INTEGRATED SPATIAL DATA ANALYSIS AND 3D VISUALISATION FOR UNDERSTANDING THE GROUNDWATER FLOW AND SALINITY PROCESSES

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INTRODUCTION

Agricultural and industrial land use intensification in the last 100 – 200 years has accelerated dry land salinity by causing increased groundwater recharge, which leads to increased groundwater flows (GWF) (Walker et al, 2003). Degradation of agricultural land due to dry land salinity and deteriorating water quality is widespread and is being addressed at both local and regional scales. A key approach to managing salinity across different landscape scales is the Groundwater Flow System Framework (Coram, 1998).

The Groundwater Flow System (GFS) is a conceptual hydrogeological model that describes groundwater behaviour in response to recharge. GFS is largely influenced by the history of landscape evolution and landscape architecture, geomorphology, geology and hydraulic properties of regolith material that determine the formation of aquifers. To understand the hydrodynamics and salinity in different landscape settings, it is necessary to investigate all landscape components.

The GFS framework relies largely on published geological maps, combined with some hydrological and topographic data to subdivide the landscape into discrete areas with similar geological, geomorphological, groundwater flow and salinity characteristics. CRC LEME is currently developing new approaches to defining GFS units that capture the full range of components determining where the salts are, and the preferred pathways along which salt is delivered to the land surface and streams.

Recent advances in desk-top-based visualisation software now provide an interactive environment where these datasets can be displayed, analysed and integrated in 3D. These techniques are now being applied to modelling 3D architecture of the regolith to better understand groundwater and salinity processes.

OBJECTIVES

This study aims to develop a consistent methodology for GIS data analysis and processing in order to provide potential input data layers for refining existing GFS. It also aims to provide visualisation methods for better understanding relationships between landscape variables, GFS and salinity processes. We focus on an integrated spatial data analysis approach that involves scientific data for various landscape components: DEM, geology (lithology and structure), physiography, ground and airborne geophysics, soil profiles and borehole analysis, climate, vegetation and land use. We attempt to build a 3D visual model of regolith architecture utilising generally available datasets at a sub-catchment scale.

Modelling outputs are:

- spatial datasets supplemented with metadata at a range of spatial scales
- maps that are easily readable for data querying and scientific analysis
- interpolated regolith constituent surfaces and a 3D regolith – GWF model at a sub-catchment scale
- images that comprehensively communicate scientific data via 3D visualisation of geographic phenomena

Derived spatial datasets and 3D regolith – GWF models will be used as inputs for:

- developing modelling framework for refining GFS
- analysis of relationships between catchment properties and GFS type to allow extrapolation of GFS to similar catchments in other areas
- hydrogeological modelling in Modflow, Cat3D, Class or other modelling software

SPATIAL DATA PROCESSING AND VISUALISATION

The availability of data for environmental use is always an issue. National or state scale data are not suitable for projects at catchment level as the information is too coarse or generalised. Sub-catchment scale data are not readily available and have to be obtained from field work, State Governments or Catchment Management Authorities (CMAs). Generally available datasets used for GFS modelling have varying density and distribution, which means that detailed study areas need to be confined to patches of data overlap. Therefore, due to data availability, there is a limitation to detailed modelling of GWF.

The study area is in the Central West CMA within the Dubbo 1:250,000 map sheet. The distribution and density of spatial datasets (EM conductivity survey grids, bore holes and soil profiles) were evaluated. A few sites were then selected for detailed study. Input datasets were analysed and prepared for modelling (Table 1).

Table 1. Input datasets and derivatives

Datasets	**Used attributes**	**Processing software**	**Derivatives**
Digital elevation model grid	elevation value	ArcGIS Hydrologic modelling	Watershed boundaries
		ArcGIS Surface modelling	Slope
		ArcGIS	MrVBF indices
		ArcGIS	Landscape classes
Borehole	standing water level (SWL) , salinity, aquifer depth etc	MS Database Access, MS Excel Surfer 8, Strater	3D shapefiles of: SWL, aquifers depth, drill logs, GW salinity and interpolated surfaces, Strater logs
Soil profiles (173 fields available)	various	MS Database Access MS Excel Strater	3D shapefiles, which contains profile depth, EC, texture, site description etc, Strater logs
Soil landscapes	various	ArcGIS	Maps, images
Geology and structures	various	ArcGIS	Maps, images
Climate (long-term averaged grids)		Anuclim	Seasonal evaporation and rainfall data
Ground geophysics EM survey grids		ER Mapper	Maps, images
Radiometric and TMI grids		ER Mapper	Maps, images
Vegetation		ArcGIS	Map, images
Land use		ArcGIS	Map, images

