THE USE OF REGOLITH-LANDFORM MAPPING TO ASSIST WITH DRYLAND SALINITY HAZARD MANAGEMENT AT CUDGELL CREEK, CENTRAL WEST NSW

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INTRODUCTION

Indicators of dryland salinity have been identified on regolith developed over the Young Granodiorite, in the Cudgell Creek catchment, central west New South Wales. These indicators include the presence of: dead trees; clear standing water; increased abundance of salt and water tolerant vegetation; new areas of salt scalded ground; waterlogged soils and hummocky ground; extensive road degradation; and reduction in crop yield. Regolith developed on granitic lithologies commonly has the ability to buffer saline solutions (Moore 1998). When salt is introduced it takes longer for the indicators of dryland salinity to manifest in many granitic landscapes, than in those over siliciclastic Palaeozoic rocks. Hence, by the time a significant dryland salinity hazard is recognised in areas with a granitic substrate, the processes causing the salinity are well developed (Moore 1998). The original source of salt in the Young district is believed to be cyclic salt from marine aerosols and in windblown dust (parna) introduced to the area over an extended period of time (> 100,000 years) (Greene *et al.* 2001). Near-surface fluid flow mobilises salt in the regolith and enables concentration in surficial waters and at the land surface as a result of evaporation concentration (Evans 1998).

Nineteen regolith-landform units were defined during compilation of a 1:25,000 scale regolith-landform map (Moore *et al.* 2001, Agar *et al.* 2002). Alluvial channels range from narrow (up to 3 m deep and 5 m wide), incised, ephemeral channels, to deeper (10-20 m wide and > 5 m deep) channels with permanent water. Alluvial plains are mainly located in the lower reaches of the catchment where Cudgell Creek enters Burrangong Creek. Bedrock crops out as tors and has been subdivided into bedrock outcrops and sub-cropping rock with less than 1 m of colluvial cover, on hills (90-300 m relief), low hills (30-90 m relief) and rises (9-30 m relief). The remaining units describe the erosional and depositional colluvial landforms that dominate the catchment. Weathering, erosion and anthropogenic modification have shaped the present landscape. Characterisation of regolith-landform units (RLUs) has allowed clearer understanding of the distribution of regolith materials with differing porosity and permeability properties, factors that control shallow fluid flow. Mapping provides evidence of spatial distribution of RLUs and this will facilitate interpretation of electromagnetic induction (EM) survey results currently being acquired by the NSW Department of Land and Water Conservation (DLWC). Regolith-landform mapping is part of a multidisciplinary approach to dryland salinity hazard management in upland areas. This approach is important for maintaining sustainable agricultural production (Franklin 1999).

DRYLAND SALINITY AND SALINITY INDICATORS

There are four known sources of salt in areas with recognised dryland salinity problems: weathering salts; fossil or connate salts; cyclic (aerosol) salts; and aeolian (parna) salts (Collin *et al.* 1997, Acworth & Jankowski 2001). Recent research has indicated that the main source of salt in the Lachlan Fold Belt is from aeolian deposits (Evans 1998). Aeolian dust usually accumulates at low rates, which means that it is often not possible to distinguish it within existing soils and sediments (Gatehouse 1998). It is therefore a difficult task identifying exactly where there is a strong influence from aeolian material in regolith materials.

Plants capable of surviving in saline areas can be used, in conjunction with other evidence, as indicators of dryland salinity. Common indicator vegetation in the central west of New South Wales includes: Sea Barley Grass (*Hordeum marinum*); Couch Grass (*Cynodon dactylon*); Annual Beard Grass (*Polypogon monspeliensis*); Spike Rush (*Juncus acutus*); Strawberry Clover (*Trifolium fragiferum*) (Figure 1); and Cumbungi (*Typha spp.*) (Figure 5) (Fogarty *et al.* 1993). When the problem of salinity is severe enough, few plants are capable of surviving. This often leaves bare patches of soil, which are referred to as salt scalds, characterised by salt crystals that form at the surface as discharging water evaporates. In areas where there are symptoms of dryland salinity, dams or water bodies often appear clear because the dissolved salt causes suspended particles to flocculate (Charman & Murphy 2000).

Figure 1: Common indicator vegetation in central west NSW, includes (clockwise from top left): Sea Barley Grass (*Hordeum marinum*); Couch Grass (*Cynodon dactylon*); Annual Beard Grass (*Polypogon monspeliensis*); Strawberry Clover (*Trifolium fragiferum*); and Spike Rush (*Juncus acutus*).

REGIONAL SETTING AND GEOLOGY

Cudgell Creek Catchment is located approximately 8 km NW of Young, NSW (Figure 2). The catchment is located in an altitude range of 340-520 m ASL and covers approximately 220 km^2. It experiences a mean temperature range of 7.6^o-22.1^{o}C. Mean rainfall is 653.5 mm per annum and the highest recorded daily rainfall was 130.8 mm in 2000 (BOM 2000).

