TDEM AND NUMIS^PLUS SOUNDINGS AT THE ASH MEADOWS NATIONAL WILDLIFE REFUGE: A CASE STUDY

Jared D. Abraham[1], Anatoly Legchenko[2], Dr. Aldo Mazzella[3], Eric White[4], John Lane[4], John B. Fleming[5]

[1]U.S. Geological Survey, Denver Federal Center, P.O. Box 25046, Mail Stop 964, Denver, CO 80225-0046, USA, 001-303-236-1318, jdabraha@usgs.gov;
[2]BRGM, Development Planning and Naturals Risks Division, 3, Avenue C. Guillemin, BP 6009, 45060, Orleans Cedex 2, France;
[3]U.S. Environmental Protection Agency, P.O. Box 93478, Las Vegas, NV 89193-3478;
[4]U.S. Geological Survey, 11 Sherman Place, Unit 5015, Storrs, CT 06269;
[5]U.S. Geological Survey, 520 N. Park Ave, Tucson, AZ 85719.

INTRODUCTION

During the summer of 2002, a cooperative project between the U.S. Geological Survey, the U.S. Environmental Protection Agency, and the Bureau de Recherches Géologiques et Miniéres was undertaken to evaluate and gain knowledge of the Iris NUMIS^Plus magnetic resonance sounding instrument. The system was deployed at several sites throughout the United States of America (USA). One of these sites was the Ash Meadows National Wildlife Refuge. The following describes the geology, hydrology, and geophysical results in this unique desert oasis environment. Ash Meadows is located in southern Nye County, Nevada approximately 145 km northwest of Las Vegas, Nevada. Ash Meadows lies within the southern part of the Great Basin, an internally drained subdivision of the Basin and Range physiographic province. Time domain electromagnetic TDEM soundings were collected at each of the NUMIS^Plus sounding locations. The (TDEM) results clearly show the resistive carbonate fault blocks as well as a horizontal resistive layer that is broken by faults. These TDEM soundings provided a resistivity section for input into the NUMIS^Plus inversions. The NUMIS^Plus inversions indicate several water rich zones throughout the Ash Meadows area. Resource managers will use the results from this study to improve the hydrologic model of the Ash Meadows.

SITE DESCRIPTION

Ash Meadows encompasses approximately 202 km^2 of desert uplands and spring-fed oases. The Ash Meadows National Wildlife Refuge covers approximately 93 km^2. Paleozoic carbonate and siliceous clastic rocks make up the primary rock types of the hills, ridges, and mountain ranges. The basins are filled with sedimentary and volcanic rocks, including sandstone, siltstone, lacustrine clay and limestone, and volcanic ash and lava flows.

Ash Meadows is located in the north-central part of the Mojave Desert and is typical of most other desert regions, characterized by short mild winters, long hot summers, and low annual rainfall. Unlike most desert communities, Ash Meadows has a high concentration of springs. More than 30 springs and seeps are aligned in a linear pattern spanning 16 km and generally oriented NE-SW. The spring flow is relatively constant (Laczinack and others 1999). The exception was in the late 1960's and early 1970's when local agricultural interests pumped large quantities of ground water to irrigate local crop fields (Dudley and Larson, 1976). A consequence of ground-water pumping was a drop in the pool level in Devils Hole, which is a shaft-like opening into the ground water system through carbonate bedrock created by a collapse. This feature provides the sole remaining habitat for the endangered Devils Hole pupfish (Cyprinodon diabolis). In 1975 the U.S. Supreme Court established a minimum pool level for Devils Hole, essentially prohibiting any significant pumping from the local area. Shortly after the mandate, all agricultural and development interests in the area faded, water levels began recovering, and spring flows returned to nearly the previously measured rates (Westenburg, 1993).

The Ash Meadows area is supplied by ground water from the north and northeast, through thick rock units composed of fractured limestone and dolomite. The ground water moves primarily through interconnected fractures within the carbonates, where it is confined between two impermeable layers as it moves towards the Ash Meadows area (Winograd and Pearson, 1976). As the ground water moves into Ash Meadows under a driving head, flow is impeded by the Ash Meadows fault system. Some of the water is pushed upward forming springs directly along faults in the bedrock at the margins of the carbonate ridges. Other springs discharge from within the alluvium, which are likely fed by faults in the underlying carbonates. Within the Ash Meadows area there are two aquifers; the deeper carbonate aquifer, and the shallower alluvial basin-fill aquifer. The carbonate aquifer is composed of 4,600 m of limestone and dolomite interbedded with minor layers of siltstone, agillite, and shale of Cambrian, Ordovician, and Devonian age. The basin-fill aquifer is exposed at the surface at Ash Meadows and is composed of a complex interbedded limestones, sandstones, gravels, siltstones, and clays. Although the study area is checkered by many wells these wells were installed for agricultural water supplies and have limited or no information on lithology and geophysical parameters.

