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Foreword

This handbook has been produced to address many of the questions by land managers and advisers about understanding and managing salinity. Although this form of land degradation is not widespread in Queensland, it causes great concern to those who find it on their land. Many land managers are aware of the impacts of salinity in southern Australia, and are seeking to minimise or prevent similar impacts in the north.

The handbook was compiled from information gathered through a series of regional salinity workshops and investigations by Queensland research and extension officers. It took into account, after consultation and many joint projects, the ideas from extension officers who were involved in providing advice on land development and land use options, and incorporated their feedback on the content and format. It was given considerable impetus from the demands to derive land clearing guidelines in Queensland in the early 1990s.

While the handbook has a Queensland focus, it has developed broad principles and provides a process understanding that allows applicability to a wide range of salinity situations. This approach has particular value in allowing the selection of investigation options ranging from simple 'back of the envelope' calculations to more sophisticated modelling options. Roger Shaw and Ian Gordon of the former Department of Natural Resources (now the Department of Environment and Resource Management) played a key role in collating and providing information and technical expertise for the production of this handbook.

The handbook aims to give a comprehensive set of information to managers and advisers. It has a very practical focus providing direct advice on the most commonly asked questions about salinity. It is divided into three main sections: understanding salinity, investigating salinity and managing salinity.

I commend this handbook to the reader. It provides an understanding of the basic principles of salinity, and enables the reader to apply the processes to their particular regional situation. The investigation and management sections will assist landholders in implementing the most appropriate management and reclamation practices to minimise the degradation of land and water resources due to dryland and irrigation salinity.

This handbook will be a very useful reference manual for landholders, extension officers and research officers, and is a valuable contribution to the national effort being directed towards managing dryland salinity in Australia.

Adrian Webb
Coordinator

National Dryland Salinity Program

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Authors and contributors

This handbook was compiled from information gathered during a series of regional salinity workshops, organised by the then Queensland Department of Primary Industries (DPI) from 1985 to 1987 (previously published in the DPI Conference and Workshop Series), augmented by subsequent investigations by DPI research and extension officers with the (then) Salinity and Contaminant Hydrology group (SalCon), now part of the Department of Environment and Resource Management and the Department of Employment, Economic Development and Innovation.

Roger Shaw and Ian Gordon, scientists with the Resource Sciences Centre, provided the substantive material which forms the basis of this handbook, and provided primary technical expertise throughout the period of the handbook's development. David Hinchley, of the former DPI Forestry, compiled and provided material relating to the use of vegetation, in particular trees, to manage salting. Further technical expertise was contributed by Clem Hill, Peter Thorburn, Lindsay Brebber, John Doherty, Ingrid Christiansen, Adrian Stallman, Geoff Carlin, Tony Dowling and Keith Hughes.

Eve Witney, a technical writer with qualifications in environmental science and in communication, compiled and rewrote available salinity information into the current format, and obtained further information as required. The publication was designed and desktopped by Melissa Whyte and produced by Scientific Publishing, Resource Sciences Centre.

Acknowledgment and appreciation is extended to other staff of the former Department of Natural Resources, Department of Primary Industries, Department of Environment and Heritage, landcare representatives and landholders. People who provided comment on initial drafts of this handbook include Bob Baldwin, Geoff Bass, George Bourne, Jon Burgess, David Carberry, John Chamberlain, David Dempster, Terry Donnollan, Geoff Falkner, Trevor Glanville, James Gourley, Keryn Hunt, Clive Knowles-Jackson, Cindy Lamb, Bruce Lawrie, Jim McClurg, Yvonne Orlando, Geoff Paton, Ernie Rider, Max Roberts, Russ Scarborough, Phil Sorby, Leath Stewart, Frank Sunners, Meryl Thomas and Geoff Titmarsh.

How to use this handbook

This handbook, based largely on work in north-eastern Australia, provides a comprehensive and practical introduction to salinity by:

- understanding salinity processes
- investigating the risk of salinity in a landscape and determining the extent of current salting
- developing an integrated salinity management strategy
- locating additional detailed information.

