

Helicopter Electromagnetic Surveys for Hydrological Framework Studies in Nebraska

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Abstract

Management and allocation of water resources in Nebraska is based in part on understanding the relation between surface-water and ground-water systems. To help understand these complex relations, the U.S. Geological Survey (USGS) conducted airborne resistivity and magnetic (frequency domain helicopter electromagnetic, HEM) surveys in Eastern (2007) and Western (2008) Nebraska. These surveys were integrated with hydrologic studies (aquifer characteristics and modeling), and ground and borehole geophysical surveys to characterize and map the hydrogeologic framework in three-dimensions. The three study areas selected in Eastern Nebraska (Ashland, Firth, and Oakland) have glacial terrains and bedrock that typify different hydrogeologic settings for surface and ground water. The Eastern Nebraska Water Resources Assessment is a joint State of Nebraska and USGS study including the Conservation and Survey Division (University of Nebraska) and the following Natural Resources Districts (NRD): Lower Platte South, Lower Platte North, Lower Elkhorn, Lewis and Clark, Nemaha, and Papio-Missouri River. Approximately 600 line km were flown with HEM in each of the three glacial terrains with a line spacing of approximately 270 m and samples every three meters. One dimensional imaging was done along the flight lines for the HEM in each area. Models were compared to ground resistivity and time domain electromagnetic soundings and to borehole lithologic and geophysical logs. The map of the subsurface hydrogeologic properties inferred from the HEM modeling significantly improves the resolution of hydrologic models and understanding of ground-water resources. Surveys in western Nebraska panhandle, were done along the North Platte River and Lodgepole Creek Valleys. The geology consists of Quaternary alluvium, and interbedded Tertiary sandstones and siltstones above Cretaceous shale. The Quaternary alluvium comprises the primary aquifer in the North Platte River Valley, whereas thin alluvial sediments and Tertiary sandstone channels comprise the primary aquifers in Lodgepole Creek Valley. Locally, Tertiary Siltstone and Cretaceous shale is weathered and incised. A prominent factor in the hydrologic setting of the North Platte River Valley is recharge through unlined irrigation canals. Surveys in western Nebraska were funded by the North Platte and South Platte NRDs. These NRDs have employed the best in science-based integrated water resources management. The ground-water flow modeling study in western Nebraska will use the HEM data as part of model datasets, to create a tool used to evaluate implications of water management options over most of the surface-water irrigated area.

Methods

Helicopter Electromagnetic Surveys

- Six EM frequencies from 400 - 140,000 Hz
- Total field magnetometer
- High Resolution GPS
- Laser Altimeter
- Line spacing 270 meters, sensor altitude 30m

Ground Geophysical Surveys

- Direct current resistivity sounding and profiling
- Time domain EM soundings

Borehole Lithologic and Geophysical Logs Hydrologic Modeling and characterization

Project Partners

ENWRA HEM

- U.S. Geological Survey
- Conservation and Survey Division (University of Nebraska)
- Lower Platte South Natural Resources District
- Lower Platte North Natural Resources District
- Lower Elkhorn Natural Resources District
- Lewis and Clark Natural Resources District
- Nemaha Natural Resources District
- Papio-Missouri River Natural Resources District
- Nebraska Department of Natural Resources

