Environmental geophysics

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Welcome readers to this issue's column on geophysics applied to the environment. Recently I was contacted by one of my previous contributors, who had a column idea that I thought was worth sharing. In this column I am happy to reintroduce Dave Allen, founder and main thinker behind Groundwater Imaging, who is spruiking developments to his towed TEM system that he calls AgTEM. Here is what Dave has to say:

AgTEM – a development story

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Figure 1. *AgTEM cart side view.*

Figure 2. *AgTEM front loop (Slingram) may be added as an option to create a second independent dataset.*

AgTEM (Figures 1 and 2) is a towed transient electromagnetic (TEM) system initially designed to survey cleared, levelled agricultural land – mostly to map salinity and help site bores. Over time it has been recognised as being useful for mining and geotechnical applications as well. AgTEM processing provides maps and vertical sections of bulk earth resistivity from just a few metres below the surface to tens of metres depth (Figure 3 shows an example data set). It is well suited to image conductive features up to 100 m deep below otherwise resistive strata. The system is normally towed behind a 4WD ute (Figure 2) but can also be towed by quadbikes, ATVs and even floated behind a boat. There is a new lightweight version that can be hand-carried in difficult terrain.

How did we get here? Well, back in the 1990s I was doing 100 m x 100 m loop TEM surveys working for one of the old contracting companies (Geoterrex) near Cloncurry in NW Queensland and was frustrated with the slow progress laying loops. I put together my first towed system, looping a whole lot of wire around a wooden structure and then towing it behind a ute. Being naïve about the limited capacity of transmitters to turn off current rapidly I hooked up 20 turns to a Geonics EM37 transmitter and surveyed away. Unfortunately, the results were disappointing due to the long turnoff time and induction into the metal towing vehicle. In the end it was an expensive experiment: the transmitter lasted that survey but shortly after some

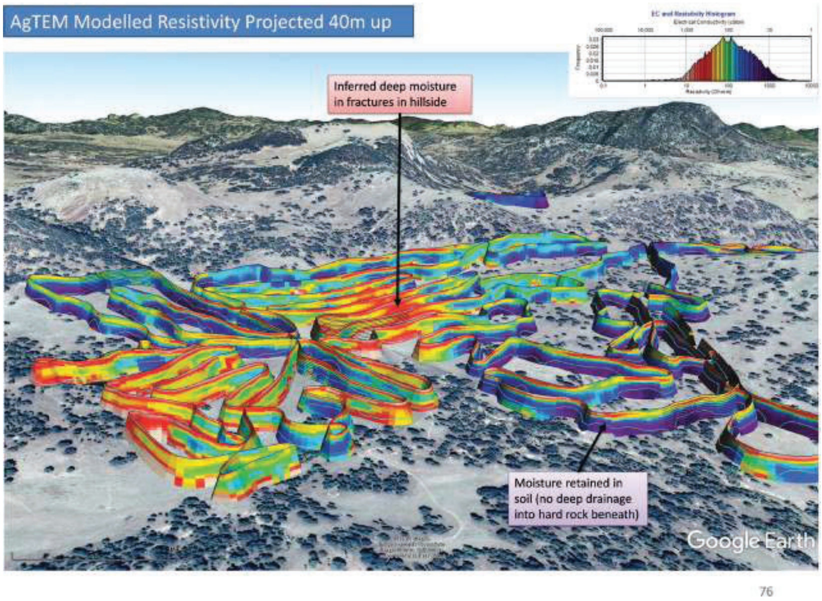

Figure 3. *A sample of AgTEM data collected in one day revealing potential groundwater sources in deep rock fractures. Data are projected along survey lines, to depth of 40 m.*

components failed due to the damage done by the high inductive load.

Back in the early 2000s I got involved with some work that Zonge Australia was doing with a University of Adelaide MSc student (Brian Barrett – with one of his supervisors, Mike Hatch), they were towing a Zonge NanoTEM equipped wooden frame behind a boat, collecting TEM data, while I was working on towing a resistivity streamer, as part of my PhD research. We were looking for salt water intrusion into the river bed and both techniques were successful. Inspired by the success on the Murray River with Zonge, I tried the same on land using a crazy, low-cost 6 m x 6 m loop of PVC pipe and electrical cable reels. Again, I used the Zonge NanoTEM equipment and single turn transmitter and receiver loops. It was good, but I thought that I could do better.

