Brian Spies and Peter Woodgate

SALINITY MAPPING METHODS IN THE AUSTRALIAN CONTEXT

Results of a review facilitated by the Academy of Science and the Academy of Technological Sciences and Engineering for the Programs Committee of the Natural Resource Management Ministerial Council through Land and Water Australia and the National Dryland Salinity Program

This book has been prepared for Programs Committee of Natural Resource Management Ministerial Council, through Land and Water Australia and the National Dryland Salinity Program.

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FOREWORD

Our ability to effectively manage dryland salinity depends upon our understanding of its causes, location and behaviour in any landscape. Accurate mapping of the saline landscape and the hydrogeological pathways that control the movement of water and dissolved salt is critical if we are to understand its causes and develop measures for remediation. This book and its accompanying user guide describe the various methods that can be used in Australian environments to acquire and present information about dryland salinity.

This book contains detailed descriptions of each method and is designed to help the potential user determine how their mapping needs can be best met. The accompanying user guide presents a short overview of the material contained in this book, and is directed towards a broader readership. This book can be read in conjunction with, or independently of, the user guide.

These publications arose from a review of mapping methods that was commissioned by Programs Committee of the Natural Resource Management Ministerial Council on the recommendation of its Science and Information Working Group. Following a public call for submissions, 36 organisations and individuals took the opportunity to make a contribution providing over 3000 pages of material. The project was overseen by a steering committee selected by the Operations Committee of the National Dryland Salinity Program.

The Australian Academy of Science and the Australian Academy of Technological Sciences and Engineering were invited by the Australian Government on behalf of the Programs Committee to review the outcome reports.

Salinised former freshwater lake – Lake Dumbleyung, WA.

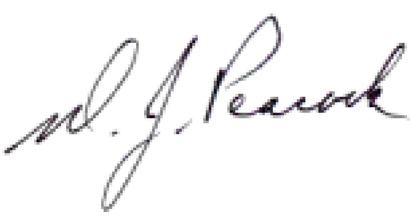
In order to fulfil their review function the joint academies undertook a number of activities as follows.

- They first convened a workshop at the Academy of Science office in Canberra in September 2003, where 24 leading scientists were invited to critically examine the first working draft of the review and to offer advice on its further revision. The workshop was hosted by Dr Jim Peacock, President of the Australian Academy of Science and opened by the Secretary of the Department of Environment and Heritage of the Australian Government, Mr. Roger Beale. It had as its guest Lord May of Oxford, President of the Royal Society. The day was chaired by Professor Brian Kennett of the Research School of Earth Sciences at the Australian National University.
- The academies then facilitated the involvement of leading scientists in the examination of specific issues as they arose in the re-drafting and we are grateful to the people who reviewed without prejudice relevant sections of the text of the draft reports as they were prepared.
- The academies then hosted a public forum at the Shine Dome, Canberra on 17 October 2003. The public forum was chaired by Dr Phil McFadden, Chief Scientist of Geoscience Australia. Over 70 participants spent the day reviewing the modified draft reports in a series of sessions that were guided by presentations from leading scientists in their field. The full transcript of the forum is available through the Academy of Science website at <www.science.org.au/conferences/salinity/>.

A panel of five scientists chosen by the joint academies undertook a final review of the reports. The panel members were Professor Kurt Lambeck (Chair), Dr Andy Green, Dr John Ive, Professor John Lovering and Dr Ian Rae. The panel was pleased with its positive interaction with the authors of the review reports.

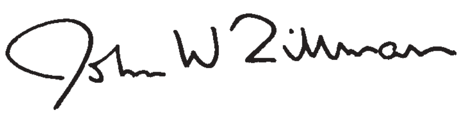
The resulting user guide and book represent a thorough process of consultation, public examination and scientific review that will contribute to our ability to better map dryland salinity and its associated risks and hazards.

The Academy of Science and the Academy of Technological Sciences and Engineering are pleased to have facilitated the review and contributed to its successful completion through our consultative processes. We expect that the reports of the Review of Salinity Mapping Methods in the Australian Context will be an invaluable resource for a wide range of natural resource managers.