In ***Understanding salinity***, the three major types of salting are described. Most salting outbreaks result from imbalances in the hydrologic system of a landscape. Certain landscapes are more vulnerable to salting than others, and the major contributing factors of climate (particularly rainfall patterns), geomorphic features (landscape characteristics and underlying geology) and human activity are discussed. Sustainable strategies for managing salinity rely on addressing imbalances in the hydrologic system.

In ***Investigating salinity***, practical information for planning and carrying out salinity investigations is provided. By looking at geomorphic features, climate and land use, it is possible to assess whether an area is at risk of salting, either currently or under changed conditions. If salting is currently suspected, detailed investigations looking at indicator plant species and soil and water data will reveal the extent of salting and the processes contributing to the problem.

In ***Managing salinity***, the major management aspects of vegetation, irrigation and engineering applications are discussed individually and in relation to each other. The process of developing an integrated management strategy that addresses the nature of local salinity processes and the extent of current salting as well as the interests of the landholder and other stakeholders is considered.

The ***Appendixes*** contain tables and charts of useful information:

- tree and pasture species suitable for saline or waterlogged conditions
- salt tolerance data for more than 130 plant species
- a diagnostic chart for identifying landscape features at risk of salinity
- software packages for analysing salinity processes and developing salinity management strategies
- sources of salinity information for further research and reference
- salinity investigations carried out in Queensland since the early 1970s.

In ***Useful conversions and relationships***, equations and charts for converting EC units, measures of salinity, units of concentration, SAR and ESP, and measures of soil volume and density are provided.

Answers to common questions about salinity

This handbook is designed to address land managers' and advisers' questions about understanding, investigating and managing salinity. Common questions about salinity are addressed in this section, with guides to the sections of the handbook where the issues raised are discussed more fully.

Understanding salinity

Why is salinity occurring in this area and not in others?
What factors have contributed to this salinity problem?

Whether and how salinity becomes evident at a particular location depends on the interaction of many factors—characteristics of the landscape itself, the climate and the effects of human activities are the most important. An understanding of the hydrology of the salt-affected area is needed to determine the likely extent of any problem. **Understanding salinity** (page 1) deals with the range of factors contributing to salinity in general as well as at specific locations.

Why are my crop returns less each year?
Why are different species growing in pasture areas?

Crop yields can be affected by salinity and/or waterlogging problems which may not be evident on the soil surface. In pasture areas, a change in species composition may indicate increased levels of soil salinity. Soil sampling to measure salinity (EC) is required to check whether in fact it is salinity that is causing these effects. Refer to the section **Soil salinity** (page 60) for information on taking field EC measures, and the appendix **Plant salt tolerance data** (page 124) for information on the relative salt tolerance of many plant species.

Investigating salinity

How 'bad' is this salinity problem?
Is it likely to get worse?

Investigating salinity (page 27) provides strategies for investigating and determining the nature of salinity at a particular location. Salinity problems often result from excess water which, as it evaporates, deposits the salts that have been dissolved in the water. This water is potentially a valuable resource that could be utilised on-farm. A simple catchment water balance calculation can be used to identify the amount of excess water that needs to be removed to alleviate the salinity problem. Calculating catchment water balance is covered in **Catchment groundwater balance estimation** (page 70). This information, together with soil salinity data, allows us to assess the extent and severity of a salinity problem.

What do I need to know to assess salinity hazard?
What factors make up a salinity investigation?

Because salinity is the result of the complex interaction of geophysical and land use factors, salinity investigations need to address a range of issues to identify the risk of salinity or the likely extent of possible salinity problems. Information about current and potential salinity levels and processes can be determined from:

- landform features and geology in the catchment
- vegetation species and communities, and specific responses to salinity or ion toxicity
- local climate and long-term rainfall patterns
- soil properties, salinity and sodicity levels
- water characteristics, salinity and sodicity levels
- land use records.

Investigation components are listed in the table **Features of salinity investigations** (page 28), along with the type of information each can contribute to a salinity investigation.

