[PS]Evaluation of Geophysical Techniques in the Determination of a Salt Contaminated Environment*

Walter Reed[1], Michael Foust[1], Heather L. Lehto[1], James W. Ward[1], and Jason Payne[2]

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[1]Angelo State University, San Angelo, TX, USA (wreed1@angelo.edu)
[2]United States Geological Survey, San Angelo, TX, USA

Abstract

Salt contaminated soils propose environmental risks for land that once flourished for agriculture use. To successfully remove or remediate a salt contaminated environment it is important to know the boundaries of the contamination, identify any sources of contaminates, and monitor the movements of contaminates. Electromagnetic geophysical techniques provide a feasible noninvasive approach to studying the subsurface and identifying the location and perimeter of a salt contaminated environment. This study compares three separate electromagnetic methods including galvanic DC resistivity, capacitively coupled resistivity, and frequency domain conductivity. Galvanic resistivity surveys have been around for quite some time and have shown to be successful for effectively and accurately modeling salt contaminated environments. However, when modeling large areas, DC resistivity lines can be very burdensome and time consuming to carry out. In order to measure the movement of a salt contaminated environment, it is more efficient to use a method that is less burdensome and time consuming to take fast and accurate data for geophysical modeling. Both the Gem-2, which uses a frequency domain method, and the Ohm Mapper, which uses a capacitively coupled method, are quick methods that can perform complete surveys in only a few hours covering areas up to 100,000 square meters. In order to evaluate these methods, a galvanic DC survey was performed using a Syscal Pro-Switch 72 along with surveys from the Gem-2 and OhmMapper. This data was then compared with well logs taken at the survey site to verify the accuracy of the data. The three methods were then compared based on their physical limitations to collect data at the site as well as their ability to collect the most accurate data. It was found that the Gem-2 has the best capability for efficiently and effectively carrying out a geophysical survey of a salt contaminated environment.

References Cited

Geophex Ltd., Gem-2 - How It Works - Detailed: Web Accessed May 14, 2016, http://www.geophex.com/Pubs/gem2_-_how_it_works_detailed.htm

Shah, S.D., B.D. Smith, A.K. Clark, and J.D. Payne, 2008, An integrated hydrogeologic and geophysical investigation to characterize the hydrostratigraphy of the Edwards aquifer in an area of northeastern Bexar County, Texas: U.S. Geological Survey Scientific Investigations Report 2008–5181, 26 p.

Texas Water Development Board, Groundwater Data Viewer: Web Accessed May 14, 2016, http://www2.twdb.texas.gov/apps/waterdatainteractive/GroundwaterDataViewer#

Trainor-Guitton, W.J., A. Ramirez, X. Yang, K. Mansoor, Y. Sun, and S. Carroll, 2013, Value of Information Methodology for Assessing the Ability of Electrical Resistivity to Detect CO_2/brine Leakage into a Shallow Aquifer: International Journal of Greenhouse Gas Control, v. 18. p. 101-13.

Xia, J., 2002, Using the Electromagnetic Method to Locate Abandoned Brine Wells in Hutchinson, Kansas: Symposium on the Application of Geophysics to Engineering and Environmental Problems, Kansas Geological Survey, Open-file Report 2001-17, Web Accessed May 14, 2016, http://www.kgs.ku.edu/Geophysics/OFR/2001/17/

Evaluation of Geophysical Techniques in the Determination of a Salt Contaminated Environment

Walter Reed[1], Michael Foust[1], Heather L. Lehto[1], James W. Ward[1], and Jason Payne[2]
[1]Angelo State University, Department of Physics and Geosciences
[2]United States Geological Survey, San Angelo, Texas

Introduction

Saline soils propose a major environmental risk to land that once flourished with plants and vegetation. Located 15 miles south of San Angelo, TX on the Scherz Ranch is a site with dimensions of 335x213 meters that has been stripped of the ability to adequately grow vegetation. Due to the oil field industry presence on this site, it's believed that the contaminated site is the result of a historic salt water spill. As a result, the salt contaminates have caused the soil to become flocculated making it difficult for plants to establish their root system and absorb water. Currently a team of research students under the oversite of Dr. James Ward from Angelo State University are seeking to remediate the site through the use of halophyte plants. The general idea is that over time salt tolerant plants will be able to establish root systems on the site and over time restore the site to its original state.

