The ERT method is an electrical testing method where current is induced in the ground using two current electrodes. The electrical potential drop is then read using two other electrodes. There are many different electrode array configurations available, but all configurations are aimed at gathering data that can be used to estimate lateral and vertical variations in ground resistivity values. ERT can be used to map geologic variations including soil lithology (e.g., clay versus gravel), presence of ground water, fracture zones, variations in soil saturation, areas of increased salinity or, in some cases, ground water contamination. ERT can be used to map bedrock depths and geometry; although in most geologic settings MASW or SRT are better suited for mapping top-of-bedrock. ERT is often the best option for mapping cavities such as caves, karst and/or evaporite dissolution sinkholes. Like seismic, the electrical method has the capacity to yield either 1D (vertical electrical sounding), 2D (profile) or 3D (volume) imaging. Olson uses the appropriate electrode array and choice of 1D, 2D or 3D based on objective and budget. Electrical methods are most affected by the geochemistry of the subsurface; that is, grainsize distribution, ground water chemistry and/or the presence of contamination.

MHS PROJECT
MANAGEMENT SERVICES

PROTECTING THE BUILT WORLD

CONTACT : +971 544290205

Figure 14 - ERT profiles acquisition.

Figure 15 - VES profiles acquisition.

Figure 16 - GPR profiles acquisition with positioning equipment.

1. Data processing and results

This section is devoted to the data processing and analysis of results.

7.1 Resistivity: VES and ERT

The VES using Wenner array were acquired in 3 points, in the positions are per Figure 13. The raw data of VES 1, VES 2 and VES 3 is presented in Figure 17, Figure 18 and Figure 19, respectively.

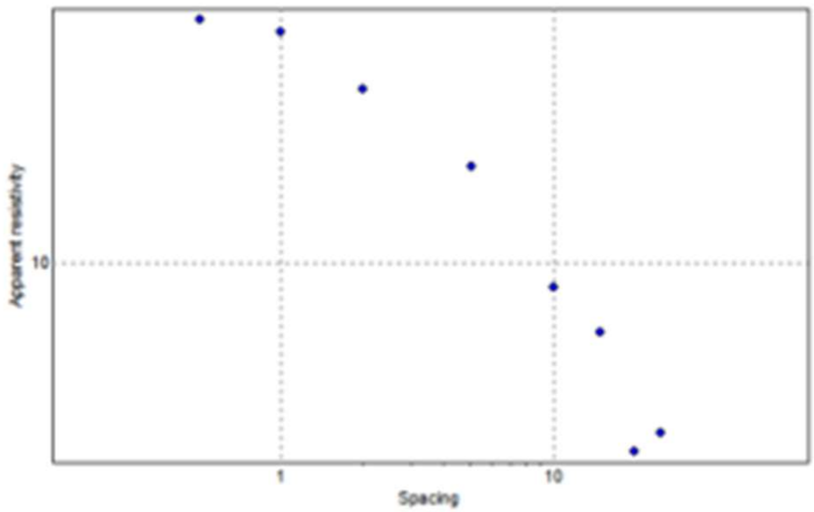


Figure 17 - Raw data of VES 1.

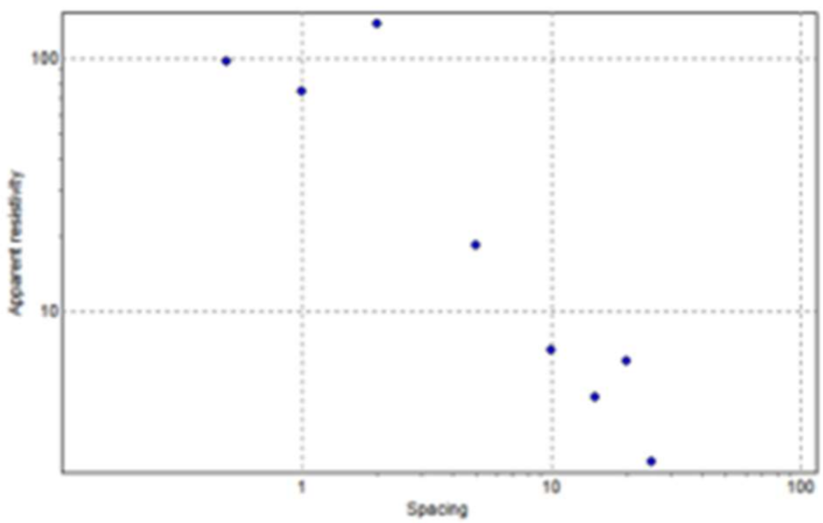


Figure 18 - Raw data of VES 2.