About this time I got the chance to visit the Hydrogeophysics Group (HGG) at Aarhus University in Denmark where the PATEM towed system (a transmitter sled with a receiver towed behind) was being developed; this system was towed by a tracked walk-beside vehicle. This project went by the wayside months later as HGG focused on developing the SkyTEM airborne TEM system, which has been a huge success for that group. Seeing the potential in the PATEM system, I was inspired to continue to develop a "niche" towed TEM system.

I got my next transmitter/receiver system from Monex Geoscope (a spinoff of some research work that Professor Jim Cull and Duncan Massie were doing). Using the terraTEM solved my instrumentation problems. After that, most of my problems were practical, structural problems – how do you tow a sufficiently large loop to get signal into the ground, without any structural metal, in field conditions that are often rough enough to damage a 4WD?

I got to test some interesting towing ideas by bootstrapping funding I got to run some TEM trials on a platinum exploration programme. I tested and ran towed TEM surveys as an adjunct to a standard 100 m x 100 m moving-loop TEM survey. For this work I towed the transmitter and receiver loops on a sheet of plastic (super tough irrigation channel liner) behind a quadbike. The 2 mm thick sheet only wore out after surveying several hundred kilometres, but it was very difficult to get the 7 m x 7 m sheet through the many farm gates in the field area. But the data sets were awesome, providing the client with high quality subcrop mapping; the subcrop complexity was surprising given the lack of evidence on the ground surface.

I conducted similar towed TEM surveys using plastic sheets at Menindee Lakes the following year; again the results were impressive revealing a number of locations that were potentially suitable for managed aquifer recharge. It was on this survey that a road train passed us at 100 km/hr as we surveyed the road verge and my 200 kg plastic sheet was lifted into the air, demolishing the transmitter. This led to the decision to avoid any further use of large, dragged plastic sheets.

The next stage in the development of the AgTEM system consisted of designing and building a large wooden platform for the transmitter loop. This proved to be too costly to maintain due to wood rot and was cumbersome to run. A receiver dragged on a separate mat far behind the wooden cart made the whole system challenging to drive, especially through farm gates and in traffic. Many designs followed with narrow towed mats and towed carts made from PVC pipe. The receiver antennae mounted on plastic mats never lasted long enough in the field, which led to their abandonment yet again, but those early plastic pipe carts showed considerable promise.

As plastic pipes are not designed for structural flexure, I started working on an extruded fibreglass cart, but that was ultimately too costly to duplicate (and operate). With a total weight of about 700 kg its non-metallic wheels and axles failed too quickly. I ran a number of surveys using that system, including one in the Burdekin Delta, where the system mapped aquifers and saline intrusion to as deep as 90 m.

I went back to the PVC pipe construction, this time simplifying the physical design by eliminating the need for a troublesome rear towed mat receiver. It took some effort and thought but I ended up using a 4 m^2 receiver loop that overlapped the transmitter loop in such a way that the system minimized the mutual induction between the receiver and transmitter loops. Once this was stabilised I found that the data were just as good as those collected using the towed mat receiver loop (and the system was far more compact and useable). The receiver and transmitter loops were mounted on boom arms that were held in place with elastic straps and could therefore fold up during the survey and pass through most farm gates and gaps between trees. I patented the structural concept and set to develop it commercially. The original "null mutual induction cart" was rather large, so I also started working on making smaller carts. With the help of an industrial engineer we also developed a lighter-weight, thinner fibreglass pipe structure.

At about this time drought started to grip eastern Australia, and demand for surveys took away all of our time and resources for development, as we sited bore after bore for farmers and local councils. When the rains started again in early 2020 the work dried up and there was again time to work on commercialising the AgTEM cart. "Interestingly" (frustratingly?), the process of moving from invention and product development to commercial manufacture is proving to be both expensive and more difficult than the development steps. Part of the commercialisation process was to design a cost-effective freight solution for the system. Once this was completed we airfreighted a system to the USA - unfortunately right in the midst of the COVID freight crisis. The system is there, finally, and is undergoing field trials at the moment.

And development continues: I have added a version of the Slingram receiving antenna that is now mounted in front of the vehicle (Figure 2). Instead of towing a receiver by cable behind the cart, which makes the towed cart array very long, with the towed receiver catching on fence posts and gates and wearing out due to ground abrasion on gravel roads, the second Slingram receiver is now mounted ahead of the towing vehicle. With the loop about 3 m off the ground it is relatively easy to manoeuvre through gates and trees on narrow tracks while towing the transmitter loop system.

Development of the AgTEM system has been a long and arduous process, but the final versions are truly tried and tested, just waiting to be used in new environments, agricultural, geotechnical and mining.