Engineering and Environmental Geophysics with terraTEM

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ABSTRACT

terraTEM™ is a very advanced transient electromagnetic survey system using the latest developments in electronics and computing. It was designed by professional geophysicists with many years of experience using TEM instruments and optimising their suitability for field use. Its great range of options makes it a very versatile system suitable for a wide range of applications from near-surface to deep exploration. These applications include environmental, geotechnical, archaeological, groundwater, mineral, geothermal and petroleum surveys. Various options make these applications possible.

Examples are presented illustrating the application of terraTEM™, in particular to ground water investigation, environmental pollution, salt water invasion of a fresh water aquifer and site characterisation. In the first example, the advantage of the faster sampling rate of terraTEM™, is exemplified in the great detail of the data and hence the excellent resolution of the situation.

Figure 1. The terraTEM™ console and Battery Pack.
Note the large screen displaying, in this case, profile results.

DESCRIPTION OF TERRATEM

Standard Features

In the one convenient console (see Figure 1), terraTEM™ has from 1 to 3 receivers recording simultaneously plus a transmitter able to output up to 10 Amps. terraTEM™ uses a powerful processor for acquisition, display and interpretation and the graphical user interface is smart and intuitive. The large 15” LCD touch screen provides for the setting up of all the operating parameters and displays the results in an unlimited range of colours. See Figure 2 as an example.

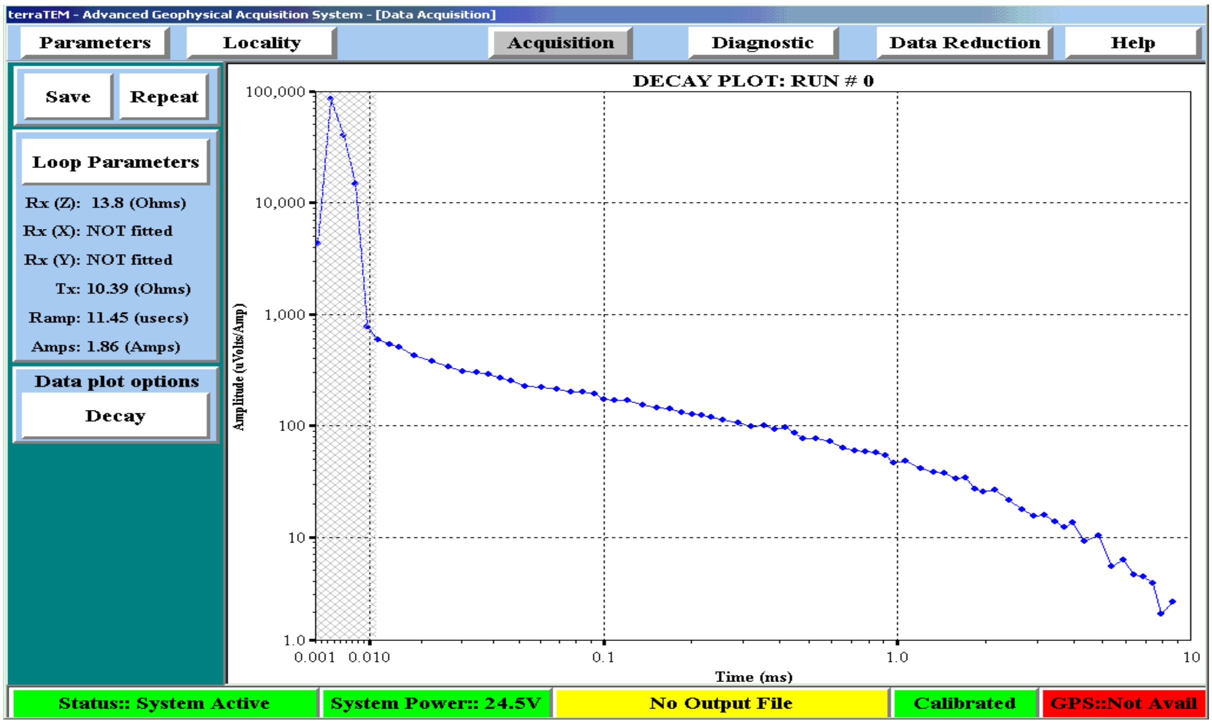


Figure 2. An example of a decay plot. terraTEM™ can also display many decays on the one plot for comparison purposes.