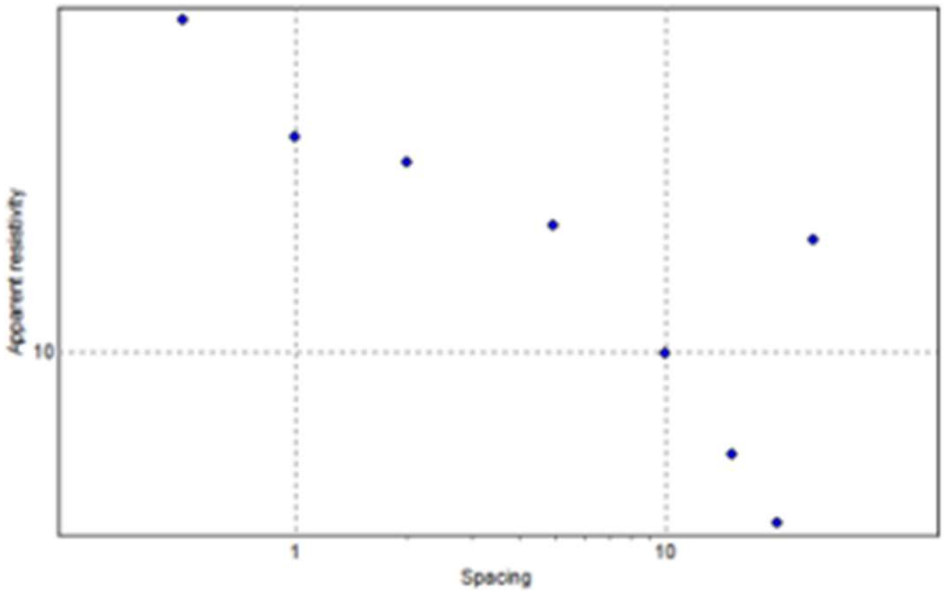


Figure 19 - Raw data of VES 3.

The inversion was carried out with the IP2 software. Results are presented for VES1, VES2 and VES3 (Figure 20, Figure 21 and both Figure 22 and Figure 23, respectively).

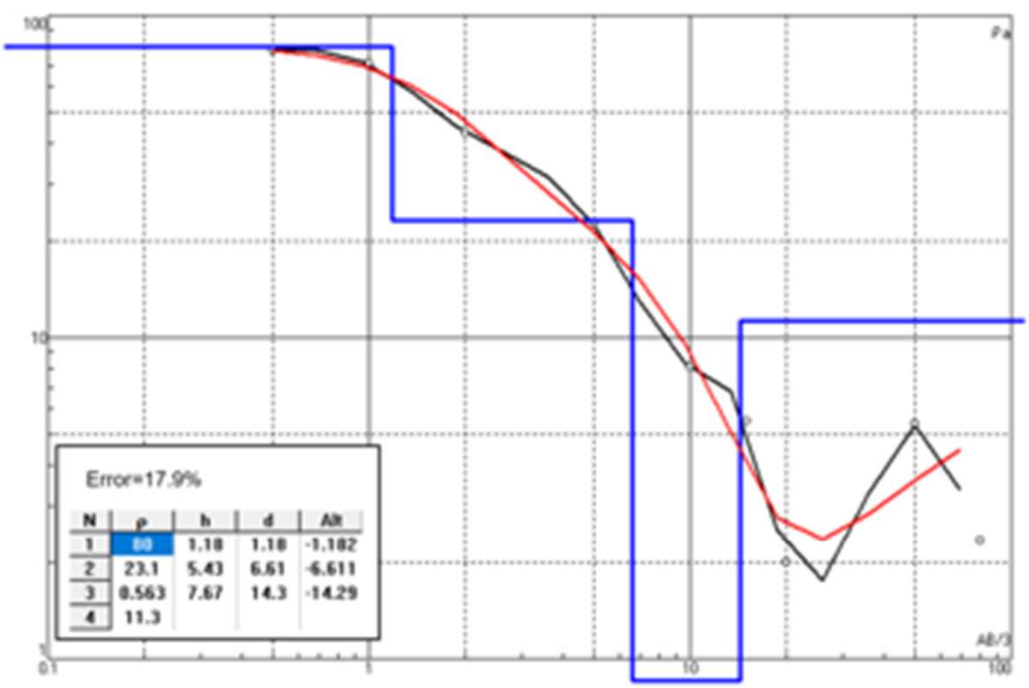


Figure 20 - Inverted data of VES 1.