Panhandle HEM

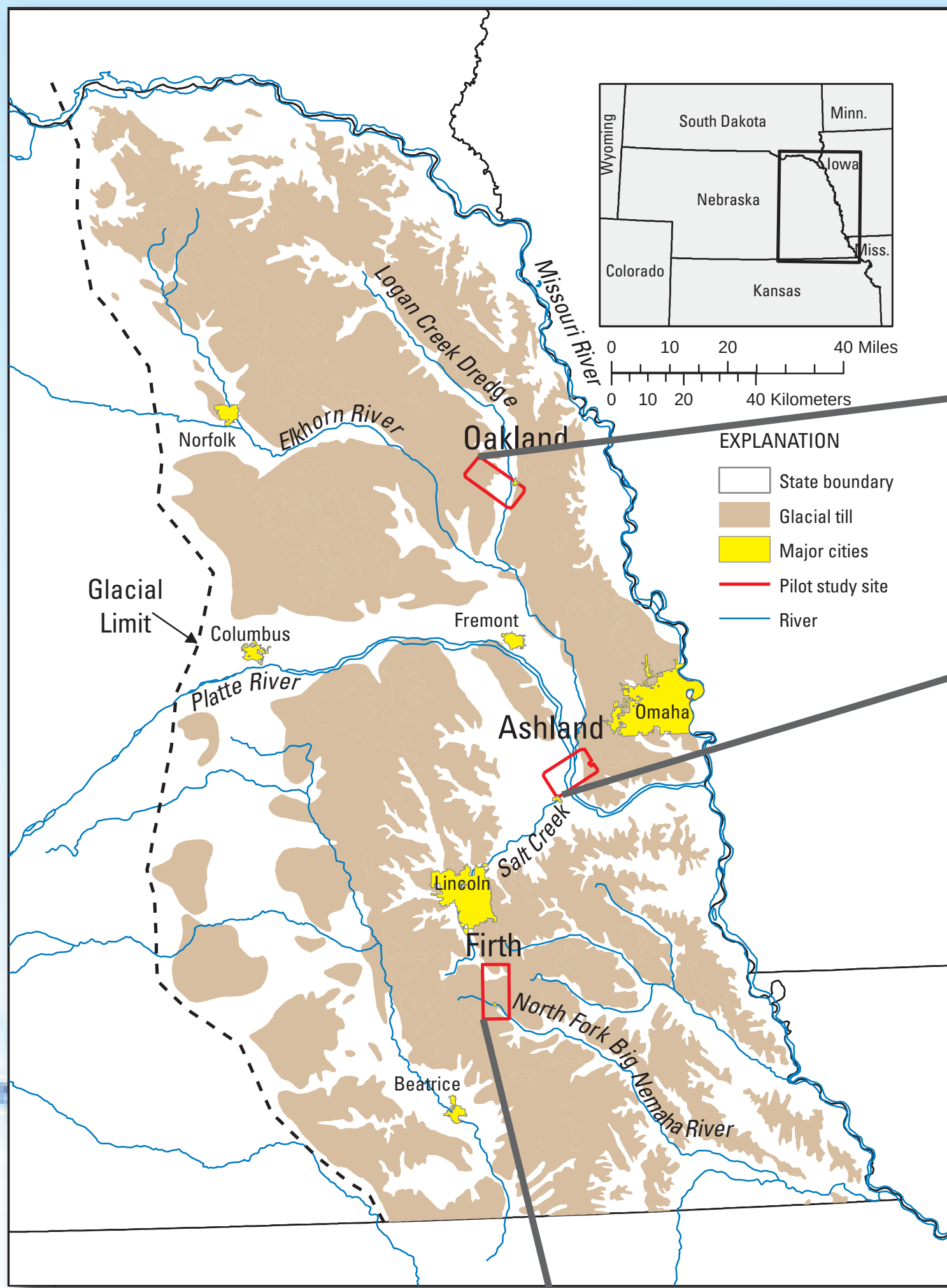
- U.S. Geological Survey
- Conservation and Survey Division (University of Nebraska)
- North Platte Natural Resources District
- South Platte Natural Resources District
- Nebraska Natural Resources Commission

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Michaela R. Johnson (mjohns@usgs.gov)
Background photo courtesy of Jesse Korus
Lower Platte South Natural Resources District

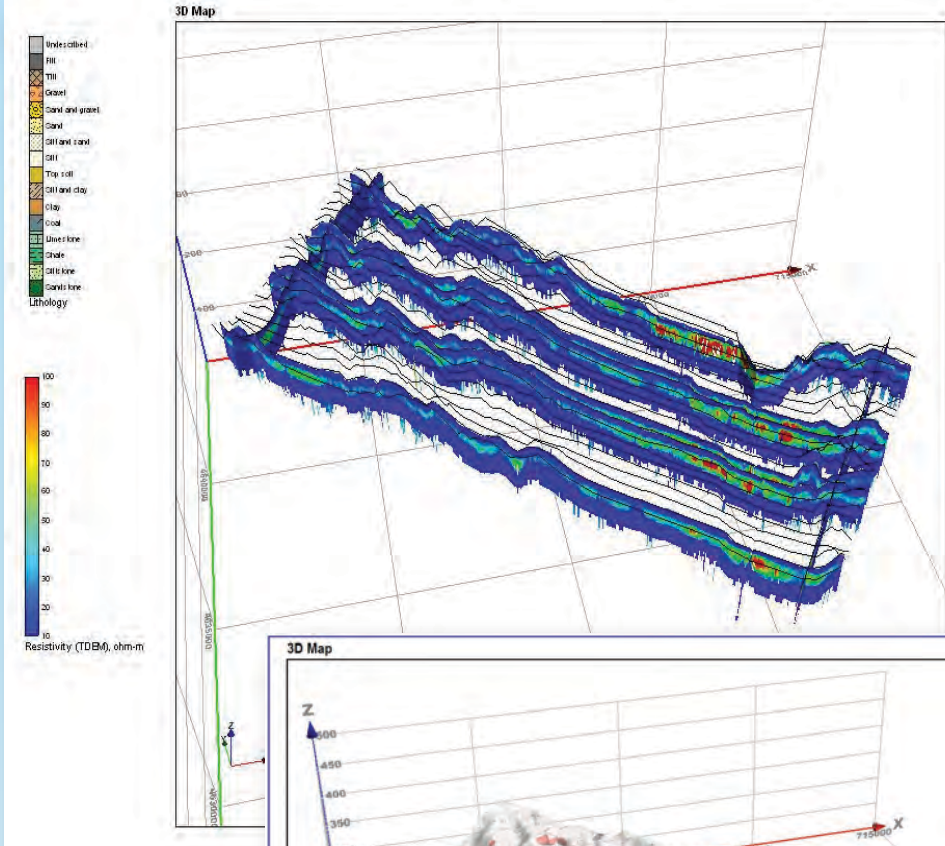
Eastern Nebraska Water Resource Assessnnt

ENWRA HEM Evaluation Sites

The HEM survey sites are shown here superimposed on the regional glacial drift map which gives an indication of the extent that bedrock is concealed.