Data is stored in 1GB of solid-state memory, sufficient for 500,000 soundings, and easily downloaded via USB to a commonly available memory stick. By sampling at 2 microseconds, a great number of very narrow windows are available to provide superior resolution and full coverage of the transient. Several timing sequences are provided but other timing sequences of different widths and times are easily added to suit the particular application or the user’s preferences. There is a wide range of gain settings to improve S/N and common types of noise are cancelled by a choice of stacking algorithms and rejection filters. These settings and many others can be defined by the user, if preferred. Advanced software is imbedded to transform the data into conductivities on-site and display it in the form of plans or sections. Images can be saved as bitmaps and transferred directly in report-ready formats. The device is powered by two readily obtained 12 Volt batteries.

Examples of the display of results are shown in Figures 3 & 4, below, in the form of amplitude profiles and depth sections.

FIELD EXAMPLES

A Groundwater Example

A terraTEM™ survey was conducted in the state of Victoria, Australia for the purpose of detecting groundwater. A known aquifer was thought to be controlled by a fault on the flanks of Mt. Major. The aim of the survey was to closely define the location of the conductive fault. The existence of an electric transmission line in close proximity demonstrated the terraTEM™'s ability to exclude power line frequency noise.

A 50 x 50 metre coincident loop configuration was employed and the results obtained at 50 m and 25 m station intervals along lines perpendicular to the strike.

Figure 3 shows the amplitude profiles from one of the lines, which is 875 m in length. The profile illustrated is just as it was displayed on the screen in the field. A strong conductor is clearly evident between 400 to 600 m distance. Due to the greater flexibility and customised capabilities of terraTEM™, the optimum parameters could be designed and applied in the field for best results. This also resulted in a significant improvement in acquisition time as the full results could be obtained without the need to interleave multiple runs with different parameters.

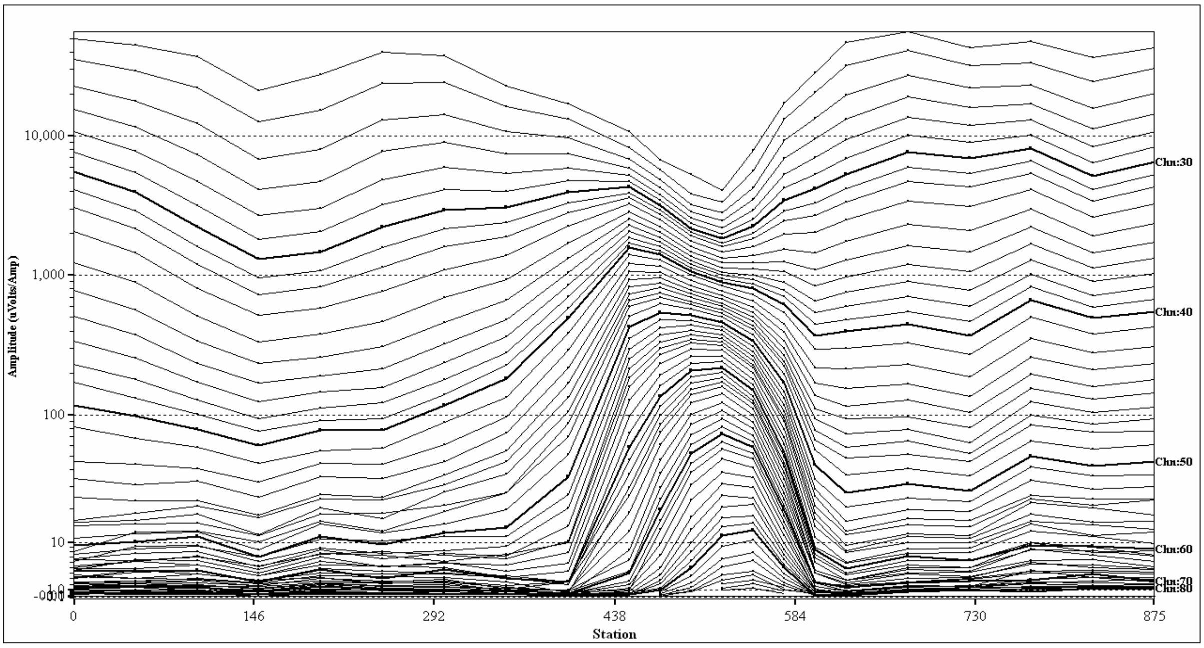


Figure 3. Amplitude profiles acquired by terraTEM^{tm} at Mt. Major.

Figure 4 is the conductivity depth section derived from the amplitude data by transformation software imbedded in the terraTEM™. They are also available in the field, if required. The results not only show the location of the conductive ground water but give a better indication of the nature of the aquifer.