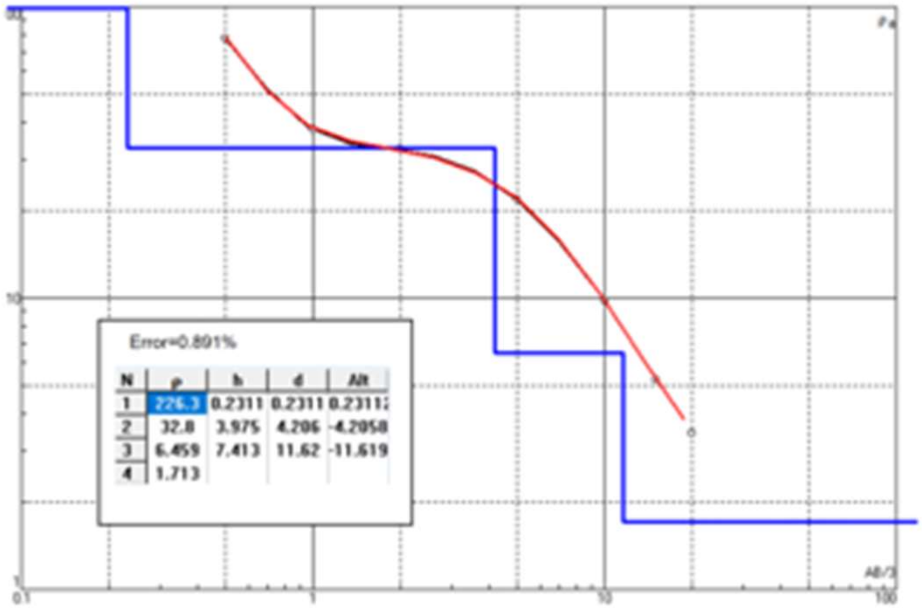


Figure 23 - Inverted data of VES 3 with eliminated point.

Conclusions for VES:

The penetration depth VES1, VES2 and VES3 was of 14.29m, 17.08m and 11.6m (with correction), respectively. Both VES 1 and VES 3 present an important difference of resistivity at 4m and 6m depth where the resistivity highly decreases. The low resistivity very near the surface could be related to the heavy rainy days that occurred few days before the measurements. The values encountered in the VES profiles cannot conclude to assure the presence of underground water given the high lateral heterogeneity of the first meters of the subsoil (possibly with fractures, boulders and gravel). In this kind of environment it is recommended to carry out ERT to have a better understanding of the both local geology and hydrology.

ERT

For each profile of the ERT lines (ERT1 and ERT2) were acquired Dipole-Dipole and Schlumberger. The raw data was processed by using RES2DINV. The first step was to eliminate bad points (out of the correct position on the horizontal line) as shown a paradigmatic example in ***Figure 24*** . It consists on deleting out of range values to decrease the error when inverting the data. After this first phase, the data is inverted (***Figure 25***).

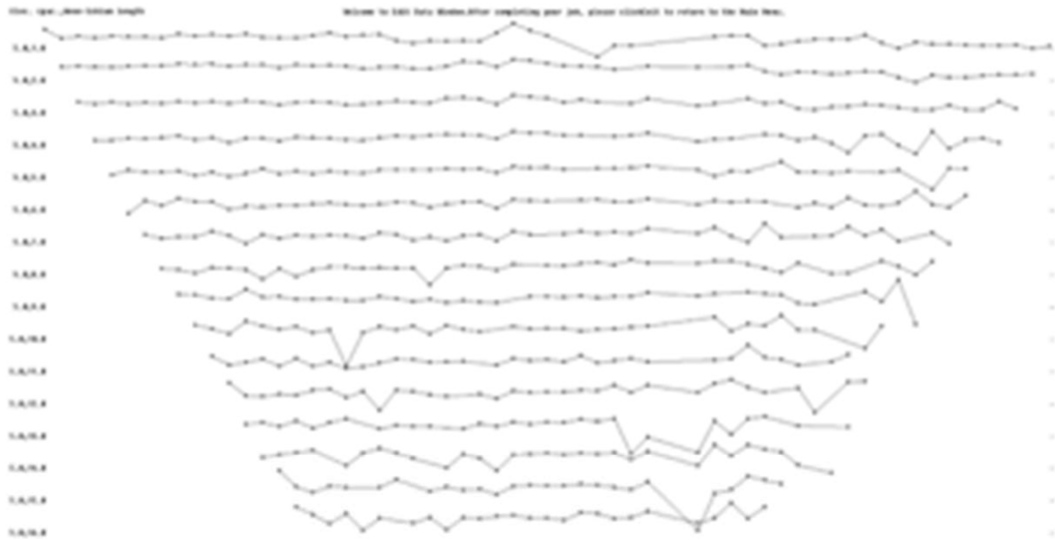


Figure 24 - Raw data exhibiting the phase of eliminating bad points. ERT2 - Schlumberger

