Appendixes

1 Landscape features diagnostic chart

2 Plant salt-tolerance data

3 Pasture species for saline soils

4 Tree species for salinity management

5 Useful software packages

6 Salinity publications for further reference

Landscape features diagnostic chart

Basalt form

Both seepage and watertable salting can occur where basalt overlies less permeable rock, where regions of variable permeability occur within the basalt, or where the basalt is in contact with adjacent formations.

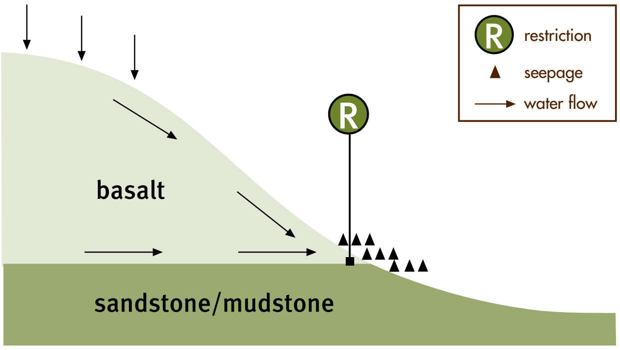


Figure 66. Salting at the contact between basalt and underlying sediments near Kingaroy, Queensland.

Alluvial fan

Discharge areas can occur where subsurface water encounters deep clays or more recent alluvia.

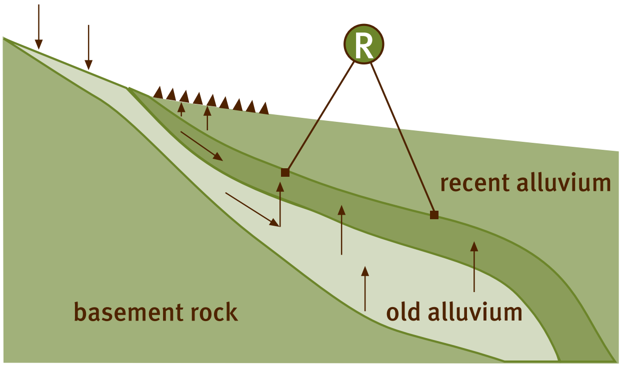
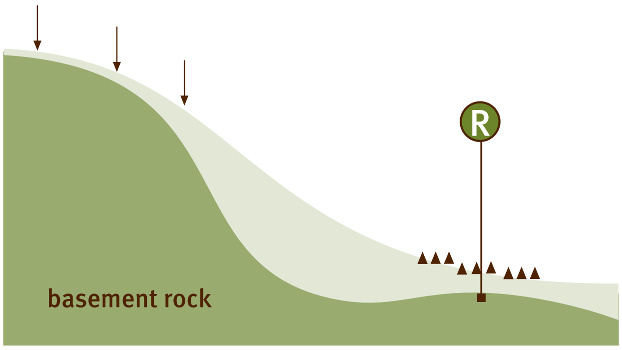


Figure 67. Expression of salt in a catena sequence upslope of a flat alluvial area near Muttapilly, Queensland.

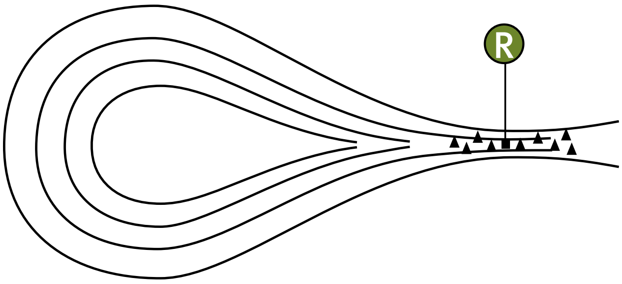
Catena form

Discharge areas can occur in the lower slope or at break-of-slope positions where soils or geologic features restrict water movement. Lower slope soils may be sodium- and salt-affected.



