

THE ORIGIN AND MOBILISATION OF SALT IN THE UPPER HOVELLS CREEK CATCHMENT, NSW

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INTRODUCTION

In Australia, secondary dryland salinity has been recognised as a major environmental management issue for at least thirty years (Csaky 2003). Furthermore, dryland salinity has been recognised in agricultural landscapes in the Murray Darling Basin for at least one hundred years (MDBC 1990). The clearing of native vegetation for the introduction of European farming practices to Australia has allowed more rainfall to move down through the soil, forcing groundwater to rise towards the surface (MDBC 1990). Salts that were stored in the regolith are mobilised and increase the concentration of salts as solutes in the groundwater. Once the salty groundwater reaches the surface, dryland salinity is triggered in arable landscapes that would otherwise be relatively unaffected. In the Australian landscape, the problem is not the presence of the salt, as Australia has always been salty, but the way we have used, and are using, the land.

Secondary dryland salinity is an issue that affects agricultural production, infrastructure and waterways throughout Australia. The Murray Darling Basin has been extensively affected, with approximately 1,520 square kilometres affected by shallow water tables or dryland salinity, with this figure estimated to increase to 13,000 square kilometres by the year 2050 (NLWRA 2000).

In the Murray Darling Basin not only is dryland salinity an important land management issue, but stream salinity is becoming increasingly important. Many farmers and townships rely on good water quality from streams in the Murray Darling Basin for irrigation, stock watering and household use. The Murray Darling Basin Commission (MDBC) in partnership with councils and communities has imposed end of valley salinity targets for each major tributary valley in the Murray Darling Basin (MDBC 2001). A credit and debit system applies for each tributary valley. Penalties apply for catchments that exceed their target. Hence, surface water quality is very important within catchments in the Murray Darling Basin system.

This study examines the hydrogeochemistry and hydrogeology of a focus area in the Hovells Creek catchment to help understand the mobilisation and origin of salt in the landscape. The benefits of understanding water movement, salt mobilisation and origins are twofold: 1) application of better land and water management practices in order to minimise the salt load entering the Lachlan River from Hovells Creek; and, 2) a decrease in the area of land currently affected by dryland salinity and rising water tables.

STUDY AREA

The Hovells Creek sub-catchment of the headwaters of the Lachlan River and is situated in the eastern uplands of the Murray Darling Basin (Figure 1). It has large areas of prime grazing and cropping land affected by secondary dryland salinity and rising water tables. Dominant vegetation is pasture and shrubs, with approximately 15% under forest cover.

Wagner (1987) studied dryland salinity in eastern NSW, and established that saline scald sites were most noticeable in the headwaters of the Lachlan River in areas that receive between

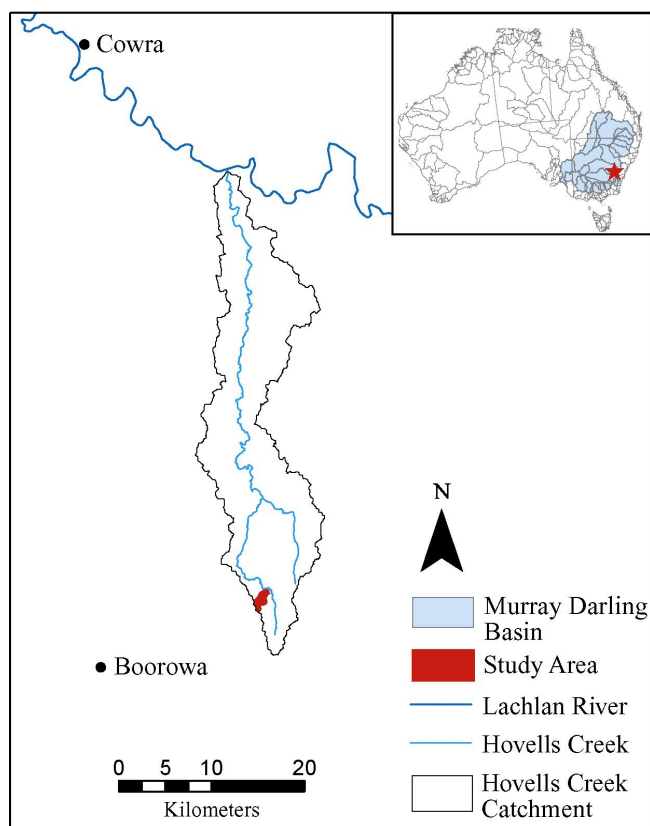


Figure 1: Location of the study area.

600 and 700 mm of rainfall annually, on sedimentary geology and on lower foot slopes and drainage depressions. Ratchford (2002) concluded that most of the salt entering Hovells Creek occurred in the upper parts of the catchment. These studies highlight the need for a greater understanding of the origin of the salts, where they are stored and the processes involved in mobilising these salt stores in the upper part of the catchment.

The study area is located in the upper reaches of the Hovells Creek Catchment (Figure 1) and covers an area of approximately 3 km². Sheep and miniature pony grazing are the prime agricultural use of the study area, however there is a small quarry situated on the western catchment boundary in the lower part of the catchment. The landholders are currently fencing off the lower portion of the catchment for perennial pastures. Approximately 10% is visually affected by dryland salinity and rising water tables. These areas are situated in drainage depressions and foot slopes of hills.