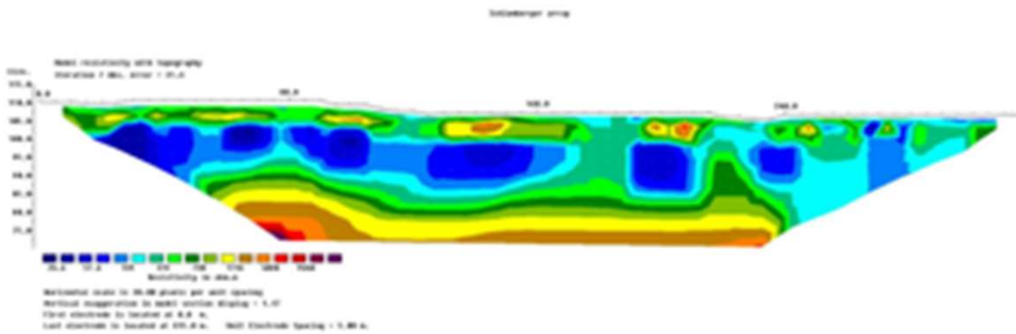


Figure 25 - Inverted raw data with no applied filters. ERT2 - Schlumberger.

The next filter was to trim the data and delete unwanted values. ***Figure 26*** shows the green line as threshold value, removing all the values on its right side.

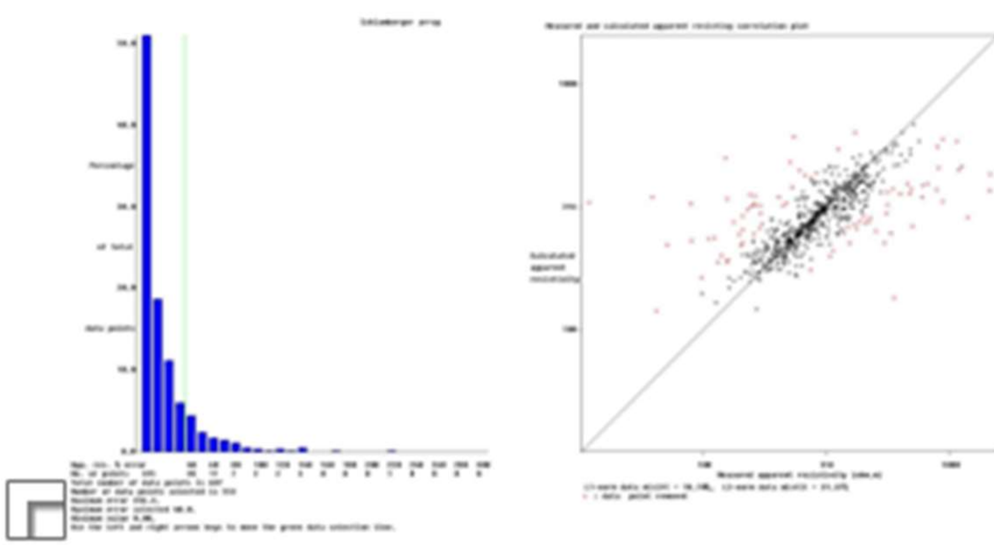


Figure 26 - Trim by eliminating extreme points - ERT2 - Schlumberger.

Two different inversions were applied to be each of acquired profile: least square method (LSM) and Robust.

The LSM seeks to minimize the sum of the squared differences between the observed data and the predicted data, subject to a set of linear constraints. This method assumes that the noise in the data is normally distributed and that there are no outliers. It provides a smoother output and is more indicative of the subsurface.

Robust inversion, on the other hand, is designed to be more tolerant of outliers and non-normal noise. It searches to minimize a robust measure of the differences between the observed data and the predicted data, such as the L1-norm or Huber loss function. This method is often used when the data is known to be contaminated with outliers, or when the noise in the data is not normally distributed.

The main difference with respect each array: Dipole-Dipole, it is generally suitable to have a relative greater depth penetration and mostly indicated to resolve lateral resistivity. A greater horizontal resolution can be provided by the Sclumberger array.

Here are shown the best results, the inversions with the least error, for each line: ERT1, Schlumberger (***Figure 27***) and Dipole-Dipole (***Figure 28***) and superimposition of both (***Figure 29***). For the ERT2 Schlumberger (***Figure 30***), Dipole-Dipole (***Figure 31***) as well as their superimposition (***Figure 32***).

Before the interpretation it is important to consider that a strong gradient of the resistivity it normally correspond to a rapid change in the material properties. High gradients could be related to fractures or to cavities. On other hand, smooth gradient are normally related to slow changes and minor changes in the materials (like compaction or water content).

In all profiles the first layer is characterized by high later heterogeneity by values varying from low resistivity 50 ohm.m to high resistivity around 2000 ohm.m (to higher values). The low values could be related to water accumulation from the heavy rain that occurred in the previous days. Contrary, the high values (2000 ohm.m) could be related to rocks such as boulders and intermediate resistivity 150 ohm.m to 400 ohm.m related to sand or gravel.

