Application of Electrical Resistivity Tomography (ERT) to Wetland Hydrogeology: An assessment of the efficacy of array configurations

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Abstract

Electrical Resistivity Tomography (ERT) is a geophysical technique used to measure and map the resistivity of the subsurface. Resistivity is typically given in units of Ohm-meters and is an intrinsic property of earth materials. ERT is frequently used for mineral and groundwater exploration, but this technique can be used in any field in which the user requires information on both the horizontal and vertical subsurface. Resistivity is determined by applying a known current on one electrode pair (C1 and C2) and taking measurements of voltage potential on another electrode pair (P1 and P2), later creating a pseudosection from the data collected. The two most commonly used electrode array configurations are Schlumberger and Dipole-Dipole. In this study, we test the efficacy of various array configurations to determine which one is best suited to help us understand the hydrogeology of geographically isolated wetlands (GIWs). These GWs provide numerous benefits to the surrounding area, such as water quality improvement, sediment and carbon retention, and flood protection, to name a few. Using twenty-eight electrodes with 0.5 meter spacing, we were able to conduct these two array configurations on the 977N wetland in the Daniel Boone National Forest. After viewing the modeled pseudosections, we conclude that the Schlumberger array provides the most accurate results. Results from the dipole-dipole array are noisy and provide a chaotic image of the subsurface whereas the Schlumberger modeled pseudosection strongly agrees with existing core data.

Methodology

ERT is a method of measuring the subsurface using an array of electrodes. The data collected are processed to create a pseudosection—image of modeled resistivity values that approximate a geologic cross-section of the subsurface. One common method is vertical electrical sounding (VES). VES (sometimes referred to as electrical drilling) is used in both the Wenner and Schlumberger array configurations (fig. 4&5). VES is widely considered the original method for ERT. ERT measurements are determined by the spacing between electrodes. Longer spacings provide deeper subsurface measurements while shorter spacing provides shallower, more detailed measurements.

Results

After running consecutive scans at the 977N wetland, we used the resultant data and AGI 2D imaging software to develop pseudosections. Pictured below are the results of each scan. All scan required removal of noisy data points. The warm tones denote high apparent resistivity while the cool tones show low apparent resistivity.

Conclusion

The results of our study showed that the Schlumberger array configuration was the most effective and accurate reflection of the wetland subsurface. The resultant pseudosection best reflects previously existing core data. With lower error levels and considerably less noisy data points, the results recommend this array configuration when working with GWs.

The Dipole-dipole array configuration proved to yield inferior results, with a substantial amount of noisy data. Much of this data had to be removed during the development of the previously picture pseudosection. We believe this is due to the high surface conductivity that is characteristic of the wetland near-surface. It is likely that the currents traveled across the near-surface in addition to traveling below the surface. With this additional current, the resultant data points would prove to be inaccurate, giving a chaotic image of the wetland subsurface.

For future research on the GWs, we recommend the use of the Schlumberger array. This array will provide a pseudosection that more accurately reflects the subsurface of GWs.

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Figure 1

(Above): The Advanced Geosciences, Inc. (AGI) Super Sling E1 performing scans on the field site.

Figure 2

(Above): Aerial view of the 977N wetland.

Figure 3

(Above): Pictured is a model of VES. Two electrode pairs (current and potential) send currents through the subsurface. From the collected data, colorful pseudosections are created in a computing system. This resultant image shows resistivity values and depth.

Figure 4

(Left): The Wenner array, invented in 1915 by American physicist Frank Wenner, is the simplest of electrode arrays. Four or more electrodes are placed an equal distance from one another (a). The inner two electrodes (P1 and P2) are potential electrodes while the outer two electrodes (C1 and C2) are the current electrodes. The Wenner array utilizes the previously mentioned VES method. While still used today, the Wenner array is generally considered outdated and has been replaced by the Schlumberger array.

Figure 5

(Right): Named after Conrad Schlumberger, the Schlumberger array is one of the most common array configurations. Four or more electrodes are placed in line with each other, centered around a midpoint like the Wenner array, the inner two electrodes (P1 and P2) are potential electrodes while the outer two electrodes (C1 and C2) are the current electrodes. This array also utilizes VES. Unlike the Wenner array, the distance between the outer electrodes varies throughout the scan (ma), while the inner electrodes maintain the same spacing (a).

Figure 6

(Left): The Dipole-dipole array again consists of four or more electrodes, both potential (P1 and P2) and current (C1 and C2). The word Dipole itself comes from the idea that when two oppositely charged objects are placed near one another, a single electric field forms instead of two separate electric poles. Each electrode is placed in line with equal spacing (a) between them. The data is constructed from a series of midpoints between the current and potential electrodes. This configuration is capable of producing images with the highest resolution (~a/2), but it also has the most sensitive to electrical noise.

Figure 7

(Above): The Dipole-dipole results from the 977N wetland proved to be quite chaotic. With a high level of error, we had to remove a large percentage of the noisy data. That being said, the overall result of this scan was substandard.

Figure 8

(Above): The Schlumberger results from the 977N scan were much improved when compared to the Dipole-dipole. With a lower error, significantly less data points were removed. The scan resulted in a clear, reliable image.

Figure 9

(Above): To compare the above data sets, we decided to create a merge of both the Dipole-dipole and Schlumberger data. Pictured above is this merge. The resultant image is still quite chaotic. The noisy Dipole-dipole data overtook the Schlumberger data, making the image less accurate than the Schlumberger scan on its own. In this case, more data is not the solution.