Does Geophysics have a role in groundwater models? An example from western Nebraska, USA.

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Nebraska Panhandle

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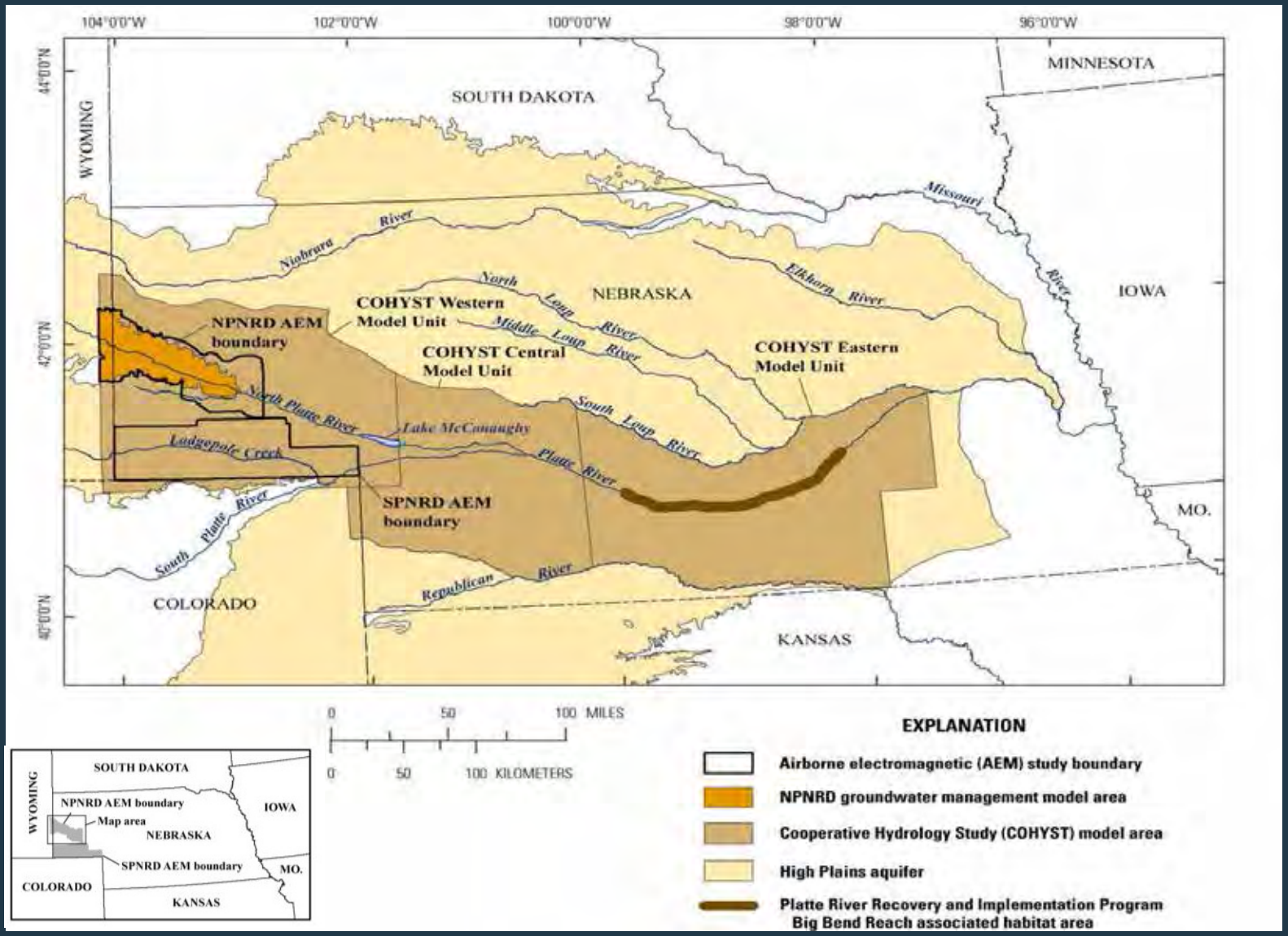
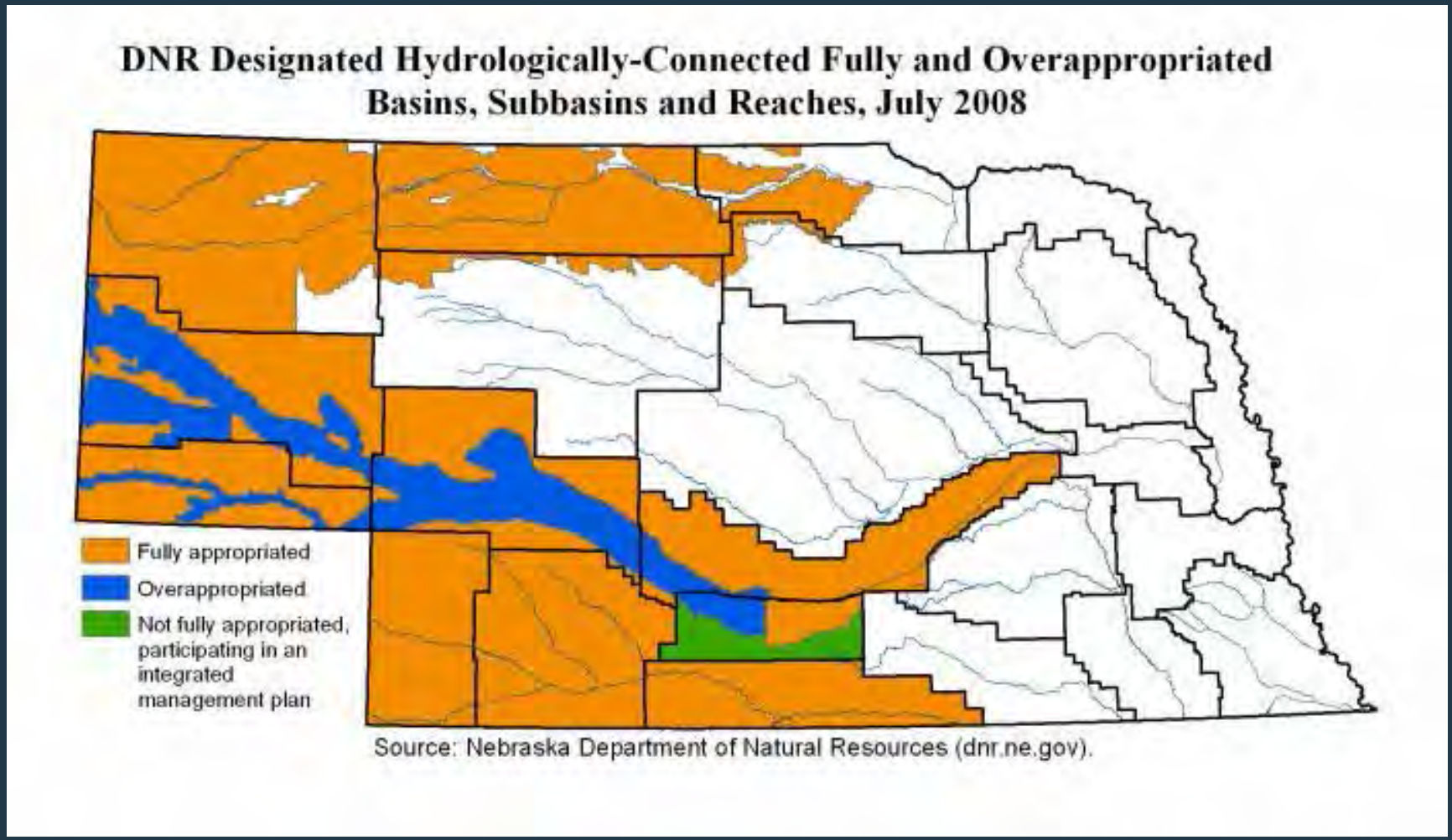
Study Location and Groundwater Models in the Area



Appropriated Designations

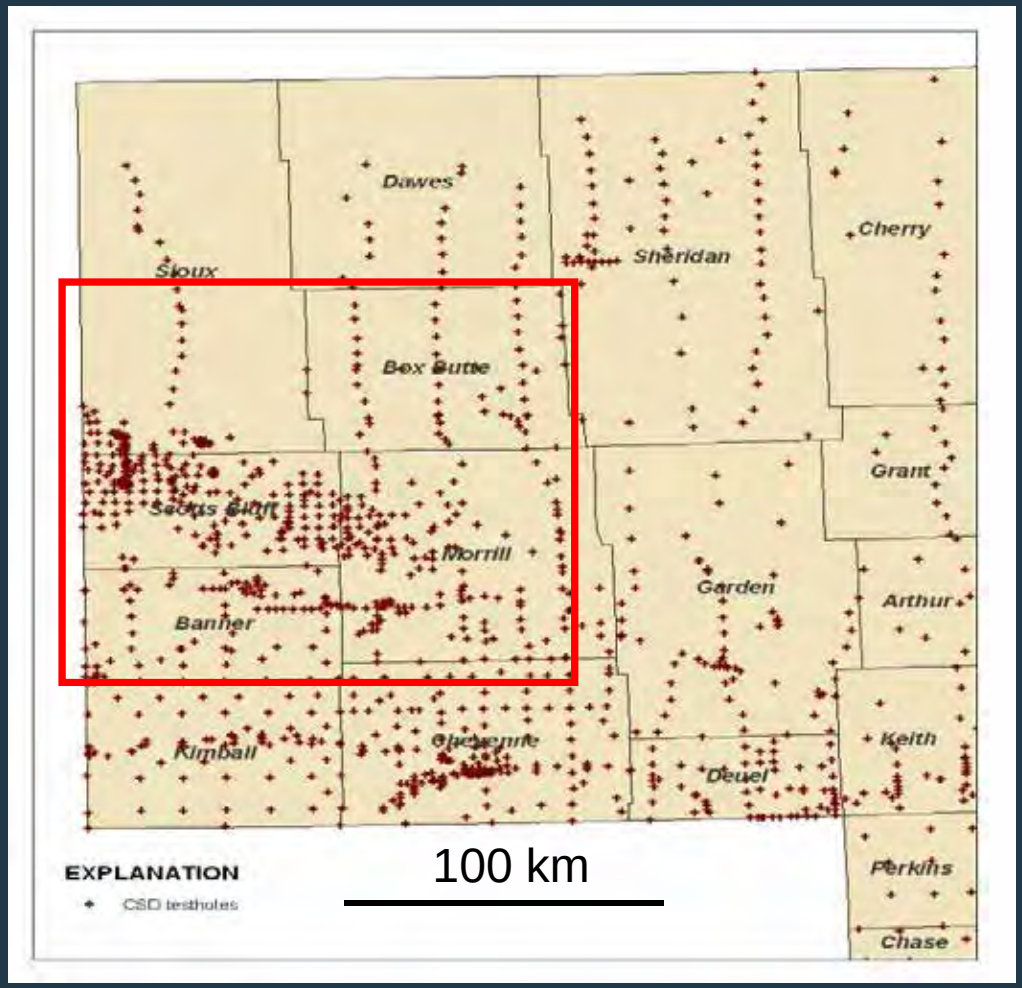


Model Background

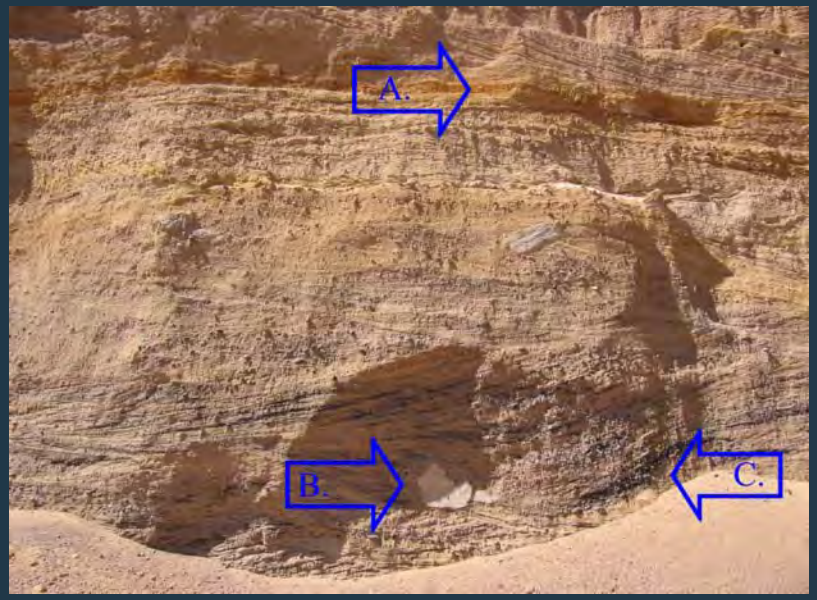
- Main objectives:
  - Analyze effects of water management options
  - Study area includes the area within the valley just downstream of Bridgeport west to ~ 10 km into WY
  - Covers the majority of the surface-water irrigated area within the NPNRD
  - Analysis goals: determine what kind of management activities provide irrigation season flows (greater than X) past Bridgeport?

