Salt mapping in the Billabong Creek catchment, New South Wales

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Abstract

The Billabong Creek catchment is located in southern New South Wales, north of Albury. Part of this catchment, to the west of Culcairn, was flown as part of the MDBC Airborne Geophysics Program to support the CSIRO Heartlands Program. The purpose was to demonstrate the usefulness of airborne geophysics for the management of salinity at a catchment scale and to help develop sustainable farming systems for salt-affected land.

In the Billabong Creek catchment, salt stores are restricted to less than a third of the area surveyed, comprising the alluvial terrace of Kangaroo Creek; a shallow, clayey blanket in the Simmons Creek subcatchment; and a deeper sump downstream of Walbundrie in the Billabong Creek alluvium. Of these, only Simmons Creek contributes noteworthy saline drainage to Billabong Creek.

Magnetics reveals prior stream systems that hold significant fresh-water reserves.

Introduction

Billabong Creek catchment is located between the much larger Murrumbidgee and Murray River catchments in southern New South Wales. Previously, the catchment had been identified as a major contributor of salt to the Riverina, but Baker *et al.* (2001) found waterlogging to be the greater threat in the upper catchment and found only modest salt exports, chiefly from the Simmons Creek subcatchment.

The upper Billabong Creek catchment, around Culcairn, has a winter-dominant rainfall pattern with mean values ranging from 680 mm in the east to 450 mm in the west. Land use is almost equally divided between cropping and grazing.

The survey area between Culcairn and Walbundrie centres upon the broad alluvial plain associated with Billabong Creek. It is flanked by undulating, erosional rises and a few low hills. Surficial materials are diverse: from alluvial sands and silts on the plains to colluvium and weathered granites on hill slopes. There are a few, source-bordering dune sands close to present-day drainage channels on the plain.

Geology

Palaeozoic/Mesozoic granites with minor Silurian volcanics dominate the higher parts of the landscape. Devonian metasediments also occur in the upper reaches of the catchment. The bedrock outcrops in areas of moderate relief, giving way to colluvium on gentler slopes. The alluvial plains are built up from sediments of the Lachlan and Cowra Formations, which host the major aquifers and, also, the salt stores as indicated by the conductivity signatures seen in the aerial survey.

Materials observed in drillholes were logged to provide a geological framework. The interpretations link conductivity patterns to geology and soil/regolith unit, seeking relationships with regional geology and landforms that may enable extrapolation of observed conductivity responses beyond the survey area.

Airborne electro-magnetics

Airborne electro-magnetics (AEM) technology provides subsurface information in 'layers' of various depth. Data gathered using AEM showed that the spatial pattern of conductivity is closely associated with landforms. Substantial salt stores are restricted to three areas:

- The alluvial terrace associated with Kangaroo Creek to the east.
- A shallow, triangular blanket over the lower Simmons Creek subcatchment.
- A deeper-seated salt store within the main Billabong Creek alluvium to the west of Walbundrie.

In addition, there are several small, very shallow salt stores that appear only in the 0- to 5-m layer, where salt is held in clayey colluvium on the lower slopes.

The pattern is depicted most clearly by the ternary conductivity image (Figure 1) in which relatively high conductivity that occurs in the 0- to 5-m layer is coloured blue, that in the 15- to 20-m layer in green, and that in the 40- to 60-m layer in red. Relatively high conductivity in all three layers becomes white. The ternary image also distinguishes a continuous belt of medium conductivity in the 15- to 20-m layer in the Billabong Creek alluvium, which is interpreted as a conduit rather than a store.

The Kangaroo Creek Terrace (drillholes BC16d, BC7; see Figure 1) exhibits high conductivities, in the range 400 to 600 mS/m, associated with clay/silt alluvial units. Sandy layers exhibit lower values. In the underlying saprolite, there is a secondary peak of conductivity below about 70 m, which tapers quickly through the saprock to the resistive basement volcanics.

Electrical conductivity (EC 1:5) values follow the down-hole conductivity closely, also distinguishing sandy layers as low salt. The relatively high alkalinity of the pore waters from some of these sandy layers indicates that they are conduits of fresh, surface-derived water.