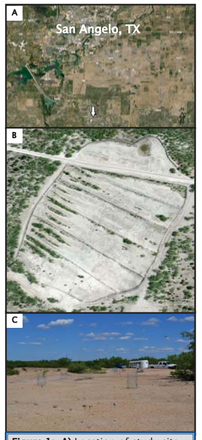

Figure 1: **A)** Location of study site, 15 miles south of San Angelo, TX. **B)** Satellite image of study site. **C)** Photograph of site where salt tolerant plants have been planted.

Objectives

The objective of this study is to identify and successfully use electromagnetic geophysical techniques in order to quickly and adequately analyze the site. Electromagnetic geophysical techniques provide a noninvasive approach that allows the ability to identify depth and concentration of salt contaminates. **Figure 2** shows the initial geophysical investigation from 2013 using traditional DC resistivity methods. This method proved to be successful in adequately identifying the depth and concentration of salt contaminates. However, this method is very slow and labor intensive. The purpose of this study is to identify other methods that can be used to identify salt contaminates at this site quickly and effectively with as little manual labor as possible so that salt concentration levels can be monitored over time as a way to gage the effectiveness of the proposed remediation technique. The following criteria were looked for when selecting EM geophysical methods.

- ❖Accurate results comparable to traditional DC resistivity surveys.
- ❖Time efficient
- ❖Minimal labor requirements (1-2 person job)

The methods selected for comparison to traditional DC galvanic resistivty surveys include the capacitvely coupled method used by the Geometrics OhmMapper and the frequency domain method used by the Geophex Gem2.

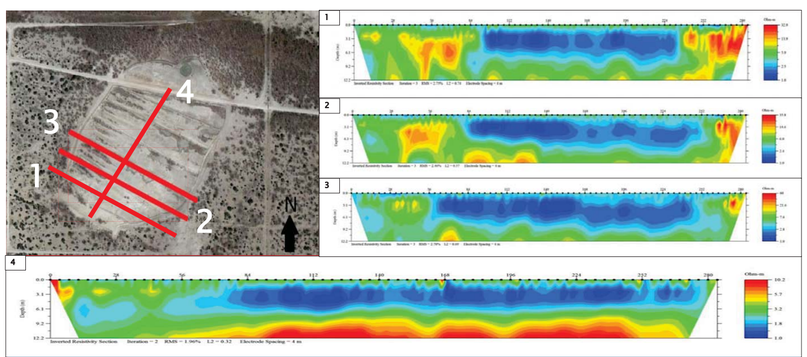

Figure 2: The original DC resistivity profiles run in 2013 show the dispersion of salt contaminates. The blue area represents a low resistivity area indicative of the salt contamination. The depth of the contamination was approximately 8-9 meters. The green and red areas represent regions of no contaminates. These resistivity values are indicative of the clay found in the subsurface as shown in figure 4. DC resistivity profiles were constructed using EarthImager 2D

Methodology

The Gem2 works off the frequency domain EM method. In the back of the ski a primary coil induces a magnetic field which penetrates into the subsurface. This in return produces currents in the subsurface along with secondary magnetic fields. The fields are then picked up and recorded as data in parts per million based on varying frequencies. This method has the ability to record data up to 10-30 meters depending on the resistivity of the subsurface. Data can be represented as resistivity or conductivity values.

The Syscal Pro Switch 72 works off the DC resistivity method. Lines consisting of 72 electrodes were hammered in the ground at 3m spacings. Two electrodes serve to input current in the subsurface while two other electrodes read a voltage difference at varying distances. This voltage difference can then be used to calculate resistivity values. Both the wenner schlumberger and dipole-dipole arrays were used in order cross check each other for error in resistivity profiles.

Well Log Data was collected from the Texas Water Development Board at this site. This allowed the methods to be confirmed with known resistivities of various rock types. Clay has resistivity values ranging from 5-100 Ω·m.

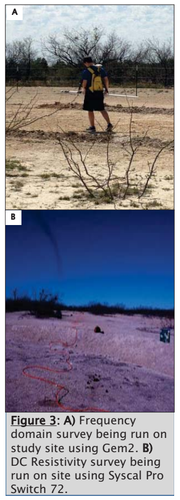

Figure 3: **A)** Frequency domain survey being run on study site using Gem2. **B)** DC Resistivity survey being run on site using Syscal Pro Switch 72.