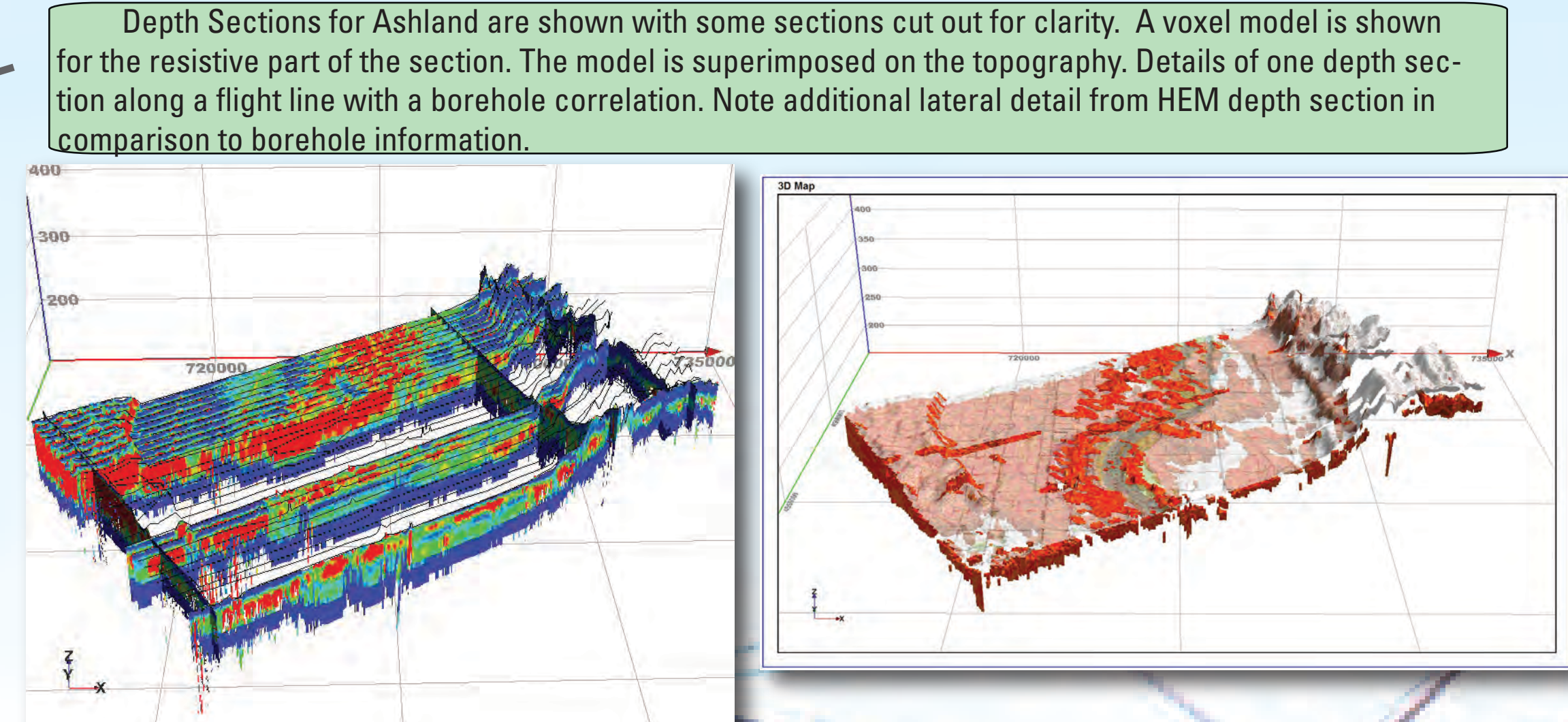


Oakland



Depth Sections for Oakland are shown with some sections cut out for clarity. A voxel model is shown for the resistive part of the section (<50 ohm meters). The glacial cover is conductive limiting the depth of subsurface HEM mapping. Also most of the shallow resistive units are in the flood plain.