Motivation for Enhancing Hydrogeologic Frameworks

- Traditional techniques (borehole logs, borehole geophysics, surface geophysics soundings, and aquifer tests) produced point data only.
- Point data are interpolated over long distances to create hydrogeologic frameworks.
- Groundwater models lack detail and cannot reliably resolve local variations.

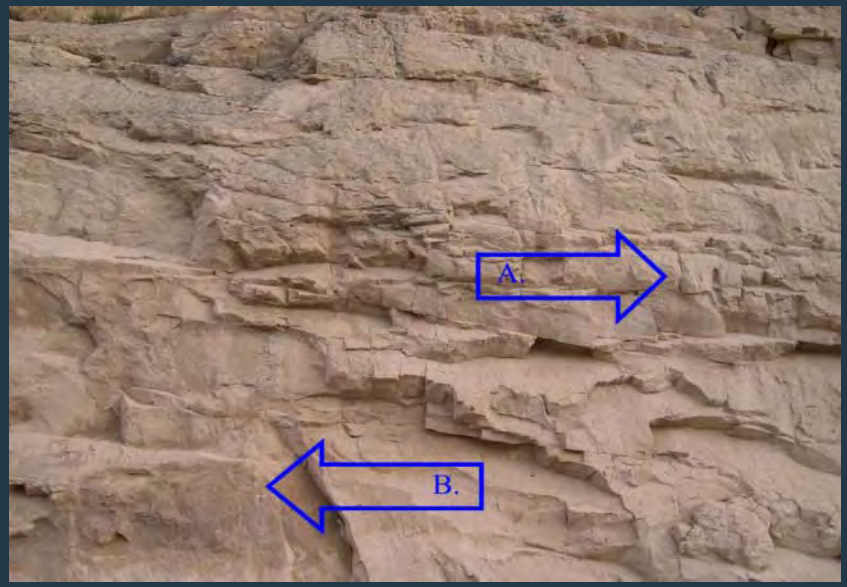


Geology and Lithology



A. Iron stained sediments
B. Siltstone clasts ~1.5 feet in diameter
C. Cross bedded, fluvial, coarse grained sediments of the Pliocene Broadwater Formation. Manganese stained sedi.

Photo taken ~ 1.5 miles north of Big Springs Nebraska facing west.



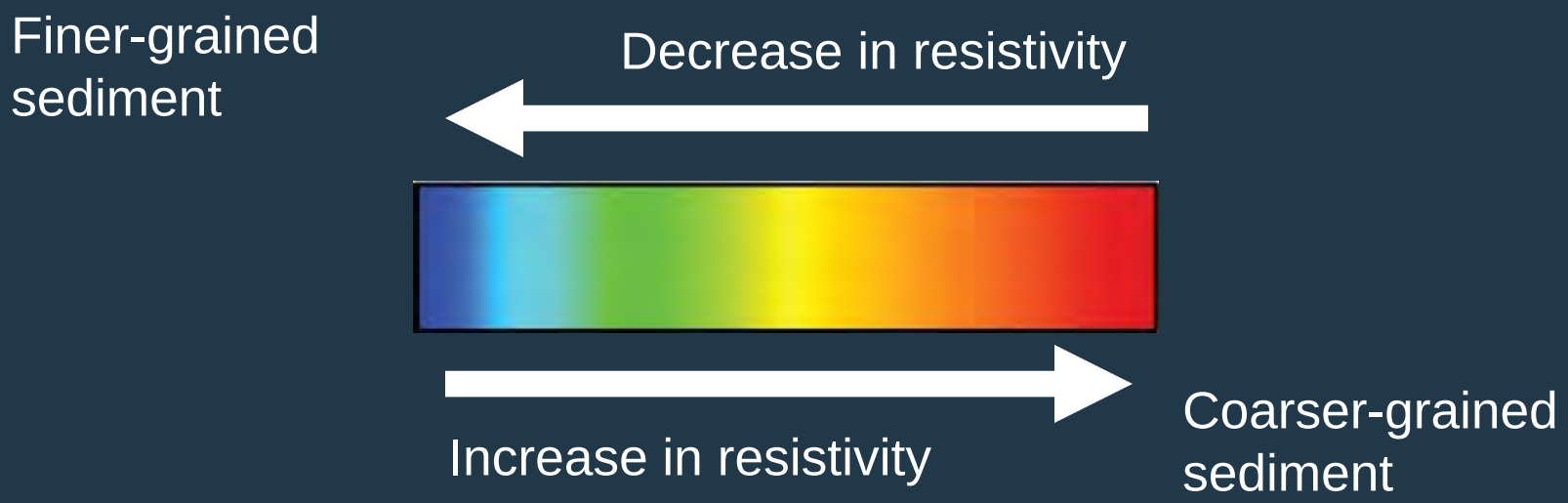
A. Tertiary Brule fractures
B. Unfractured Tertiary Brule
Photo taken along summit road between tunnels 1 and 2,

Scottsbluff National Monument, facing east.

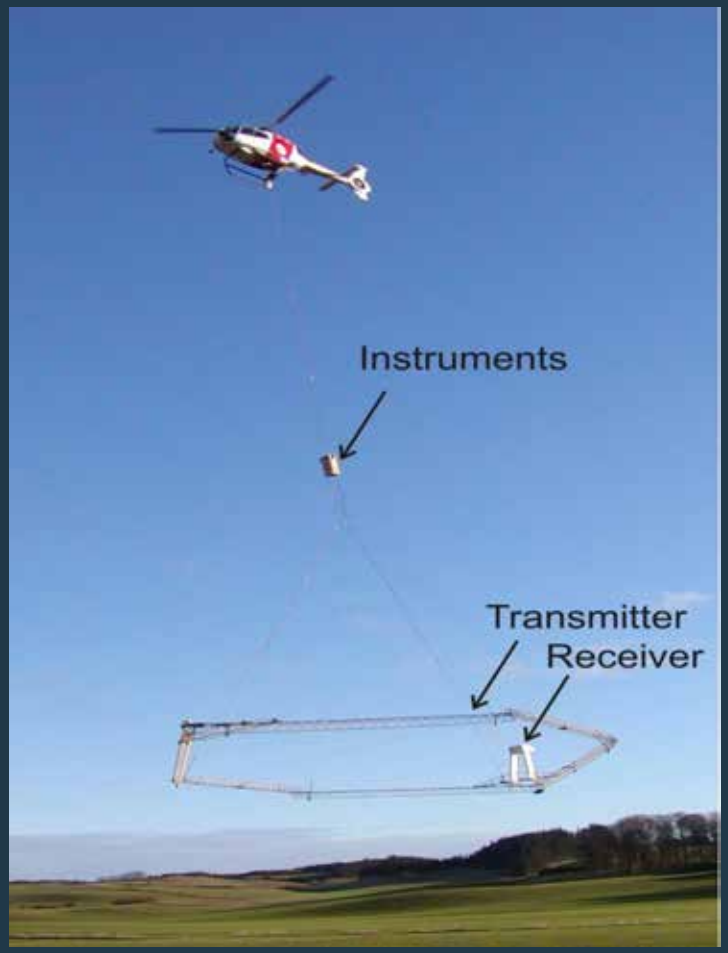
What AEM Provides to Groundwater Investigations

- AEM surveys provides nearly continuous data that can be calibrated to existing borehole logs and other mutually supportive data.
- AEM data can be quickly collected without disturbing delicate environments (e.g., arctic tundra) and economically important agricultural crops (e.g., corn and wheat).
- AEM data is more economical than ground geophysics over large areas