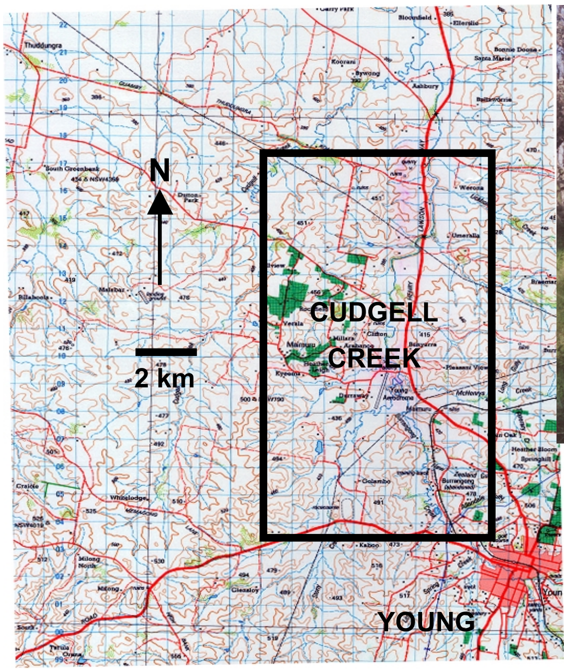

Figure 2 (left): Location of Cudgell Creek catchment NW of Young (NATMAP 2000).

Figure 3 (above): Slightly weathered bedrock developed on the Young Granodiorite, which typically outcrops as tors up to 2 m in height (SS_1). A halo of subcropping bedrock with shallow colluvial cover (SS_2) surrounds most outcrop.

Cudgell Creek flows in a northerly direction from the southwest to the northeast, where it joins the Burrangong Creek.

The geology of Cudgell Creek catchment consists dominantly of the Young Granodiorite (Figure 3). The batholith extends for 170 km south from Bumbaldry as an elongated intrusion with a north-south trend and a total area of 3,640 km². It is a medium- to coarse-grained Early Silurian S-type intrusion with a uniform composition of 10-40% plagioclase and K-feldspar, 30-40% quartz and 10% biotite, altered to chlorite in some parts (Lyons *et al.* 2000). Many dykes of andesite to rhyodacite composition, the majority having a north-south trend, have intruded the Young Granodiorite. Weathering of the overlying Goobarragandra Volcanics has exposed the Young Granodiorite at the surface. Parna is present throughout the catchment as lee-side accumulations and modified soils (Evans 1998). Further degradation of the granodiorite and development of the regolith mantle has produced the current landscape. It is thought that changes to vegetation and land use in the last 200 years, with the introduction of ruminants into the landscape, felling of timber and large scale land clearance, have enhanced land degradation and augmented formation of most regolith landform units, especially alluvial units (Wooldridge 1999).

RESULTS

Regolith-landform mapping is an iterative process involving polygon characterisation using aerial photograph stereopairs with other available spatial data and field checking to describe regolith materials and confirm the reliability of the landform boundaries. The RTMAP (Pain *et al.* in press) regolith-landform unit classification scheme has been used to code the regolith-landform polygons, however, the scheme has been modified slightly for use in landscapes that have been intensely modified by agricultural practice. The most significant change is the incorporation of a land use modifier to compliment descriptions of extant native vegetation associated with regolith-landform units. The principal modes of regolith material transport in the central west of NSW are colluvial and alluvial movement, but there is also a small influence from aeolian material. Drainage in upland catchments is usually incised in the upper reaches, with wider, larger streams towards the lower extent (Ollier 1984).

Figure 4 (left): Slightly weathered bedrock on an erosional low hill ($SSel_{1,2}$) with colluvial sediments on the flanks of the hill (Cel).
Figure 5 (right): Alluvial channel (ACa3), with water ponded behind a road. Abundant cumbungi (*Typha spp*) in the swampy area (Aaw).

***In Situ* Regolith-Landforms (SSeh, SSel, SSer)**

Slightly weathered bedrock outcrops as tors up to 2 m in height (Figure 3, Figure 4). Outcrop is more abundant in the southern high-relief part of the study area. Exposed bedrock is typically found on crests and upper slopes of erosional hills (90-300 m relief), low hills (30-90 m relief) and rises (9-30 m relief), and in the upper reaches of alluvial erosional depressions and incised alluvial channels. Excavation shows that subcropping bedrock with shallow colluvial cover commonly forms a halo around areas of exposed bedrock and between tors. Colluvial material between tors consists of quartzose and lithic pebbly gravels and sands with minor silt. Areas of outcrop cannot be cultivated so these either retain small remnants of native vegetation or are used for limited grazing on unmodified pasture. Areas with subcropping bedrock are moderately to intensely grazed on modified pasture and are commonly used for cereal cropping. The crestal location and presence of open joints in exposed bedrock suggests that these are areas of recharge in this local groundwater system.