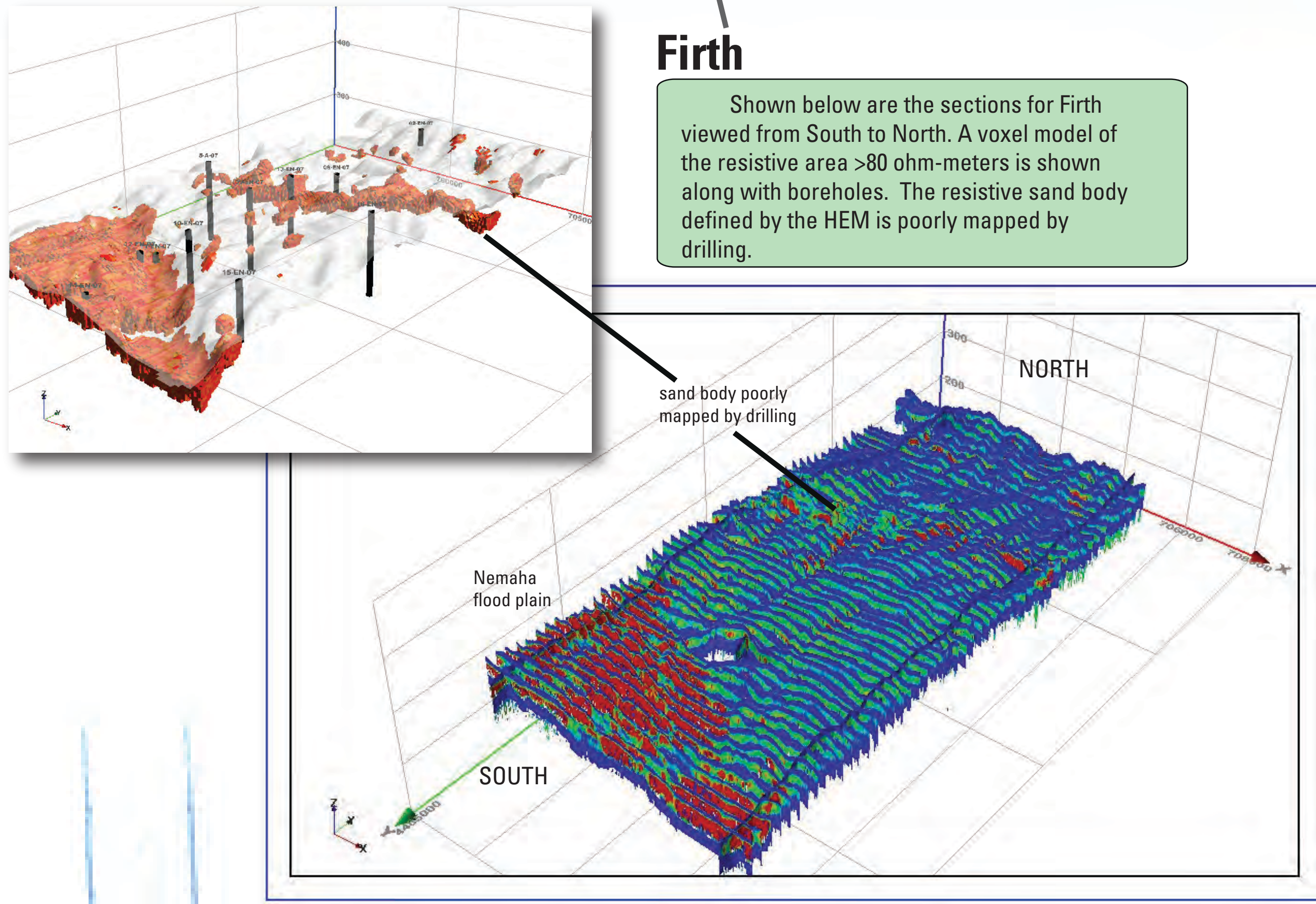
Ashland



Depth Sections for Ashland are shown with some sections cut out for clarity. A voxel model is shown for the resistive part of the section. The model is superimposed on the topography. Details of one depth section along a flight line with a borehole correlation. Note additional lateral detail from HEM depth section in comparison to borehole information.