Resistivity Applied to Sediments



Airborne Electromagnetic Survey

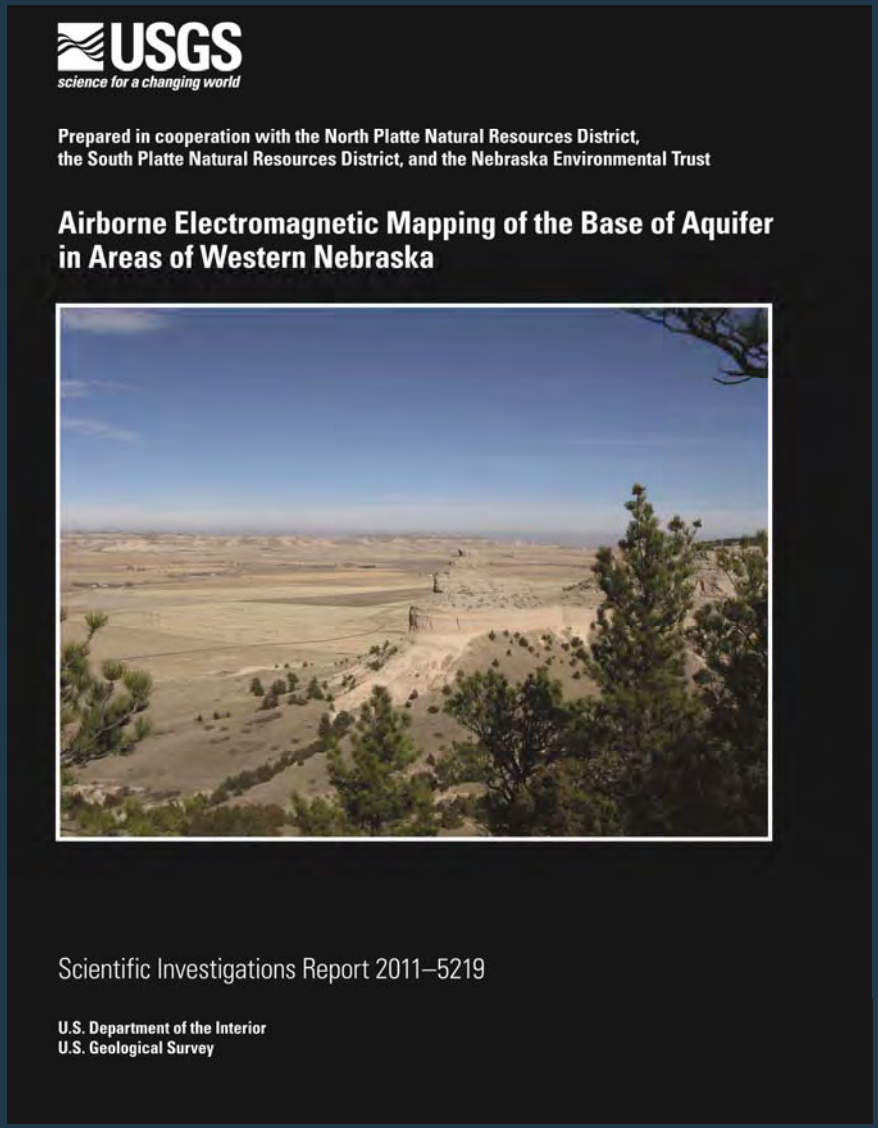


SkyTEM Time Domain System

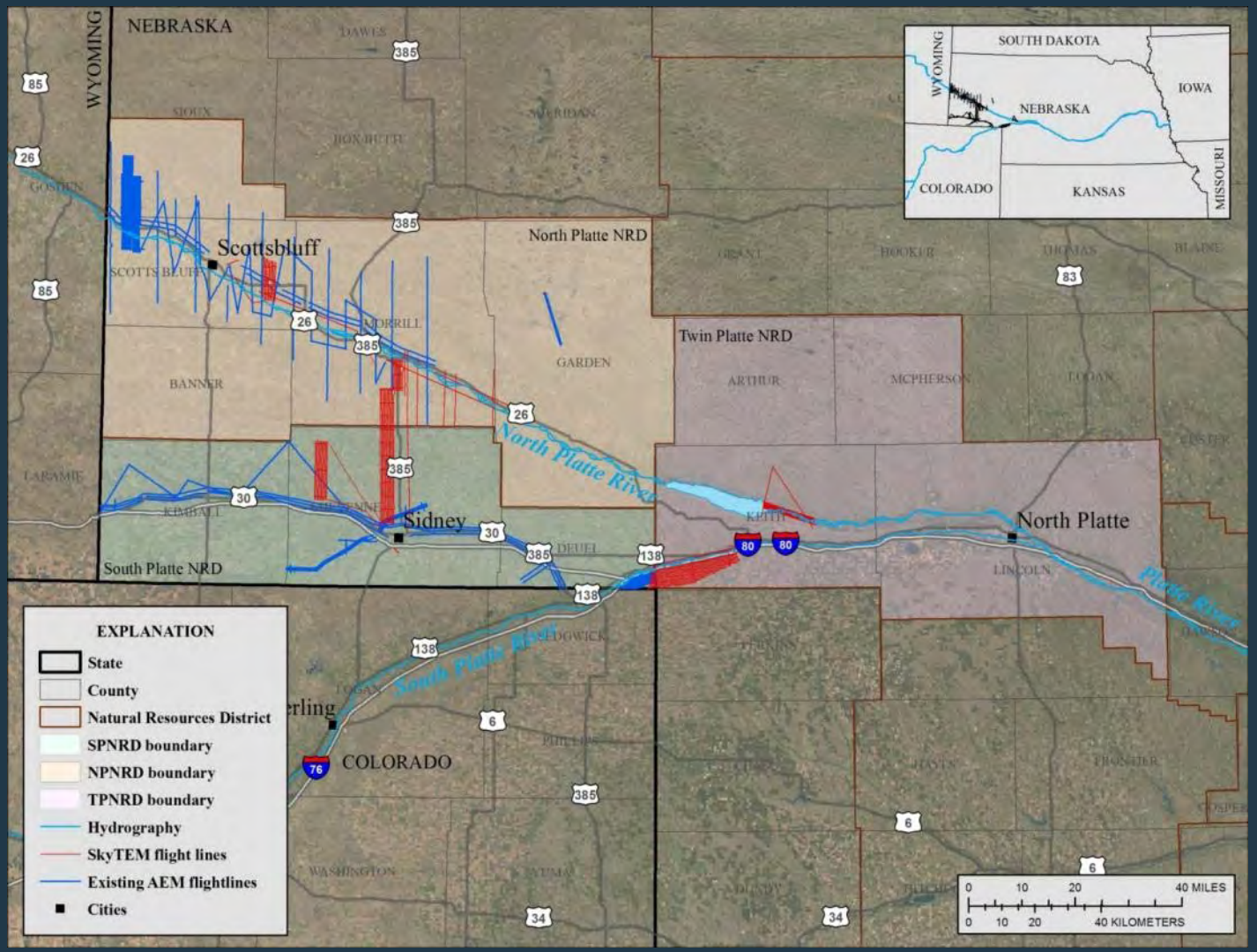
Fugro Resolve Frequency Domain System

Airborne Electromagnetic Surveys

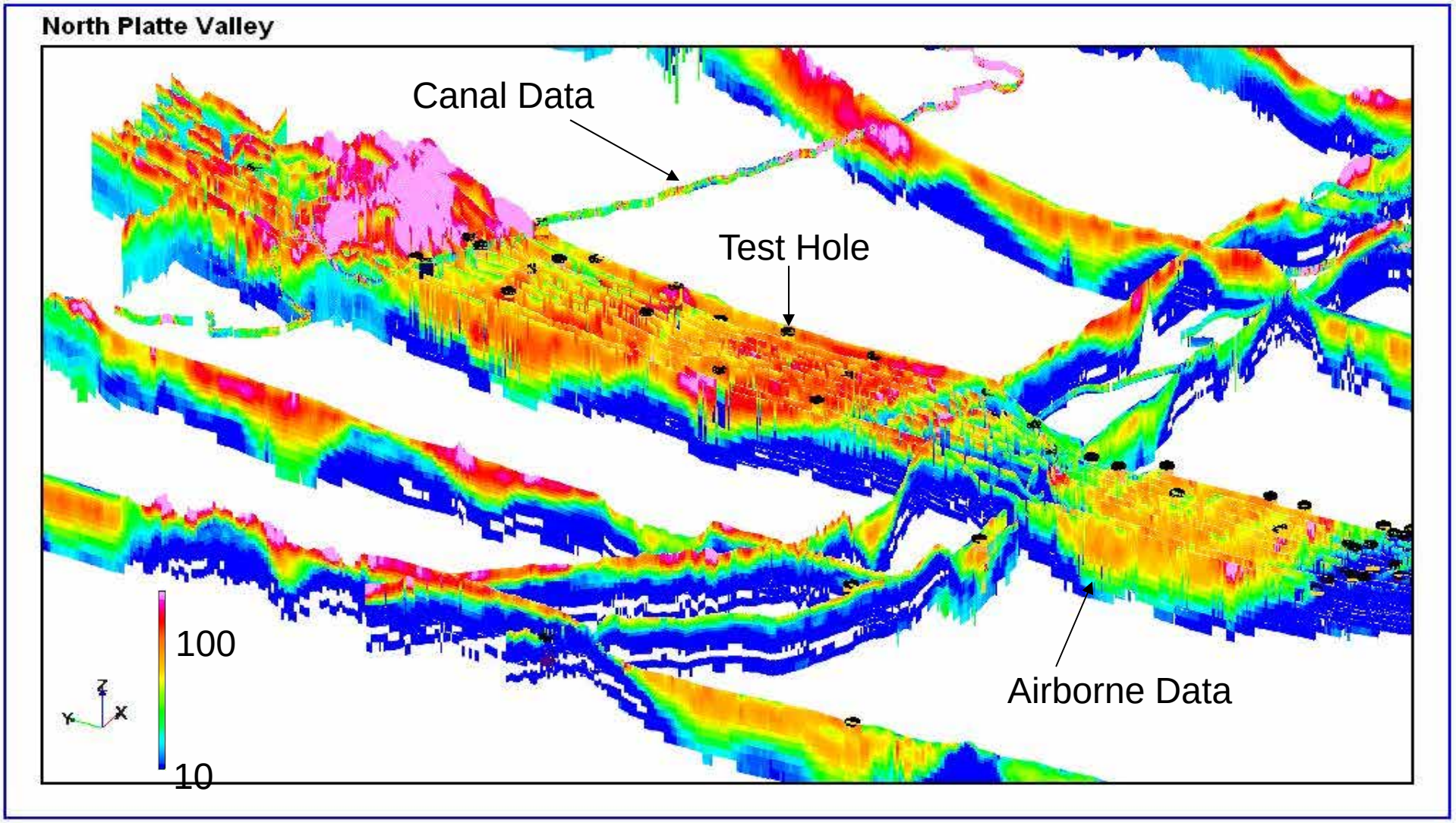
- Translating resistivity to hydrogeologic framework
- USGS OFR 2009-1110
- USGS OFR 2010-1259
- USGS SIR 2011-5219



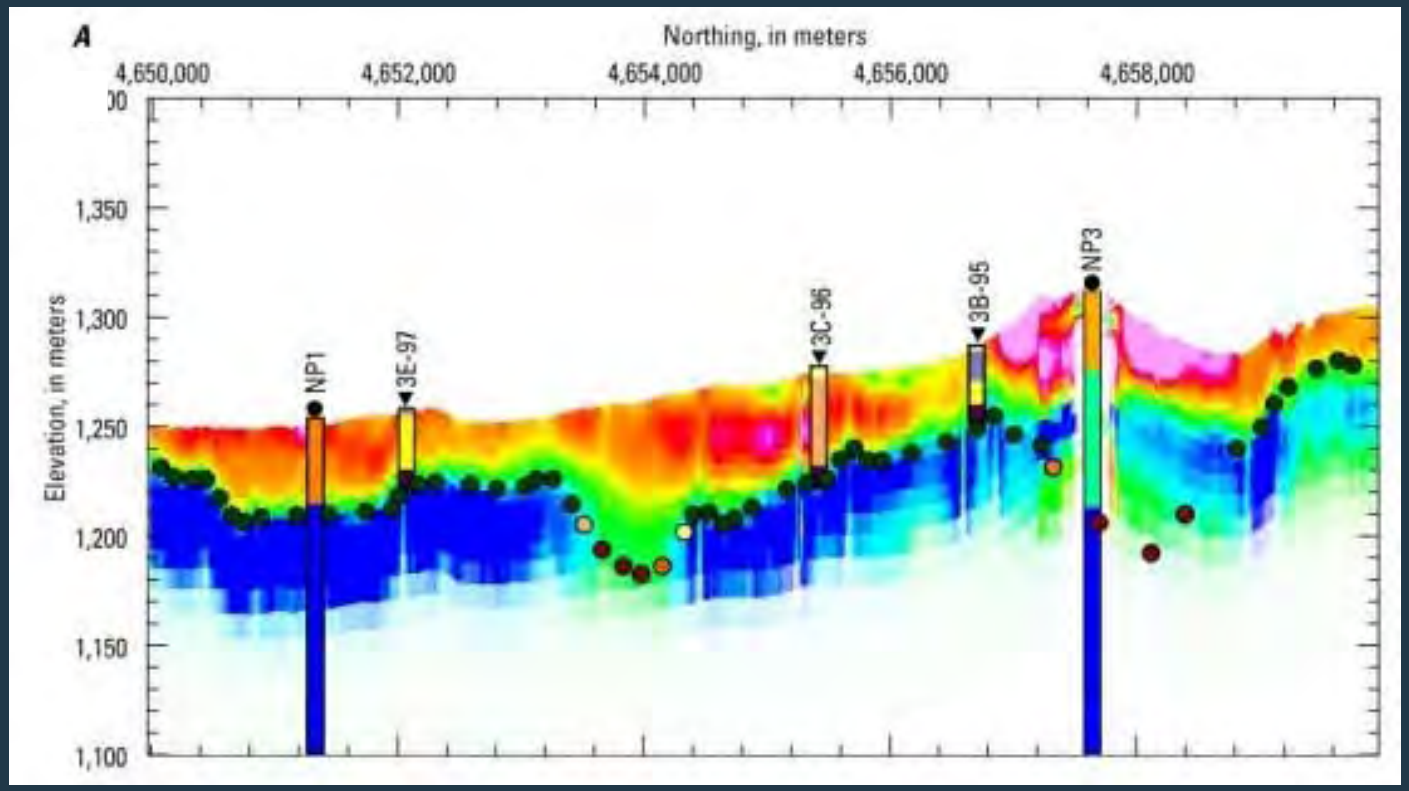
Location of Airborne AEM Surveys

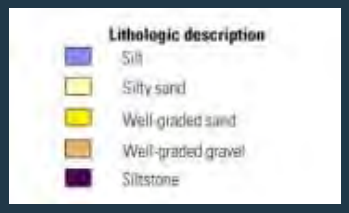


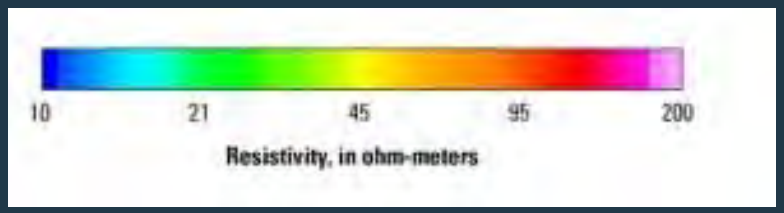
Block Flights and Reconnaissance Lines

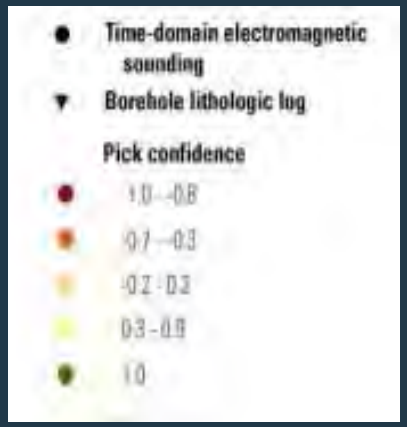


Interpretation of EM Inversions (displayed as 2-D Section)









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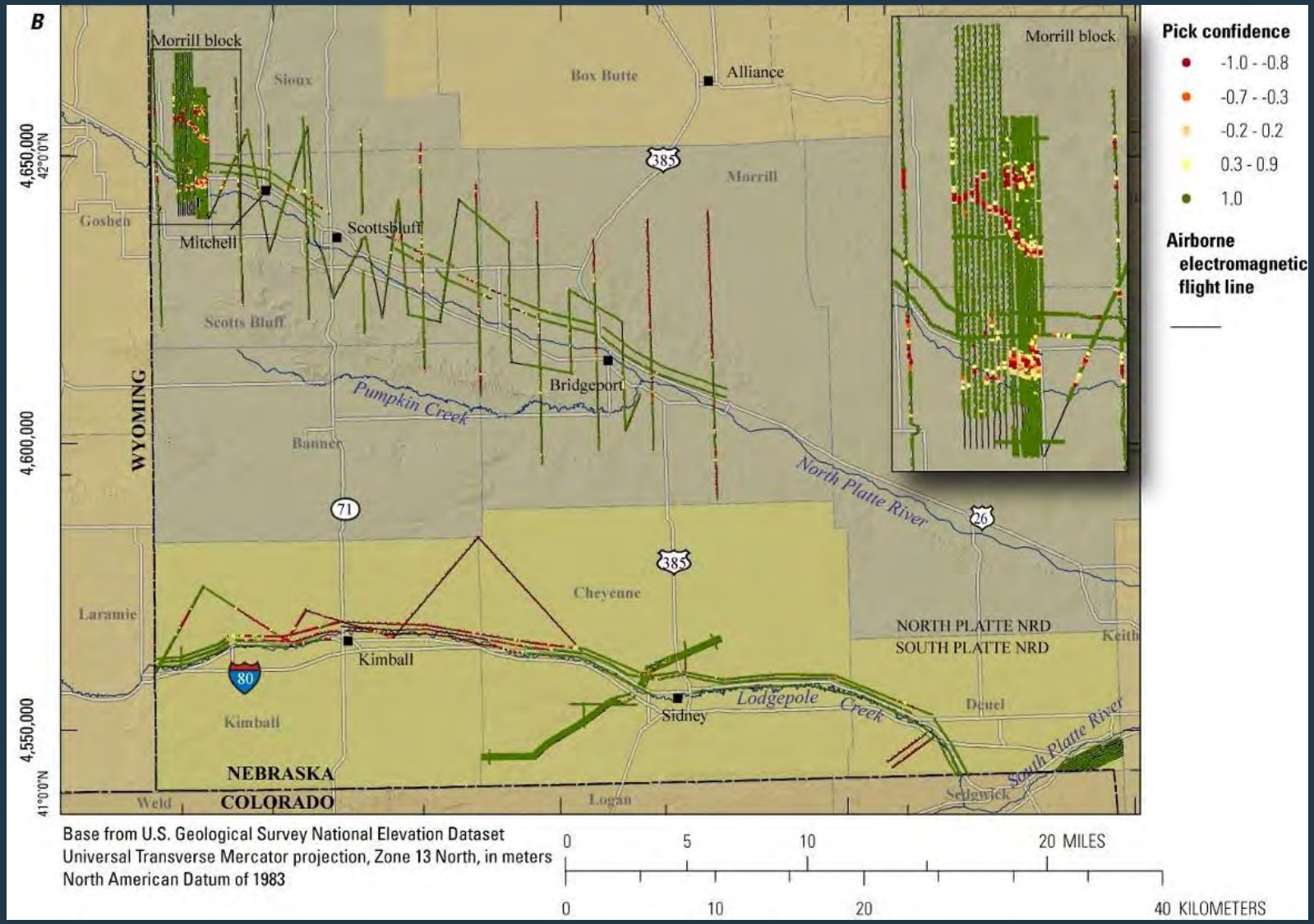
Pick Confidence



