USGS science for a changing world

NORTH PLATTE Natural Resources District | SOUTH PLATTE Natural Resources District | The Nebraska Environmental Trust

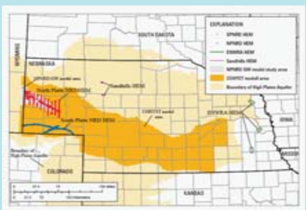
H53B-0930

Design of Reconnaissance Helicopter Electromagnetic and Magnetic Geophysical Surveys of the North Platte River and Lodgepole Creek, Nebraska

By Bruce D. Smith (1, bsmith@usgs.gov), James C. Cannia(2), and Jared D. Abraham(1)

(1) U.S. Geological Survey, Crustal Imaging and Characterization Science Center, Denver, Colorado
(2) U.S. Geological Survey, Nebraska Water Science Center, Lincoln, Nebraska

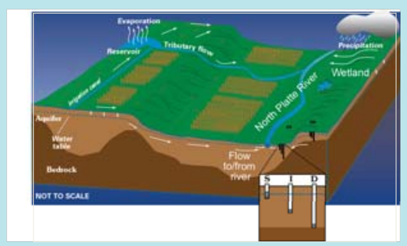
Introduction



An innovative flight line layout using widely separated lines was used for frequency domain helicopter electromagnetic (HEM) surveys in 2008 and 2009 in the Panhandle of western Nebraska. Use of HEM methods for hydrologic mapping had been demonstrated by HEM surveys conducted in 2007 of sites in the glaciated Platte River Basin in eastern Nebraska. These surveys covered township-scale areas with flight lines laid out in blocks where the lines were spaced about 270 m apart. The purpose of this poster is to demonstrate the underlying principles critical in design of the HEM survey. There is a temptation to use widely spaced lines to reduce survey cost, but this can be done only when survey objectives, system performance, and background information are all carefully considered. Much of the background information was obtained from the Cooperative Hydrology Study (COHYST), a hydrogeologic study of surface and groundwater resources in the Platte River Basin of Nebraska upstream from Columbus, Nebraska.

The HEM survey design was developed as part of a joint hydrologic study by the North Platte Natural Resource District, South Platte Natural Resource District, UNL-Conservation and Survey Division, and U.S. Geological Survey to improve the understanding of relationships between surface water and groundwater systems critical to developing groundwater flow models used in water resources management programs.

TThe block diagram describes the conceptual model of the hydrogeologic framework of the North Platte River valley illustrating the interaction of groundwater and surface water. This complicated system includes surface water, canal systems, streams and groundwater all interacting with one another to create this unique hydrologic system. The diagram shows how paleochannels of the ancestral Platte River System are eroded into the impermeable bedrock. These channels create subsurface topographic highs of bedrock that are barriers to groundwater movement and contain the alluvial aquifers of the area. It is this complex relationship between alluvial fill and bedrock that the HEM survey can map in detail – a feat traditional methods can not accomplish.



Geology and Lithology

The following sediment types make up the bulk of sediments in the project area. In most places, the Quaternary alluvium and Pliocene Broadwater Formation alluvium overlie the Tertiary Brule Formation of the White River Group siltstone. The coarse sediments of the alluvial deposits are electrically resistive, whereas the siltstone is electrically conductive.

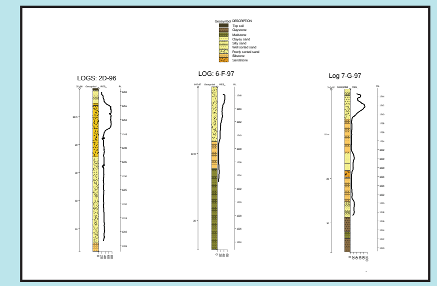
Cross-bedded, fluvial, coarse grained sediments of the Broadwater Formation. Photo taken facing west ~ 1.5 miles north of Big Springs, Nebraska
A. Iron-stained sediments.
B. Siltstone clasts ~1.5 feet in diameter
C. Manganese-stained sediments.