In Schlumberger (***Figure 27***) the inversion was carried out with only 8.6% of error achieved around 30m depth. At around 10m depth from the beginning of the profile until 160m it is perceived a continuous body characterized by low resistivity. This could be related to the presence of gravel or sand saturated with fresh water. It is possible to be fresh water since salty water has normally values less than 20 ohm.m. On the right side, the resistivity is higher than the previous cited body, suggesting that the water content might be less. Around 240m it is visible a fracture that could be lead entry of fresh underground water. Between 20m to 25m the very high resistivity could be associated to the highly compacted rock: limestone or ophiolites (based on research of local geology) that acts as a waterproof body, impeding the possible existing water to penetrate to deeper levels.

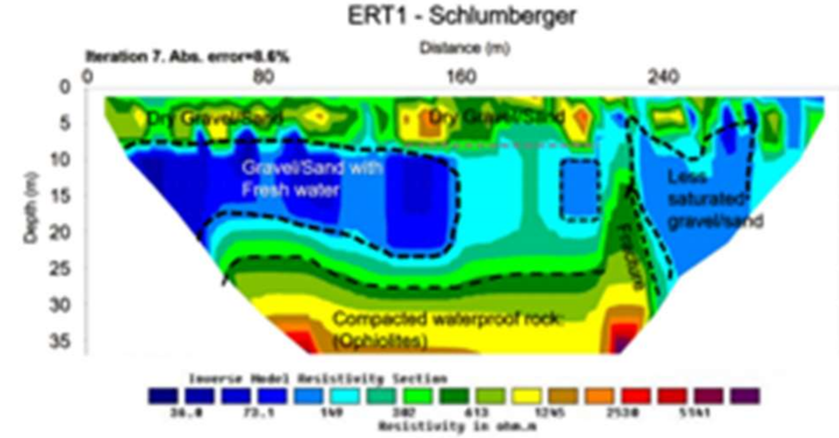


Figure 27 - ERT1 - Schlumberger: processed and interpreted.

In the same location (*Figure 28*) with the array dipole-dipole, with 7.6% error in the inversion, achieving approximately 60m depth. The profile show the same type of geology when compared to the Schlumberger profile. However, the main difference relays on the detection of the fracture that is clearly visible on the Schlumberger. This is due to the fact that the dipole-dipole does not offer sufficient horizontal resolution. Another aspect is the geometry of the compacted rock (being flat in Schlumberger unlike in dipole-dipole).

Nevertheless, the position of the areas with lower resistivity that could be related to the possible water body is identified in the same location.

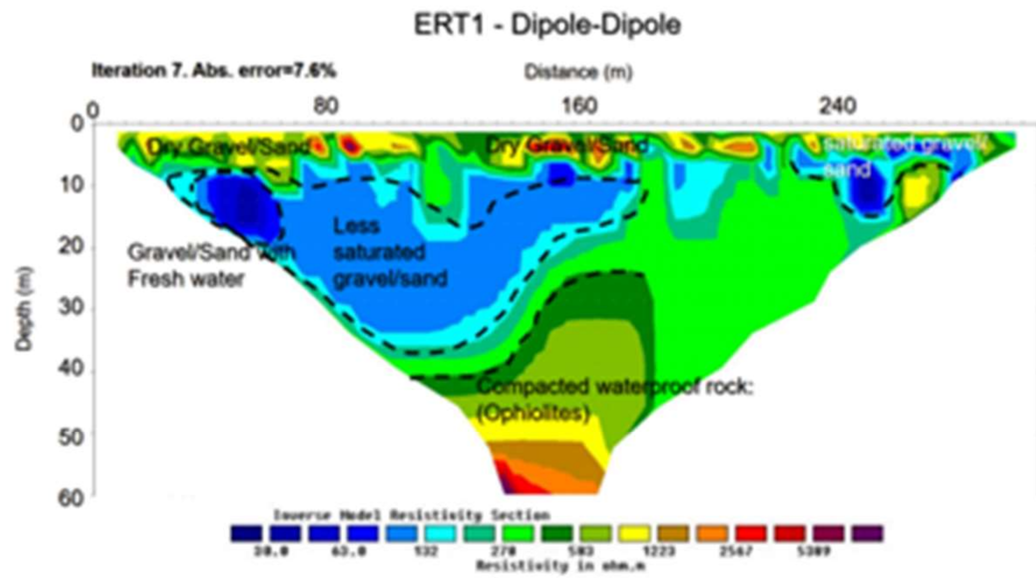


Figure 28 - ERT1 - Dipole-Dipole: processed and interpreted.

The superimposition of the dipole-dipole with the Schlumberger (*Figure 29*) allows comparing exactly the position of anomalies. As described before, the position of the possible water body (in absence of clay) matches in the beginning of the profile.