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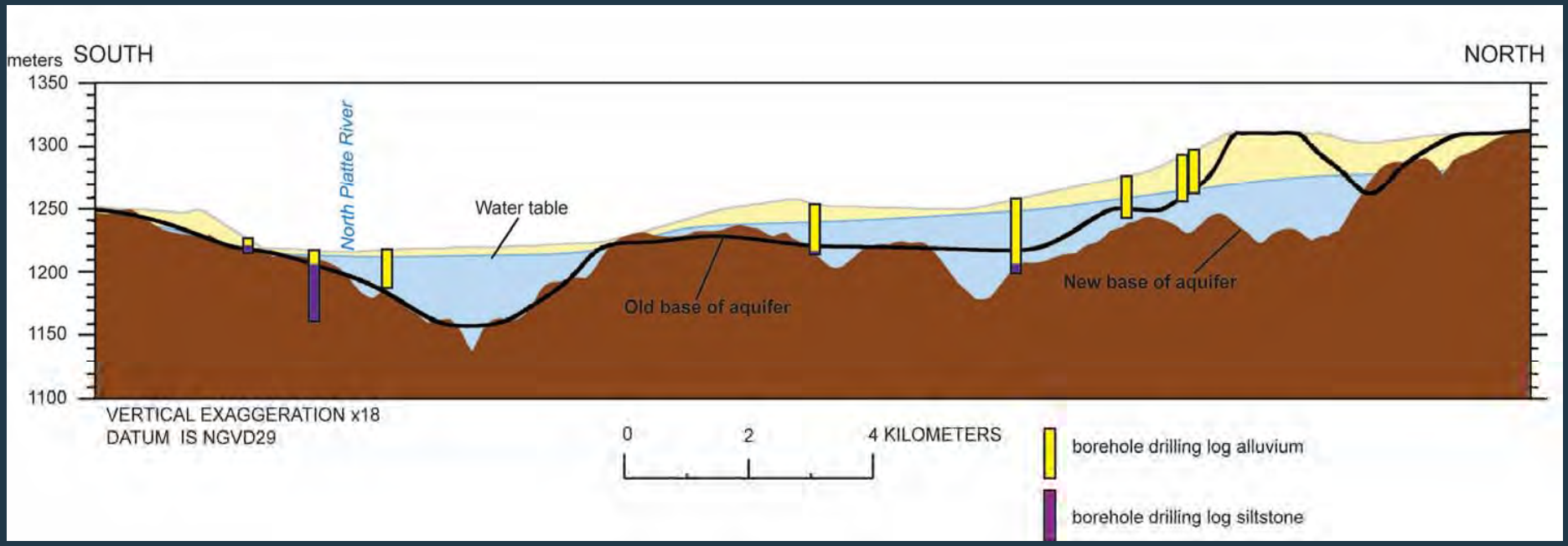
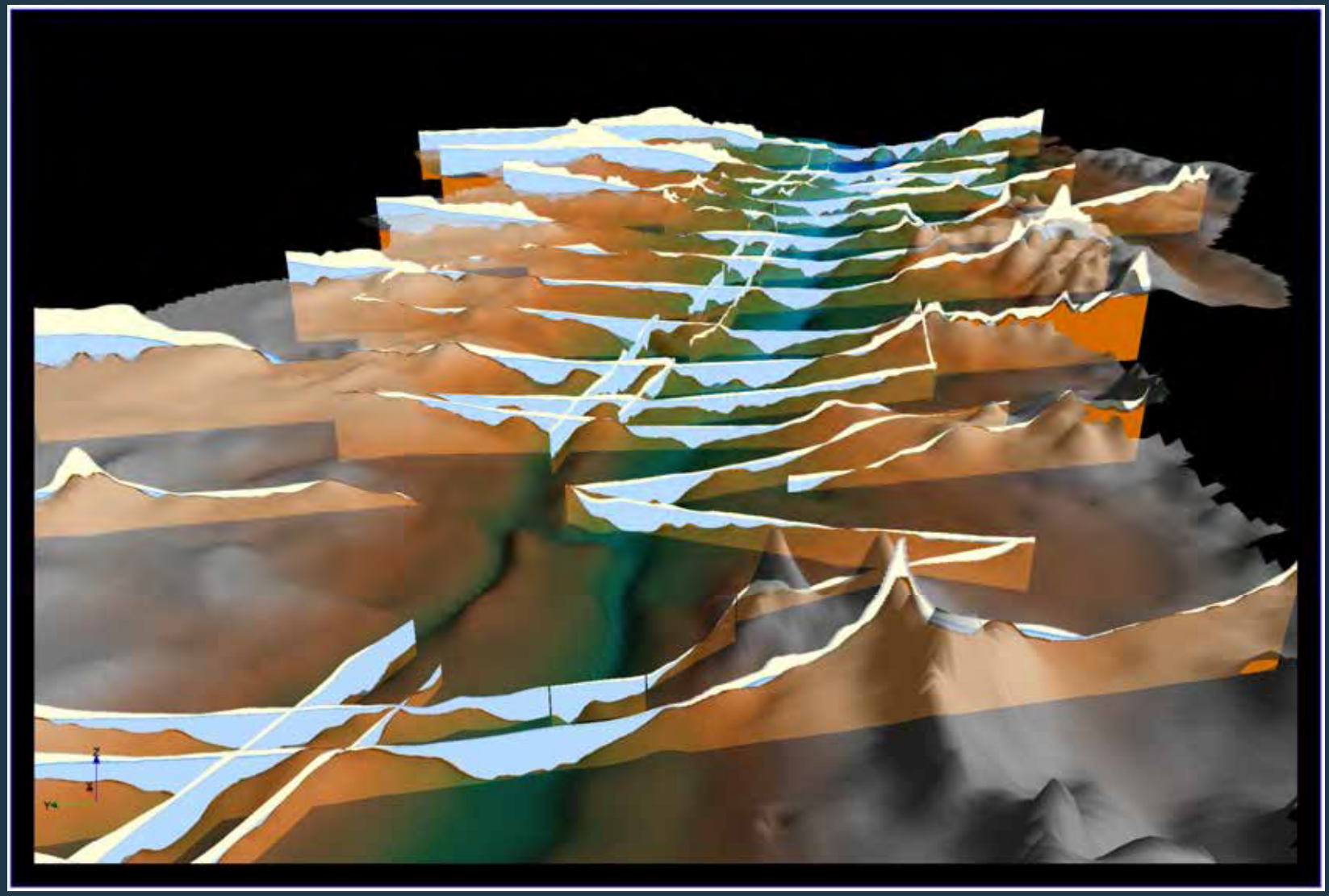
Results of Interpretation



Selected Sections from 3-D Model



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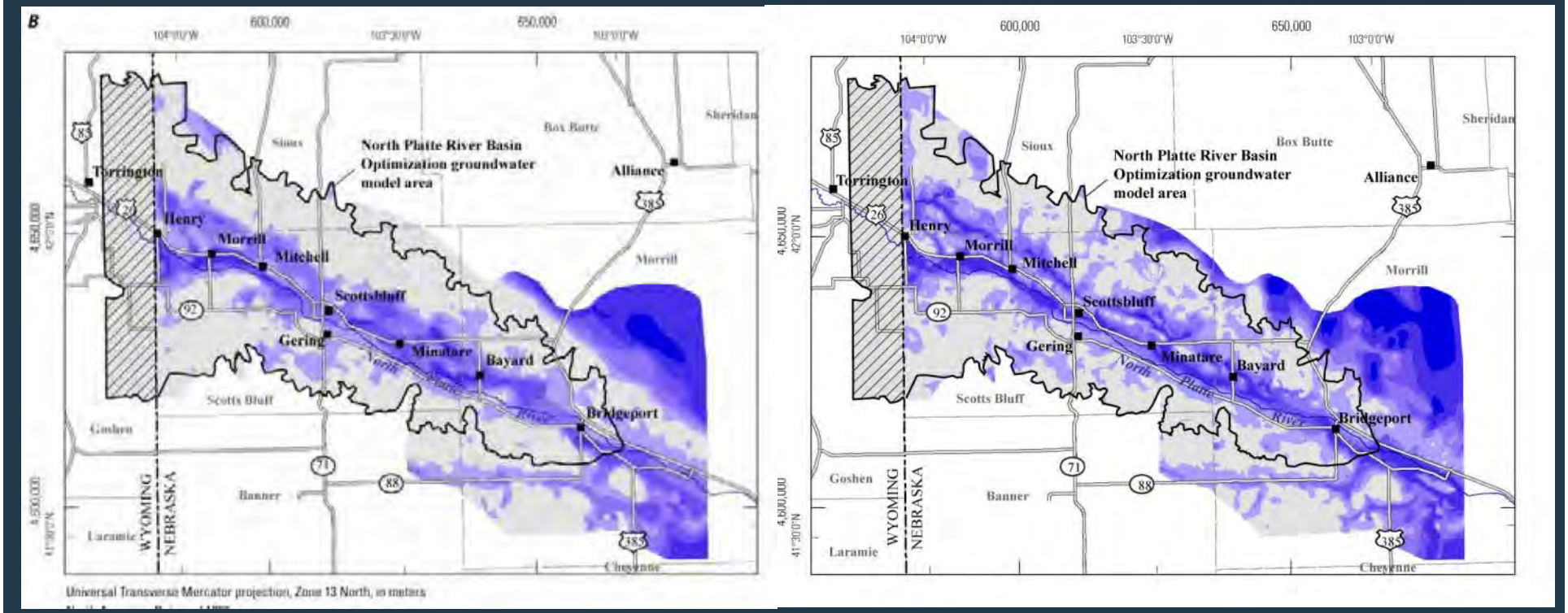
Change in Saturated Thickness

Previous Saturated Thickness

New Saturated Thickness



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For the area of the airborne geophysical surveys, an additional 458 gigaliters (GL)
(3.7 million acre-feet)
of water in storage was identified or 34% additional water in storage