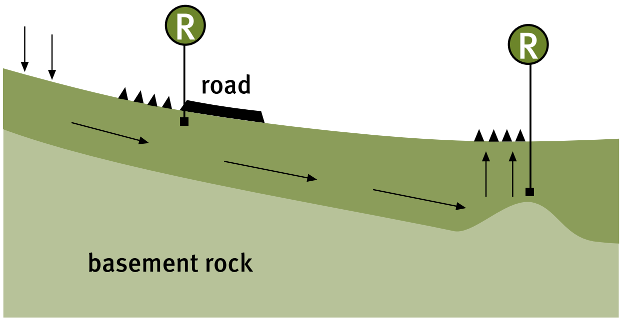
Catchment restriction—natural

Salting can occur upslope of natural or artificial restrictions that narrow the width or depth of the catchment throat.



Catchment restriction—artificial

Salting can occur upslope of roads or stock routes that have compacted the soil.



Alluvial valley

Salting can occur where the valley is very flat and the hydraulic gradient is very low.

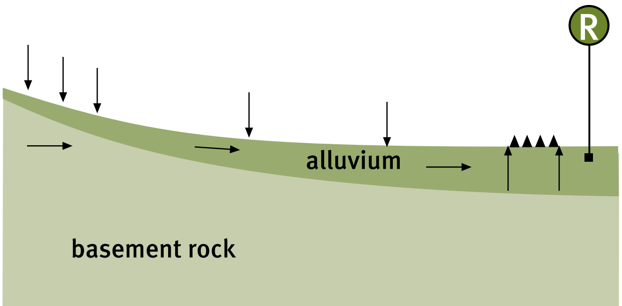
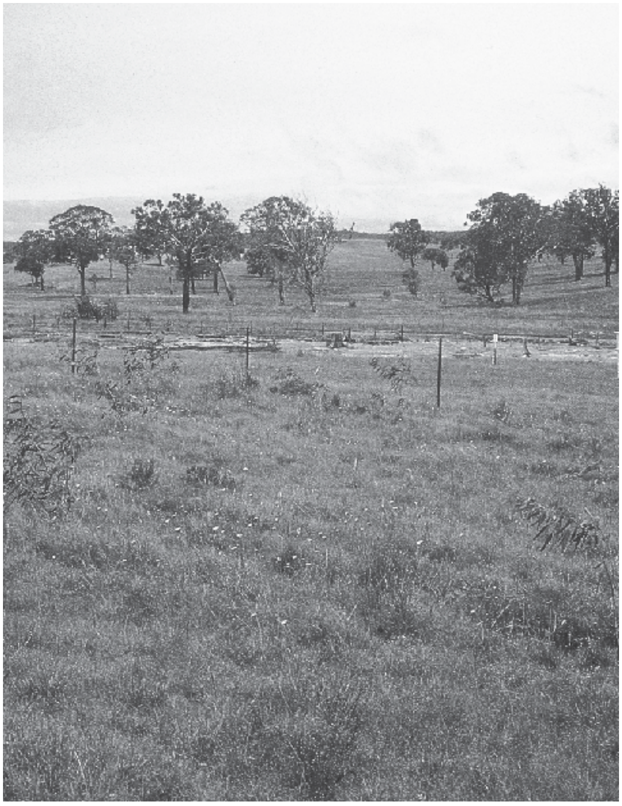


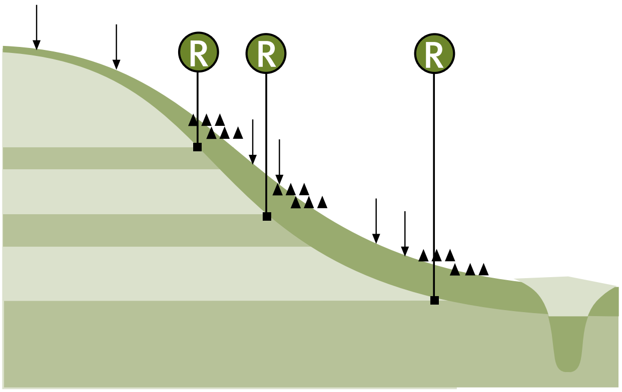
Figure 68. Salting on the floodplain of the Todd River upslope of the hydrologic restriction by the Macdonnell Ranges at Alice Springs, Northern Territory.