Is it possible to undertake a simple, initial investigation to determine whether a more detailed investigation is necessary?

Yes. An initial assessment of current salinity and salinity potential can be undertaken at very low cost. A lot can be determined about the current extent of salting by considering a few observable or readily measurable factors and using available information. The features to consider are:

- electrical conductivity of surface waters and accessible groundwater points
- depth to the groundwater in existing bores
- catchment shape and landscape features
- average annual rainfall and seasonality
- vegetation—composition and vigour of crops, pasture and native species
- current land use, and history of land use
- field soil electrical conductivity.

Once the likely risk area can be pinpointed from an initial investigation, the consequences for the area and the catchment need to be assessed. The scale of the subsequent investigation needs to be tailored to the available range of management options.

Detailed information on salinity investigation strategies is provided in **Investigating salinity** (page 27).

Can I look for particular plant species that indicate salinity?

Within a particular biogeographical zone, certain grass, shrub and tree species will have adapted to waterlogged and/or saline conditions. The presence of these species, in combination with other factors, can indicate salinity problems (both existing and potential). These species and the other factors to be considered are covered in **Plant communities as salinity indicators** (page 49).

Can I identify an area that has the potential to develop salinity? What if initial investigations indicate such sites, but current salinity levels aren't affecting land use?

Because salinity develops due to the interaction between salt sources, landscape characteristics and human activity, it is possible to identify which combinations of features will make a catchment, or specific sites within a catchment, more sensitive to salinity. Criteria for identifying and classifying areas that may be prone to salting are presented in **Guidelines for retaining trees** (page 107). If salinity has not yet occurred, it would be wise to assess possible risk and monitor current salinity development before undertaking works or developments which will affect the hydrologic balance of the landscape, such as clearing vegetation, building dams, irrigating or subdividing rural land. Monitoring would involve periodic soil profile analyses and checking watertable levels in existing bores or specially installed piezometers. After all, prevention is much more cost-effective than reclamation.

Can the effect of salinity on plant productivity be predicted?

Some plant species are better adapted for coping with salinity than others. Most studies on the salt tolerance of plant species have been conducted in laboratories. However, plant salt tolerance in any field situation will depend on the interaction of a number of factors not readily accounted for in laboratory experiments, such as stage of growth, management practices, climate and fertility levels. Two measures of salinity in the root zone have been derived which enable plant response to be predicted under field conditions. **Plant response to salinity and specific ions** (page 51) looks at how plants cope with salinity, factors which affect plants' ability to cope, and measures of salinity in the root zone which can be used to predict plant response.

What are the water quality requirements for irrigation? Can I predict how irrigation water use will affect soil properties over time?

Irrigation water quality criteria depend on soil properties, climate, plant species and management practices. Water composition alone will provide only a general guide for average conditions, and may provide inadequate information for local conditions. The recommended approach is to assess water quality parameters in conjunction with soil properties (particularly leaching). Leaching is the critical property of a soil that must be considered when predicting how a particular soil will respond to a particular irrigation water. The interaction of soil salinity and the sodium adsorption ratio of the soil water (SAR) will determine how leaching will be affected by the irrigation water. Several relationships have been developed that will allow changes in SAR and soil salinity to be predicted over time. These and other issues are addressed in **Irrigation** (page 81).

What are the water quality requirements for human and stock use?

Criteria for assessing the quality of water for human and stock use have been developed by ANZECC (1992, currently being revised). A summary of this information is provided in **Water quality** (page 79).

Managing salinity

How can we develop an integrated management strategy that best addresses the landholder's needs, the type and extent of salinity, and the available options?

The best way to develop a strategy with the greatest likelihood of success is to comprehensively investigate the processes and severity of salinity in the area, and then to develop a plan which incorporates whole-of-catchment processes and whole-of-farm activities. Management options include revegetating (with crops, pastures or trees) or retaining existing vegetation, installing drainage or pumps as engineering solutions, and possibly irrigating with the excess groundwater. These issues are discussed comprehensively in **Management issues** (page 92).

How much will it cost to manage salinity? What can be done cheaply?