~$124 million USD

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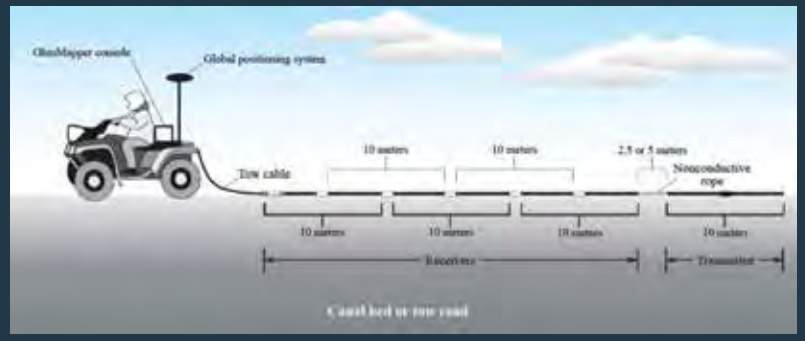
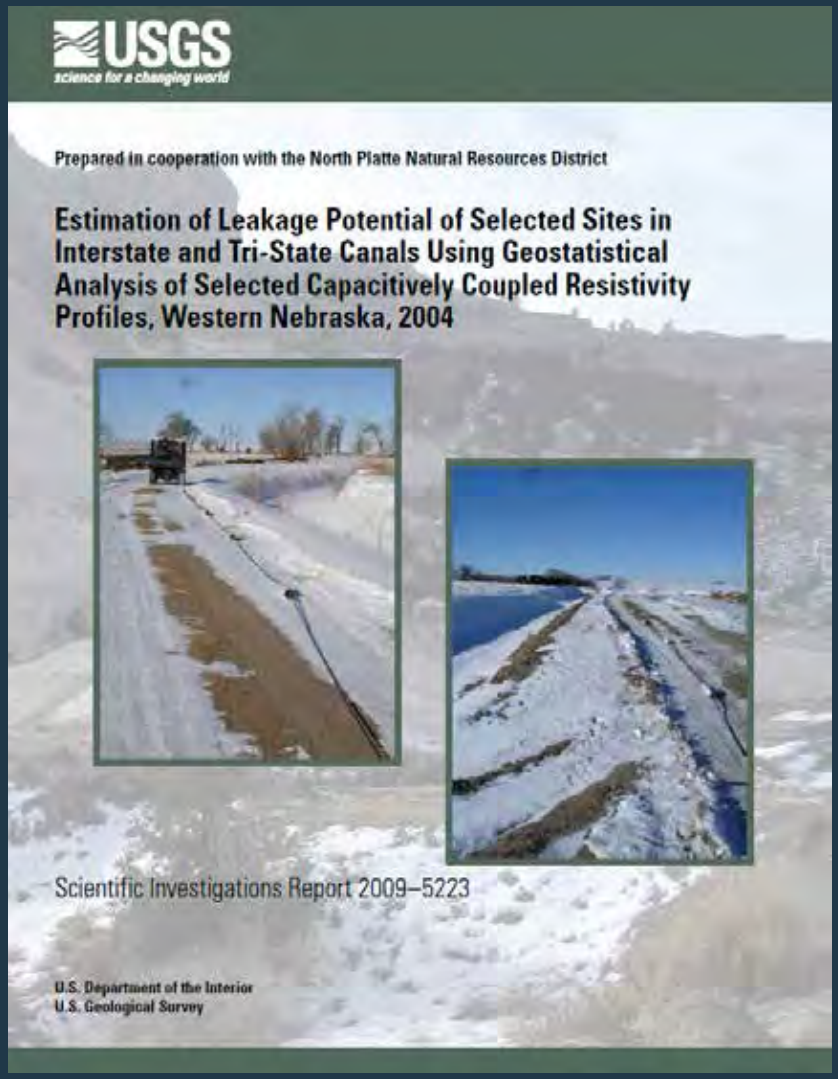
Canal Leakage Potential



- Translation of resistivity to leakage potential
- USGS SIR 2006-5032
- USGS SIR 2009-5194
- USGS SIR 2009-5223
- USGS SIR 2010-5226



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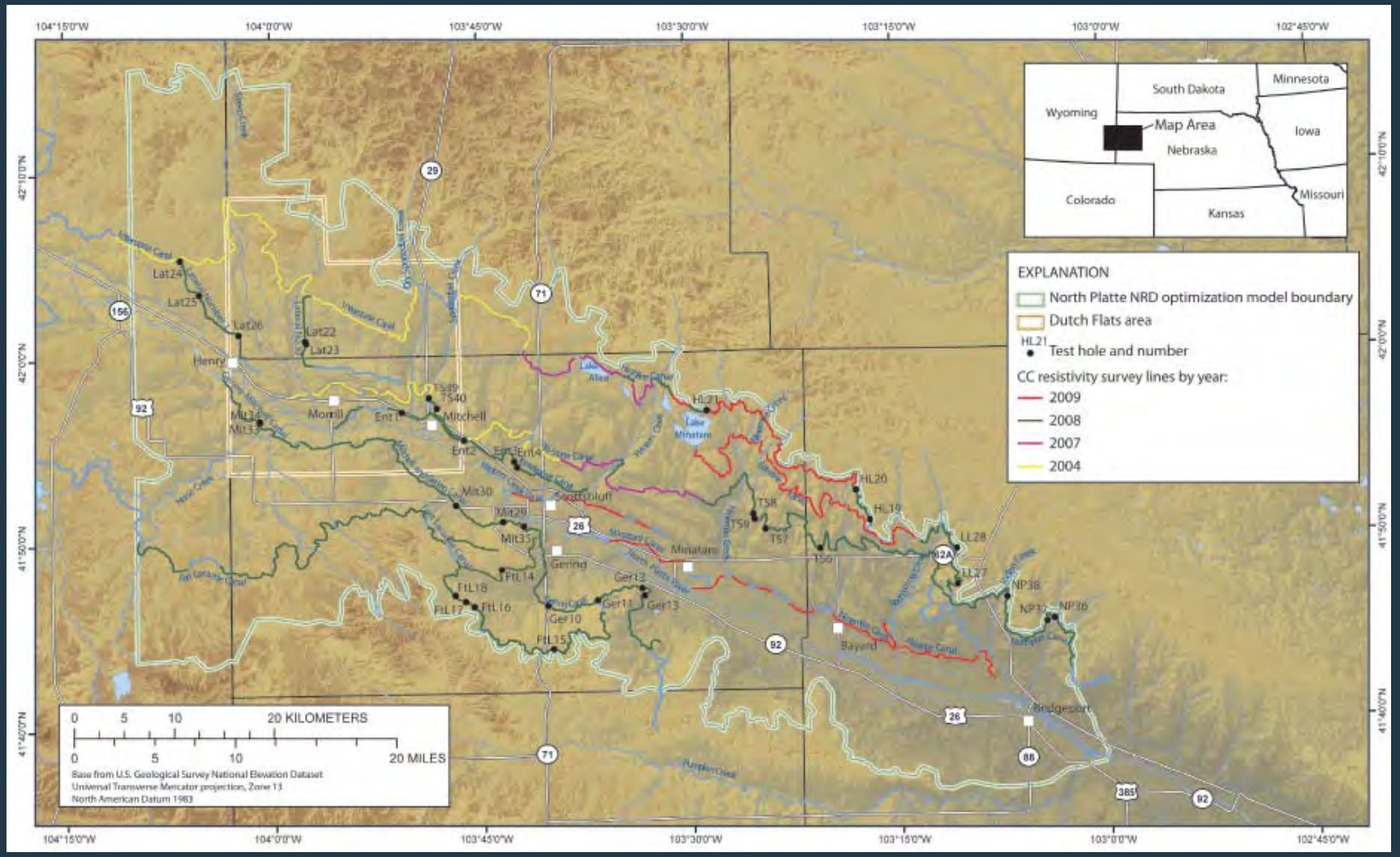
Miles of 565 km of data



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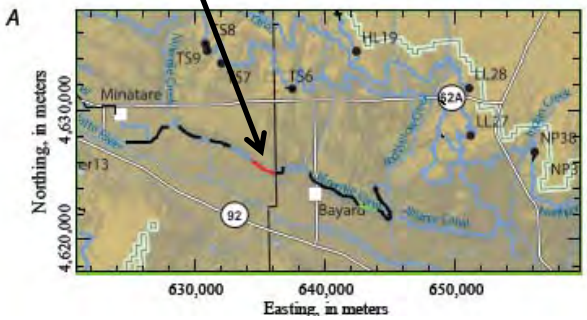
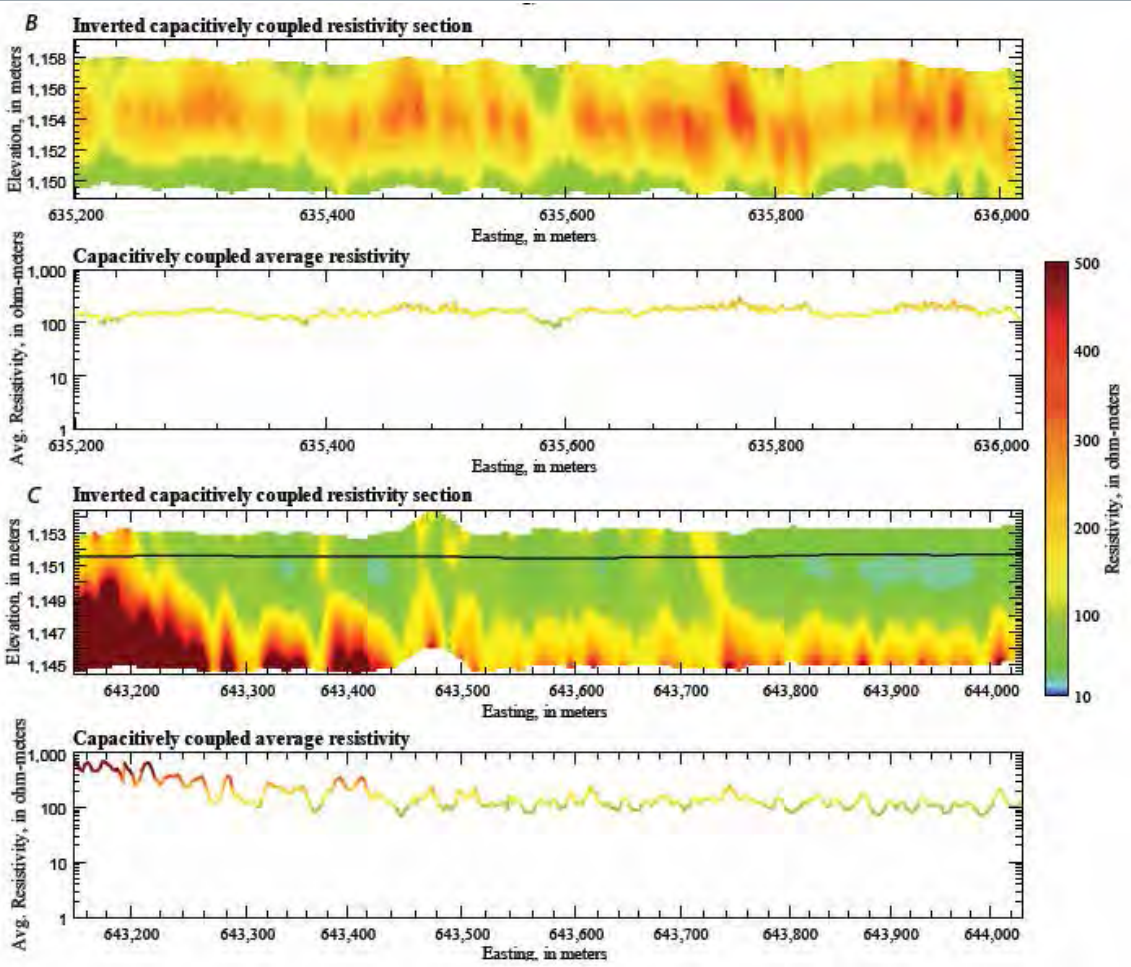
34TH International Geological Congress