Simmons Creek subcatchment shows a quite different conductivity pattern that appears to disperse quickly after 10 to 15 m (BC8, 9, 17d). There is no strong landform association, in contrast to Kangaroo Creek. In this case, there may be a surficial component of redistributed, aeolian[1] silt/clay material in the upper salt-bearing layer. Once again, however, conductivity is dominated by salt-bearing regolith rather than bedrock. The pattern is closely associated with the restricted catchment of Simmons Creek, and all drainage is confined to areas of sediment deposition, carrying leached salt out through the small creek and the adjacent prior stream.

The Walbundrie Sump in the Billabong Creek alluvium exhibits medium conductance at the near-surface but elevated values below 20 m. Drillhole BC19d confirms this pattern. There is close correspondence between down-hole conductivity and both EC 1:5 and pore fluid EC in the upper (Cowra Formation) alluvium to 50 m below surface. Below this, the lower (Lachlan Formation) alluvium exhibits medium conductivity associated with clay texture, high water content, but low salt content. Within the upper alluvium, low salt is associated with high alkalinity, indicating flushing with surface-derived low-salt water.

A striking feature in several drillholes is the high water content and transmissivity of thick colluvium derived from the deeply weathered, granitic saprolite. Almost universally, this groundwater is low in salt, and this is confirmed by the low conductivity values exhibited by the colluvial cover over much of the landscape.

Airborne magnetics

Airborne magnetics measures the earth's natural magnetism. While commonly used to identify possible ore bodies, it can also be used to define old river channels (prior streams) where these contain iron nodule.

Several prior stream networks can be observed in the total field magnetics image. Four locations (BC10, BC11, BC12, and BC13) were drilled to elucidate these features; each drillhole intersecting magnetic signatures of varying intensity and thickness. A large magnetics signature evident on the airborne-magnetics images (not included) and targeted by BC12 shows a thick sandy sequence of moderate conductivity (250 mS/m). The dispersed (large) magnetics signature indicates sediments deposited in a broad alluvial system and potentially further travelled than those identified by smaller signatures. Drillhole BC 12 was abandoned due to excess water, which was a good sign for water exploration using magnetics data.

Airborne radiometrics

Radiometrics measures the natural radioactivity of the earth to a maximum depth of 50 cm. This allows different soil types to be identified and their distribution to be mapped spatially.

Figure 2 shows the ternary gamma radiometric image in which the potassium signal is coloured red, thorium is green, and uranium is blue. A strong signal from all three radioelements becomes white. The most prominent feature of the image is the very intense potassium (red) signal from granite outcrops, notably Goombargana Hill and Mullemblah Hill, and the strong thorium-uranium signal from the granite south of Walla Walla. The clay floor of the swamp west of Henty is also picked out by a high-potassium signal. Outcrops of metasediments (siltstone-sandstone) on the northwest–southeast trending ridges of the Burrumbuttock Hills and the big ridgebacks that form the neck of the upper Billabong Creek valley north and south of Culcairn are picked out in pink.

Downslope of the summits and crests, the intense signal from the aprons of locally transported material gives way on the footslopes to a weak (grey) signal that indicates thick, strongly weathered colluvium.

The Murray alluvium to the southwest and the Billabong Creek alluvium exhibit distinctive patterns. The radiometrics picks out the intricate pattern of leaves, back swamps, and circular ponds, with different mixes of clayey sediment identified by distinctive signals (as described above for the swamp west of Henty) and flooded ground showing black.

The Billabong Creek alluvium appears much more homogeneous, the dull grey signal indicating strongly weathered material, similar to the slope colluvium, with active and recent channels picked out by lighter values. The Kangaroo Creek alluvial terrace, already identified as a salt store, is sharply delineated; but the Simmons Creek salt store is not. The only distinguishing feature on the ternary image is a green (high-thorium) hue draped over the lower Simmons Creek valley. Its position in the lee of Mullemblah Hill suggests that this may indicate aeolian material, similar to that mapped further north in the Murrumbidgee and Bland Creek catchments by Wilford *et al.* (2001).