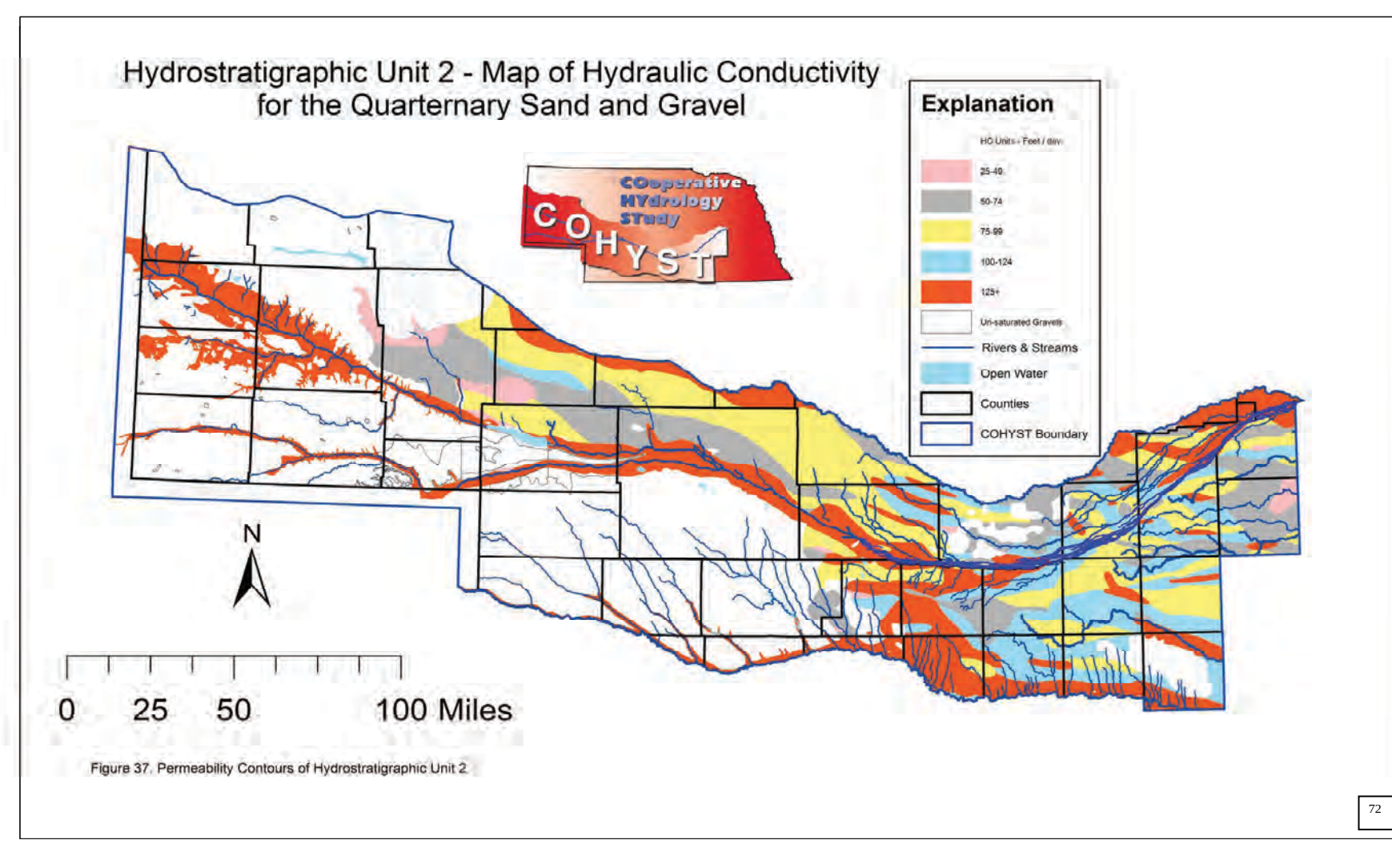
Firth

Shown below are the sections for Firth viewed from South to North. A voxel model of the resistive area >80 ohm-meters is shown along with boreholes. The resistive sand body defined by the HEM is poorly mapped by drilling.