The rock types found in the study area are predominantly shales, silts and sandstones of the Middle to Late Ordovician Adaminaby Group (previously known as the Adaminaby Beds, Abercrombie Beds and Abercrombie Series). The group consists of quartz turbidite and black shale successions that consist dominantly of fine to medium grained quartz rich sandstone with generally thin beds of siltstone, shale and slate (Geoscience Australia 2004). These beds have been intensely folded and faulted and regionally metamorphosed (Offenberg 1974).

Yearly rainfall in the catchment is on average 600 mm, and is spread relatively evenly throughout the year, with slightly less rainfall in January to May. However, there is no set pattern, as can be seen with the decrease in rainfall in September and November (Figure 2). In comparison with average annual rainfall Australia wide, rainfall is low to moderate in volume, with the lowest rainfall less than 200 mm in much of Australia's desert regions, and up to over 3,200 mm in some tropical areas. The volume of rainfall that the study area receives makes it more susceptible to salinisation (Wagner 1987). Evaporation is relatively low compared to rainfall, and in proportion to rainfall, evaporation is greatest in the spring and summer months and lowest in the autumn and winter months (Figure 2). As rainfall is much greater than evaporation in all months, there is a potential for recharge if transpiration is less than the rainfall minus evaporation. Mean maximum temperature ranges from 30°C in January, to 12°C in July and mean minimum temperature ranges from 15°C in February, to 2°C in July.

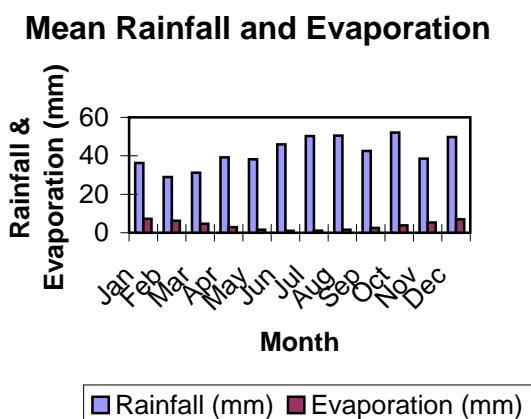


Figure 2: Mean rainfall for the Frogmore Station (1898-1990), mean evaporation for the Cowra Research Centre (1943-2004) (Bureau Of Meteorology 2004).

ANALYSIS AND TECHNIQUES

Bedrock was sampled from a quarry in the study catchment and from the top of hills (*in situ*) within the study area. Physical characteristics such as colour, weathering and location were recorded in the field. X-Ray Diffraction (XRD) analysis was undertaken to identify minerals present in the rocks. X-Ray Fluorescence (XRF) analysis was undertaken to identify the bulk chemistry of the rocks. Thin-section and Scanning Electron Microscopy (SEM) analysis was undertaken to confirm mineral identification by XRD.

Regolith sampling was conducted along transects spanning the width of the catchment using a hand auger. Regolith samples were taken when colour, textural or other differences were noted. Physical properties such as colour, texture, depth of roots, slaking and dispersion properties, presence of organic matter and gravel sized material (> 2 mm), and percentage water were noted. XRD analysis was performed for bulk regolith samples and on the clay fraction. Samples were selected for 1:5 soil:water solutions, tumbled end over end for one hour, left to settle in a refrigerator for four hours then electrical conductivity (EC) and pH were measured. An extract was then taken and filtered at 0.45 µm. This was then submitted for cation (ICP-AES) and anion (IC) analysis.

Water was sampled from hand-augered holes, surface seeps, stream water, dam water, water lying in the quarry and from polyurethane rainwater tanks. EC, dissolved oxygen, pH, Eh, temperature and an alkalinity titration were measured for each sample. Cation and anion analysis and was undertaken on all these waters. Analysis for the stable isotopes of oxygen ($\delta^{18}\text{O}$) and deuterium ($\delta^2\text{H}$) was also undertaken. Pore waters were extracted from a suite of regolith samples, measured for EC, pH and alkalinity, and analysed for cation and anion analysis.

RESULTS

Bedrock properties

The dominant rock type is black shale, characterised by its black colour, fine-grained texture and perfect, slaty cleavage. Weathering ranges from highly weathered at the surface, characterised by red, orange and yellow colours on the surface and along cleavage planes of the rock, to no visible signs of weathering (i.e., cannot be broken by hammer) in the deeper parts of the landscape. Associated with the shale is a coarser-grained sedimentary rock that is more weathered and tends to be softer than the black shale. The more weathered rock (at the surface) is predominantly red in colour, and the less weathered rock (at depth) is predominantly cream to yellow in colour. Quartz veins are present at the surface in both shale and sandstone lithologies.