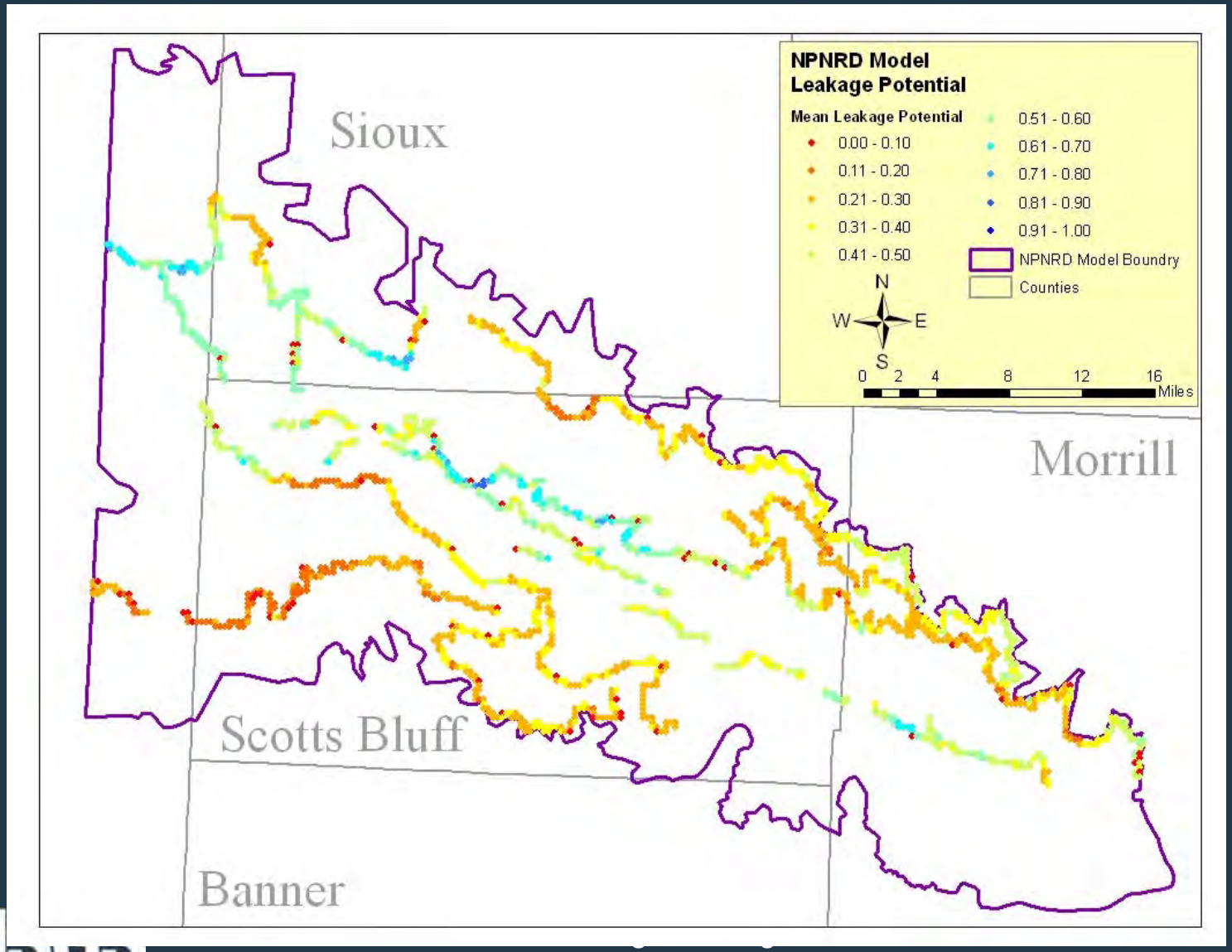
Resistivity Profile of Alliance Canal

Red indicates location of section





Canal Leakage Potential



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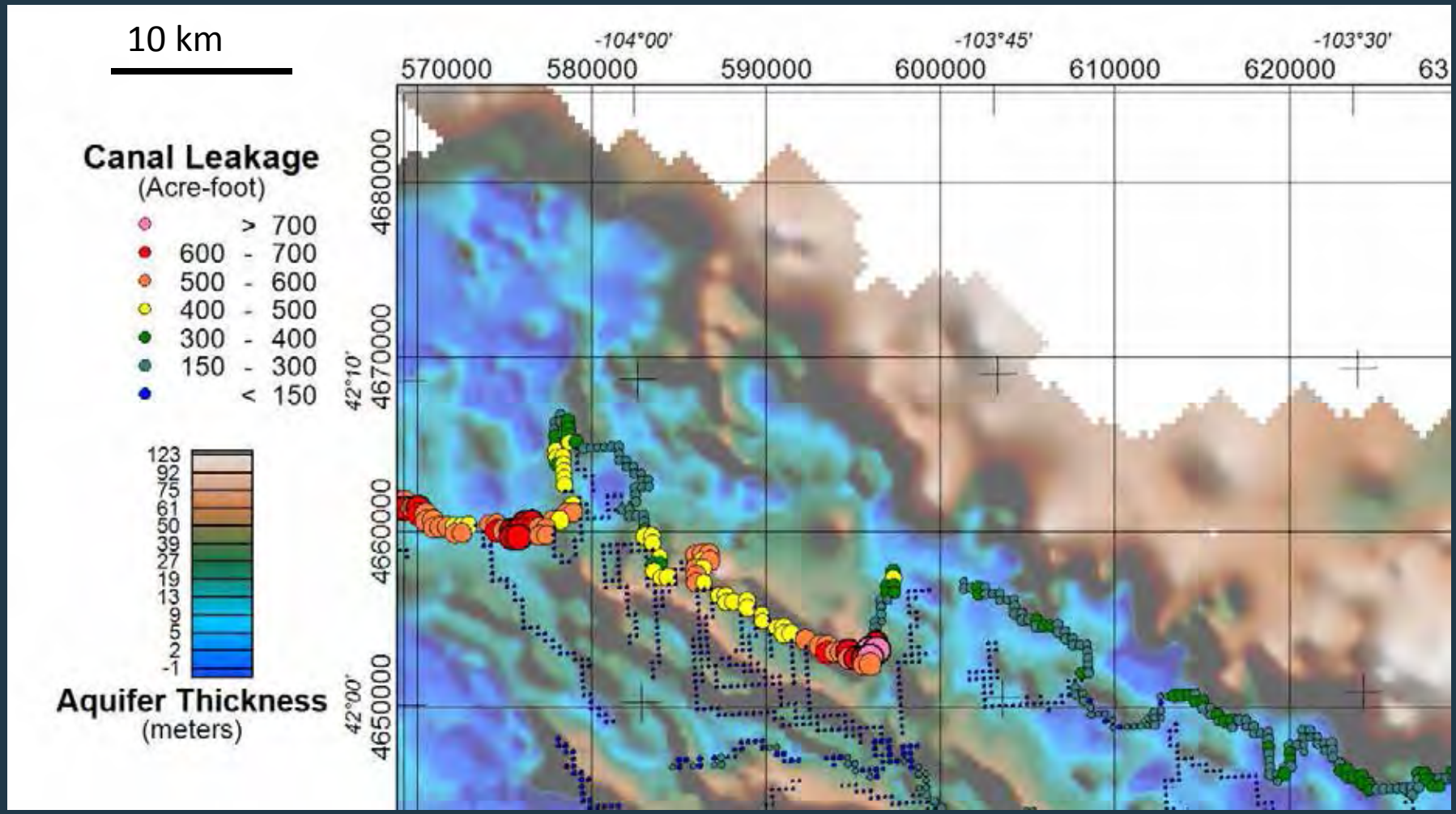
Canal Leakage



Variations in hydraulic properties

Tertiary Ogallala
Clay, silt, sand, gravel,
Claystone, siltstone,
sandstone, conglomerate

Up to 150 meters thick

“The trash can of the Rocky Mountains”

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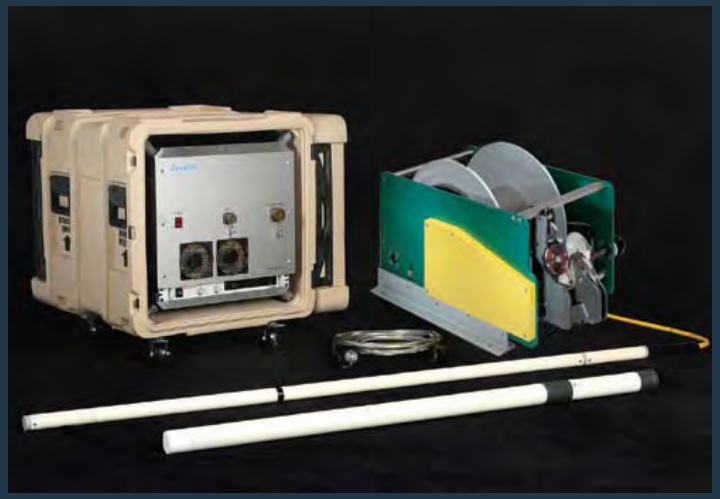
NMR Systems



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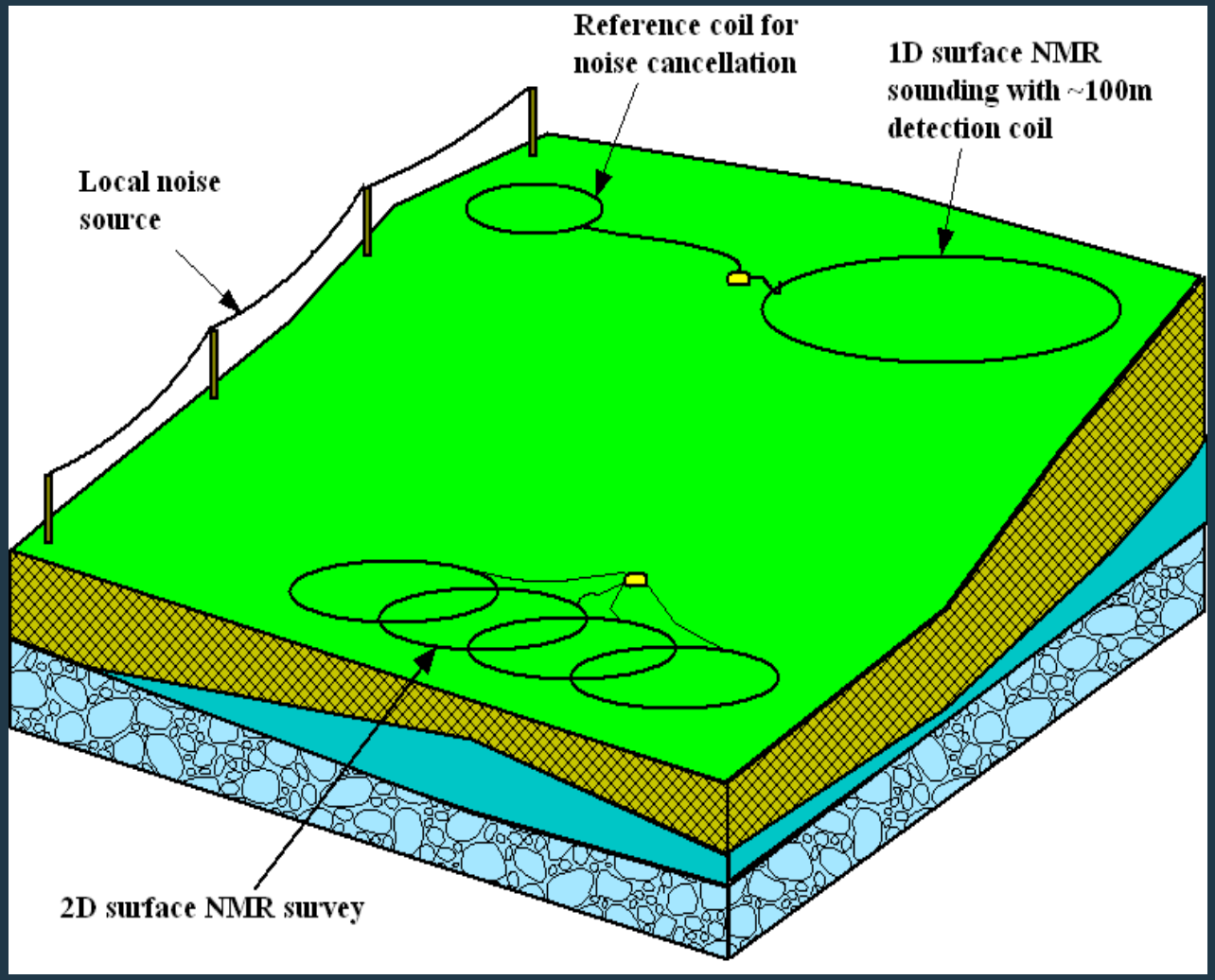
Surface NMR Layout