The very sharp differentiation of soil parent-materials by this high-intensity imagery, in combination with the digital elevation model (Figure 3), offers an excellent basis for enhanced soil mapping at a scale of 1:25,000. Good use can also be made of some of the associations between salt stores and landform/regolith unit to extrapolate the mapping of salt stores beyond the areas covered by AEM.

Implications of the project for the management of salinity

The following discussion is based on Dent (2003). The combination of airborne geophysical techniques affords a three-dimensional perspective, providing new insights into the location of salt in the landscape and its delivery to streams and to the land surface. First, large parts of the landscape are salt-free. Secondly, salt is lodged in various facets of the landscape, and these may be unique to a particular landscape, related more

[1] Deposited or formed by wind.

to soil (or regolith) than to geology. Salt is stored in clays, while the conduits that carry groundwater (and salt) through the landscape are interconnected sands and gravels: commonly current and prior stream beds and alluvial fans; sometimes thick, coarse-textured colluvium.

Mobilisation of this salt can now be addressed by hydrogeological modelling using the 3-dimensional framework (Figure 4), management options can be identified with greater confidence, and the precise areas where this management is required can be specified. The economic and social implications are profound.

Cost is a key issue. At current prices for airborne geophysical survey and drilling, the kind of information provided for the areas overflown in the Billabong Creek (and Honeysuckle Creek) catchments can be provided at a cost of $5/ha. But once the nature and patterns of salt stores and conduits are established for key areas with the full range of airborne geophysics and ground calibration, this knowledge can be extrapolated to the wider landscape using existing information that often includes airborne magnetics and radiometrics. In this way, management recommendations for whole catchments may be developed at a cost of the order of 50c/ha.

With this information, management can be applied rationally to the areas where it will be effective, rather than blindly to whole landscapes or to those areas where opportunity happens to arise.

Airborne data as collected for this project may be used at both the catchment and farm scale, since the line spacing used may be translated to maps at 1:25,000 scale without loss of detail, although farm-level planning will require the appropriately detailed level of interpretation.