Cultural impacts are very minor in the Ash Meadows area with only small power lines supplying the Refuge Headquarters and the few private residences within the area. During the 2002 NUMIS survey at Ash Meadows, local thunderstorm activity caused problems with data collection. NMR data were only collected early in the morning, prior to afternoon thunderstorms; therefore, spatial coverage of NMR soundings was severely limited. 60 Hz EM noise in the Ash Meadows area was relatively low as determined by measurements collected at selected NMR sites using a 60 Hz EM total field system, which was developed by the USGS. The average 60 Hz total field noise was 1005 nT with a standard deviation of 228 nT. Magnetic susceptibility measurements were made using a handheld magnetic susceptibility meter. The magnetic properties of the surface sediments at the Ash Meadows area are moderate with an average susceptibility of 73×10^{-5} S.I. units.

RESULTS

Fourteen TDEM soundings were collected at Ash Meadows. A TDEM sounding was completed at each NUMIS^{Plus} sounding location. The TDEM soundings provide a resistivity section that can be used as the input model for the NUMIS^{Plus} inversions, as well as stand alone resistivity map. A Geonics Protem 47 was used with a single turn 40 m transmitter loop in a central loop configuration (Rx centered within the Tx loop). The TDEM soundings provide a generalized view of the site containing a large resistive limestone block and very possible a fault to the east. In the E-W TDEM profile (Figure 1a) a high resistivity zone can be noted centered at Site 21.5 extending to the west and east to Site 22 and Site 20. This is interpreted as the buried portion of the carbonate outcrop at "Point of Rocks Spring." A semi-discontinuous layer can be observed from Site 24 to Site 22 with an elevation change at Site 23.5. This may be a layer of limestone or resistive water within a more porous rock. On the east side of the profile there is a noticeable break between Site 20 and Site 18, which indicates a fault or a discontinuous layer of resistive rock within the valley fill sediments.

The Iris NUMIS^{PLUS} was deployed at eight sites within the Ash Meadows study area. The data collected were of appropriate quality to allow inversion. Resistivity vs. depth profiles calculated from the TDEM soundings were used by the NUMIS^{Plus} inversion. Detailed description of the Inversion of surface NMR data can be found in Legchenko and Shushakov (1998). Profiles of estimates of percent water and permeability for E-W profile were prepared (Figure1b and 1c). The NUMIS^{Plus} percent water profile displays water contents from 0 to 11 percent, between Site 24 and Site 23 a zone containing 4 to 10 percent water from near the surface to 10 m of depth (680 m in elevation) this zone pinches out toward Site 22. Another zone of 4 to 8 percent water occurs at 675 to 660 meters in elevation. At Site 18 zone of 4 to 8 percent water is imaged between 685 and 695 m in elevation and continues east under Site 19 where another deeper zone of 2 to 4 percent water is imaged between 660 and 674 m in elevation. These layers are probably related to the faults or just the complicated sedimentary structure in the valley fill at Ash Meadows. The plots of water content show a break in the structure between Site 23 and Site 22 and between Site 22 and Site 18. Carbonate rocks buried beneath the section between Site 22 and Site 18, or the faults associated with the carbonates, may cause the breaks in the imaged layers. The NUMIS^{Plus} profile of permeability (Figure 1c) indicates a permeable zone between Site 24 and 23. As expected, the distribution of permeability is similar to the distribution of percent water in Figure (1b).

SUMMARY

Maps of increased water content and increased permeabilities can be produced, however the fact that the NUMIS has an averaging effect over the investigated volume, may preclude an exact correlation with water contents and permabilities. Due to the highly 3-D nature of the subsurface at Ash Meadows, a qualitative view of the water contents and the permabiltites may be the only outcome that can be achieved. The NUMIS^{Plus} results combined with the TDEM soundings can give a generalized model of the subsurface at Ash Meadows. This alone is a powerful tool for resource managers. However, without good well data, including detailed lithological, neutron and induction logs, a quantitative assessment of the NUMIS^{Plus} and TDEM data collected at Ash Meadows cannot be achieved.

ACKNOWLEDGEMENTS

This work has been funded in part by the United States Environmental Protection Agency under Interagency Agreement DW14939604 to the United States Geological Survey. It has been subjected to Agency review and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

REFERENCES

Dudley, W.W., Jr., and Larson, J.D., 1976, Effects of irrigation pumping on desert pupfish habitats in Ash Meadows, Nye County, Nevada: U.S. Geological Survey Professional Paper 927, 52 p.

Laczinack, R.J., DeMeo G.A, Reiner, S.R., Smith, J.L., and Nylund, W.E., 1999, Estimates of ground-water discharge as determined from measurements of evapotranspiration, Ash Meadows area, Nye County, Nevada: U.S Geological Survey Water-Resources Investigation Report 99-4079, 69 p.

Legchenko, A.V., and Shushakov, O.A., 1998, Inversion of surface NMR data: Geophysics, 63, 75-84p.

