INTERPRETING THE ELECTRICAL CONDUCTIVITY RESPONSE OF REGOLITH MATERIALS IN VARIOUS GEOMORPHIC SETTINGS ACROSS AUSTRALIA

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INTRODUCTION

Airborne, ground and river-based electromagnetic surveys were carried out across various parts of Australia with the intent to assist in managing land use, water resources and environmental issues. Study areas included the four NAP projects sites in South Australia (*i.e.* Jamestown, Angas Bremer Plains, Tintinara and Riverland), the lower Balonne in Qld (in the vicinity of St. George), the Gilmore project area in the Bland sub-catchment of NSW and the current SA Murray floodplains, Victoria's Sunraysia and Murray River Corridor project areas. The objectives of the geophysical surveys vary between the project areas, but involve identifying areas of high salt loads and perched fresh water lenses, determining the salt stored in the unsaturated zone, identifying areas and thickness of clay for recharge calculation, and providing insight into salinity dynamics and groundwater flow paths.

Data products used in these studies included pseudo-coloured images of interval conductivities which show spatial patterns of ground conductivity for particular depth intervals (also referred to as conductivity-depth slices or CDI's) and apparent conductivity images. Identifying and interpreting conductivity patterns on the images is not straight forward. In the absence of massive sulphides in the regolith, the main causes of bulk conductivity are pore fluid volume and electrolyte concentrations (*i.e.* salinity) (Rhoades *et al.* 1976). The product of these two factors is termed salt load. Air and ground EM data are most suited to determine and map, salt loads in the regolith. However, interpreting the conductivity patterns and deriving products to assist in managing land and water use also requires other information, including hydrogeological and petrophysical data.

INFORMATION NECESSARY FOR INTERPRETATION OF CONDUCTIVITY PATTERNS

Both lithological and hydrological conceptual models are essential to interpreting conductivity-depth interval data as these provide an overall framework on which any interpretation of the conductivity patterns is based. High resolution elevation data such as LiDAR is useful in identifying spatial correlation between geomorphic units and shallow conductive patterns, and is especially useful on floodplains where variations in elevations between terraces, fluvial channels and scroll bars are less than 5 m. Delineated geomorphic units allow the inference of the textures and hydrological parameters such as recharge rates. The standing water level (elevation) is another important data as the thickness of the unsaturated zone can be calculated, which helps differentiate the influence of lithologic materials (eg. clay) and groundwater on the observed conductivity structure. From the groundwater conductivity information, a range of bulk conductivity values for various lithological units can be postulated.

PATTERN RECOGNITION

Large scale features with sharp boundaries can be identified on interval conductivity images, and they usually reflect either lithological or hydrologic changes (*i.e.* saturated and unsaturated zone). On the other hand, subtle or gradual boundaries usually indicate the presence of salinity variations. In the unsaturated zone, variations in conductivity may also be due to variations in moisture content associated with textural differences. Small changes or more subtle variations in conductivity values are more difficult to interpret. Thus, ground validation to obtain down-hole conductivity logs and drill cuttings for laboratory analyses may be necessary to help remove ambiguity in the interpretation.

CASE STUDIES

An in-stream NanoTEM survey (Berens *et al.* 2004) was conducted on the Murray River in the vicinity of the Loxton irrigated area in SA (Figure 1). The NanoTEM response reflects the resistivity of the river sediments down to 15-20 m depths. The survey results show the presence of shallow resistivity layers in some areas but the dominant response is conductive to some depth. Borehole records show that the lithology is predominantly channel sand for the top 4 m beneath the river bed throughout the stretch of the river surveyed, and a grey shelly muddy sand present at 5-6 m depths along parts of the river. Since the lithology and associated porosities and water contents (at saturation) of the sand are similar, variations in the resistivity reflect changes in salinity, with the resistive sand containing non-saline pore fluids from the river and the conductive sediment hosting saline groundwater.

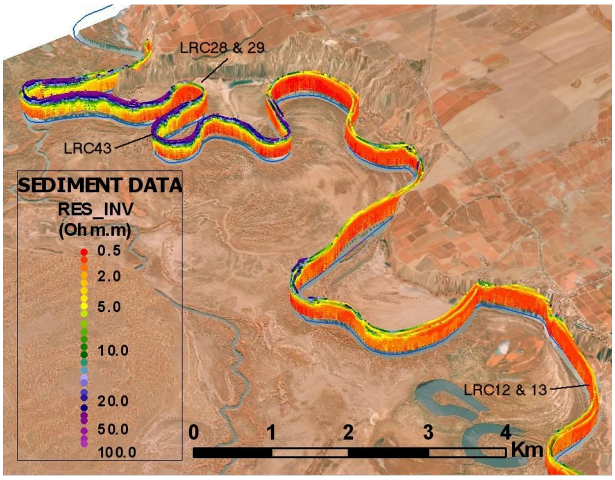

Figure 1. Oblique view of in-stream NanoTEM resistivity values along part of the surveyed River Murray showing stretches of resistive (blue) and conductive (yellows and reds) zones of the river sediments. (Adapted from Berens et al., 2004).