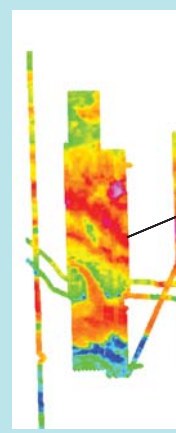
Photo taken facing east along summit road between tunnels 1 and 2, Scottsbluff National Monument.
A. Fractured Brule Formation.
B. Unfractured Brule Formation.

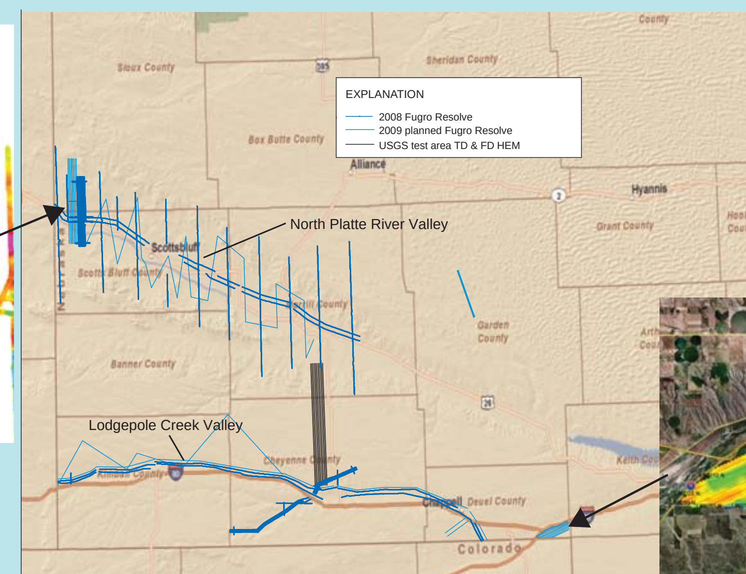
Drill Hole Lithology and Geophysical Logs

One of the more critical elements in planning the location of the widely spaced lines is the information from drill holes. Conservation and Survey Division Test hole location map shows where each site is in relation to the project area. These test holes were originally used in developing the COHYST hydrostratigraphic units map. However the HEM data provides greater spatial detail both laterally and with depth

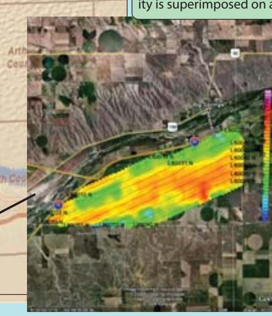
The geophysical logs demonstrate that the gravels overlying the electrically conductive bedrock has higher, variable, electrical resistivity. The logs verify the conceptual model that the design of the HEM flight lines was based on. These test holes are used in the project as ground truth for the airborne resistivity maps and depth sections.



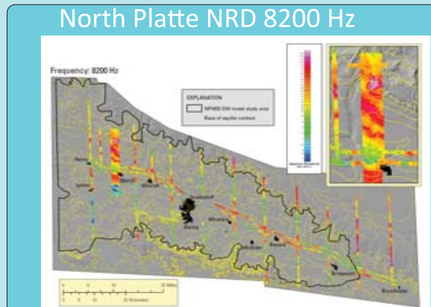


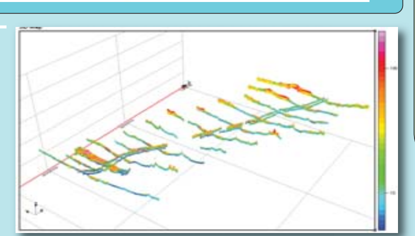


Based on the 2008 flying in the Lodgepole Creek area, a detailed block was flown in 2009 at the eastern end (Western Canal block). An inset shows the apparent resistivity at 8,200 Hz for the detail area. High resistivity areas indicate buried alluvial sands and gravels. The apparent resistivity is superimposed on a Google Earth image.