The cost of salinity management will depend on the processes contributing to the problem (and hence the viable management options), combined with the choice of options that are most compatible with the land owner's goals. Options range from 'fence and forget' (for the cost of fencing combined with the loss of productivity from that site, balanced against potential future losses for not taking this action) to extensive tree planting on recharge areas or engineering works.

How long will it take for salinity management strategies to work? What do I look for to tell if the management is working?

Changes in the hydrology of a catchment can result in salinity problems that may not manifest for 30 to 50 years. However, once a problem arises, it will be much more difficult to manage, and sub-critical conditions may reduce productivity for years before the problem becomes readily apparent. Preventative management in sensitive catchments is highly recommended.

Just as salinity problems can take 30 to 50 years to develop, so it may take a similar time frame for saline sites to be reclaimed, particularly if pursuing vegetation options for management. However, engineering options could be successful in alleviating problems in just a few years. To check on the effects of salinity management, monitoring the depth of the groundwater, quality of the groundwater, and soil salinity are most important. Within a framework of property management planning and utilising the range of decision support resources available, the effect of management strategies on the land and on property operations can be charted.

What is the best use for this land? Should I stick with crops, or should I go to pasture or plant trees? Which is best for controlling salinity?

Vegetation can be used in recharge, transmission and discharge areas to manage salinity in the catchment depending on water use needs, local conditions and the landholder's farm management strategy. It is most important that any vegetation strategy uses species which are well suited to the site conditions to improve the chances of survival and good growth under potentially unfavourable conditions. Refer to **Vegetation management** (page 98) for discussion on selecting the most appropriate vegetation strategy as well as information on establishing and maintaining pasture, crops and trees.

Where should I clear trees, and how many can I clear, to minimise the likelihood of salinity developing?

In vulnerable landscapes, salinity can become apparent from 20 to 50 years after vegetation is cleared. This is not to say that all tree clearing in vulnerable landscapes results in salinity. Clearing can be planned to make land available for alternative land uses as well as minimising the risk of salinity developing. This will depend on the results of local salinity investigations. The section **Tree retention** (page 107) provides information on identifying areas at risk from salinity and recommends strategies for tree retention.

What species of plants—trees, crops or pastures—can I plant, and where should I plant them?

If planting vegetation is a viable option for managing salinity or waterlogging, information on plant salt tolerance and soil and water salinity can be used to select appropriate species for the prevailing conditions. Tree planting is a long-term and potentially expensive option for managing salinity. However, tree planting provides many opportunities for diversifying farm income with the production of timber, farm wood, fuel wood, honey, oils or seeds. Trees provide additional benefits for existing farm activities, such as providing windbreaks and shade, shelter and potential forage for stock. These issues and points on establishing and maintaining trees planted for salinity management are discussed in **Tree planting** (page 106). A detailed listing of trees suitable for salinity management, tolerances and potential multiple uses are provided in the appendix **Tree species for salinity management** (page 137).

A comprehensive listing of crops with information on salinity tolerance is provided in the appendix **Plant salt tolerance data** (page 124). Information on growing crops in salted catchments is provided in **Crops** (page 103).

Salt-tolerant pasture species suitable for Queensland conditions are listed and discussed in the appendix **Pasture species for saline soils** (page 133). Other information on the salt tolerance of various plant species is provided in the appendix **Plant salt tolerance data** (page 124). In **Pasture** (page 102), issues in establishing and maintaining pasture are considered.

What type of drainage works or other engineering options would best suit these conditions?

Engineering options include surface and subsurface drainage and groundwater pumping. These options have specific application in a limited number of situations, and can best be used to manage salinity in conjunction with other management practices. When incorporating any engineering option, the responsible disposal of drainage effluent must be considered. These issues, and techniques for designing and installing engineering options, are discussed in **Engineering methods** (page 110). The type and design of any drainage scheme implemented to manage salinity or waterlogging at a particular location will depend on soil properties, aquifer properties and disposal options. Information on selecting and designing drainage works is provided in **Drainage** (page 110). Drainage effluent (wastewater) must be disposed of in a way that does not impact on water quality downstream. Depending on water quality, options range from fully constrained disposal basins to dilution or reuse (as discussed in **Drainage water disposal** page 110).