Dr Jim Peacock, AC, FAA, FRS, FTSE,

President, Australian Academy of Science



Dr John Zillman, AO, FTSE, FAIP, FAIM, FEIA, FRMetS,

President, Australian Academy of Technological Sciences and Engineering

CONTENTS

APPENDICES

ABBREVIATIONS

AEM	airborne electromagnetics
AGSO	Australian Geological Survey Organisation
ALS	airborne laser scanning
ALTM	airborne laser terrain mapper
ANSTO	Australian Nuclear Science Technology Organisation
API	aerial photo interpretation
ASCE	American Society of Civil Engineers
ASEG	Australian Society of Exploration Geophysicists
BRS	Bureau of Rural Sciences
CALM	Conservation and Land Management
CDI	conductivity depth image
CEC	cation exchange capacity
COAG	Council of Australian Governments
CC	catchment characterisation
CMA	Catchment Management Authority
CRC LEME	Cooperative Research Centre for Landscape Environments and Mineral Exploration
DAFF	Department of Agriculture, Fisheries and Forestry
DEM	digital elevation models (also DTM)
DEH	Department of Environment and Heritage
DIPNR	Department of Infrastructure, Planning and Natural Resources, NSW
DNRE	Department of Natural Resources and Environment, Vic
DTM	digital terrain models (also DEM)
EAGE	European Association of Geoscientists and Engineers
EEGS	The Environmental and Engineering Geophysical Society
EC	electrical conductivity
EM	electromagnetics
GIS	geographic information system
GFS	groundwater flow systems
GPS	geographical positioning system
GPR	ground penetrating/probing radar
HEM	helicopter electromagnetics
IP	induced polarisation

ISFETS	ion-specific field-effect transistors
LEI	layered-earth inversion
LIDAR	light detection and radar
LMU	land management unit
LPLMC	Liverpool Plains Land Management Council
LWA	Land and Water Australia
MDBC	Murray-Darling Basin Commission
MDBMC	Murray-Darling Basin Ministerial Council
MSS	multispectral scanner
NaCl	sodium chloride
NAGP	National Airborne Geophysics Project
NAP	National Action Plan for Salinity and Water Quality
NDSP	National Dryland Salinity Program
NHMRC	National Health and Medical Research Council
NHT	Natural Heritage Trust
NLWRA	National Land & Water Resources Audit
NMR	nuclear magnetic resonance
NRM	natural resource management
OP	osmotic pressure
PC	principal component
PMSEIC	Prime Minister's Science, Engineering & Innovation Council
PRISM	practical index of salinity models
PUR$L	Productive Use and Rehabilitation of Saline Lands
R&D	research and development
SAR	sodium adsorption ratio
SWIA	south-west irrigation area
TDR	time-domain reflectometry
TDS	total dissolved solids
TM	thematic mapper
TEM	transient electromagnetics
TOR	terms of reference
US EPA	United States Environmental Protection Agency
WHO	World Health Organization

(see also risk definitions, p. 24)
(see also electromagnetic definitions, p. 45)

ACKNOWLEDGMENTS

The authors would like to thank the 36 organisations and individuals who responded so willingly to the call for submissions from the public to the report and to the many individuals involved in the review. The submissions and reviews comprised over 3000 pages of reports and papers in addition to the maps and CDs which are summarised in the appendices to this report.

The authors are also grateful for the assistance of the Project Steering Committee of Dr Sharon Davis (Chair), Dr Richard George—for his insight and extraordinary support in so many ways, and Dr Mirko Stauffacher, the Australian Academy of Science, the Australian Academy of Technological Sciences and Engineering and the Operations Committee of the National Dryland Salinity Program. The representatives of the clients Mr Simon Veitch (Australian Department of Agriculture, Fisheries and Forestry) and Ms Annette Bleys (Australian Department of Environment and Heritage) are gratefully acknowledged for their fine guidance and helpful contributions throughout the review.

The authors gratefully acknowledge the significant input of the Australian Academy of Science and the Australian Academy of Technological Sciences and Engineering. In particular, Sue Serjeantson, Ian Rae, Andy Green and Chris Warris for organising the Scoping Workshop of 24 select specialists on 1 September 2003, the subsequent Public Forum on 17 October 2003 and the final technical review.

EXECUTIVE SUMMARY

Salt is a *hazard* when it has the potential to be moved to where it can threaten assets such as agriculture, infrastructure, water resources and biodiversity. Salt stored in the ground may be mobilised by water and transported vertically and horizontally. Australia's growing problem of dryland salinity cannot be reliably assessed without a thorough three-dimensional understanding of the landscape and the hydrological processes that operate within it.