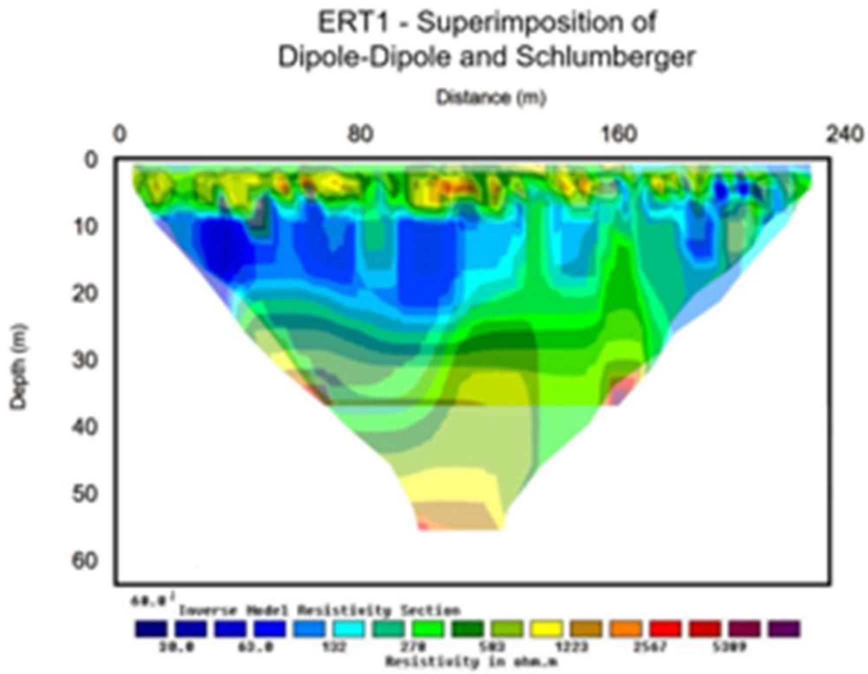


Figure 29 - ERT1 - Superimposition of Dipole-Dipole and Schlumberger results:processed and interpreted.

The *Figure 30* is associated with the line ERT2 carried out with the array Schlumberger at 11.8% error in the inversion, penetrating up to 23m depth. In this case, it is presented a robust inversion that offered less error compared to LSM inversion method. Similar to the previous profiles, high resistivity zones are encountered near the surface indicate continuity in terms of geological content. The position of the low resistivity values is determined to be between 50 ohm.m and 100 ohm.m. The position of the compacted rock is quite shallow when compared to the profile ERT1. Two fractures are observed and this could be one of the feeding points of the possible aquifer.

The dipole-dipole in the second case, *Figure 31* show an inversion with an error of 20.1% in the inversion, penetrating up to 35m depth. Once again the position of the possible water body is matching with the previous ERT2 Schlumberger. The position of the second fracture is the same but in this case a second fracture was detected towards the beginning of the profile. As in ERT1 it was detected the position of the bedrock (around 17m depth) at similar depths but given the difference between the arrays, the geometry of the bedrock is different.

Figure 32 represents the superimposition of both array as previously done with the ERT1 profile. There is a significant discrepancy on the left side on the tomography, not in terms of the values of the resistivity but in terms of the depth. Contrary, the position of possible water body on the right side is perfectly coincident as well as the position of the bed rock.

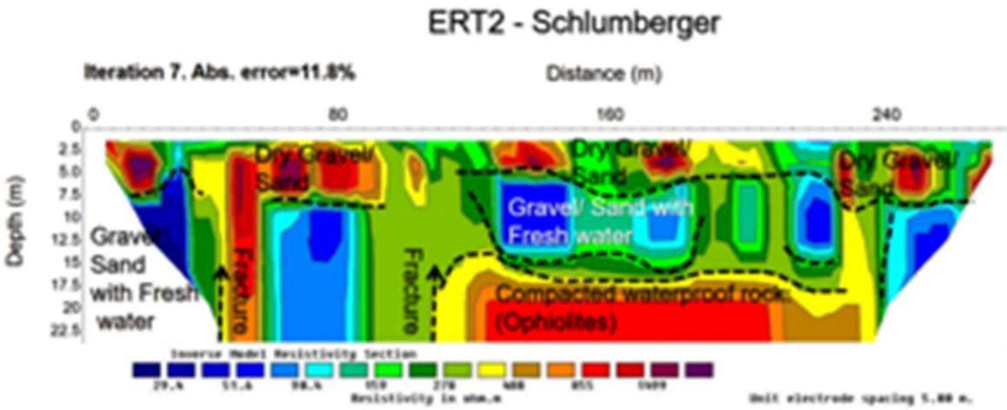


Figure 30 - ERT2- Schlumberger: processed and interpreted.