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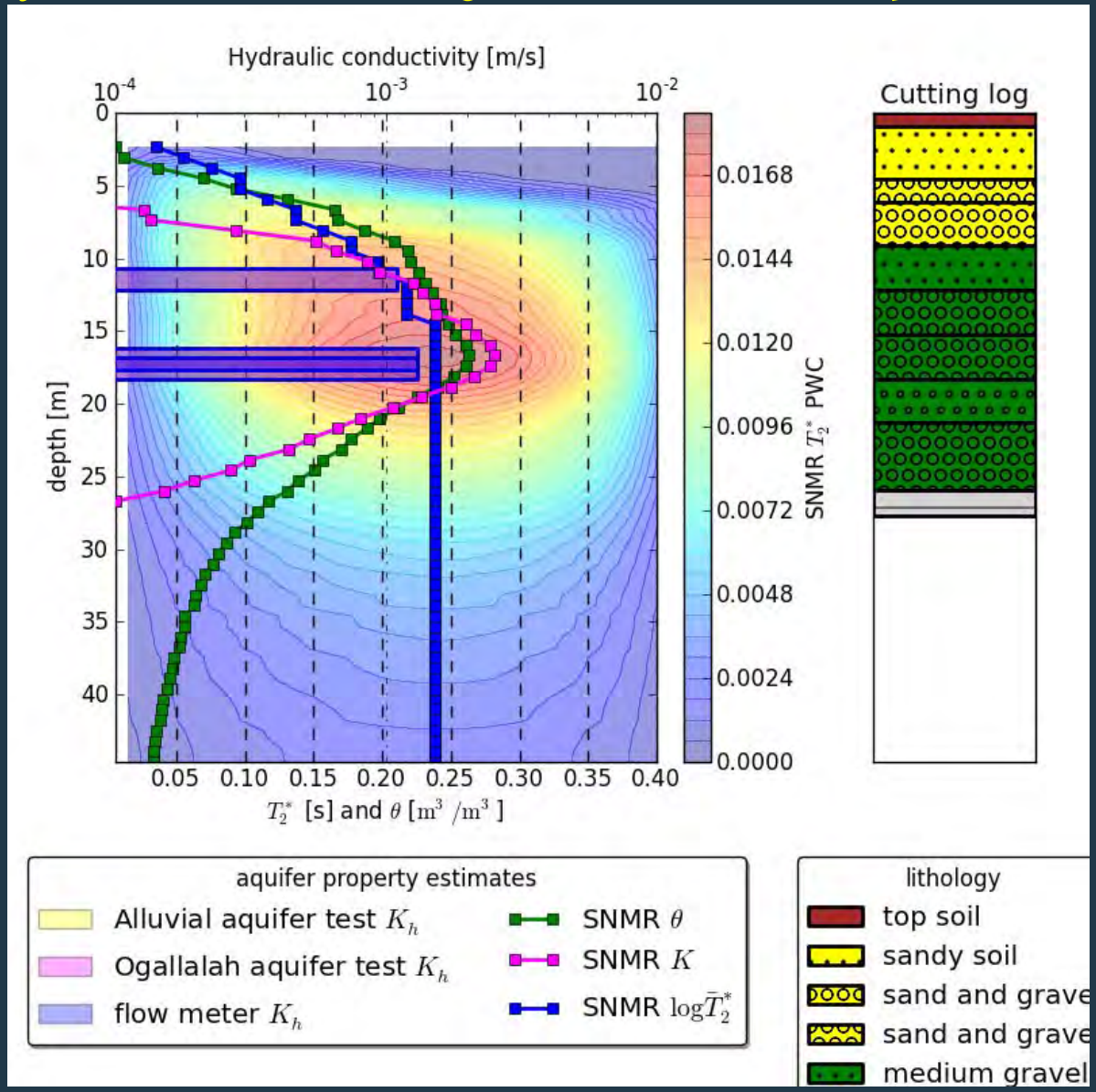
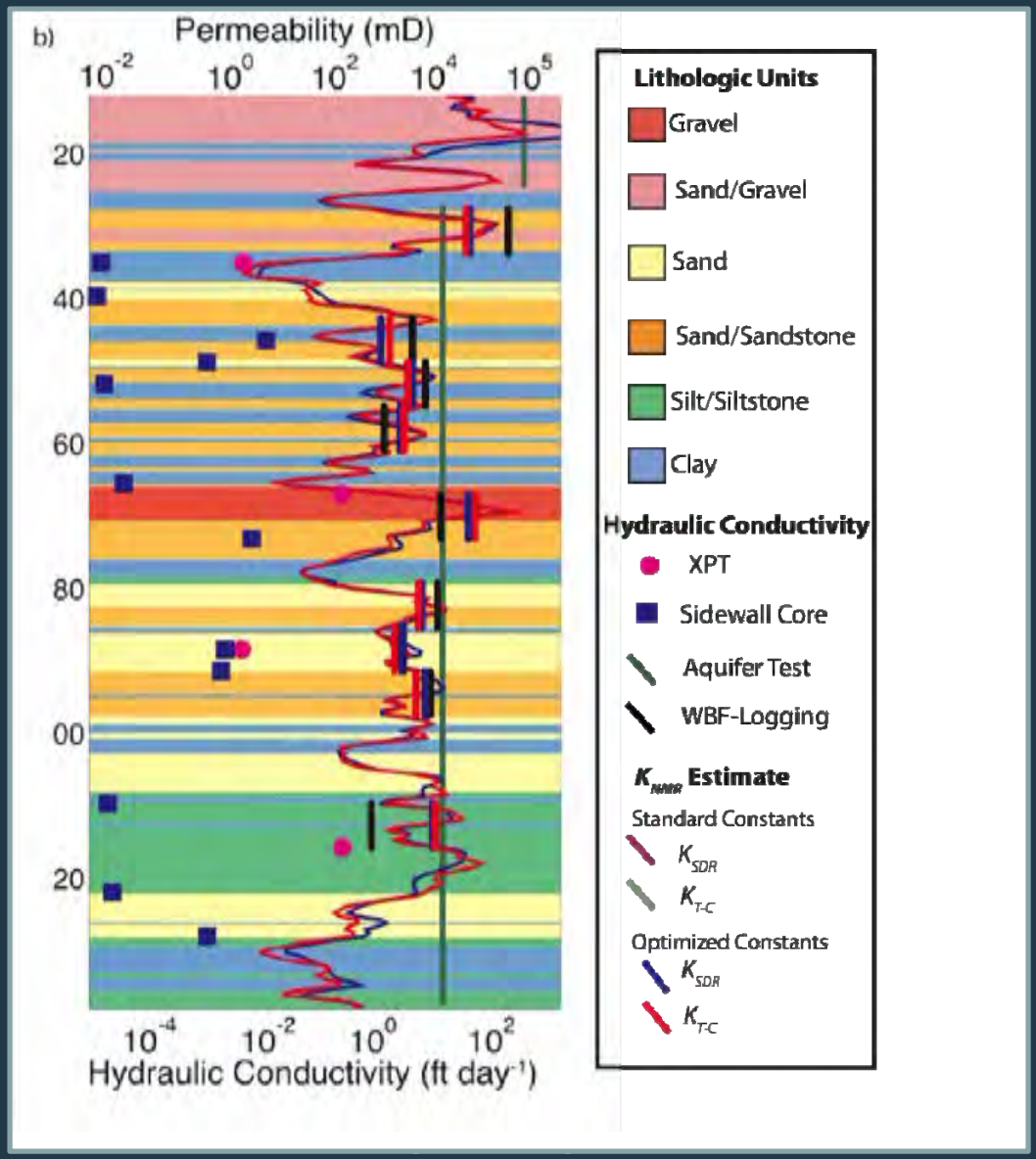
Surface NMR Hydraulic Properties



Borehole NMR Hydraulic Properties

Dlubac and others, 2012



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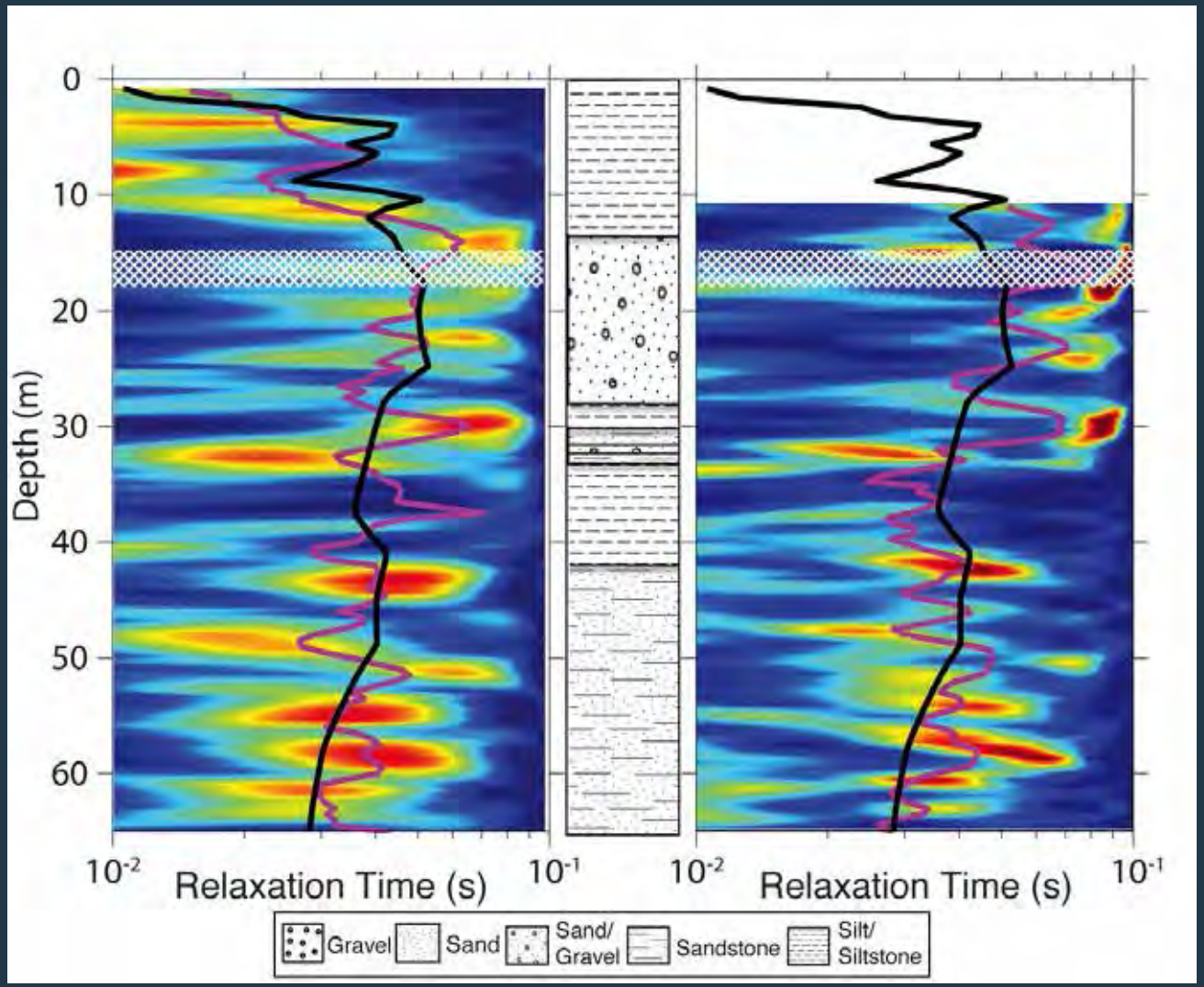
Borehole and Surface NMR

Knight and others, 2012



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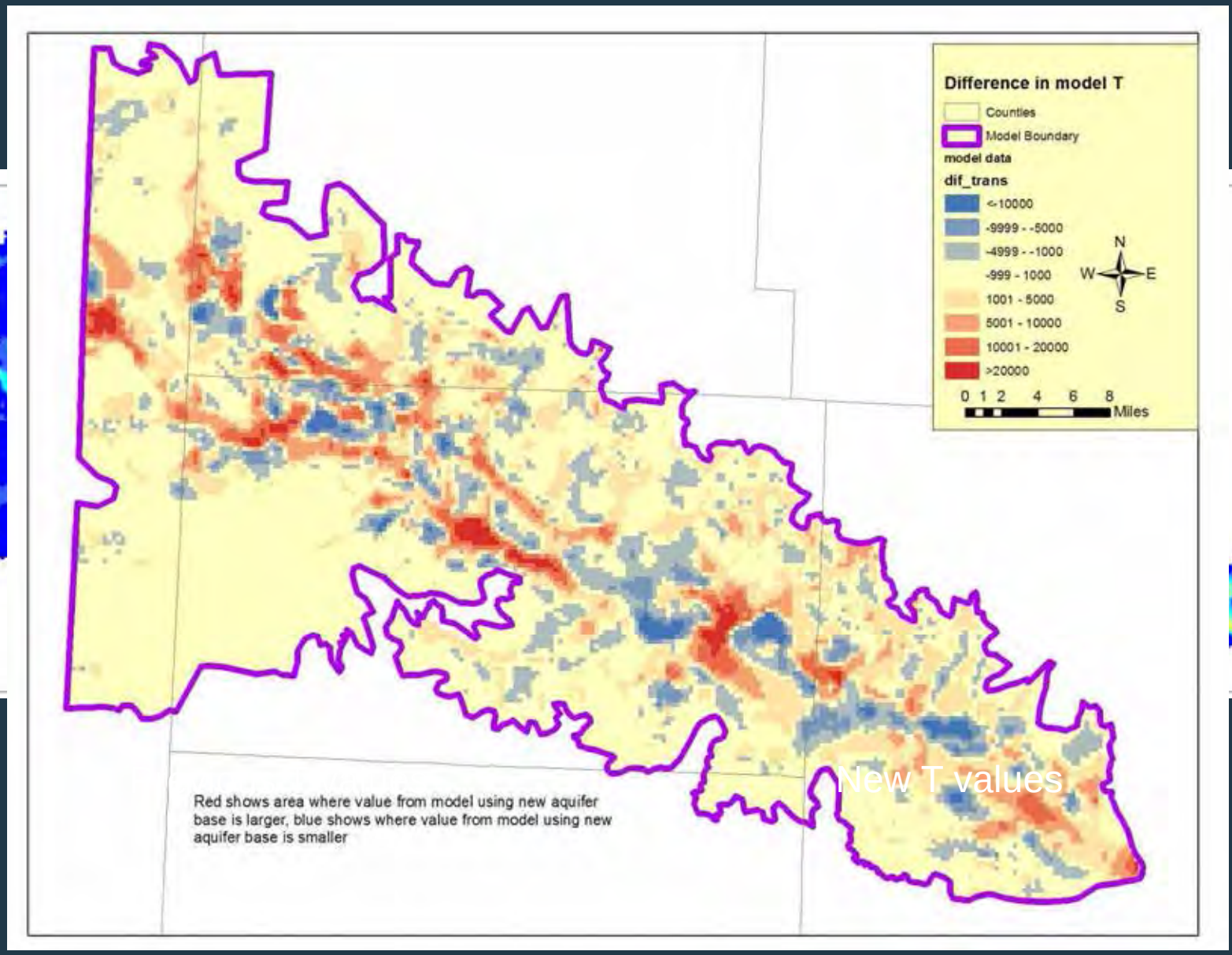
Approach- Bringing it All Together