On the Mallee at Riverland, surface elevation data and standing water level information suggest that the unsaturated zone is approximately 15-20 m thick, with some low lying areas where the water table is at less than 10 m depth. As shown on the apparent conductivity image (Figure 2), variations in conductivity of the unsaturated zone reflect changes in salt load associated with moisture contents and textures. Finer textured materials (e.g. Blanchetown Clay) contain higher moisture contents, with saline pore fluid, and are more conductive than dry sand (Tan *et al.* 2004). However, conductive saturated sand in low lying areas is also depicted on this image, so a constrained inversion of the EM data was carried out to remove the ambiguity in the interpretation of the conductivity image and to produce a clay thickness map (Green *et al.* 2004).

On the Chowilla floodplains, the geomorphic features can indicate the factors influencing in the observed conductivity values and patterns as shown on the CDI with LiDAR DEM overlay (Figure 3). Borehole information suggests that the standing water levels on the floodplains are at 2-4 m depth. The resistive zone bordering the Murray River and along its anabranch is due to relatively fresh river water leaching the sediments of salt. This zone is referred to as the flushed zone. The resistive areas bordering the floodplains are predominantly unsaturated sequences of Loxton Parilla sands at higher elevation. On the floodplain, the resistive areas include lake bordering lunettes and remnant river terraces, are commonly unsaturated, but in places may indicate the presence of a perched fresh water lens. Elsewhere, subtle variations in conductivity reflect changes salt load as a result of either salinity or texture. This will be validated with the current drilling program.

CONCLUSIONS

Interpreting electrical conductivity patterns on pseudo-coloured conductivity images is not straight forward and commonly requires additional information on the local hydrogeology and geomorphology. High resolution DEMs can assist interpretation of EM data. However, ground validation is needed to positively identify the causes of the observed conductivity responses.

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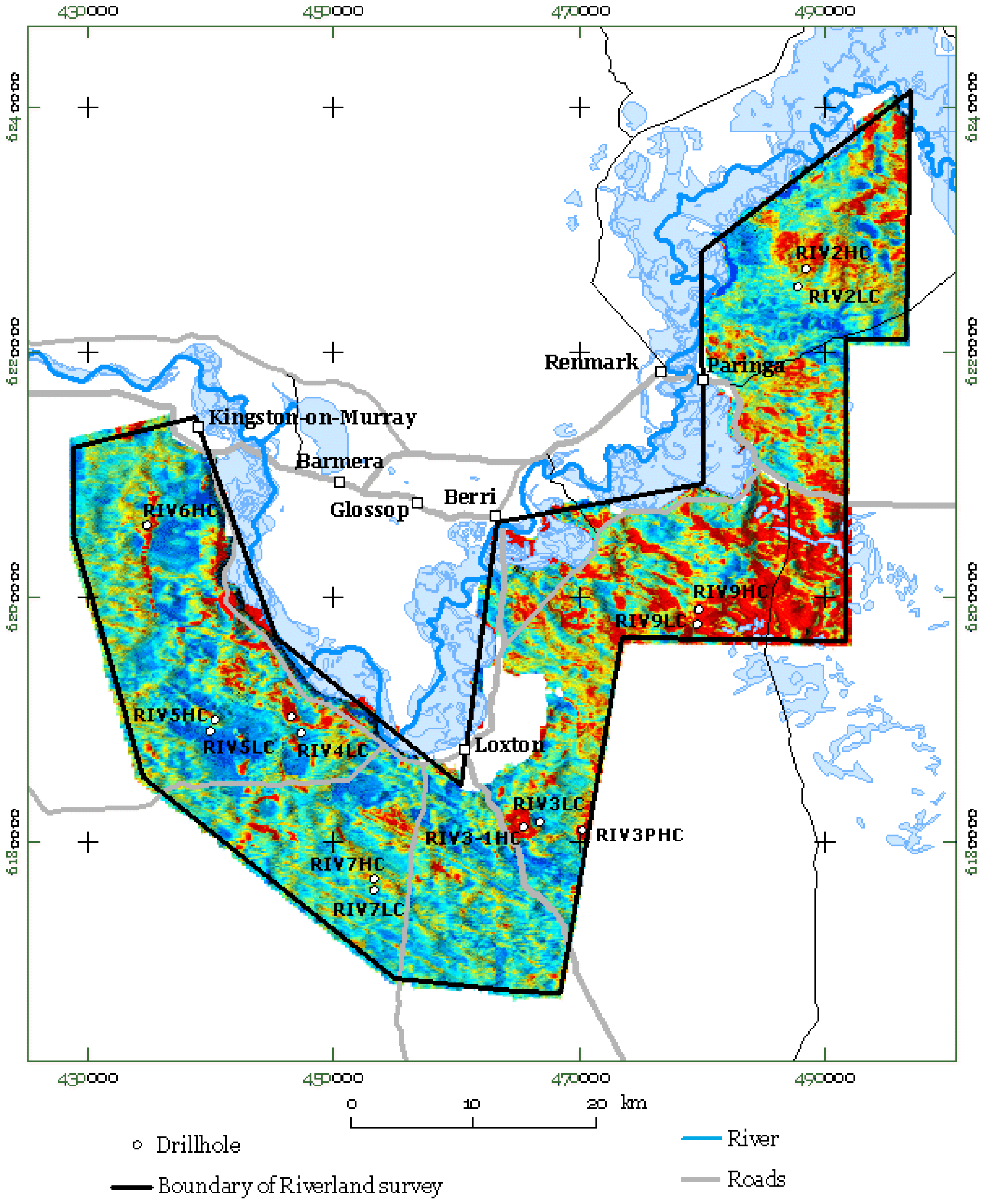

