Chasing down the salt in Australia

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Abstract

The threat of dryland salinity in Australia is huge but elusive. It has proved difficult to build up a coherent picture of the spread of salinity, let alone devise workable solutions, from extrapolation of widely spaced measurements in boreholes and major rivers. It has seemed to be too big to handle, too diffuse to nail down, and valiant efforts at community level have had little or no impact.

A multi-disciplinary team drawn from several institutions has applied new tools from airborne geophysics to determine with precision and confidence: *Where* the salt is and where it's not, in three dimensions and to a depth of at least 150m below the surface; *What* are the salt stores and how much salt do they hold; *What* are the pathways of salt movement through the landscape; What are the *rates of delivery* of salt to the surface and to rivers.

Salinity can now be treated as a point source problem instead of a diffuse problem. Things that we can do now that we couldn't do before include: set meaningful, achievable targets for water and salt delivery at property, catchment and regional scales; contemplate a market in salinity and infiltration credits, and prioritise the delivery systems in terms of salt loading and the sensitivity of the receiving system; *p*recisely locate options for engineering interventions, *e.g.* pumping from underground conduits into evaporation basins; predict the effects of changes in land use for each facet of the landscape; and find fresh water resources.

The trouble with salt

The trouble with salt is its affinity for water. Plants have to work against salt in the soil to extract the water that they need. We have the same problem; if we drink saltwater it extracts water from us. Salt is also very mobile: it moves through the landscape wherever water moves and concentrates when the water accumulates and evaporates. Salt rise and washout cause structural damage to roads and buildings and corrodes metal and concrete.

Australia is the driest continent. Over millions of years, salt blown in from the sea has not been flushed out of the landscape, so that salt-bearing soils are extensive (Figure 1). The presence of salt is not the problem: it is a fact of Australian life. The problem is the mobilisation of this salt by the way we are using the land. Crops and pastures use less water than the native vegetation. The surplus water percolates through the soil, raising water tables, bringing the salt to the surface and leaching salt to the streams. Irrigation adds even more water to the landscape, bringing even more salt.

(Figure 1)

Figure 2 shows areas of salinity hazard - where salt is stored in the landscape and rainfall surplus to the demands of crops and pastures will mobilise the salt. The area at hazard encompasses approximately 80 per cent of Australia's cereal growing acreage and all irrigation schemes. In the absence of effective action, Australia stands to lose a large proportion of its wheat exports, irrigated agriculture, water supplies to country towns, costly infrastructure and rural employment. The prognosis is not good for Adelaide, which draws its water from the end of the national drain (the Murray-Darling). Without further intervention, Adelaide's water is likely to exceed World Health Organisation salinity guidelines two days in five by 2020.

(Figure 2)

No strategy has been demonstrated that maintains production and jobs and, at the same time, arrests salinity. Tree planting in areas already affected by surface salinity has failed to stop the salt. Blanket tree planting, although it would arrest salt exports, is unacceptable because it would also eliminate rural industries and communities, and curtail valuable water supplies. The only really effective action to date has been to pump saline groundwater into evaporation pans.

To be effective in combating salinity, we need to know:

1. Where the salt is (and where it is not);
2. What are the salt stores and how much do they hold;
3. Where are the pathways of salt movement through the landscape; and
4. What is the rate of delivery of this salt to streams and groundwater.

New tools and, equally importantly, a systems approach, developed by an Australia-wide multidisciplinary team, can now deliver this information.

The new approach

The new approach to chasing down the salt combines advances in three types of airborne geophysics: electromagnetics, magnetics and gamma radiometrics. It also depends on rigorous calibration by bore drilling and laboratory analysis that has driven further advances in modelling. Finally, and most importantly, it is based on a multidisciplinary scientific team spanning geophysics, geological systems, regolith, soils, landforms, hydrogeology, hydrology and land use planning, to provide expert interpretation.

The most exciting tool is the TEMPEST airborne electromagnetic (AEM) system which, when in operation, sets up a time varying primary magnetic field from a transmitter loop slung around extremities of the aircraft. The primary magnetic field penetrates the ground and induces a secondary electrical current flow in the sub-surface, which has an associated secondary magnetic field. This secondary (and relatively small) secondary magnetic field is detected in a towed bird that is slung behind the aircraft (Figure 3). Variations in the detected field can be related to variations in the conductivity of the ground.

Where the ground is non-conductive (resistive), the induced magnetic field is very small. In contrast, however, conductive materials, especially those containing saline groundwaters, are characterised by stronger signals. The conductivity measurements can be translated into three-dimensional images that may indicate the concentration of salt to considerable depths (up to 100m or more in some circumstances). Figures 4 and 5 show examples of the results that have been obtained.