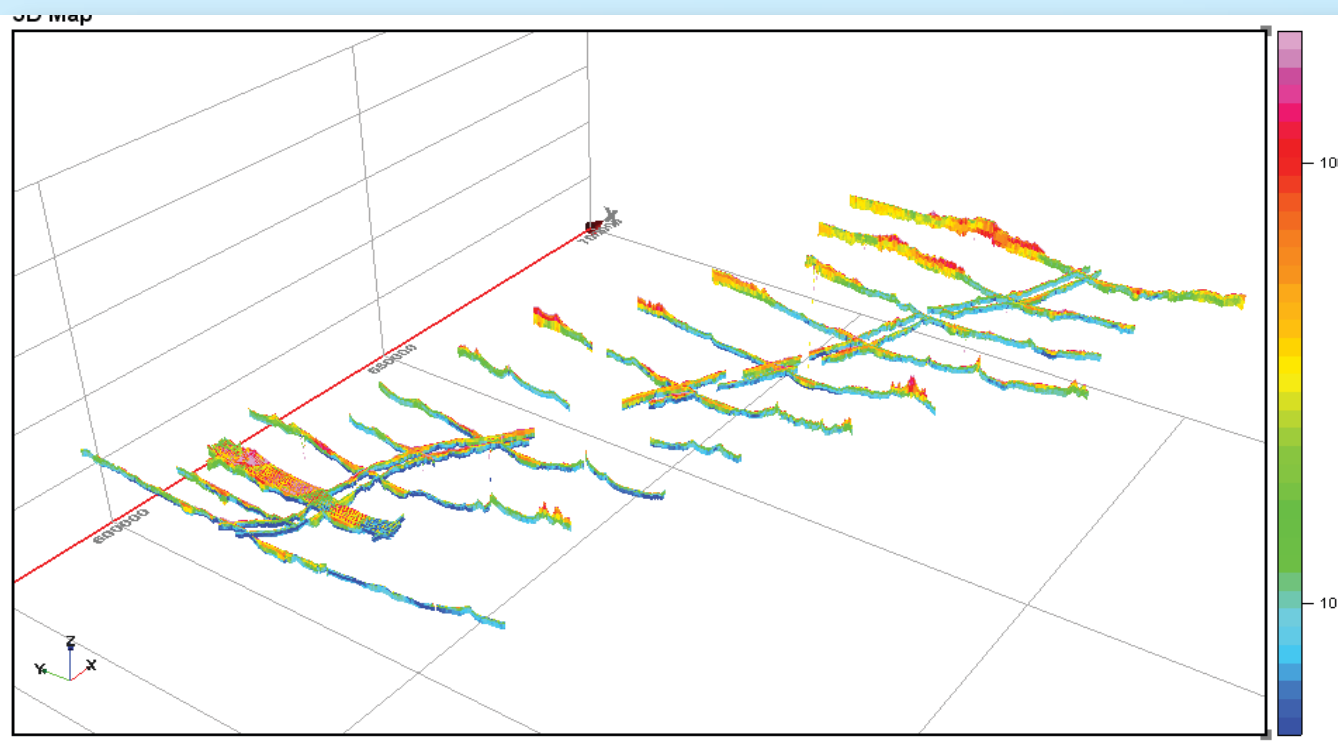
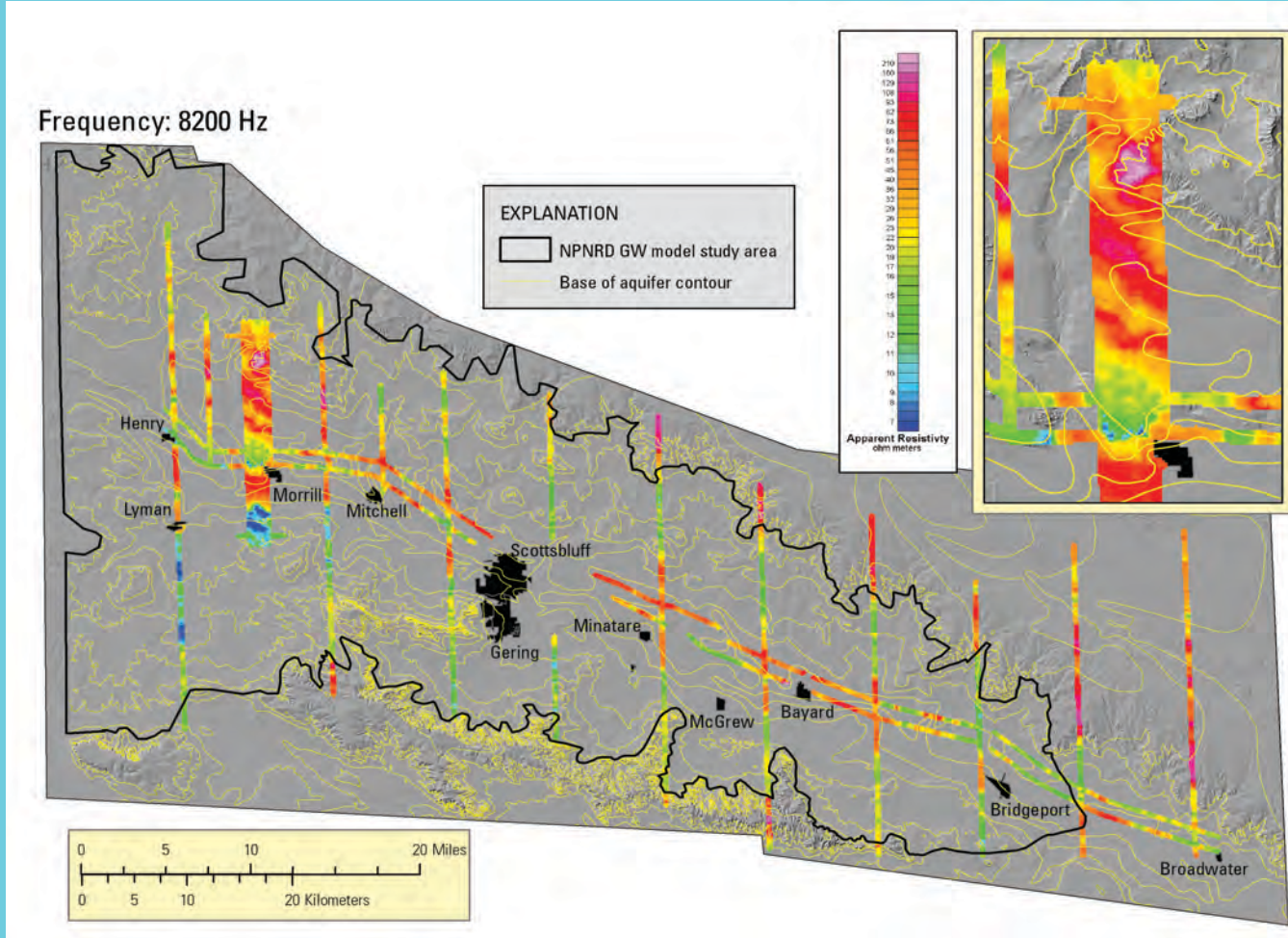
Western Nebraska Water Resource Studies

The successes of HEM applications in Eastern NE lead to a program to apply air-borne mapping for the panhandle area in Western NE. A ground-water modeling program continues for the North Platte and South Platte Natural Resources Districts. Shown is an index of the flight lines which were designed as partly reconnaissance and partly detail. In either case the information gained from the HEM flights shall be used in both models. Also shown is the boundary of the Cooperative Hydrology Study (COHYST) regional groundwater model. A sub-regional numerical ground-water flow model is being developed for optimization of management scenarios is also being made for part of the North Platte area.