North Platte NRD 8200 Hz

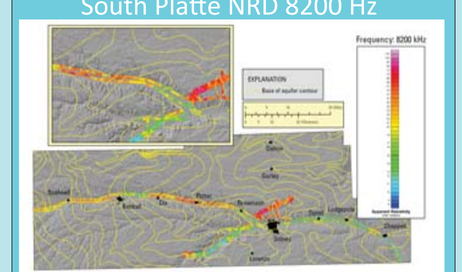


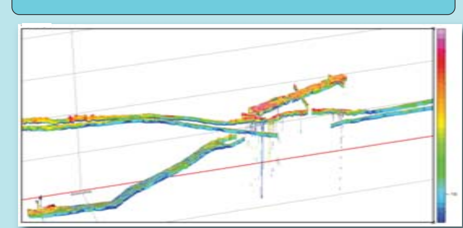


Resistivity depth sections have been constructed along the flight lines and are shown for the North Platte River and Lodgepole Creek survey areas. The high resistivity (red) areas define coarse grained sediments and sandstone channels that are important in understanding the groundwater flow. The flight lines are from the 2008 survey. Data from this survey have been released as USGS Open-file-Report 2009-1110 (http://pubs.usgs.gov/of/2009/1110/). The block flight lines in the Morrill area helped to understand spatial variations of resistivity for the North Platte survey area. Both 2008 and 2009 flight lines are shown above. The additional fill-in for the Morrill block, done in 2009, was needed to help map a poorly located buried alluvial channel (compare 2008 and 2009). This is an example of a target that is not appropriate for widely spaced lines.

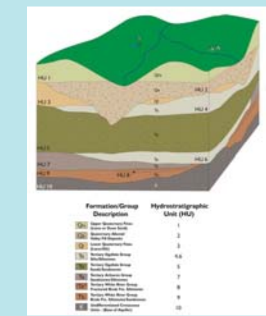
Resistivity depth images are shown for the 2008 flying for both areas. Fence diagrams using depth images are a more appropriate display of data from the widely spaced lines than the resistivity maps. This is due to the difficulty of displaying data without implying a lateral extent. Present work is to develop methods to easily display these depth sections in a web display, such as Google Earth.

South Platte NRD 8200 Hz





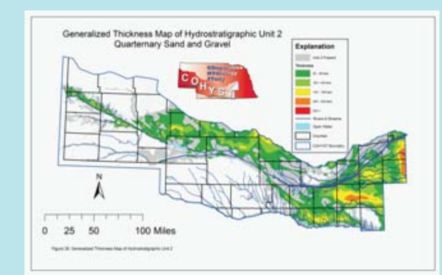
Hydrostratigraphy



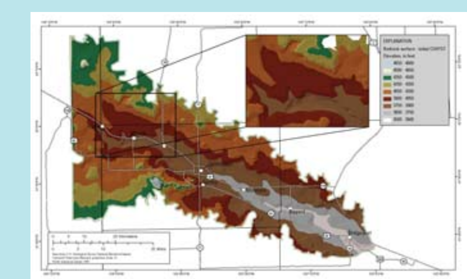
Three-dimensional diagram of the hydrostratigraphic units (HU) used in the COHYST groundwater model. The units of greatest importance to be mapped by this project are HU 1 and 2 which make up the primary aquifers of the valley and HU 8 and 9 which make up the basal confining units of the area.

