MULTI-SCALE GROUNDWATER FLOW SYSTEMS: APPLICATIONS FOR UNDERSTANDING SALINITY PROCESSES AND MANAGING DRY SALINE LAND.

John Wilford[1], Jeremy James[1] and Larysa Halas[1]

[1]CRC LEME, Geoscience Australia, GPO Box 378, Canberra, ACT 2601

INTRODUCTION

Widespread salinisation of land and river systems is a major environmental problem affecting agricultural regions throughout Australia. Predicted area of high risk from shallow water tables and/or high salinity hazard is estimated to rise nationally from ~5 658 000 ha in 2001 to ~17 000 000 ha by 2050 (NLRA, 2000). To better manage salinity the Groundwater Flow System (GFS) framework was developed (Coram 1998, Walker et al. 2003). This relies on published geological maps, supplemented by hydrological and topographic data to subdivide the landscape into discrete areas with similar geological, geomorphological, groundwater flow (i.e. recharge, transmission, discharge) and salinity characteristics. This paper discusses a new approach to significantly improve GFS in upland landscapes by adding in detailed regolith and structural information across a spectrum of landscape scales. Although regolith and structural characteristics are recognised as being important in the original GFS framework these components are often not shown spatially on the GFS maps. Yet, most landscapes in Australia exhibit a high degree of regolith and structural variability that has a major control on salt stores and the preferred pathways along which salt is delivered to the land surface and streams (Lawrie et al. 2003).

MAPPING APPROACH

The new approach builds on the original GFS framework by developing spatially-explicit flow system maps for upland landscapes that incorporate detailed soil, regolith, landform and structural information. This is achieved through the interpretation and integration of datasets and knowledge frameworks across a range of scales. As a result, the revised GFS framework accommodates local-scale implementation strategies for salinity management as well as providing a useful resource for undertaking broader-scale land management assessments. The approach has broad application in upland landscapes because it largely utilises existing geoscientific data including aerial photography, airborne geophysics, digital elevations models, boreholes and published geological and soil maps (Figure 1). Where appropriate, newly-acquired data including, drilling, stream conductivity measurements and ground-based geophysics (gamma-ray, magnetics, EM31 and 38, NanoTem) are integrated as part of the analysis.

The first step in compiling the GFS involves the development of a landscape evolution model for the region being studied. This assists in identifying the controls on landscape development and the characteristics that influence the distribution and mobilisation of salts. Regolith materials and associated palaeo- and present-day geomorphic and weathering processes are identified during this process. Major bedrock structural domains and individual structural elements are also delineated. Geological maps are used to characterise the lithological component of the fractured bedrock system. A hierarchy is then developed that ranks the importance of these controls or components across different spatial and temporal scales. Therefore a hierarchy developed for one region might not transfer to another due to differences in bedrock type and landscape history.

Generally, at the broadest scales, major relief/elevation and bedrock characteristics are identified. Major groups at this level have different geomorphic and bedrock characteristics that describe the general nature of regolith and landform relationships (e.g. regolith type, thickness, relief and elevation). At the next level down variations are associated with landform processes and evolution, and lithology. Below this, soil and regolith toposequences and associated weathering and geomorphic processes are identified. At this level there are often complex inter-relationships between regolith/soil type and thickness, slope angle distribution, hydrological and geomorphological process, landscape position and geology. An example here would be changes in regolith (compostion and thickness) and hydrology across a colluvial slope (e.g. upper, middle and lower slope positions).

Depending on dataset availability, landforms are either delineated by interpreting aerial photography or from analysis of DEMs where a range of morphometric characteristics are used to describe geomorphological land units (Figure 1). The use of DEM terrain indices to predict a range of hydrological and geomorphological processes is well established (Beven & Kirby 1979, Moore et al. 1991, Wilson and Gallant 2000). These are integrated into the GFS at different scales. For example, at local scales, landscape position classes including upper, mid and lower hillslope facets are identified. These facets have the potential to link into hydro-pedologically based toposequence models (Fitzpatrick, 2005 and Thomas et al. 2005) that describe soil, water (salinity) and slope inter-relationships. We found that the effectiveness of the toposequence modelling for identifying different hydrological regimes was greatly improved when interpretations were constrained within the overall mapping hierarchy. It allows detailed site observations or toposequences to be placed in a regional regolith-landform context and provides likely constraints on how far local scale observations can be extrapolated.