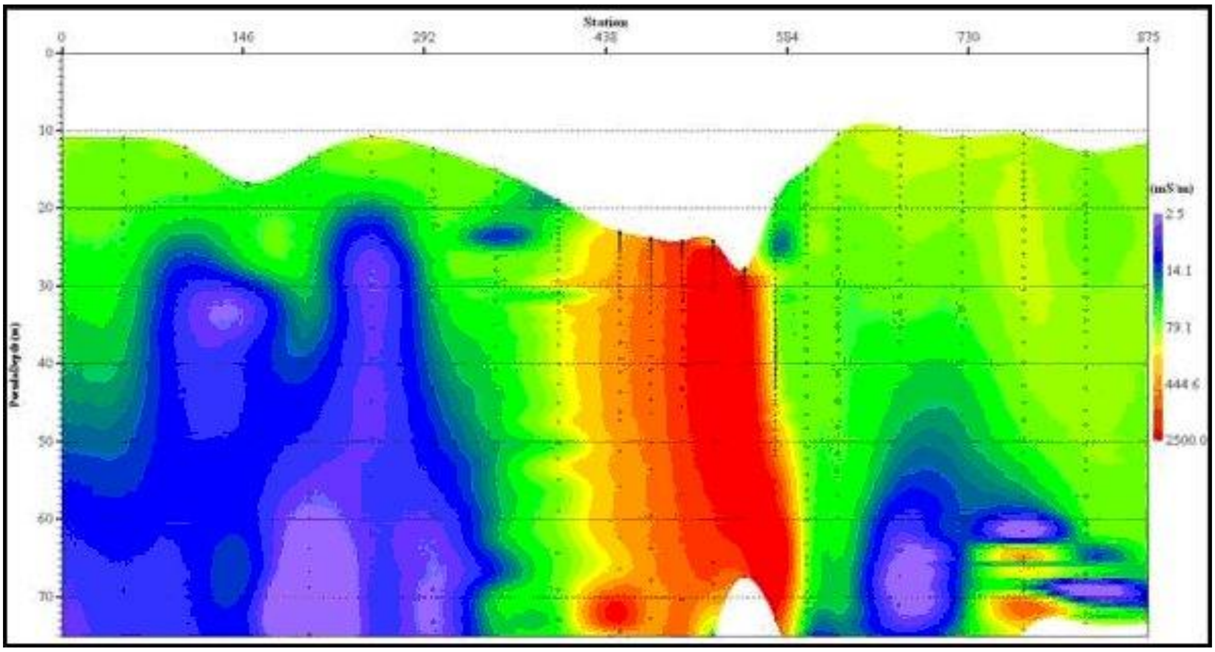


Figure 4. Apparent Conductivity Section derived from terraTEM™ data

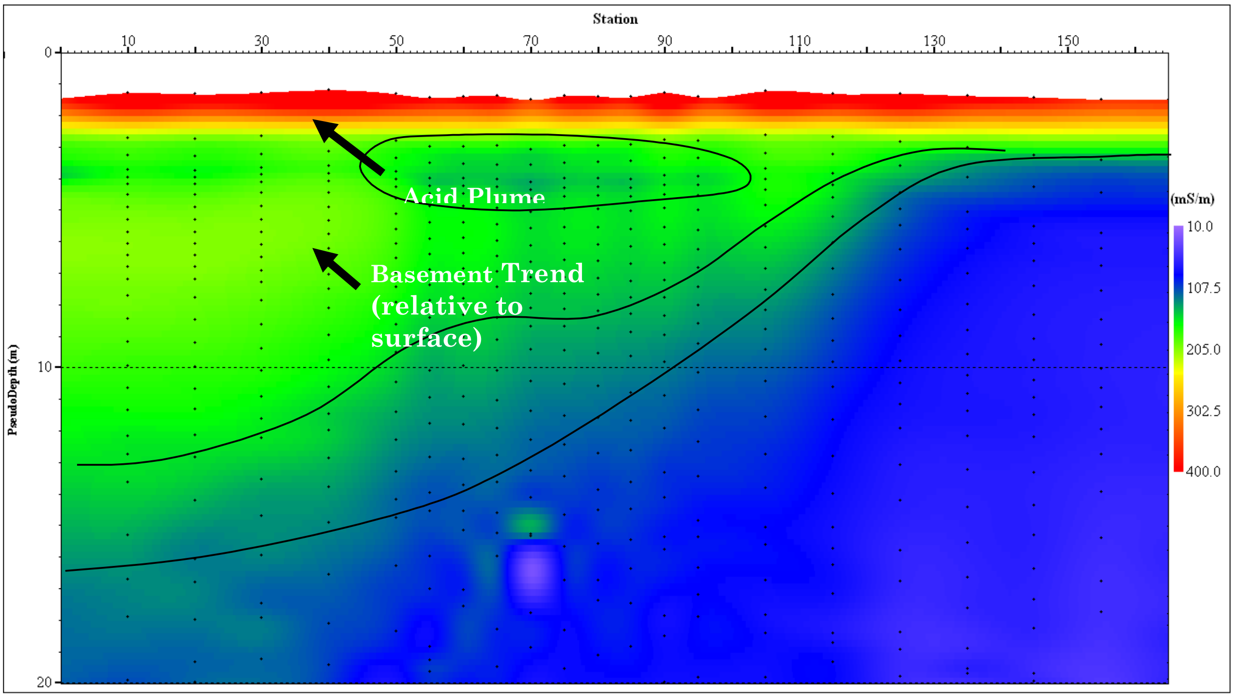


Figure 5. A terraTEM™ conductivity depth section showing an acid drainage plume detected at only less than 2 m depth. The "basement" topography is also revealed.

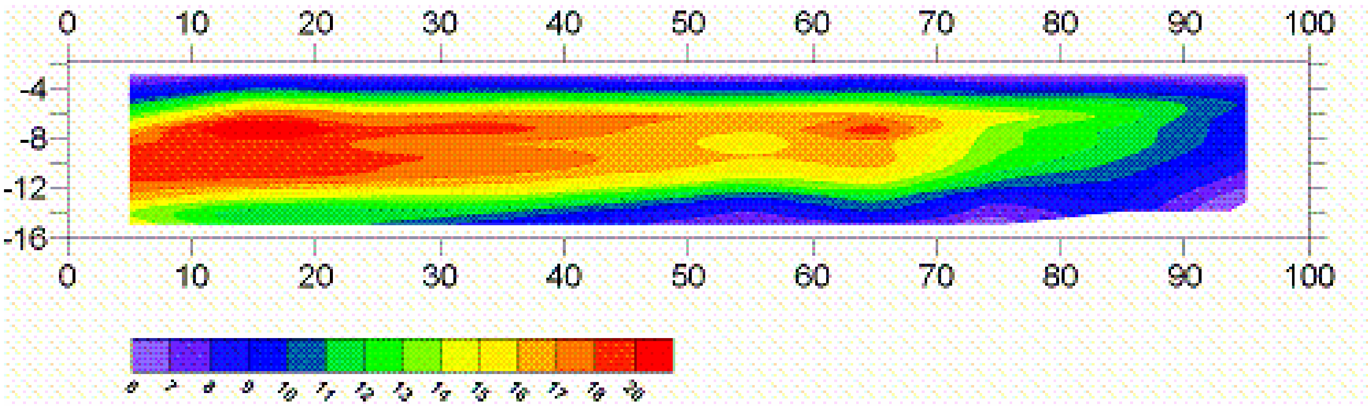
Example of Environmental Pollution – High Definition

Figure 5 is a result from an area of acid mine drainage at a coal mine where terraTEM™ has detected significant leakage beneath the stored surface spoils. The data was acquired with loops of only 10m x 10m and with a current of 2A. The very fast turn-off capability of terraTEM™ and the very high resolution of 500kHz sampling permits the recording of a very detailed decay curve (like the one in Figure 2) and only a few microseconds after turn-off which allows an inversion to depth to be as shallow as 2m or less. Note the depth scale in Figure 5 is 0-20m. Also "basement" topography is clearly identified as a strong conductivity contrast with trend lines consistent with its surface outcrop.

Example of Saline Water Intrusion

At Marathon, Greece, a terraTEM™ survey was carried out near the coastline to map the extent and the salinity of salt water invasion into a fresh water aquifer which had a depth to top of only 2 m depth. A transmitter loop of 10 m square with a receiver loop of 3 m square inside was used with a station interval of 10 m. The results are illustrated in the conductivity-depth section (Figure 6) over the distance of 100 m. The high conductivity values measured from the terraTEM™ match well with representative water samples taken from the aquifer and are indicative of highly saline water invading from the sea.

The plot shows the detailed extent of the invasion and its gradual variation through out the zone. This result is achieved more easily, much faster and more thoroughly than if the mapping had to be carried out by water sampling alone.



Conductivity in mS/m

Figure 6. A conductivity depth section showing the higher conductivity in the aquifer due to the invasion of sea water.