ARCSCENE 3D VISUALISATION

The main procedure for creating a 3D scene is to drape data layers over a created terrain surface by assigning a source of base hight values from a DEM. Visualisation of point features such as boreholes and soil profiles requires preliminary preparation of a dataset for using depth information to display, for example, stratigraphic or soil profile layers. Also, for the purpose of emphasizing regolith structure and GWF, rock units of similar permeability and porosity properties have to be grouped. Point features are extruded to vertical columns; rock properties are differentiated by colour symbology whereas thickness of layers is shown by extrusion using depth intervals.

Similarly, borehole data are a source for interpolation of various sub-surfaces, regolith bodies and aquifers or Water Bearing Zones (WBZ) considered of being important in GWF modelling. Although the 3D Analyst tool of the ArcGIS package has interpolation capabilities, Surfer 8 (Golden Software suite) has been chosen for interpolation procedures as it incorporates more options in surface creation with fewer artefacts.

Prepared data layers are integrated into a 3D view ready for analysis or to be exported as perspective images of landscape features, salinity data and sub-surface regolith structure (Fig. 1 and Fig. 2). A GWF model is constructed based on perspective view images and detailed analysis of borehole and soil profile logs using Strater (Golden Software suite). Information from various datasets is integrated and assigned to GFS type.

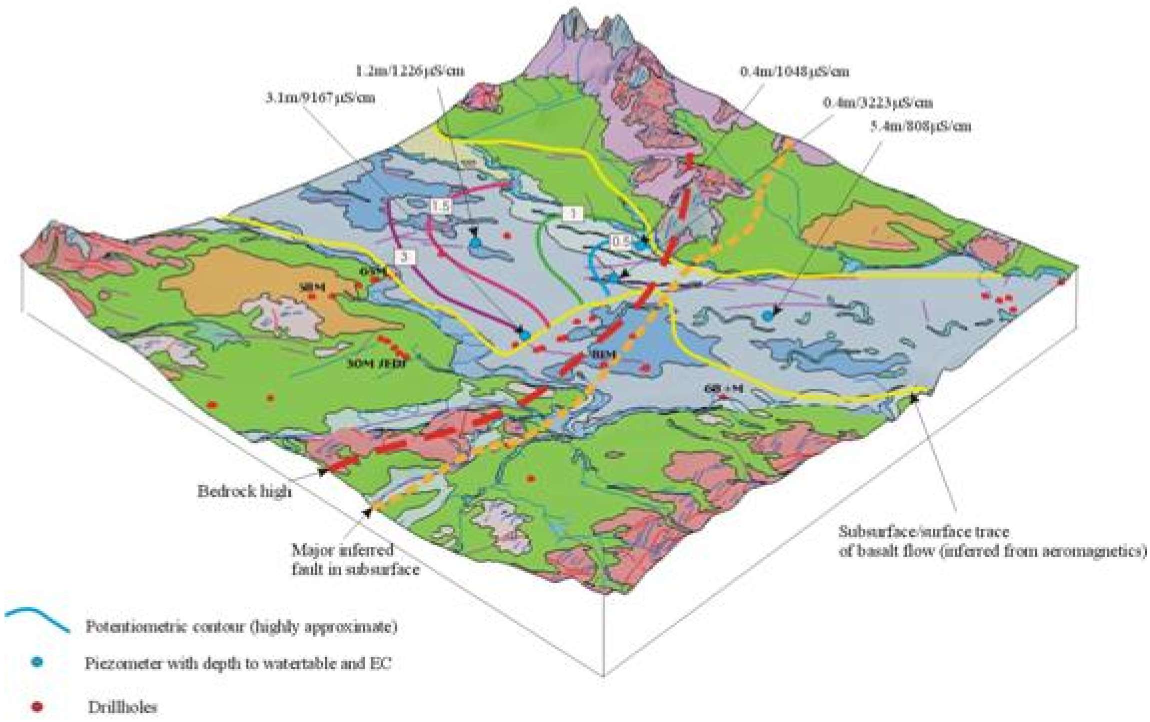

Figure 1. Perspective drape looking to northwest showing interpreted bedrock constriction in the Timor West area, lower part of Bet Bet catchment, Victoria. (CRC LEME restricted report 234R)

