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Environmental geophysics

Mike Hatch
Associate Editor for
Environmental Geophysics
michael.hatch@adelaide.edu.au

Mapping water movement through agricultural landscapes

Welcome readers to this issue's column on geophysics applied to the environment. I'm back to thinking about some of the holy grails of environmental geophysics – and one forcibly presented itself to me this week. It came in the form of a query about pricing from an environmental consultant I work with every now and then. His client was a farmer who has a sizeable farm (seems sizeable enough to me – about 2.5 km x 3 km) not too far from Adelaide. The goal of the project was to understand the extent of the unconfined aquifer and the volume of water contained in the subsurface on his land so that it could be sustainably used. This would (if possible) include understanding recharge and discharge pathways to/from the aquifer (aquifers?) every year, and how these flows varied seasonally. I guessed that the budget for this work would not be large, but decided to see what I could come up with – based on 'commercial' rates.

The groundwater in the area is both shallow (<20 m in most places) and pretty fresh, so an easy target for EM/resistivity in some ways (being shallow), but tough in others (not likely to be much contrast between the relatively resistive host and the good quality water). So maybe I wasn't too imaginative, but I went with what I know. I decided that the best approach in this situation would be to start with an EM survey to capture information about local shallow structure and, perhaps, to start mapping the location of the groundwater. Then, to help remove some of the response ambiguity that is always part of an EM survey, I wanted to map the groundwater directly with a programme of NMR soundings (and in the process get an understanding of unit porosity/permeability). In my experience with groundwater studies, resistivity/EM rarely provides enough information to unambiguously identify the depth to groundwater. I think that additional information is almost always needed, whether from a relatively dense network of bores, or from other (complementary) geophysical techniques.

So, for the shallow EM part of the project, I started by thinking about the costs of a ground survey that would cover the entire area (most of you already know that this will be expensive, but just go with it for now). Let's say a crew of two costs something like $3000 per day (including expenses and processing), and that they are able to collect 50 stations of shallow TEM in that day. At a 20 m station spacing that is $3000 per line km. For the 2.5 km × 3 km survey, with a 200 m line spacing (perhaps a bit coarse) you would collect data on 12 × 3 km long lines; so a total of 1800 stations, and all 12 lines would take about 36 days to finish – already up to a staggering $108 000.

Alternatively, you could go with a high resolution helicopter-based airborne EM survey (AEM) and cover the area in less than a day for something like $100 000 (including processing, QA/QC, etc.). For that price you would probably be able to collect 500–600 line km in two days. I've been reliably told that this is the minimum time that you should think of hiring an AEM system and you would therefore try to get other farmers in the area involved so that the costs could be spread between you and the neighbours. If that worked you might be able to survey over five adjacent farms and then get the price down to $20 000 per farm. There are other options – some of the mobile EM surveys that companies like Groundwater Imaging run might help with the price, getting close to AEM productivity by driving/towing an EM frame over the farmer's ground.

For the NMR I thought that ultimately the best strategy would be to collect the complete EM data set first and then to decide on where to position the NMR sites based on EM results. Nevertheless, for budgeting purposes, I figured that 40 soundings over this 2.5 × 3 km area might be enough. In good, electrically quiet conditions (as anticipated on a relatively remote farm) a crew should be able to get four stations per day – for a total reading time of 10 days. If we assume the same crew cost for the NMR this comes to $30 000. So our total for data acquisition and data imaging could come in at ~$140 000 and we haven't even started interpreting the data sets. Of course the price would go down if you could get some of the neighbours to go in on an AEM survey, or used larger loops for the TEM, or if a faster more mobile EM system was used. But then add on the interpretation costs.

I didn't expect that my consultant friend would be too impressed with these numbers, but sent them to him anyway to see what he would say. Remember I didn't know how much money the farmer was willing to spend and thought 'what if this farmer is both rich and curious'? I was informed that the budget was $20 000. Nowhere near enough for what I had 'quoted', but actually a reasonable amount of money – what I would call real money to answer real questions.

For interest I spoke with the consultant some more about what he was going to propose to the farmer, and he said that they were probably going to run a relatively standard set of pumping tests based on a new bore to estimate the usual hydraulic parameters for the aquifer (transmissivity, hydraulic conductivity, etc.). He would then (I assume) extrapolate those results to the rest of the property. I think that both he and the farmer would have preferred a study that would provide information about the entire property – like the geophysics that was originally envisioned, but that was pretty well out of the budget.

So, what is the punchline of all of this? When I started writing this piece I wasn't sure what it would be, but as I wrote and thought it through it became clearer. I think that it is in the national interest to give farmers the sort of information that this sensible farmer wants to have about water movement through his land – and is willing to pay a reasonable amount to obtain.

Ultimately, if farmers have this information they will be able to farm smarter and more efficiently. Australia is not an easy country to farm, and more information is better than less (stating the obvious perhaps, but…). Giving farmers the information that our farmer wants would improve the longevity of farming operations for most farmers in our part of the world – which would ultimately improve prosperity for all of us.

I think that there are at least two challenges here. Firstly I think that there is a challenge for us (the geophysical community) to work on improving the various technologies available for this kind of work so that the price of surveys is reduced and the quality of information improves as well. It's time to bring on improvements in collecting IP data from EM/AEM surveys; time to figure out airborne NMR (hmm, now that's a challenge); time for faster cheaper surveys based on drone platforms; and, more than anything, it's time to figure out how to make some of the standard surveys that we do cheaper and easier for 'normal' people to access and understand. Secondly (fifthly?), I wonder if it is time for the Australian governments (state? federal?) to cover most farming country with high quality AEM. This base data set would go a long way towards understanding where the water is coming from and is going, and give clues as to how deep the various aquifers are; it would then be up to individual farmers to do infill surveys or add well-sited bores to flesh out the information that they need to effectively farm their holdings.

I would be interested in your views and in any suggestions you might have about alternatives to the approach I have suggested to obtaining baseline information about water movement through the Australian agricultural landscape. Please write to me and maybe we can put your ideas into a future column.

Australia needs this!