Colluvial Regolith-Landforms (Ceh, Cel, Cer, Cpd)

Colluvial sediments drape erosional regolith-landforms (Ceh, Cel, Cer) and accumulate to form depositional regolith-landforms (Cpd). Colluvial erosional regolith-landforms are typically found in association with outcropping bedrock, sub-cropping bedrock (Figure 4) and incised drainage. Colluvial sediments are typically composed of quartzose and lithic pebbly gravels and sands with minor silts. These units are moderately to intensely cropped (e.g. wheat, canola, lucerne) and grazed on modified pasture. The lower flanks of colluvial erosional regolith-landforms may have areas of saturated ground and appear to be areas of discharge in this local groundwater system. They may have a slight gradient (up to 5°) and are composed of quartzose and lithic silty sands with minor quartz gravel. Land on this unit is intensely cropped and grazed on modified pasture. Field observations suggest that the colluvial depositional plains may act as discharge zones in some parts of this local groundwater system.

Alluvial Regolith-Landforms (Aed, ACa, Aaw, Aap)

Alluvial sediments can be subdivided into: sediments associated with fluvial channel systems including drainage depressions (Aed), channels (ACa) and swamps (Aaw) (Figure 5); and sediments associated with plains (Aap). Although alluvial drainage depressions form incipient drainage lines throughout the catchment, they are more typically associated with small, incised, v-shaped channels (ACa_1) that drain the steeper parts of the landscape in the south of the study area. Alluvial drainage depressions are up to 3 m wide but are typically shallow (~0.5 m). Upland v-shaped alluvial channels are up to 5 m wide, less than 3 m deep, and may have bedrock exposed in the channel. These units contain quartzose gravels and sands with an angular lithic pebble component. Alluvial drainage depressions are intensively cropped and grazed but the rockier upland alluvial channels support only limited grazing on unmodified pasture. In areas of lower relief broader, flat-bottomed channels dominate ($ACa_{2,3,4}$) (Figure 5) becoming increasingly incised into the alluvial plains as Cudgell Creek approaches the confluence with Burrangong Creek. These have been discriminated on the basis of size with flat-bottomed channels ranging from 5 m wide, less than 3 m deep with minor plains (ACa_2), through to broader alluvial channels 5-10 m wide and less than 5 m deep, with minor plains (ACa_3), to deep alluvial channels 10-20 m wide and greater than 5 m deep (ACa_4). Land on these units is not cultivated and is rarely grazed. Dominant vegetation in areas of ponded water is cumbungi (*Typha* ssp.) (Figure 5), with less abundant spike rush (*Eleocharis* ssp. and *Juncus* ssp.) and more limited populations of other water-tolerant species. Alluvial drainage depressions are zones of ephemeral surface water movement. The main water transport in the fluvial channel system is surface flow. Alluvial plains (1-9 m relief) are located adjacent to channels in the low-lying parts of the landscape, and are more common in the north of the study area. The smallest alluvial plains are up to 9 m wide immediately adjacent to channels (Aap_1). The broader plains are up to 50 m wide and have gradients of 2-5º (Aap_2), or < 2º (Aap_3). The most extensive plains are broader than 50 m but less than 200 m with gradients typically < 2º. These units consist of quartzose silt and sands with minor quartz gravels. Land on these units is intensely cropped and grazed on modified pasture.

DISCUSSION AND CONCLUSION

The areas in the Cudgell Creek catchment where most recharge takes place are found where tors and subcropping bedrock occur. Some infiltration also occurs on erosional hills, low hills and to a lesser extent rises. Discharge zones in the Cudgell Creek catchment are predominantly along the boundaries between erosional rises and alluvial plains, coinciding with a break in slope where regolith materials are no longer eroded, but rather deposited. This boundary may often also mark a change in soil texture from sandy to clay soils. Other discharge zones include natural flow paths, such as channels and gullies where groundwater seeps from alluvial erosional depressions and channels. The discharge in these areas may be year-round, or restricted to certain times during the year such as during spring depending on the amount of rainfall.

The principal areas of concern for dryland salinity hazard are: areas above bedrock constrictions; areas above infrastructure constrictions; areas above dams on flow lines; and areas along existing flow lines. Bedrock constrictions are natural constrictions to water flow occur in areas where the underlying geology creates a narrowed path through which surface- and groundwater can flow. In areas where constriction points occur, ponding of water may take place above the constriction. The natural flow paths of surface- and groundwater are often affected by infrastructure such as roads that prevent the sub-surface flow of water because underlying soils are more compacted. Flow lines allow water within a catchment to exit, along with most dissolved salts. Dams situated on flow lines cause the water exiting the catchment to become ponded causing a build-up of salt upstream of the constriction. Areas that experience low flow at different times of the year may have a high concentration of salts dissolved in the water during these periods (Wooldridge 1999) This means that salt can no longer exit a catchment, and can become concentrated in surface water during these events

Characteristics of regolith-landforms, noted here, influence the way in which water moves through the landscape. Regolith-landform maps are useful for helping interpret other layers of data. When data layers are combined, they provide more useful information which helps users interpret why salinity problems are evident in any particular area. Results gained using this multi-disciplinary approach are useful to help make more informed land management decisions. These maps can show areas with similar hydrologic properties (e.g. recharge and discharge zones), so areas in need of mitigation can be targeted. Regolith-landform mapping is an essential part of a multidisciplinary approach to dryland salinity hazard mitigation in upland areas. Tools that allow effective interpretation of spatial data from mapping and geophysical surveys contribute to contemporary sustainable land management practices.

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