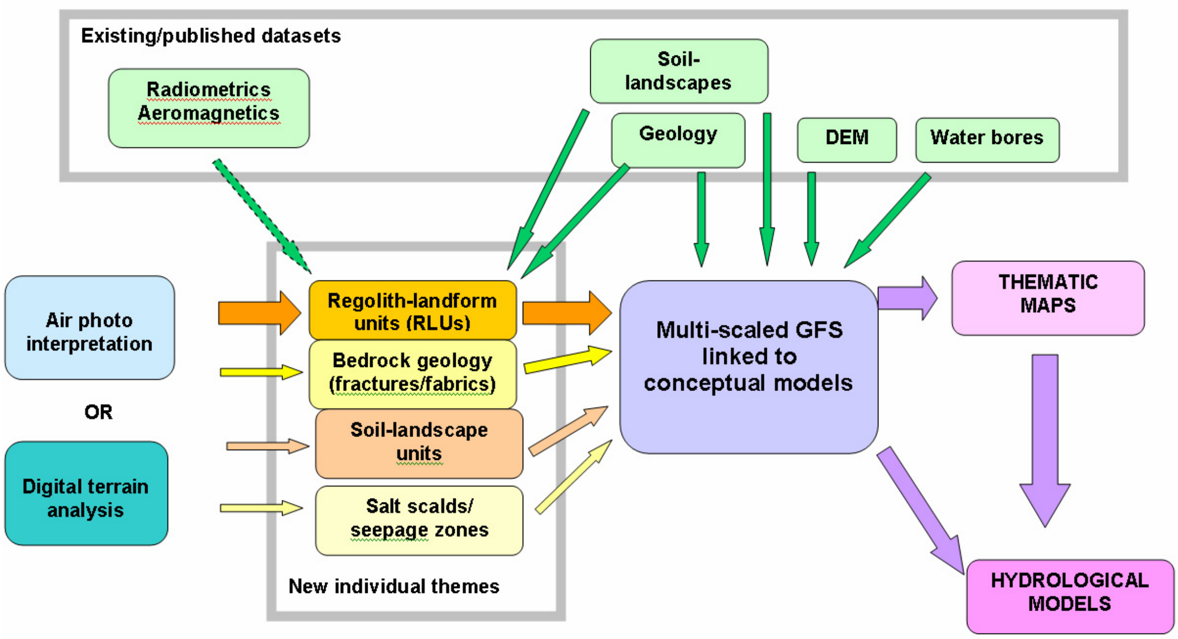

Figure 1: Methodology used to value-add Groundwater Flow Systems.

RESULTS AND DISCUSSION

This approach is being applied by CRC LEME to the Bet Bet Catchment in Central Victoria (Wilford et al. 2006) and an area that includes Dubbo and Cowra in Central West NSW. Both areas are typified by a high degree of variability in the nature and distribution of regolith materials, salt stores and groundwater flow systems that operate over a range of different scales. These characteristics are not unusual but instead, typify many Australian landscapes that have had a protracted weathering and erosional history. In each area detailed nested GFS units have been compiled that classify the landscape based on soil/regolith, bedrock (type and structure), landform and salinity characteristics. Broader-scale GFS are linked to conceptual hydrological and salinity models, whereas finer-scale landform and regolith attributes enable the land manager to target land and creek salinisation in specific parts of the catchment.

The multi-resolution approach has significantly improved the original GFS by providing an understanding and spatial prediction of regolith materials, structural components and hydrological and salinity processes at different nested scales in both space and time (Figure 2). The approach also accommodates the fact that most local flow systems within these upland landscapes are nested with larger ones.

In each area the approach has led to an improved understanding of groundwater and salinity processes. In particular, it has provided a better understanding of the relationships between regolith (composition, thickness, architecture & hydrological properties), bedrock geology (lithology and structure) and salinity (salt stores, saline groundwater flow and its surface expression). For example, in the southern part of the Bet Bet catchment a new nested flow system model has been developed that changes our understanding of how recharge and discharge processes operate which, in turn, has changed where we intervene in the landscape. In addition, the new thematic layers, including soils, regolith and bedrock structures generated from this type of analysis, are now being incorporated into improved hydrological models such as 2C and CAT3D.

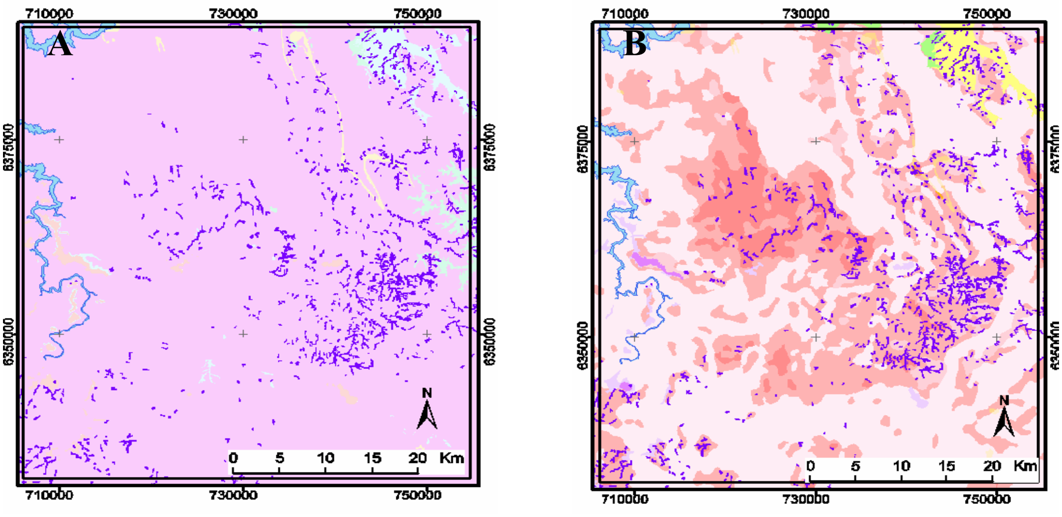

Figure 2: A – part of an existing GFS map with salt scalds in dark purple. GFS largely classified as one unit that consists of a local fractured bedrock groundwater flow system. B – new map showing the high correlation between highly weathered GFS units (red hues) and salinity. The regolith units are associated with low relief erosional landforms and associated colluvial slopes.

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