Figure 2. Riverland apparent conductivity image at 25 kHz draping over a digital elevation image. Conductive areas are in red whereas resistive areas are blue.

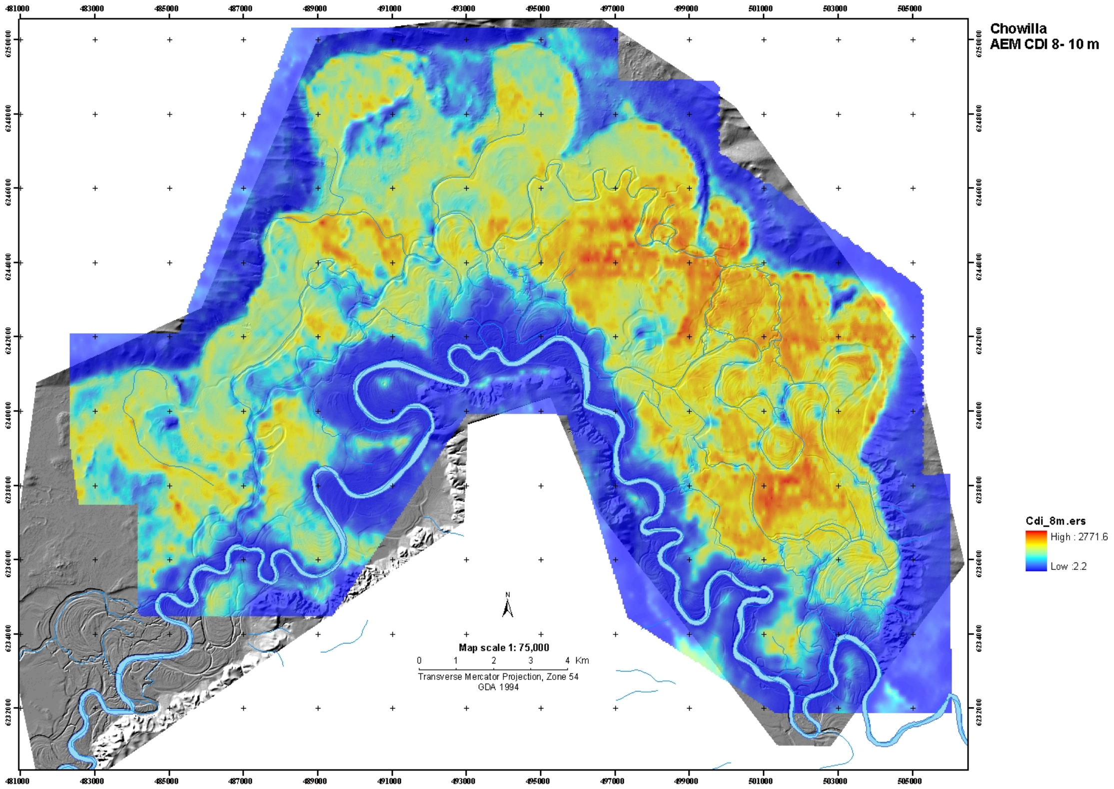

Figure 3. Chowilla floodplains - 8-10 m interval conductivity image draped over LiDAR DEM.