IMPROVING THE OUTCOMES OF SALINITY MANAGEMENT IN AUSTRALIA'S REGOLITH LANDSCAPES: LESSONS LEARNED FROM 5 YEARS OF RESEARCH IN CRC LEME, AND NEW OPPORTUNITIES IDENTIFIED

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ABSTRACT

In the last five years, CRC LEME, in partnership with a range of Natural Resource Management (NRM) agencies and regional communities across Australia, has successfully demonstrated how multi-disciplinary geoscience approaches can be used to address more effectively a range of salinity-related NRM issues. In particular, new insights into Australia's regolith landscapes, and processes operating within these landscapes, combined with the acquisition of new 3D geospatial data layers, have significantly improved confidence levels in models that are used to prioritise and target salinity management investments across a wide range of landscapes and land use settings.

While there have been significant outcomes from salinity research in Program 4 (P4), much remains to be done. For example, fundamental flaws in the methods used to predict salinity in the National Land and Water Resources Audit (2000) have not yet been addressed, and great uncertainty remains about the future extent and timeframes for the development of salinity across Australia. In this context, salinity is a symptom of broader water balance and climate change issues, and some fundamental research remains to be done to ascertain climate change impacts, and the hazard from infrequent extreme events in particular. There is also still considerable scope for research into the dynamics of salinity in a range of landscapes, climate zones and land use scenarios, and significant gaps in our understanding of the capacity of natural systems to respond to salinity under its diverse manifestations, risks and hazards.

In summary, a demand has now been created for regolith-based services and products to underpin salinity management and broader NRM issues in Australia. CRC LEME has pioneered the development of new approaches and products in a number of case studies, although it is not clear how these will be rolled out in a post-CRC LEME world. Knowledge transfer is hampered by a lack of suitably skilled staff in many NRM agencies and the private sector. This is not just an issue confined to Australia, as much of P4's science has relevance internationally.

KEY LESSONS LEARNED IN THE FIRST 5 YEARS OF PROGRAM 4 (P4) RESEARCH

There have been over 40 projects carried out in P 4 in the past 5 years, and many of these projects have contributed valuable new science insights, as well as assisting with salinity and broader environmental management outcomes. It is not possible in this paper to summarise all the program achievements, so a few key highlights are documented below.

1. ***Development of a holistic, multi-disciplinary, multi-scale systems approach to mapping and predicting salinity hazard and risk in regolith landscapes.***
   At a high level, this approach underpins the whole program approach to mapping and predicting salinity hazard and risk, and underpins development of appropriate salinity risk management strategies and management actions. The approach has provided the conceptual framework for demonstrating the relevance of geoscience datasets and approaches, notably the perceived value and relevance of airborne and ground geophysics and regolith studies in NRM applications. Adoption of a systems approach has been recommended by the joint Academies Salinity Mapping Review for application to the mapping and prediction of salinity hazard and risk in Australia, and underpins the airborne geophysics component of the $20m Australian Government Community Stream Sampling and Salinity Mapping Project.

   The approach seeks to map and characterise key biophysical components of the hydrogeological system critical to the movement of water and salts in the landscape, and to integrate spatial characterisation with studies of water and salinity dynamics. This approach has enabled geophysical and regolith datasets to be integrated with hydrogeochemistry, and through appropriate modelling interfaces, has led to the development of a range of new salinity hazard and risk products, management intervention strategies and actions. The approach is not landscape or technique specific, and can be modified to underpin research into a range of NRM and mineral exploration issues. The approach was developed out of the GILMORE project, and is applied generally within P4 and more importantly, has been adopted by a variety of agencies.

2. ***Cost-effective use of airborne electromagnetics (AEM) for salinity management***
In Australia's low-relief and floodplain landscapes, it has been demonstrated that airborne electromagnetics (AEM) can be used cost-effectively to improve salinity management outcomes. In the Murray-Darling Basin appropriately designed and interpreted AEM products have proven important to the more effective targeting of salinity interception schemes, locating water storage facilities, designing salinity disposal strategies, informing irrigation re-zoning, and in understanding the spatial patterns of salt accumulation in the River Murray floodplain. EM products (airborne and in-river) are being used to underpin strategies to target environmental water flows for sustaining Groundwater Dependent Ecosystems as part of the Living Murray Initiative.

3. ***Research into landscape scale***
Research into the scales at which landscapes function geomorphologically and hydrogeologically has been crucial to determining the scale at which remotely sensed data and field calibration data should be acquired. This science underpins development of our multi-scale approach to landscape analysis, and has been pivotal in demonstrating the limitations in using Digital Elevation Models (DEMs) and other remotely sensed datasets for interpreting how landscapes function. This research provides a fundamental scientific underpinning of a number of key products, including our 'next generation' Groundwater Flow System ("GFS+") products in erosional landscapes, and is the basis for constraining salinity hazard and risk maps and salinity management strategies particularly in erosional landscapes.