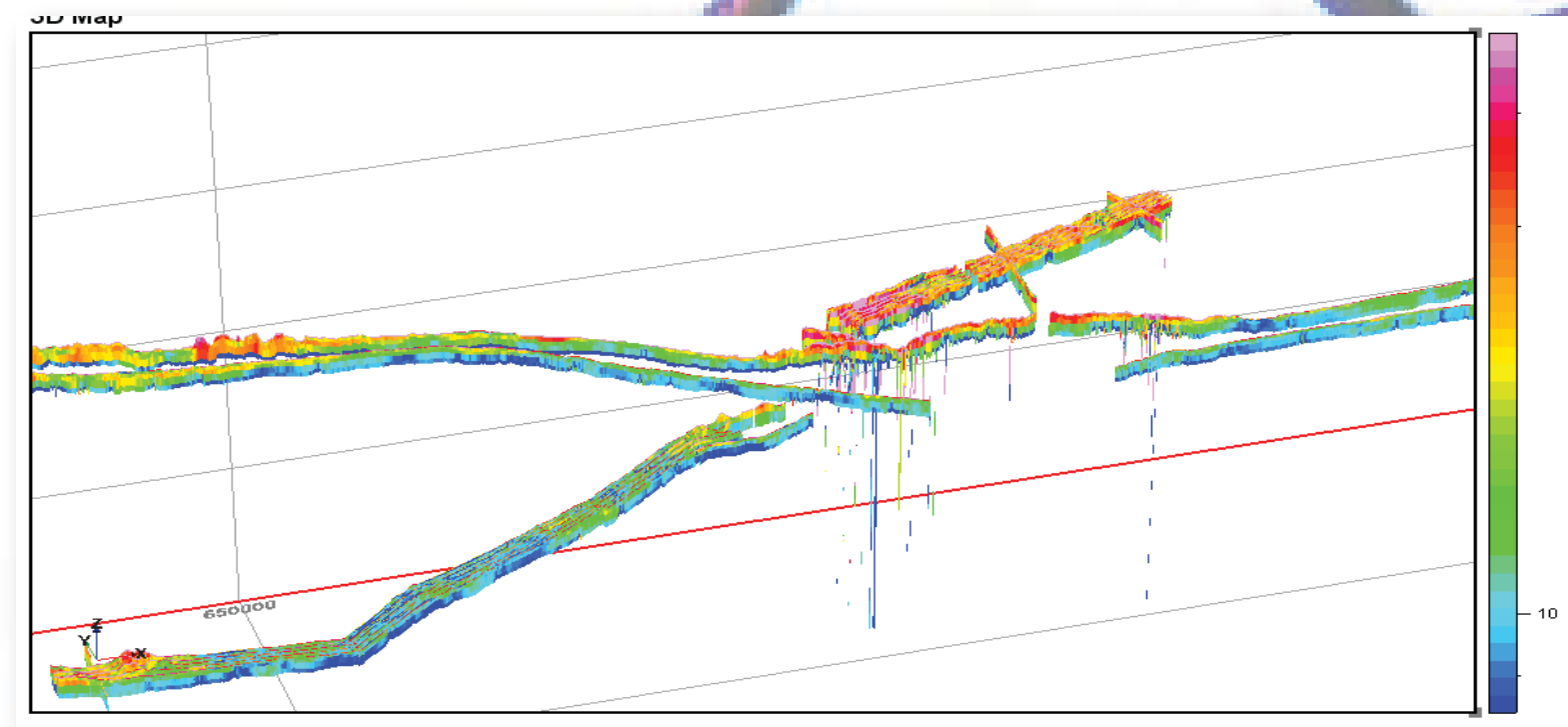
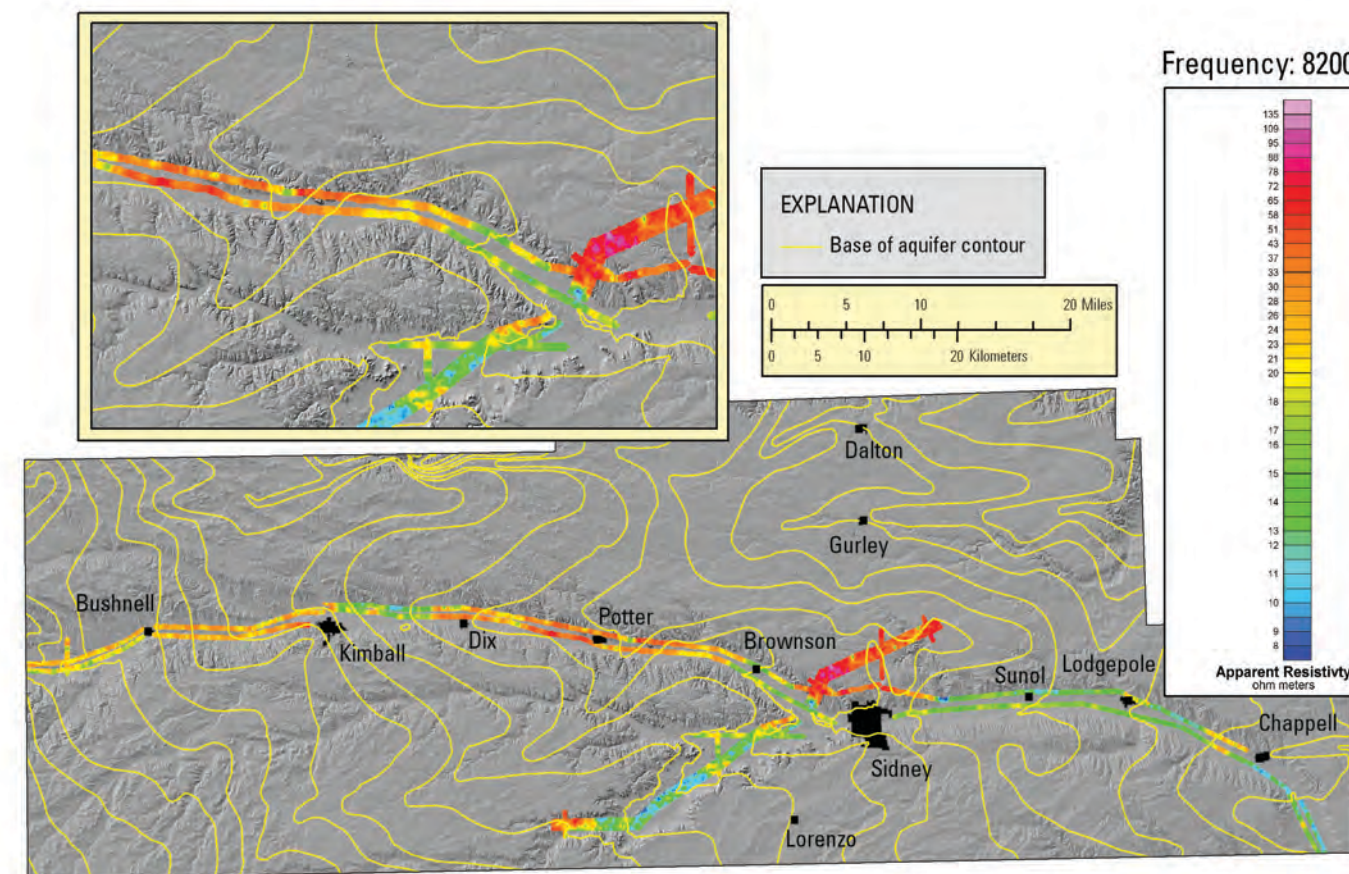
Preliminary interpretation has begun for the HEM resistivity data by computation of resistivity-depth sections along flight lines. Ground geophysical surveys, borehole logs and geologic mapping will be combined with hydrologic studies in the final interpretation