Can I use groundwater to irrigate? How can I best manage irrigating with this water?

If groundwater is of good or marginal quality, it can be used to irrigate existing or proposed crops, trees or pastures on the property. Irrigation needs to be managed to avoid watertable rise and control the build-up of salinity or sodicity in the irrigated soils. Specific practices are recommended for irrigating with marginal quality saline and sodic waters. Water quality criteria and likely impacts of irrigation water on soils and plants are discussed in **Irrigation** (page 81), and strategies for irrigating effectively are outlined in **Irrigation management** (page 115).

Obtaining more advice

Where in Queensland has salinity been investigated, and what was found? How was it dealt with?

Many of the numerous papers and reports that have been compiled on salinity in Queensland are listed, by locality, in the appendix **Salinity publications for futher reference** (page 145).

What reference materials will help me with my investigations and decision making?

A list of recommended reading material for further information on salinity and related topics is provided in the appendix **Salinity publications for further reference** (page 145).

Where can I get more advice and assistance?

For advice or assistance on salinity-related issues, contact DERM or DEEDI or visit the DERM website: ‹www.derm.qld.gov.au› for the latest information.

Abbreviations

A	area, either surface area or cross-section of a vertical face as specified
ADMC	air dry soil moisture content
AHD	Australian height datum
ARZS	average root zone salinity
BD	bulk density
CCR	CEC to clay content ratio
CEC	cation exchange capacity
Dd	deep drainage below the root zone
E	evaporation rate
EC	electrical conductivity
EC1:5	electrical conductivity of 1:5 soil water suspension
EC1:5 /EC_{Cl}	ratio of EC1:5 to EC due to Cl in 1:5 soil water suspension
ECs	electrical conductivity at water content approximating field capacity
ECse	electrical conductivity of soil saturation extract
ESP	exchangeable sodium percentage
ET	evapotranspiration rate
ΔH	hydraulic gradient
K	hydraulic conductivity of a porous medium
Ks	saturated soil hydraulic conductivity
LF	leaching fraction
LR	leaching requirement
PLF	predicted leaching fraction
Q	quantity of water
RA	residual alkali (sodium carbonate plus bicarbonate)
S	surface seepage rate
SAR	sodium adsorption ratio
SP	saturation percentage
T	transmissivity of an aquifer
TDI	total dissolved ions
TDS	total dissolved solids
TSS	total soluble salts
Wmax	maximum field water content, measured or predicted from relationships of Shaw and Yule (1978); Wmax is a measure of 'field capacity' which is more appropriate for swelling clay soils than laboratory techniques
WF	weighting factor for soil depth increment
WUW	water uptake weighted, usually applied to root zone salinity or leaching fraction
Y	plant (crop) yield
z	depth of root zone

Units of measurement

Quantity	Symbol	Unit	Equivalence in base units
Length	m	metre	
	cm	centimetre	10^{-2}m
	mm	millimetre	10^{-3}m
Area	m^2	square metre	
	ha	hectare	10^4m^2
Time	s	second	
	d	day	
	yr	year	
	myr	million years	
Temperature	°C	degrees Celsius	
Mass	kg	kilogram	
	g	gram	10^{-3}kg
	mg	milligram	10^{-6}kg
	t	tonne	10^3kg
Volume	m^3	cubic metre	
	L	litre	$10^{-3}m^3$
	ML	megalitre	10^3m^3
Concentration	mmole/L	millimoles/litre	10^{-3}mole/L
	mmolec/L	millimoles (charge) per litre	
	meq/L	millequivalent per litre	
	mg/kg	milligrams per kilogram	
	ppm	parts per million	
Electrical conductivity	dS/m	decisiemens/metre	
	mS/m	millisiemens/metre	10^{-2} dS/m
	µS/m	microsiemens/metre	
	S/m	siemens/metre	
Pressure/suction	kPa	kilopascal	10^3 Pa