System	Series	Geologic Unit	Hydrostratigraphic Unit	Description
Quaternary	Holocene	Valley-fill deposits	Unit 2	Gravel, sand, silt, and clay with coarser materials more common. Generally stream deposits. Upper fine material, if present, is assigned to Hydrostratigraphic Unit 1. Lower fine material, if present, is assigned to Unit 3.
	Pleistocene and Holocene	Dune sand	Unit 1	Generally fine sand but may contain some medium and even coarse sand. May also contain some finer material. Wind-blown deposits.
		Loess deposits	Unit 1 when above Unit 2, otherwise Unit 3	Generally silt, but may contain some very fine sand and clay. Deposited as wind-blown dust.
	Pleistocene	Alluvial deposits	Unit 2	Gravel, sand, silt, and clay with coarser materials more common. Generally stream deposits. Upper fine material, if present, is assigned to Hydrostratigraphic Unit 1. Lower fine material, if present, is assigned to Unit 3.
Tertiary	Pliocene	Broadwater Formation	Unit 2	Coarse fluvial gravel and sand dominate with some silt and clay. Assigned to Hydrostratigraphic Unit 2. Generally found in channel deposits north of the North Platte and Platte River.
	Upper and middle Miocene	Ogallala Group	Units 4-6	Heterogeneous mixture of gravel, sand, silt, and clay. Generally stream deposits but also contains wind-blown deposits. Upper fine material, if present, is assigned to Hydrostratigraphic Unit 4. Center coarse material, if present, is assigned to Unit 5. Lower fine material, if present, is assigned to Unit 6. Often sandstone and conglomerate layers exist through our area.
	Lower Miocene and upper Oligocene	Arikaree Group	Unit 7	Predominately very fine to fine-grained sandstone but may also contain siltstone. Locally, may contain conglomerate, gravel, and sand.
	Lower Oligocene	Brule Formation of White River Group	Unit 8 of High Plains aquifer or Unit 9 below High Plains aquifer	Predominately siltstone, but may contain sandstone and channel deposits. Sometimes highly fractured with areas of fracturing difficult to predict. Upper part of Brule Formation is included in High Plains aquifer and Hydrostratigraphic Unit 8 only if fractured or contains sandstone or channel deposits, otherwise it is Unit 9 and is excluded from the High Plains aquifer. Wind-blown volcanic deposits with some fluvial deposits.
	Upper Eocene	Chadron Formation of White River Group	Unit 9; below the High Plains aquifer	Silt, siltstone, clay, and claystone. Generally forms impermeable base of High Plains aquifer. Fluvial deposits and wind-blown volcanic deposits.
Cretaceous	Undifferentiated	Undifferentiated	Unit 10; below the High Plains aquifer	Shale, chalks, limestone, siltstone, and sandstone. Except for a few minor areas of Fox Hills Sandstone in the extreme western part of the COHYST area and the Dakota Group in the extreme eastern part of the area, generally forms an impermeable base of High Plains aquifer. Deep marine deposits to beach deposits.

Table gives the stratigraphic description of geologic and hydrostratigraphic units used in the Cooperative Hydrology Study. Aquifer HU's in yellow and confining units in Green



The extent and thickness of Hydrologic Unit 2 which is the primary aquifer is shown for the COHYST area. This aquifer is the major groundwater source within the North Platte River valley. It is relatively thin and limited in areal extent. It is hydrologically connected to the surface water canals and streams of the area and provides considerable base flow to the North Platte River.



The map of the elevation of the bedrock surface (Brule member of the White River Formation) was based on well data and other information prior to the HEM survey. The need for additional detail in critical areas for hydrologic modeling was determined, in part, from information gaps in the resolution of the bedrock surface elevation. For example, the Morrill area was ranked as a high priority for a detailed survey.

Conclusions

- **The design of HEM surveys using widely spaced flight lines must be based on survey objectives, system performance, and hydrogeologic background information.**
- **Survey data are best displayed as depth images along the widely spaced flight lines.**
- **Display of data in web applications such as Google Earth is an effect means to convey qualitative information.**
- **Additional widely spaced lines and more detailed flight blocks may be flown pending availability of funds.**

Project Partners

North Platte Natural Resources District, South Platte Natural Resources District, Nebraska Environmental Trust Fund, University of Nebraska Conservation Survey Division, U.S. Geological Survey

Version 2.0 December 08, 2009 BDS