References

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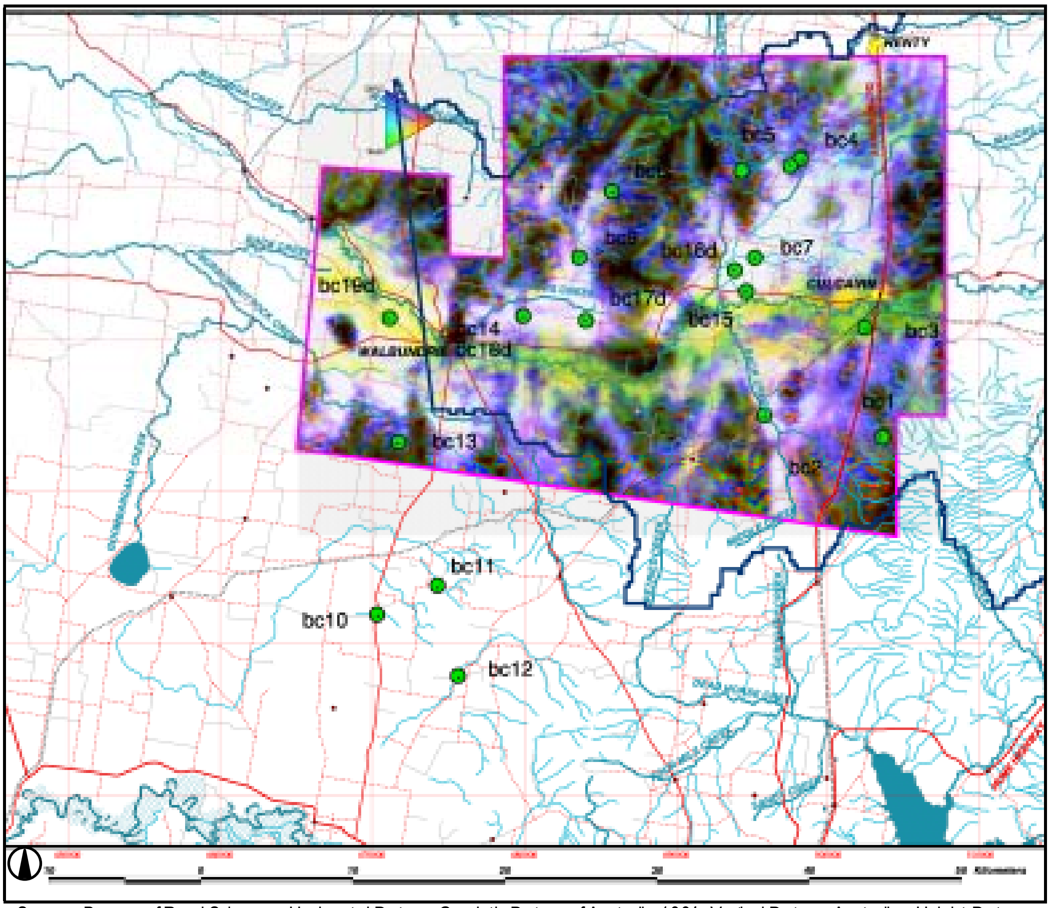
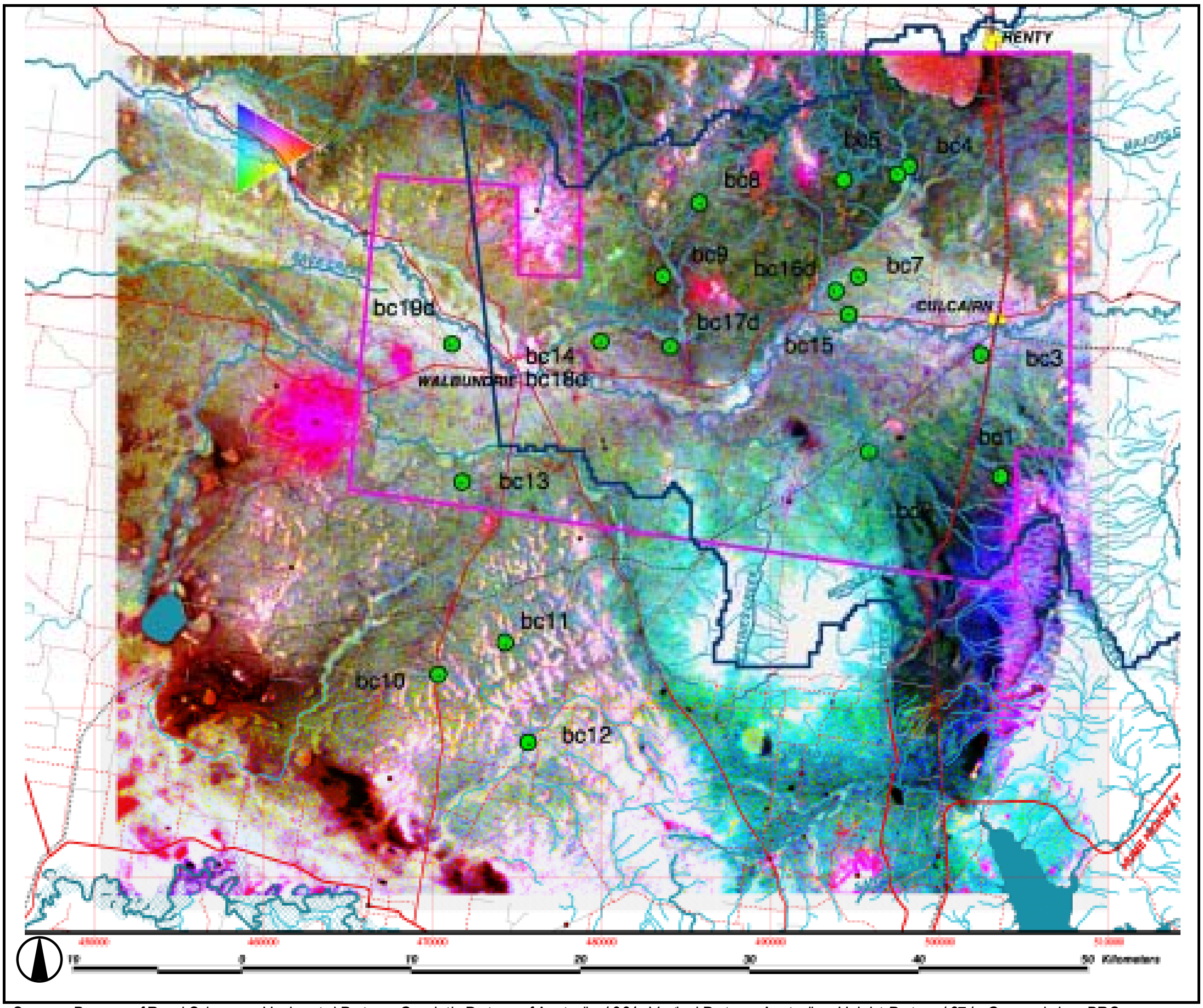