4\. ***Regolith landscape evolution and characterisation***.
To put the value of regolith landscape studies (regolith material descriptions and characterisation and landscape evolution) in P4 projects into context, it is important to realise that many P4 projects have been carried out in landscapes where there has been a paucity of regolith research previously (in the last 15-20 years). These include some of Australia's principal agricultural areas (eg the Murray-Darling Basin and WA Wheat Belt). Therefore, studies in SE Australia (eg in the Murray Basin) and more widely across Australia including coastal landscapes in north Queensland (e.g. Burdekin) and the Ord in WA, have thrown up some real surprises, and are leading to significant re-evaluation of landscape evolution and neotectonics in Eastern and NW Australia.

Significant new insights have come both from the application of modern sedimentary facies analysis techniques to the study of transported materials, and from the study of weathering overprints both in transported and weathered bedrock materials. This research has necessitated the development of novel ways of interpreting geophysical datasets, and has incorporated studies that range from grain scale to catchment scale. Regolith characterisation underpins the mapping of aquifer systems, and has led to development of new salinity risk assessments, delineation of new groundwater resources, and development of new hydrogeological models in depositional environments.

More generally, this research has shown that one cannot rely on an understanding of surfical landcapes to predict sub-surface regolith architecture in Australia. In the dryland landscapes of the Murray-Darling Basin, new geoscience approaches have been used to develop the next generation of Groundwater Flow System (GFS) products designed to underpin salinity investment decisions at sub-catchment scales. Use of these new products within the appropriate hydrogeological and land use models have demonstrated considerable improvements in identifying *within sub-catchments* those areas in the landscape where salinity management interventions should be targeted.

5\. ***Development of constrained inversions for AEM data analysis and interpretation***.
Development of constrained inversions for AEM data analysis and interpretation has been essential for accurate calibration of AEM datasets: e.g. in the Lower Balonne, increased r^2 correlations between AEM and borehole conductivity measurements were improved from 0.2 to 0.8. This technique has enabled a whole range of new products to be developed (e.g. salt store maps, recharge maps, water resource estimates, salinity hazard and risk maps, maps of aquifer systems etc.). This has also given confidence and impetus to the incorporation of these outputs in a range of hydrogeological and NRM models.

To date, constrained inversions have been successful carried out in the Lower Balonne and Riverland projects. Conductivity depth images developed using this technique (compared with the standard AEM products) dramatically changed the perception of salinity hazard and risk in the Lower Balonne project area. In another first, the use of the constrained inversion techniques in the Lower Balonne project showed that AEM systems could give reliable results even where there was a conductive basement, something not previously demonstrated. The technique is now being used routinely.

6. ***In-river nanoTEM geophysics**.*
The development/application of an in-river nanoTEM surveying technique in Australia was initially carried out as a P4 student project through Adelaide University. This is a first class example of technology development and application that has become widely adopted. This research showed the potential of such technologies to map gaining and losing reaches of waterways. Subsequently, in-river nanoTEM surveys of the Murray River have been used to assist with the siting of salt interception schemes on the river, and these have attained measurable reductions in salt loads in the River Murray

SOME GAPS AND OPPORTUNITIES

While there have been significant outcomes from P4 research, there are also some frustrations at missed opportunities, and strategic gaps that have yet to be filled in Australia's response to management of salinity. For example, fundamental flaws in the methods used to predict salinity in the National Land and Water Resources Audit (2000) have not yet been addressed, and great uncertainty remains about the future extent and timeframes for the development of salinity across Australia. Input from CRC LEME is only now being sought to provide the necessary calibration of predictive models (e.g. in the Murray-Darling Basin), however this would require a post-LEME commitment from the relevant agencies. Knowledge transfer is hampered by a lack of suitably skilled staff in many NRM agencies and the private sector. This is not just an issue within Australia, as much of P4's science has relevance internationally. Similarly, a demand has now emerged for largely geophysics-based projects to provide input to projects where the principle objective is asset protection.

In terms of salinity research, one fundamental problem remains the lack of data and knowledge about landscape evolution and regolith architecture in many areas of Australia impacted by salinity. There are also some key gaps that still exist in our understanding of climate interactions and in understanding the threat of salt mobilisation resulting from environmental flows or natural flooding events (e.g. salt mobilisation of post-flood recession salt in floodplains). There remains considerable scope for research into the dynamics of salinity in a range of landscapes, climate zones and land use scenarios, and significant gaps in our understanding of the capacity of natural systems to respond to salinity under its diverse manifestations, risks and hazards.