- Use AEM data to refine aquifer base
- Use surface-geophysical data to refine canal leakage distribution applied to the groundwater flow model
- Use NMR to constrain hydraulic conductivity estimates
- Use Soil-Water Balance Model to estimate rangeland recharge
- Use latest in Parameter Estimation for calibration
- Use latest Ground Water Management (GWM) process for MODFLOW to perform analysis


Difference in model T
Counties
Model Boundary
model data
dif_trans
<-10000
-9999 - -5000
-4999 - -1000
-999 - 1000
1001 - 5000
5001 - 10000
10001 - 20000
>20000
N
W
E
S
0 1 2 4 6 8
Miles
New T values
Red shows area where value from model using new aquifer base is larger, blue shows where value from model using new aquifer base is smaller

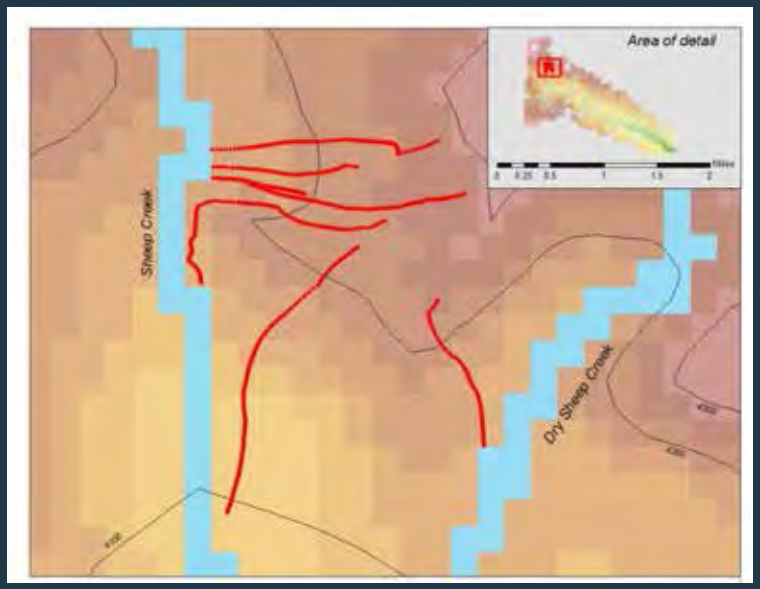
Calibration

- Groundwater flow model calibration improved when aquifer base elevations were refined using the airborne data
  - Mean residual for the North Platte River at Bridgeport was 1,274 l/sec (45 ft^3 /sec) less than the model using the previous aquifer base (this is ~10% of the average gaged flow)
  - What does this mean?
  - 1,274 l/sec (45 ft^3 /sec) also amounts to 40 Gigaliters (32,600 acre-ft) per year, or similar to the amount of some of the surface-water irrigation districts in Western NE
  - Improvement in overall calibration of simulated: predevelopment steady state water levels and stream base flows as well as transient development period water levels and stream base flows for 1950-2008

Flow paths

Previous Base of Aquifer

New Base of Aquifer



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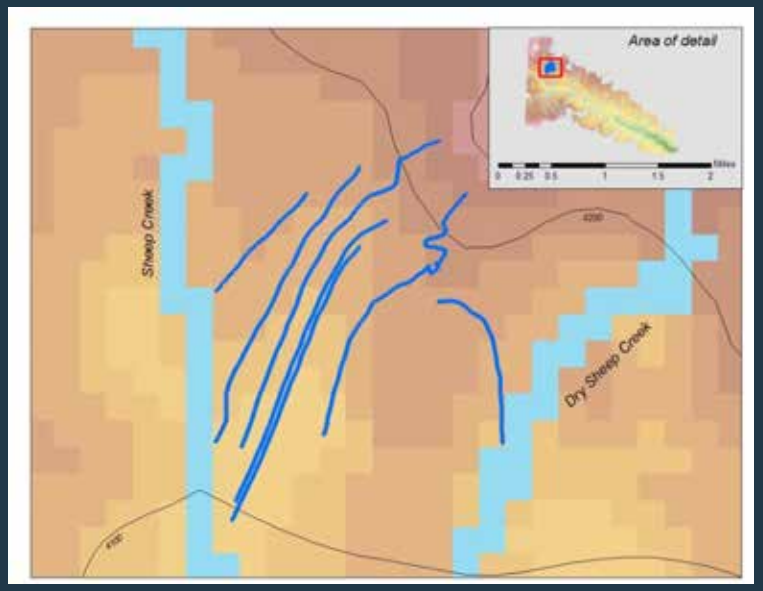
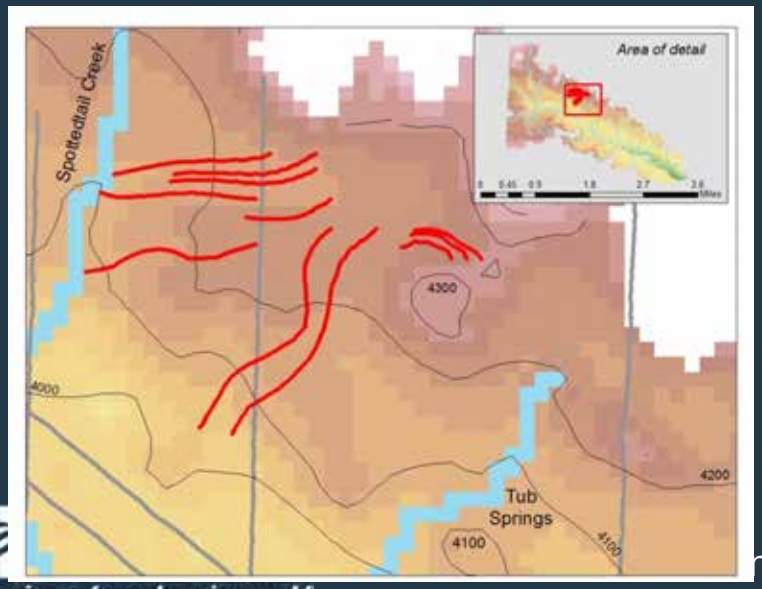
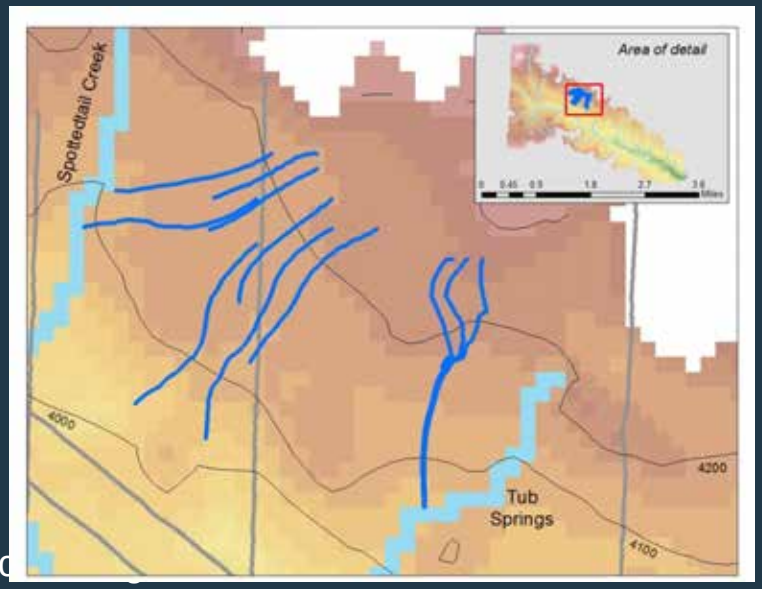
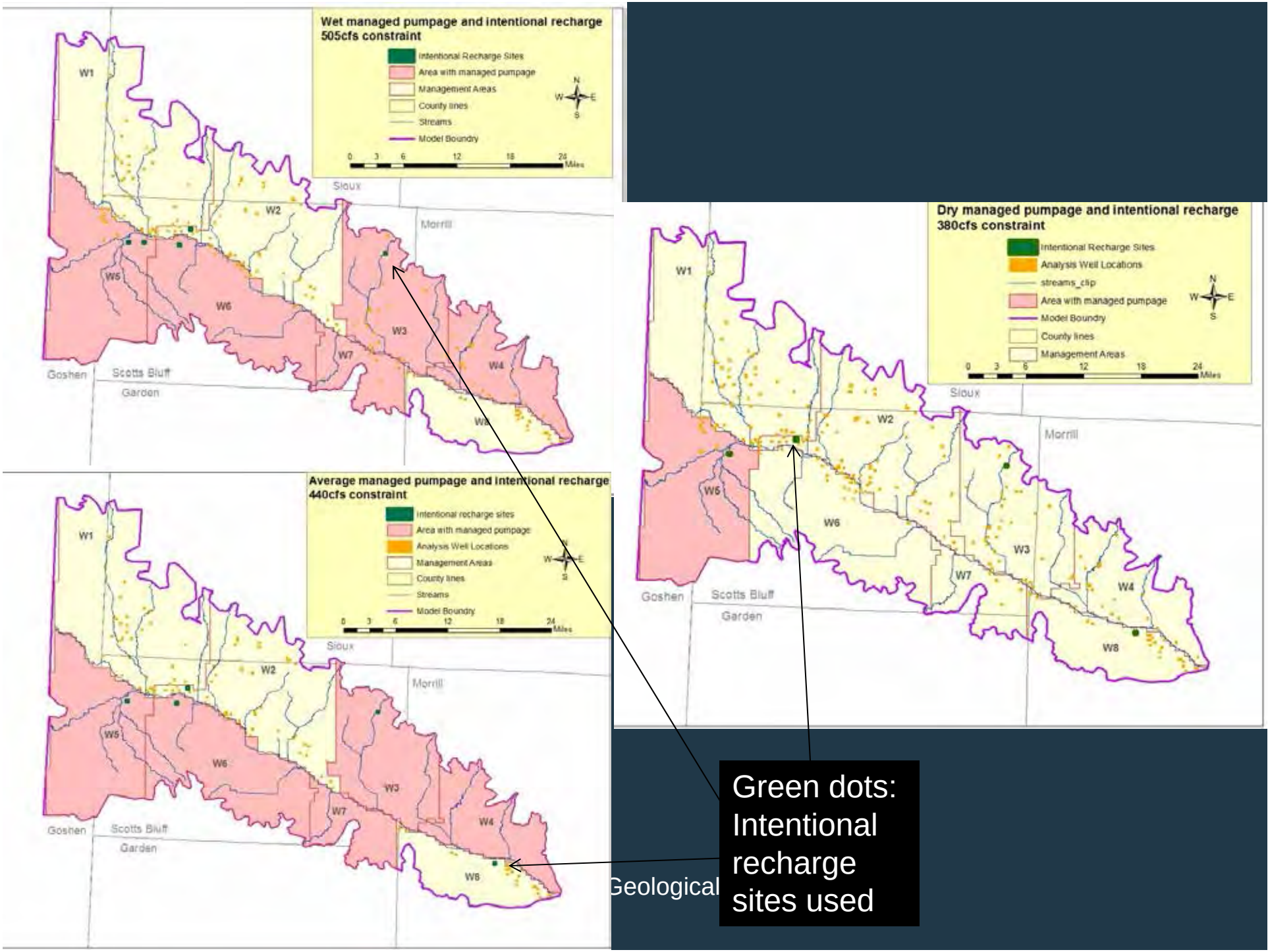




2)




Wet managed pumpage and intentional recharge
505cfs constraint
Intentional Recharge Sites
Area with managed pumpage
Management Areas
County lines
Streams
Model Boundry
Miles
Dry managed pumpage and intentional recharge
380cfs constraint
Intentional Recharge Sites
Analysis Well Locations
streams_clip
Area with managed pumpage
Model Boundry
County lines
Management Areas
Average managed pumpage and intentional recharge
440cfs constraint
intentional recharge sites
Area with managed pumpage
Analysis Well Locations
Management Areas
County lines
Streams
Model Boundry
W1
W2
W3
W4
W5
W6
W7
W8
Sioux
Morrill
Goshen
Scotts Bluff
Garden
Green dots: Intentional recharge sites used
Geological

Optimization Model Summary

- Interpretive analysis shows benefit of where to manage pumpage or intentional recharge; and what flows are infeasible

- Model accurately simulates stream base flow with a level of detail not found in previous models of the area

Geophysics HAS a role in groundwater models

- Integrate managers and groundwater modelers at the beginning
- AEM is useful for improving frameworks
- Capacitively Coupled Resistivity provides leakage estimates of canals
- Incorporating NMR with AEM improves the distribution of hydraulic properties
- The geophysics provides a representation of the natural system not achievable by other methods
- These improved models allows for greater confidence because the assumptions in model calibration are validated by observations

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Thank You

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