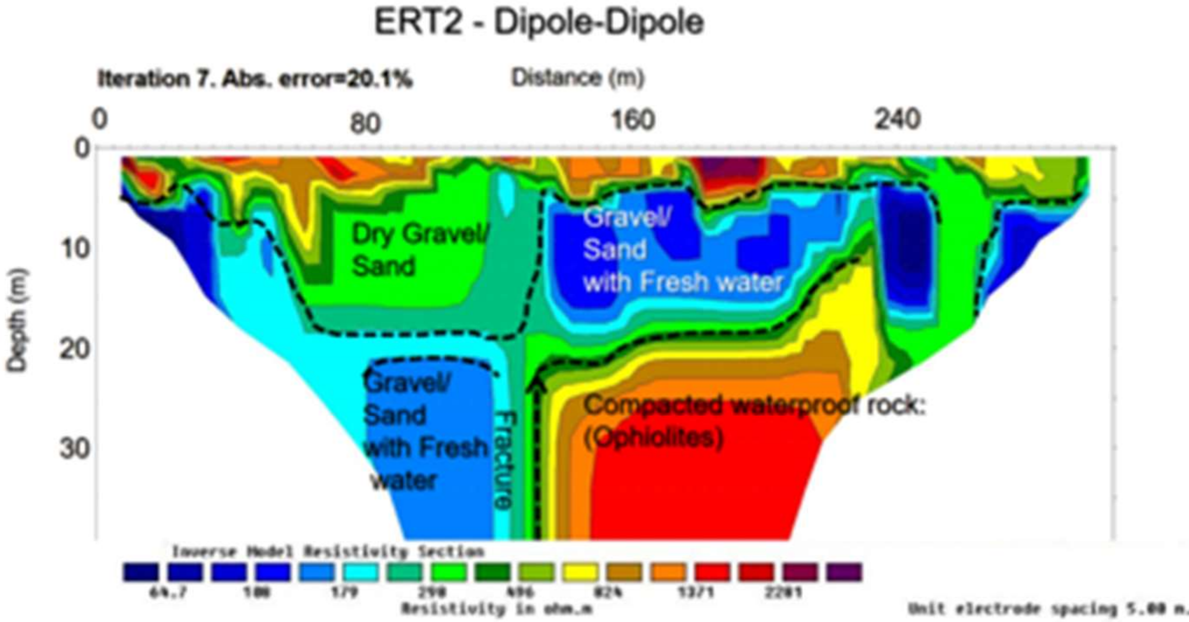


Figure 31 - ERT2- Dipole-Dipole: processed and interpreted.

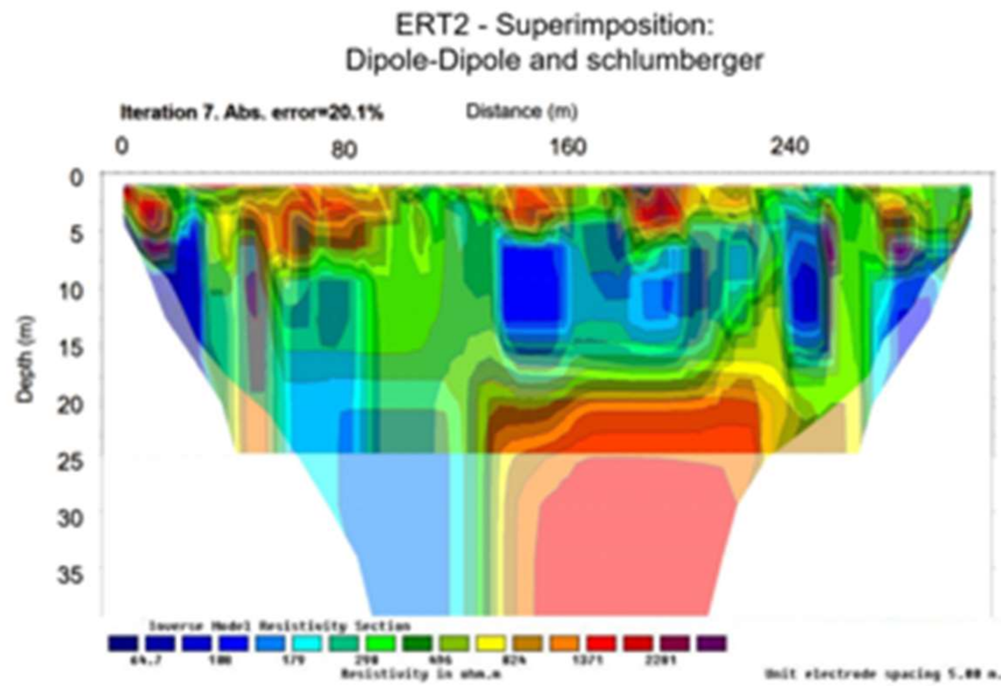


Figure 32 - ERT2 - Superimposition of Dipole-Dipole and Schlumberger results.

Topography was inserted in the profile ERT2. However, the unevenness of the surface does not represent any change in the actual depth of the anomalies as shown in ***Figure 33***. The aforesaid was observed on site in ERT1.