Figure 69. Bare drainage line due to salinisation in a catchment near Kingaroy, Queensland.



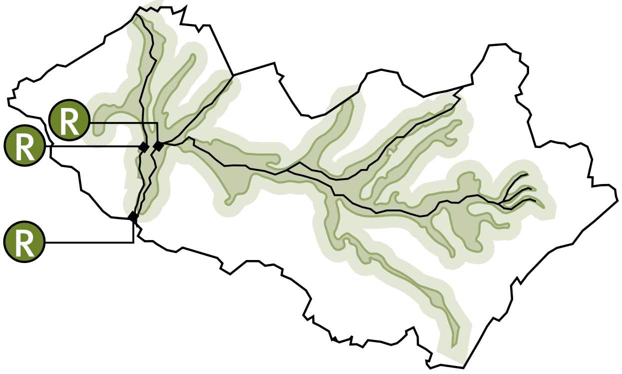
Stratigraphic form

Small seepages and salted areas can appear on hillslopes where water flow encounters layers of rock with reduced permeability.



Confluence of streams

Watertables can rise where streams join and deposits of fine sediments with low lateral permeability restrict groundwater flow.



Dykes

Incipient or permanent salting can develop where water movement downslope encounters less permeable dykes across the direction of the slope.

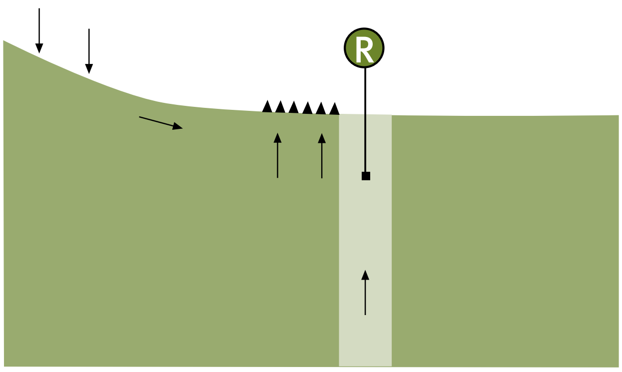
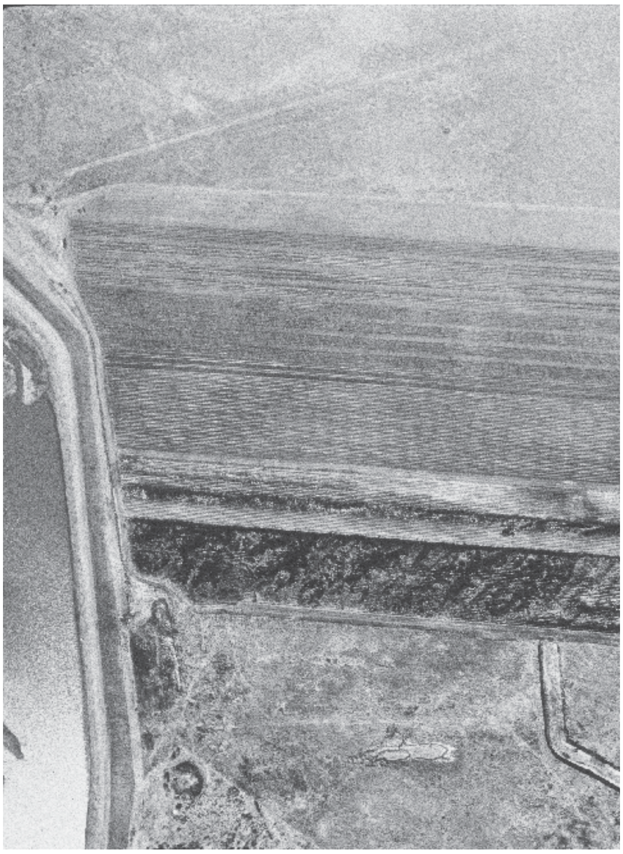


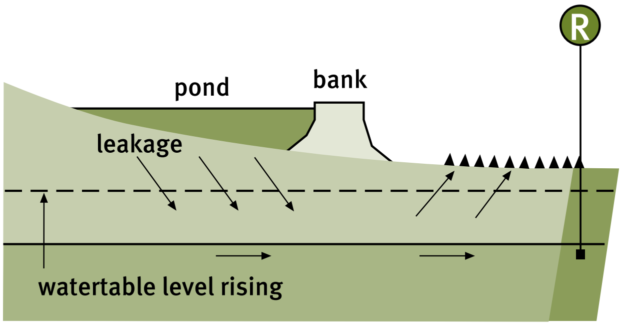
Figure 70. Hillslope saline seepage on the Darling Downs, Queensland.