Top (ft.)	Bottom (ft.)	Description
0	7	brown Silty Clay
7	10	Caliche
10	21	Tan Silt & Clay
21	32	Tan/Orange Silt & Clay
32	43	Tan Silt & Clay
43	50	Medium Hard Siltstone Layers

1

Top (ft.)	Bottom (ft.)	Description
0	5	Brown Silty Clay
5	8	Pink Silt & Clay
8	18	Tan Silt & Clay
18	22	Pink Silt & Clay
22	33	Tan Silty Clay
33	49	Tan Silt & Clay Layers
49	50	Tan Siltstone Layers
50	60	Tan Siltstone & Clay
60	70	Siltstone (Hard)

2

Top (ft.)	Bottom (ft.)	Description
0	2	Brown Clay
2	16	Tan Silty Clay
16	30	Yellow Silty Clay
30	49	Tan Silty Clay
49	52	Limestone Layers
52	53	Tan Sandstone Layers
53	57	Limestone

3

Top (ft.)	Bottom (ft.)	Description
0	3	Brown Silty Clay
3	20	Tan Silty Clay
20	32	Tan Shale & Gray Clay
32	45	Gray Shale & Clay
45	47	Limestone Layers
47	48	Tan Sandstone
48	51	Gray Limestone & Shale

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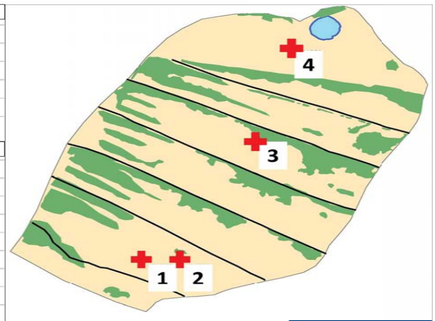


Figure 4: A total of four wells were dug on the site in 2008 that indicate the subsurface of the site is mainly comprised of silt and clay for the first 50ft with some limestone and sandstone occurring after 50ft.

Results: DC Resistivity (Syscal Pro)

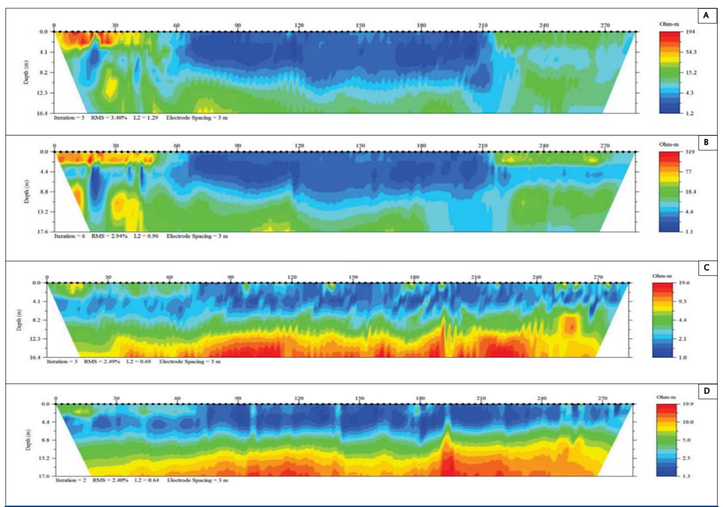
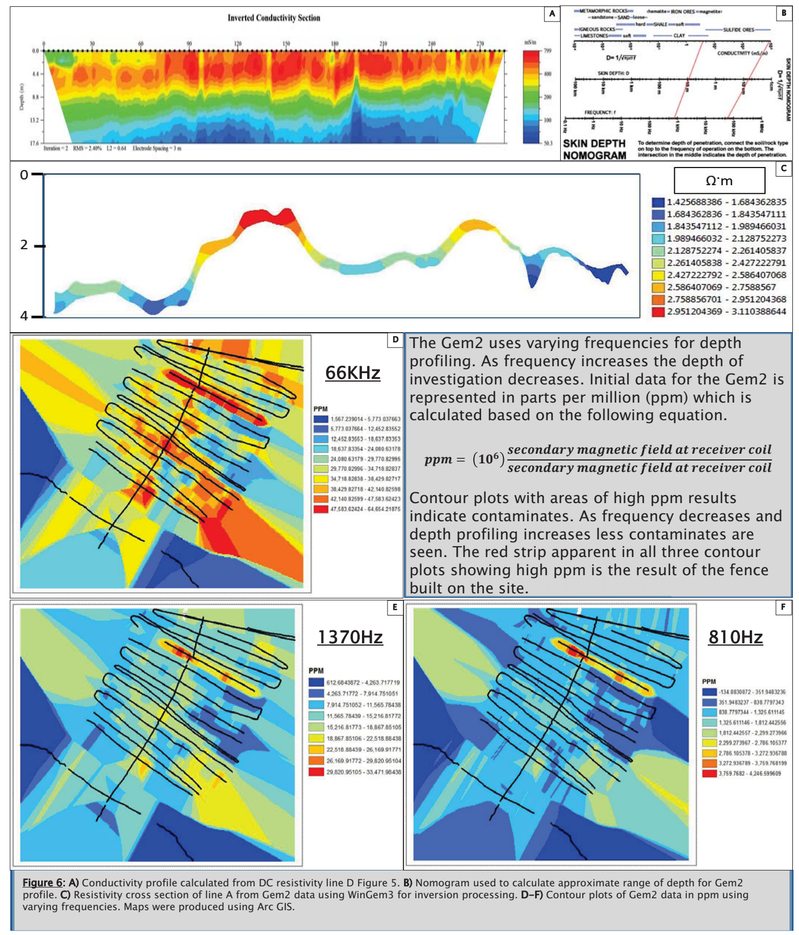