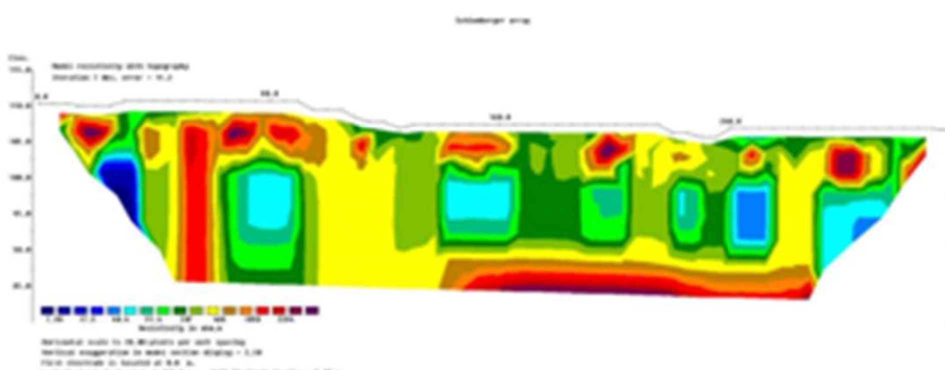
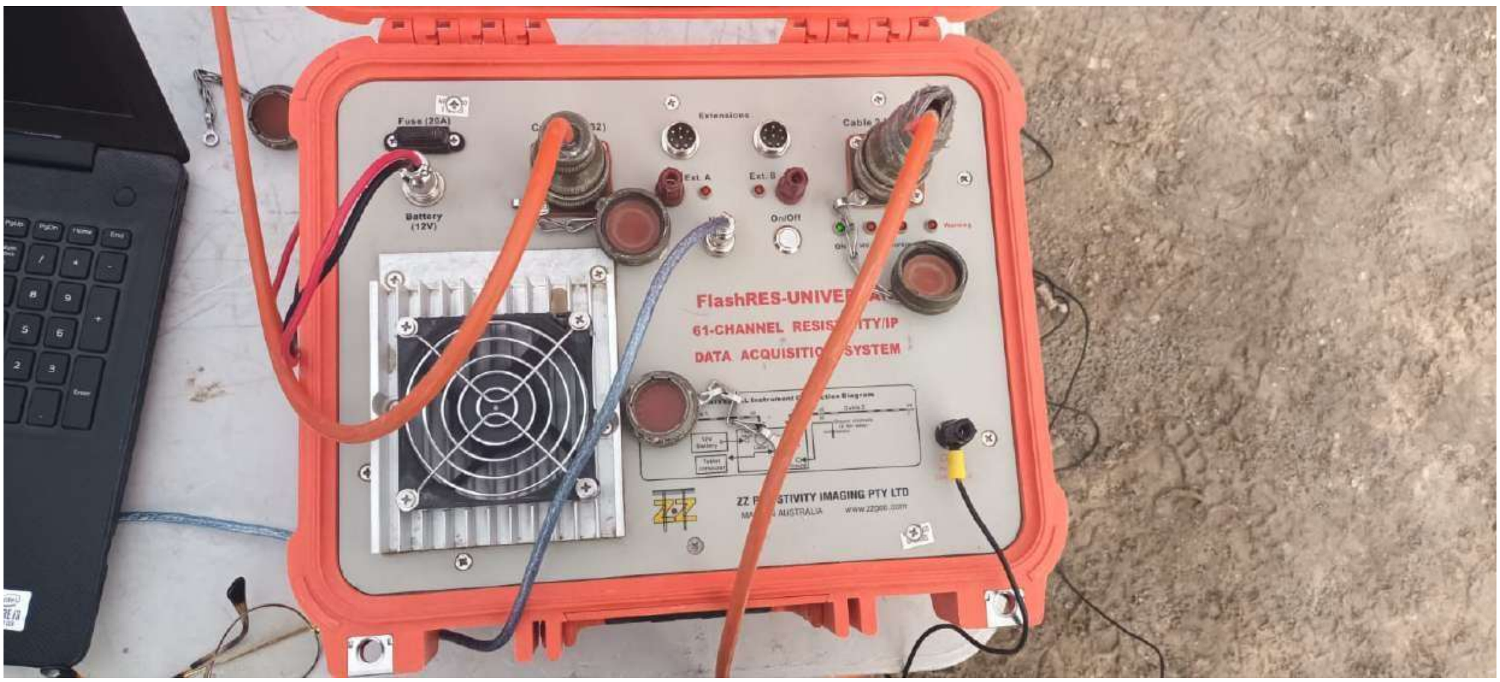


Figure 33 - ERT2- Schlumberger with robust inversion results;processed with topography included.


DELL


FIBERGLASS
50Meter




250m


AGL