Westenburg, C.L., 1993, Water resources data for Devils Hole area, Nye County, Nevada, July 1978-September 1988: U.S. Geological Survey Open-File Report 90-381, 13 p.

Winograd, I.J., and Pearson, F.J., Jr., 1976, Major carbon-14 anomaly in a regional carbonate aquifer--Possible evidence for megascale channeling, south-central Great Basin: Water Resources Research, v. 12, no. 6, p. 1125-1143.

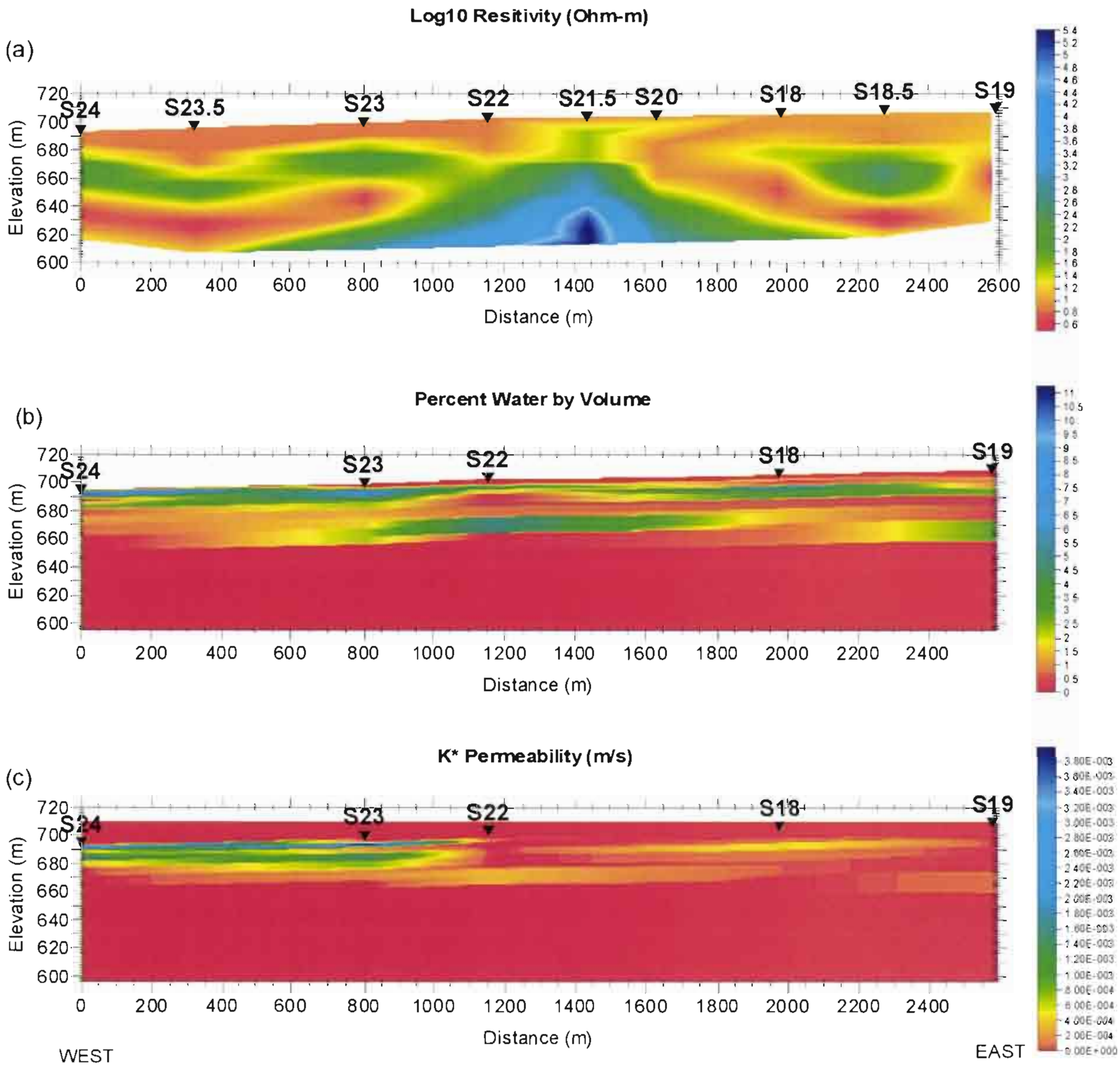

Figure 1. Results of TDEM and NUMIS soundings along the E-W profile at Ash Meadows, Nevada (a) Inverted TDEM data in $\log_{10}$ (resistivity) (b) NUMIS percent Water content, and (c) NUMIS permeability (m/s).

MRS

2ND INTERNATIONAL WORKSHOP

on the Magnetic Resonance Sounding method applied to non-invasive groundwater investigations

19 - 21 November 2003 - Orléans - France

PROCEEDINGS

Organizer

Co-organizer

Support