(Figures 3, 4 and 5)

Rigorous calibration by borehole logging and laboratory analysis has confirmed that the patterns of conductivity are, indeed, patterns of salt distribution (Figure 6). The calibration continues to drive advances in software that can now give us an accurate, three dimensional picture, not only of the salt stores but, also, of buried stream channels and other transmissive layers that carry salt through the landscape. Figure 7 shows an example of a saline stream lying 30-40 m below Houlaghan's Creek near Cootamundra, New South Wales. The surface catchment delivers fresh water, but the buried drainage system delivers salt continuously into the Murrumbidgee River. Interception of the groundwater before it flows into the surface stream would prevent some 10-20 tonnes of salt per day from entering the Murrumbidgee River.

(Figures 6 and 7)

High-resolution airborne magnetics also delineates underground streams that bear magnetic gravel (Figure 8). The combination of techniques allows us to map not just saltwater pathways but, also, conduits carrying valuable freshwater.

(Figure 8)

It is difficult to use airborne electromagnetics in the hill country because the plane must fly very low. Over the hills, we have applied radiometric imagery that measures the natural gamma radiation emitted by potassium, uranium and thorium. The gamma signal may be interpreted in terms of rock type and the degree of weathering, erosion, transport and deposition of weathered products. Field observation of surface water salinity suggested a relationship between salt discharge and areas of thick clay soils. The thicker the clay, the more salt held, and the greater difference between the rock gamma signal and the total gamma signal. This means that we can make a first cut of the landscape by plotting the difference between the gamma signal of the rock signal and the total gamma signal (Figures 9 and 10).

(Figures 9 and 10)

The combined results of all these techniques reveal a picture more complex than we ever knew, and have spurred a conceptual leap from mapping salt, to plotting the plumbing system that delivers the salt. Pump tests and laboratory measurements estimate the transmissivity of the various aquifers. In turn, this allows us to model water flow, both saline and fresh, and predict the response of each facet of the landscape to management, whether this be through changes in land use or by engineering interventions.

What we can do now that we couldn't do before

The new information transforms salinity from a diffuse problem to a point-source problem. We can now plot the distribution of salt in the landscape, the plumbing system, and the recharge areas where infiltration forces water through the plumbing system, sucking salt out of storage. With the new information, we can target intervention and expenditure to those places where it will be effective. The water that is driving the spread of salinity can be intercepted by engineering works; or used *in situ*. Fresh groundwater can be drawn up and used for irrigation. We can also avoid intercepting good quality water so that it runs to the streams to dilute the salt and provide valuable water supplies.

Figure 11 shows a farm-level land use plan for hill country near Young, NSW, based on these principles. Green arrows indicate salt movement to the stream under present land use. Areas shown in red are salt-bearing and happen to be the best soils in the district. They may be managed to maximise water use, for instance using perennials such as lucerne or relay cropping. Black arrows indicate recharge areas which feed into the salt-bearing soils. On these steeper slopes, water could be intercepted before it forces salt out of the salt stores. Because agriculture is less viable on these thinner soils and steep slopes, tree planting might be an attractive option here. The good news is that over the remainder, the vast majority of the area, no special management is needed as far as salt is concerned. Similar land use plans could be derived for other types of salt delivery systems.

(Figure 11)

The new approach also enables us prioritise catchments for intervention. Figure 12 shows an example of a salt delivery system flow chart for the area bounded by the Cootamundra 1:250,000 map sheet. From the east, the Murrumbidgee brings in 150 000 tonnes of salt per year. By the time it leaves the area, the salt load has grown to 420 000 tonnes per year. The bottom of the figure shows some of the streams contributing to the Murrumbidgee’s salt load. To the north of the watershed, both streams drain into a large sump (the area shown in Figures 4 and 5), which is at present absorbing much of the salt, so these catchments would not likely be the first priority for intervention. Of the streams draining directly to the Murrumbidgee River, Jugiong Creek and Muttama Creek are the largest salt contributors. To reduce their salt load, salt-bearing areas in the hills they drain would have to be managed as in the example shown in Figure 11. Houlaghan’s Creek and Billabung Creek derive their salt load from sumps, so local land use change would have little effect on the salt load in these streams, but engineering measures, such as diverting them to evaporation basins could be quite effective and yield rapid results.

(Figure 12)

Using this sort of information, we can construct a range of future land use scenarios with their economic, salt and water implications, as a basis for negotiation among stakeholders.

We can also set rational targets for water and salt delivery for each catchment, and introduce market-based drivers of land use change, for instance salt credits and infiltration credits.

Acknowledgments

This paper summarises the results to date of a collaborative project involving some sixty scientists drawn from sixteen institutions across Australia, especially from the Australian Geological Survey Organisation (AGSO), the Bureau of Rural Sciences (BRS), the Cooperative Research Centre for Advanced Mineral Exploration Technologies (CRC AMET) and the Cooperative Research Centre for Landscape Evolution and Mineral Exploration (CRC LEME). It has been supported by some 36 institutions ranging from the Grains Research and Development Corporation (GRDC) to the mineral industry, which has provided data for 2000 boreholes in the study area.

Further reading

The figures are reproduced with permission from:

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