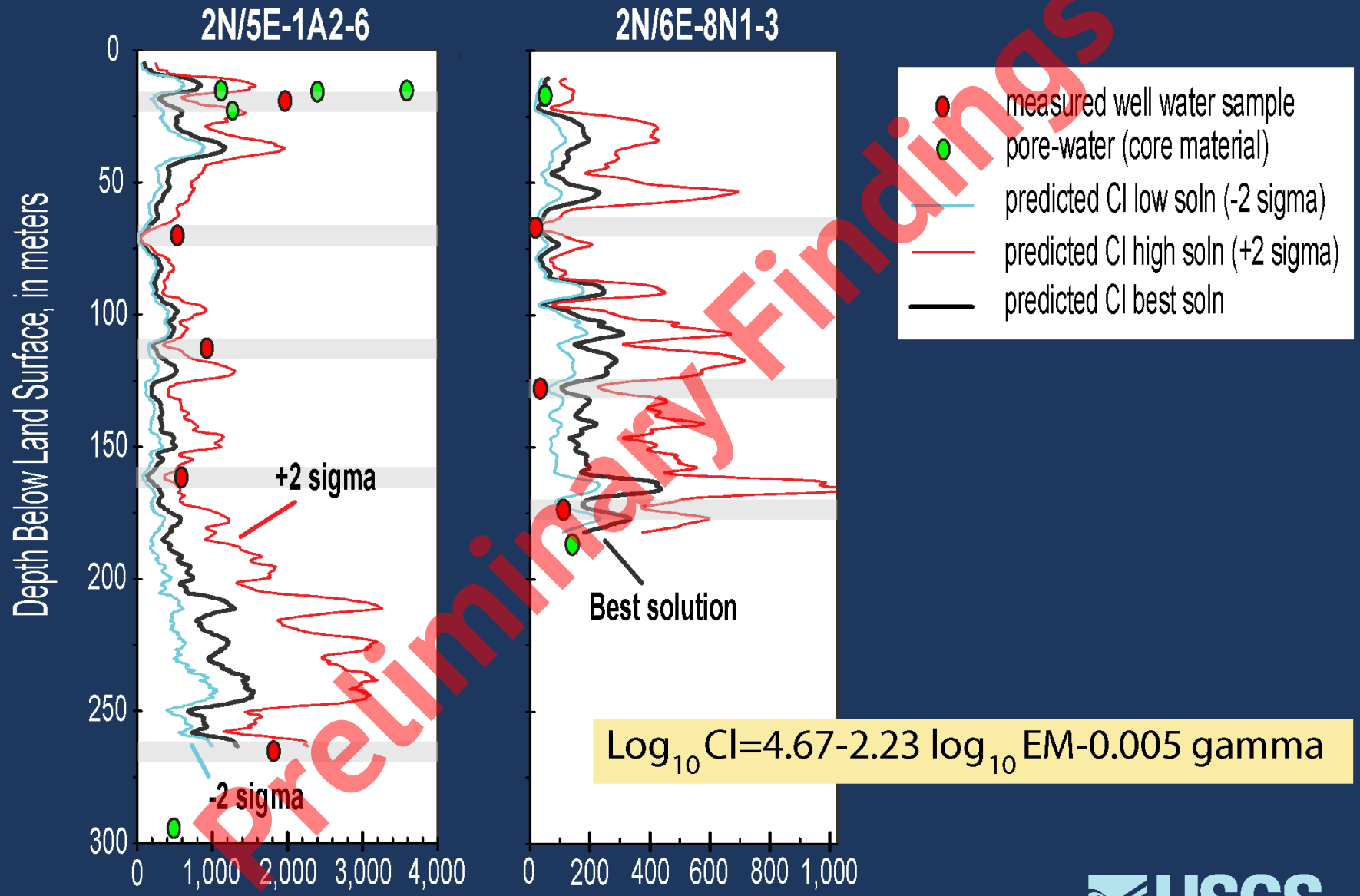
USGS science for a changing world

Relation between chloride and EM resistivity



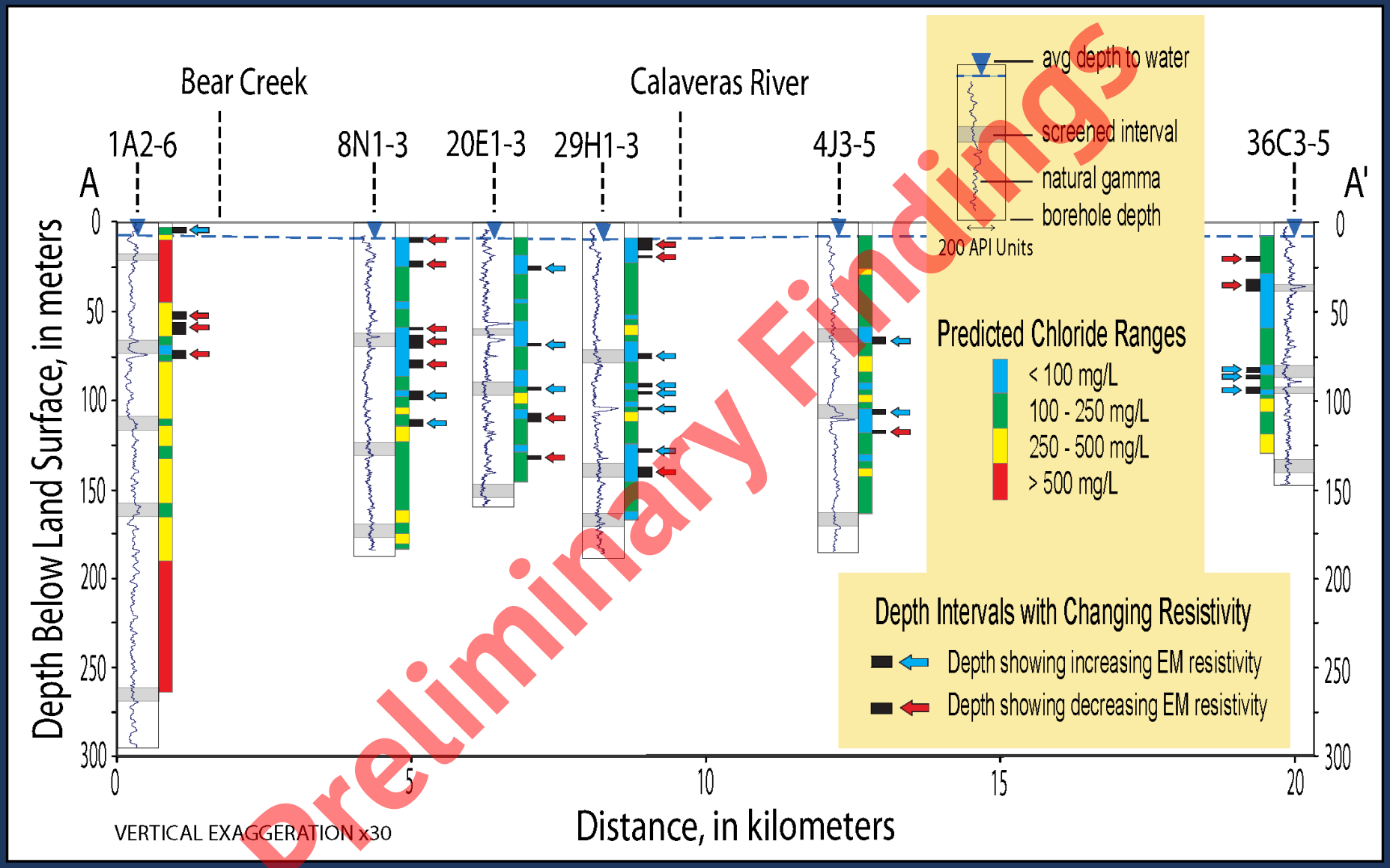
USGS science for a changing world

Chloride estimations and associated uncertainty



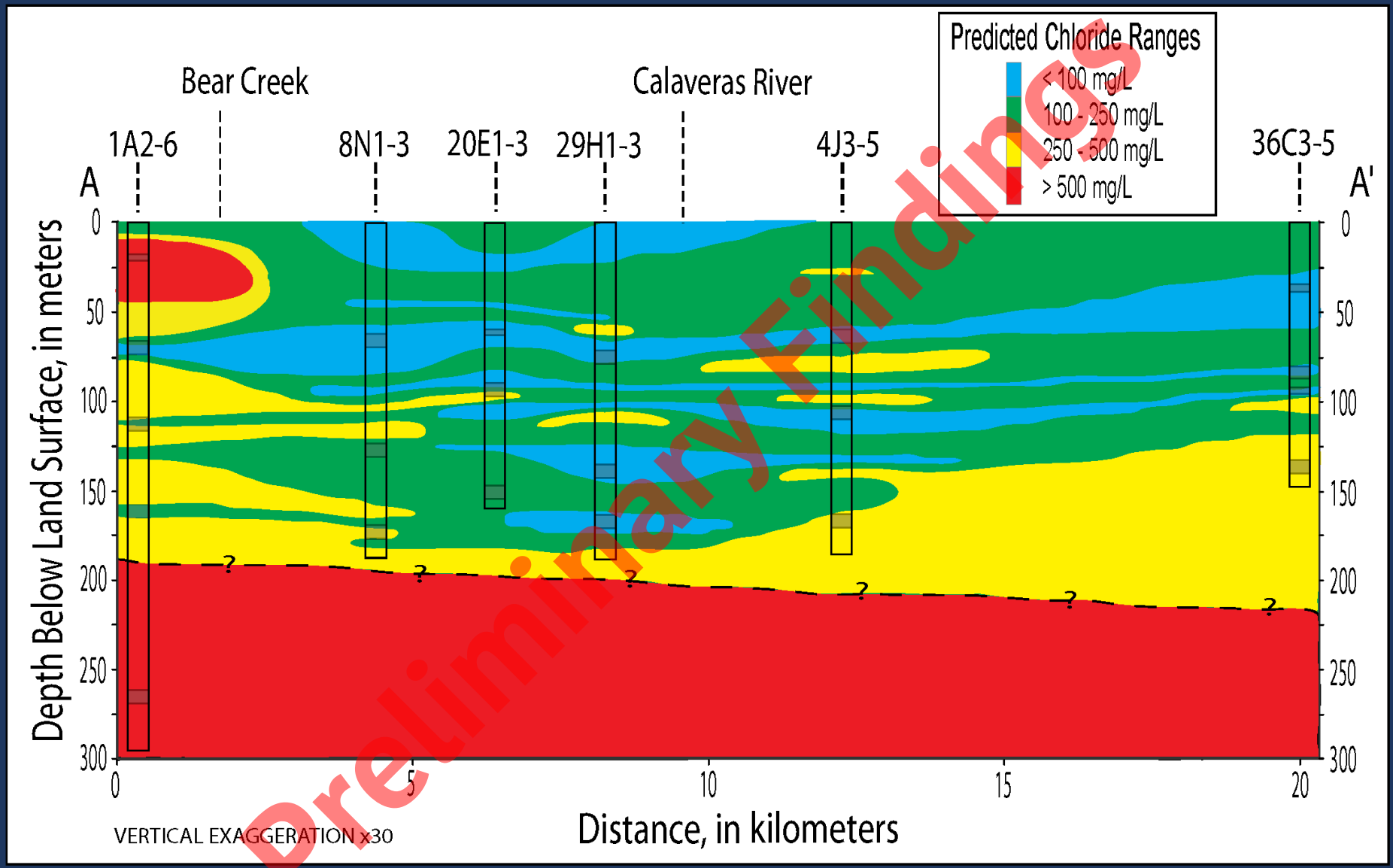
USGS science for a changing world