North Platte NRD 8200 Hz



Resistivity depth sections have been constructed along the flight lines and are shown above for the North Platte survey area. The high resistivity (red) areas define coarse grained sediments and sandstone channels that are important in understanding the ground-water flow. The voxel models for the Morrill detail area are shown for high resistivity indicating unconsolidated sand and gravels. The green surface corresponds to low resistivity siltstone and shale that are confining units. The boundaries for these units will be input into the ground-water flow model providing much more detail than available from interpolation between bore holes and surface outcrops.

South Platte NRD 8200 Hz



General Conclusions

- Frequency domain HEM methods need a broad frequency band (400 to 140,000 Hz) to map both shallow and deep hydrogeologic features critical in understanding the extent and distribution of aquifers as they relate to surface water features.
- HEM surveys have mapped both resistive and conductive features in 3-dimensions. Where sufficient density of flight lines exist, volumes of coarse grained (resistive) sediment can be calculated. When combined with water table maps a saturated thickness maps and estimates of groundwater in storage can be determined.
- Resistive zones can be subdivided and associated with different hydrostratigraphic units such as mostly gravel or mostly sand, potentially, allowing the determination of areas of higher transmissivity.

Future Work

- In areas where glacial deposits are relatively conductive or targets are deeper, time domain airborne methods may be more appropriate. Parts of the North Platte block and the Sand Hills area (index figure above) have been flown to evaluate the method.