Regolith properties

In the upper parts of the landscape, soils are light to medium in texture, are characterised by dark brown loams overlying red, orange and yellow medium clays, clay loams, sandy clays and saprolite, and have a high organic and gravel (> 2 mm) content. The colour, lack of patterns, depth of rooting and moisture content relative to soils in the lower parts of the catchment indicate that the soils are well drained. In the lower parts of the landscape, soils are heavy in texture and have a moderate organic content on the surface, but a low organic content at depth. Yellow and orange mottles with red to orange nodules in a grey and/or olive coloured heavy clay with some parts characterised by black mottles with a smell of hydrogen sulphide. The colour, density and depth of the patterns indicate that the lower part of the landscape is poorly to very poorly drained.

EC of 1:5 soil water extracts ranged from less than $10 \mu\text{S}/\text{cm}$ to over $1,700 \mu\text{S}/\text{cm}$. The magnitude of the EC of 1:5 soil water extracts increased the further down in the landscape the sample was taken. Individual auger hole profiles either increased or decreased with depth or had a bulge down-profile. pH ranged from 4.3 to 7.2. Dominant anions were sulfate and chloride and dominant cations were sodium, magnesium and calcium.

Water properties

Dominant anions in groundwater and stream water were sulfate and chloride. Dominant cations were sodium, magnesium and calcium. EC of groundwater and stream water ranged from $3,580 \mu\text{S}/\text{cm}$ to $5,160 \mu\text{S}/\text{cm}$. EC of standing surface water samples (quarry and dam) were $4,000 \mu\text{S}/\text{cm}$ and $13,000 \mu\text{S}/\text{cm}$ respectively. Tank water had low EC values ($30 \mu\text{S}/\text{cm}$ to $60 \mu\text{S}/\text{cm}$) and all elements were low to below detection except for sodium calcium, chloride and sulfate. Pore water EC ranged from $300 \mu\text{S}/\text{cm}$ to over $23,000 \mu\text{S}/\text{cm}$ and pH ranged from 4.7 to 6.7.

DISCUSSION

Atmospheric salt is assumed to be the source of salt in the landscape of the study area (Evans 1994, Jolly *et al.* 2001), however, little is known about the role the sedimentary rocks in the area play in contributing salt. In the neighbouring Boorowa catchment, Somerville (2004) concluded that mineral weathering processes in the volcanic (Kenyu Formation; Douro Volcanics) and granitic (Wyangala Batholith) lithologies contribute salts to the landscape. Apart from accumulation of atmospheric salts and mineral weathering, the other main argument for the origin of salt is connate salt that was trapped in the rocks at time of deposition, however, little research has been done to investigate this argument.

Results from regolith, water and bedrock analysis indicate that salt is being mobilised from the bedrock, either as a result of mineral weathering or the mobilisation of connate salts. In places of bedrock outcrops and in the quarry, salts are clearly seen precipitating on cleavage plains of the bedrock (only observed on black shale).

The processes that affect the occurrence of salt on the land surface are: 1) a change in hydrological balance in a catchment; 2) discharge of salty groundwater; and, 3) evapotranspiration of water concentrating salts in the near surface layers of the regolith. Salinisation taking place in any given area often involves a combination of the above processes.

In the study area all three processes are occurring. The clearing of vegetation in the mid 1800s has resulted in an increased volume of recharge to the groundwater system, and as a consequence, the water table has risen, mobilising salts. Discharge of salty groundwater occurs at the break of slope between hills and alluvial plains. This is partially a consequence of rising groundwater and of the change in the texture of the regolith between the hills and the alluvial plain. Evapotranspiration concentrates ions near the surface, which are either slowly leached downward into the groundwater, or are washed into the stream by runoff. Groundwater is discharged into the stream.

IMPLICATIONS FOR LAND MANAGEMENT

Even though a proportion of the catchment (approximately 15 %) is under forest cover, there is an abundance of water being recharged into the system, mobilising salts and carrying them through the landscape into places of accumulation such as groundwater discharge areas and the stream. As a result of the accumulation of salts in these areas and overgrazing, bare patches occur, and because of the concentration of salts in these areas, vegetation does not regrow, leaving them susceptible to erosion. The landholder has plans to plant perennial pastures in the lower portion of the catchment. This is where salt is accumulating in the landscape and groundwater is discharging. ECs of up to 23,000 $\mu\text{S}/\text{cm}$ were measured in this part of the landscape, and any pasture will have difficulty growing, if at all in these areas. The high salinity of the stream is a concern, as the salt is being transported down-stream, accumulating the further it flows and adding to the salt in the Lachlan River. Although the stream water is still drinkable for sheep, the dam water is not. This is a concern for the landholder, as this defeats the purpose of a dam.

Recommendations for the landholder include sowing a water- and salt-tolerant species in the lower portion of the catchment to help reduce groundwater discharge, at the same time as planting high water use pasture species such as lucerne in the upper parts of the catchment to help minimise recharge to the groundwater system. Paddocks are quite large (four main paddocks cover the study area), and there would be a substantial benefit from fencing off smaller paddocks (albeit expensive) and crash grazing on a rotating basis to encourage growth, add large amounts of organic matter and increase biodiversity of the pasture species. To assist with the cost of restoring this catchment, funding can be applied for through various state and federal projects.

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