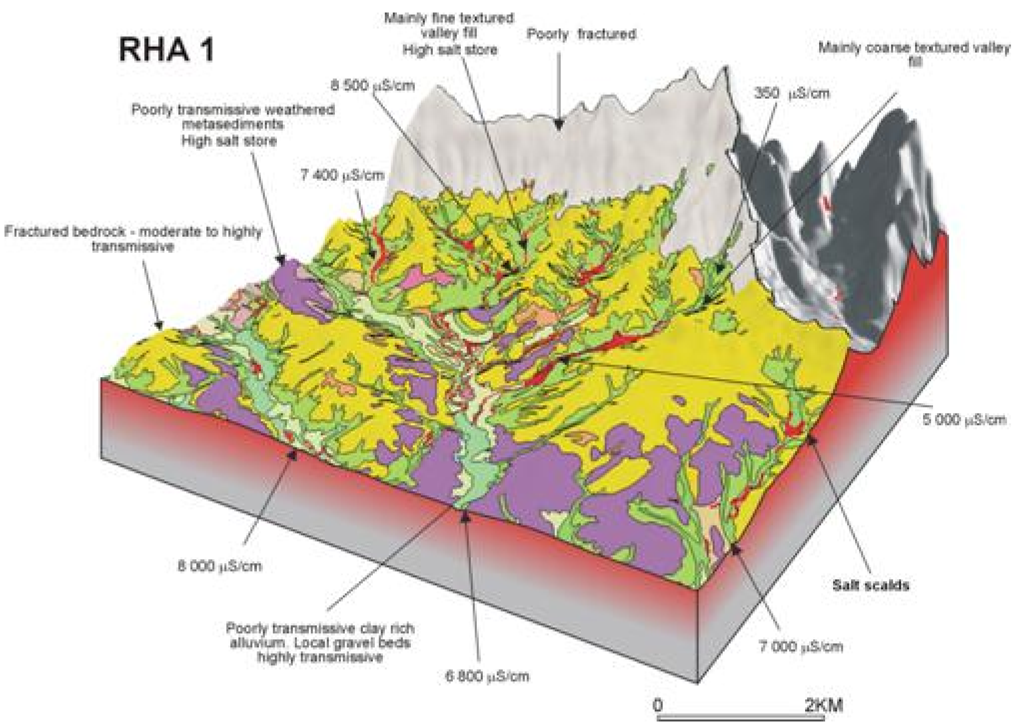

Figure 2. Perspective view showing distribution of RHUs and hydrological/salinity attributes, example from Bet Bet catchment, Victoria. (CRC LEME restricted report 234R)

CONCLUSION

Incorporating 3D Analyst ArcScene capabilities into scientific data analysis enhances viewer perception by overcoming gaps in simple 2D map displays. This compares with real-world visualisation of geographical phenomena, which reveals 3D spatial patterns and relationships between various data layers. Furthermore, ArcScene utilities allow data integration and 3D analysis, including volumetric calculations, profiling, contouring, and steepest descent tool. These can be used to identify GWF pathways if applied to an interpolated impermeable basement surface.

Data integration and visualisation techniques described in this paper are leading to a greater understanding of groundwater and salinity processes across a range of scales. The work is providing new insights into the relationships between regolith (composition, thickness, architecture & hydrological properties), bedrock geology (lithology and structure) and salinity (salt stores, and saline groundwater flow pathways).

In particular, 3D conceptual models constructed from 3D datasets linked to GFS units help to visualise, communicate and describe inter-relationships between soil, regolith and bedrock materials and associated hydrogeomorphological and salinity processes. The 3D models are constructed from a combination of surface and sub-surface information including airborne magnetics, gamma-ray spectrometry, digital elevation models, regolith and geological maps, AEM, drill hole logs (including derivative surfaces), down hole geophysics (EM logs), ground geophysics and stream measurements (EC). New insights gained from this type of analysis are leading to the development of predictive rules on groundwater systems that allow extrapolation into other areas that don't have the same level of information.

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