Example of Site Characterisation

In an area where underground storage tanks (UST) were thought to have existed, a terraTEM™ survey was conducted to locate the tanks now buried by soil. The steel reinforcing used in the construction of the tanks would provide a sufficient conductor to be located by TEM. As the area of the conductors was expected to be of the order of 10 m to 20 m across, a Coincident Loop geometry measuring only 5 m x 5 m was used. The station interval was 5 m and a transmitter current of 5 Amps was employed. Figure 7 (see next page) is a time slice of the amplitude values at a time delay of 0.5285 milliseconds which illustrates the anomalies well. (Time slices can be presented for any and all the delay times recorded). The most prominent features in this plot are the two strong conductors measuring about 20 m across near the north-east and south-west edges of the survey. These features coincide with less distinct magnetic anomalies and are believed to be the foundations that were the object of the search.

CONCLUSION

The recent development of terraTEM™ has taken advantage of current advances in electronics and more particularly, software, to result in a flexible system with many additional capabilities. All the known methods to improve signal to noise ratio have been incorporated. Many functions can easily be changed to suit the particular circumstances, or user preferences, if required. The system has proved to be capable of a wide range of applications, only some of which have been illustrated here. Other common applications of terraTEM™ include mining and geothermal targets. The engineering and environmental examples are notable for the shallowness of detection, being only 2 metres in some cases. This requires very good signal to noise ratio and very early delay time measurements. It was for these reasons that terraTEM™ was recently given an award by the Australian SEG for innovation in the fields of instrumentation and data acquisition.

ACKNOWLEDGEMENTS

The data for the salt water intrusion example was kingly provided by Petros Karmis of the Greek Institute of Geology and Mineral Exploration.

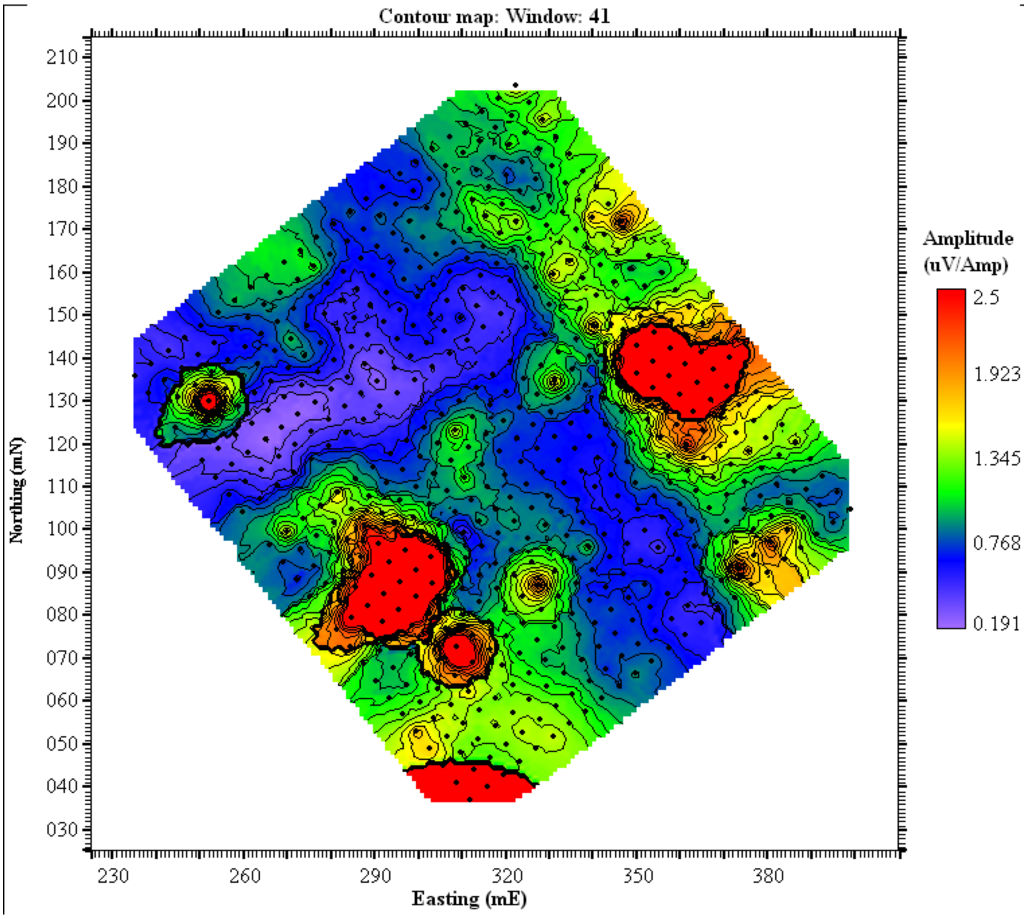


Figure7. terraTEM amplitudes at 0.5285 msecs delay at foundation site.