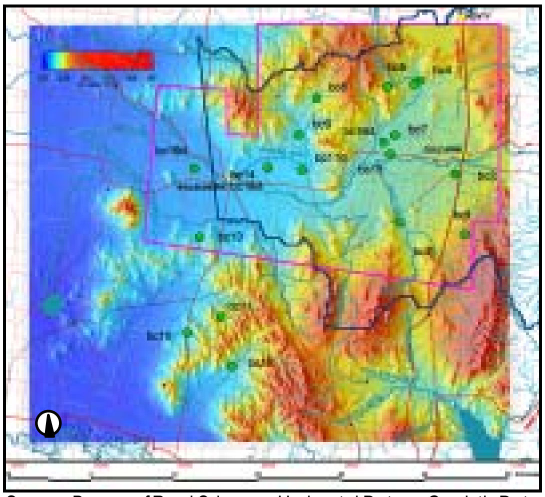
Source: Bureau of Rural Sciences. Horizontal Datum: Geodetic Datum of Australia 1994. Vertical Datum: Australian Height Datum 1971. Green circles–BRS drillholes; magenta line–airborne electro-magnetics boundary; navy blue line–upper Billabong Creek catchment.

Figure 1: Ternary conductivity image.



Source: Bureau of Rural Sciences. Horizontal Datum: Geodetic Datum of Australia 1994. Vertical Datum: Australian Height Datum 1971. Green circles–BRS drillholes; magenta line–airborne electro-magnetics boundary; navy blue line–upper Billabong Creek catchment.

Figure 2. Ternary gamma radiometrics image.



Source: Bureau of Rural Sciences. Horizontal Datum: Geodetic Datum of Australia 1994. Vertical Datum: Australian Height Datum 1971. Green circles–BRS drillholes; magenta line–airborne electro-magnetics boundary; navy blue line–upper Billabong Creek catchment.

Figure 3. Digital elevation model.

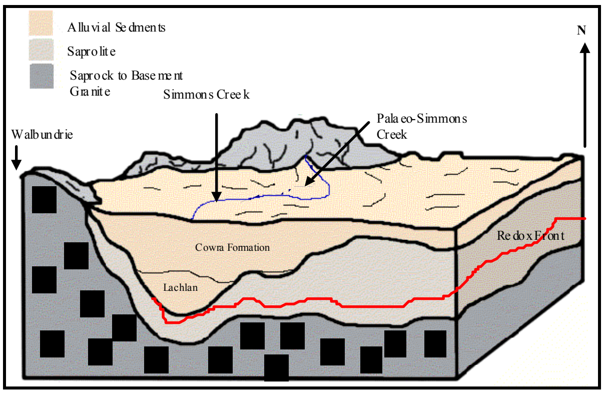


Figure 4. Simmons Creek catchment block model, an example of 3-dimensional hydrogeological modelling.