Depth intervals with changing EM resistivity



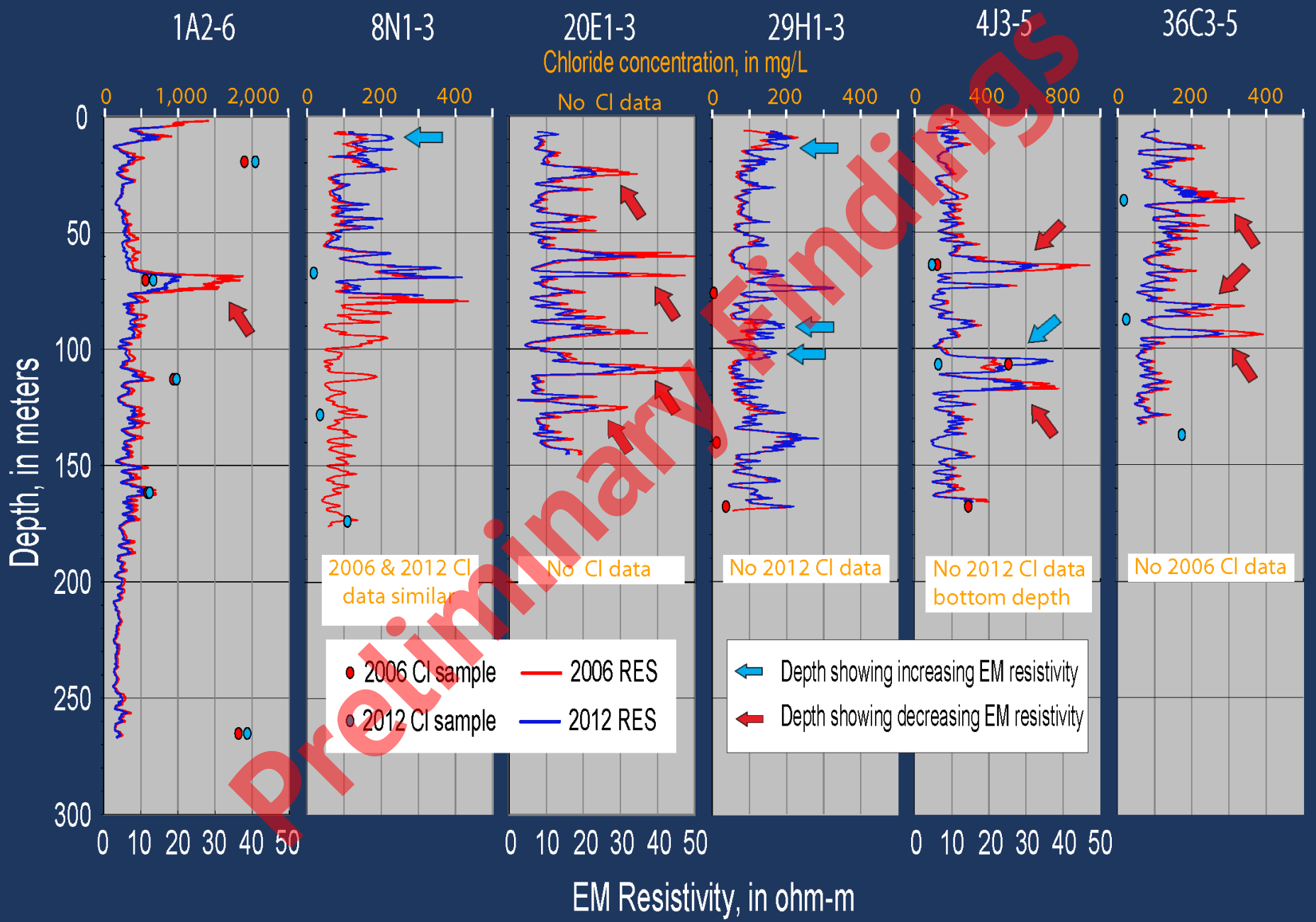
USGS
science for a changing world

Predicted chloride concentrations



USGS
science for a changing world

Comparative Electromagnetic (EM) Logs, 2006-12



Conclusions

- Chloride moves laterally from the Delta inland, primarily thru thin, coarse-grained zones.
- Sequential EM logging suggests degrading water quality in numerous thin zones (1-7 m thick), particularly in the northern and southern parts of the study area.
- EMI can provide a continuous profile of changes in groundwater quality within an aquifer penetrated by a PVC-cased well, thereby permitting the identification of zones of poor-quality water that may otherwise be missed by traditional water quality sampling from wells.
- Sequential EM logging may be a useful screening tool for detecting the early onset of increasing chloride concentrations as EMI logs can be used to identify brine invasion before concentrations reach levels of concern for groundwater management.