Figure 5: **A)** Resistivity profile running NW to SE slightly under Line 1 from Figure 2 using the dipole-dipole configuration. **B)** Profile representing the same line as A using a wenner schlumberger configuration. **C)** Profile running NE to SW mimicking line 4 from Figure 2 using the dipole-dipole configuration. **D)** Profile representing the same line as C using a wenner schlumberger configuration. Both methods were used for comparison to assure the data was consistent with no erroneous data. Resistivity values from lines indicate expected resistivty values of clays from well log data

Results: Frequency Domain Method (Gem2)



The Gem2 uses varying frequencies for depth profiling. As frequency increases the depth of investigation decreases. Initial data for the Gem2 is represented in parts per million (ppm) which is calculated based on the following equation.

$$ppm = (10^6)\frac{\textbf{secondary magnetic field at receiver coil}}{\textbf{secondary magnetic field at receiver coil}}$$

Contour plots with areas of high ppm results indicate contaminates. As frequency decreases and depth profiling increases less contaminates are seen. The red strip apparent in all three contour plots showing high ppm is the result of the fence built on the site.

Figure 6: **A)** Conductivity profile calculated from DC resistivity line D Figure 5. **B)** Nomogram used to calculate approximate range of depth for Gem2 profile. **C)** Resistivity cross section of line A from Gem2 data using WinGem3 for inversion processing. **D-F)** Contour plots of Gem2 data in ppm using varying frequencies. Maps were produced using Arc GIS.

Discussion of Results

The Gem2 results showed that it was capable of identifying salt contaminates and reproduced resistivity values comparable to the DC resistivity lines. The time and man power that it takes to run a Gem2 survey is significantly less than traditional DC lines which makes it an ideal geophysical method to use over the DC resistivty lines.

Future work will consist of carrying out the capacitively coupled survey using the OhmMapper. Improvements can be made on graphical representation of Gem2 data with additional software to better improve understanding of the data.

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References

"Gem-2 - How It Works - Detailed." Gem-2 - How It Works - Detailed. http://www.geophex.com/Pubs/gem2_-_how_it_works_detailed.htm
"Groundwater Data Viewer | Texas Water Development Board." Groundwater Data Viewer | Texas Water Development Board. http://www2.twdb.texas.gov/apps/waterdatainteractive/GroundwaterDataViewer#
Shah, S.D., Smith, B.D, Clark, A.K., and Payne, J.D., 2008, An integrated hydrogeologic and geophysical investigation to characterize the hydrostratigraphy of the Edwards aquifer in an area of northeastern Bexar County, Texas: U.S. Geological Survey Scientific Investigations Report 2008–5181, 26 p.
Trainor-Guitton, Whitney J., Abelardo Ramirez, Xianjin Yang, Kayyum Mansoor, Yunwei Sun, and Susan Carroll. "Value of Information Methodology for Assessing the Ability of Electrical Resistivity to Detect CO2/brine Leakage into a Shallow Aquifer." International Journal of Greenhouse Gas Control 18 (2013): 101-13.
Xia, Jianghai. "Using the Electromagnetic Method to Locate Abandoned Brine Wells in Hutchinson, Kansas." Symposium on the Application of Geophysics to Engineering and Environmental Problems 2002.