Mapping is the means by which we gain an understanding of what lies on and beneath the Earth's surface. The major uses of mapping in the studies of dryland salinity are to delineate areas affected by surface or vegetation expressions of dryland salinity, and to identify areas not yet affected but at risk of salinisation.

At least 30 satellite, airborne and ground mapping techniques are available for mapping and delineating soils, landforms, water flow and pathways through the subsurface.

- Some can be used to detect or infer the presence of salt at the Earth's surface or contained in the soil profile.
- Satellite and airborne remote sensing techniques can reveal existing surface salinity and can track changes over time.
- Airborne geophysical techniques, combined with ground and borehole control, are important tools in understanding salinity and hydrology at depth at a variety of scales.
- Only borehole sampling and electromagnetics (EM) techniques can detect and resolve salinity in the subsurface at depths in and below the root zone. EM techniques can also give complementary information on palaeochannels and structures which often control groundwater flow.

Salt lake developed from rising saline groundwater – Arthur River catchment, WA.

Salinity risk is a measure of the chance that a salt hazard will cause harm to an asset at some time in the future. Risk should be assessed in the context of the assets to be protected, including agriculture, water quality, infrastructure and the environment. Cost–benefit analyses in salinity management should take into consideration total cost and total benefit in context with the value of all assets.

The optimum strategy for mapping salinity hazard and risk depends on the scale (farm, community or catchment) and resources available to the user. Users need to make best use of existing information and then integrate a range of the available mapping methods so that they best address their specific problem. No single method has primacy, nor is there a 'magic bullet' for salinity mapping or prediction. Effective use of mapping methods requires expert knowledge or access to trained personnel.

A lot is known about salinity in the top few metres of ground—from dying vegetation, salt scalds and saline water seeps. Each landowner has a good idea of what is visible on their property. A wide range of satellite and airborne techniques can be used to assist in mapping surface expressions of salt and have a useful role in extrapolating from the existing knowledge of surface expression of salinity, obtained by visual inspection and near-surface EM conductivity mapping.

Managing salinity more strategically is hampered by a lack of knowledge about the location of concentrations of salt in the subsurface and whether they are likely to be mobilised by groundwater and pose a risk to assets. Hydrology is the key to understanding how salt stores are mobilised through the earth, both vertically and horizontally. The only broadacre, remote sensing technique that can detect and resolve salinity in the subsurface deeper than the root zone is electromagnetics (EM). Interpretations of EM (and most other

Photo: Pauline English. © CSIRO 2005. Reproduced with permission.

techniques) needs to be done by specialists and be checked by targeted ground-truthing, including drill holes and borehole logging. Magnetics can give complementary information on palaeochannels and other structures that could be zones of preferential groundwater flow.

This book covers 26 different methods for mapping salt stores, dryland salinity hazards and risk. It sets out the benefits and limitations of each technique together with useful information on costs, scale, survey design and the depth to which each technique is useful. The book comprehensively summarises the science that justifies the use of each mapping method and refers the reader to a range of references that will provide an even fuller technical explanation if necessary.

This book describes the usefulness of all relevant mapping methods (in use and proposed) for mapping dryland salinity in Australia, and describes their efficacy in the assessment of salinity hazard and risk. The book has the following elements:

- background and context;
- typical questions posed at farm, community, catchment and national scales;
- a description of the interplay of salt and water movement in the landscape that controls salinity (framework factors);
- an assessment of salinity hazard and risk, and costs and benefits of mapping;
- information on mapping the landscape at different scales to solve salinity-related questions;
- a brief description of methods to map the landscape from the surface, boreholes, aircraft and satellites—salinity mapping methods are categorised as those that directly detect salt and those that use surrogate or indirect attributes to infer the presence of salt and are stratified by the level below the surface at which they operate;
- illustrative case histories describing the process of selecting appropriate mapping techniques for particular problems, including assessment of the future distribution of salinity as it is likely to affect the assets in the landscape such as agricultural production, biodiversity and infrastructure;
- appendices with expanded descriptions of each mapping method; and
- a glossary of key terms.

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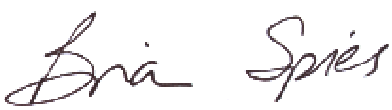

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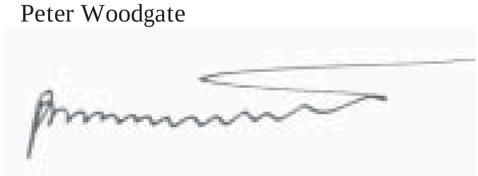

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