Figure 71. Linear pattern of salting as a result of geologic dykes below a leaking farm dam in the Lower Burdekin, Queensland.



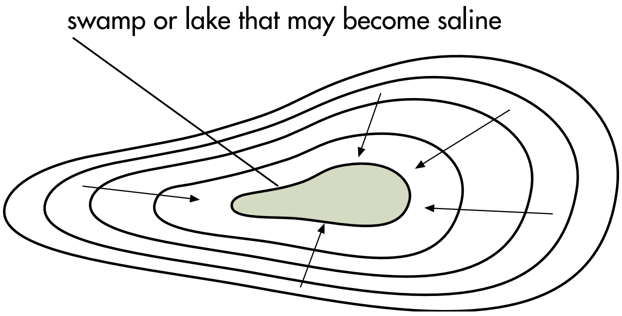
Dams

Salting can occur upstream of any dam or downstream of a leaking dam where a less permeable subsoil layer underlies the leak.



Lakes

Salt can accumulate where surface flushing is limited and the lake acts as a surface or groundwater terminus.



Geologic faulting

Incipient or permanent salting can develop where water movement downslope encounters faults. Faults can also provide a preferential flow path for the water to the surface, resulting in springs.

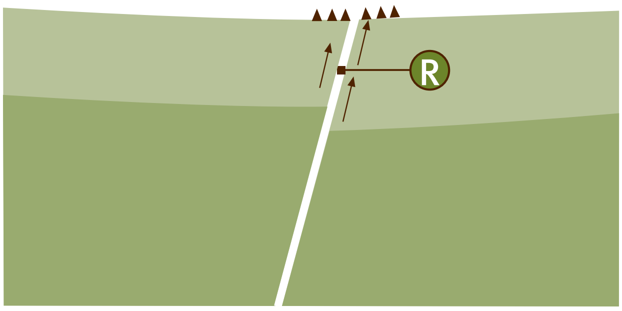
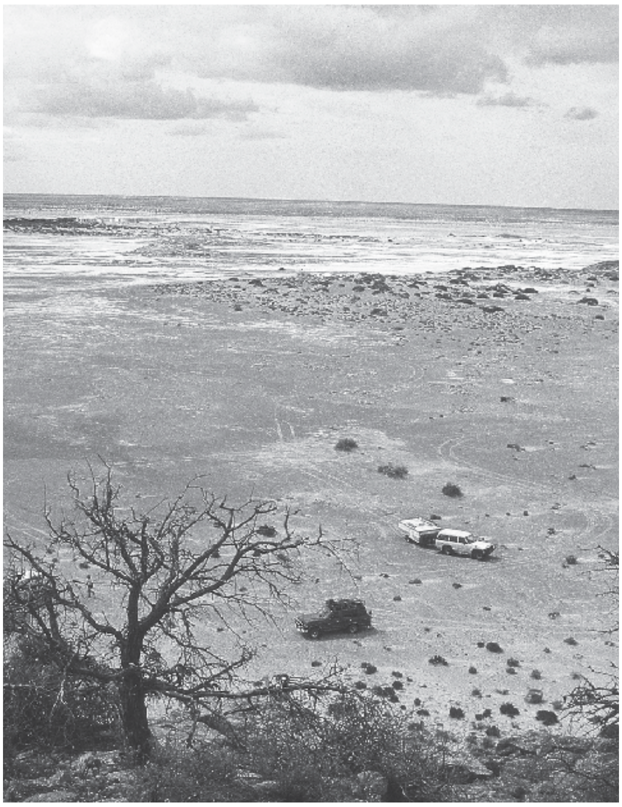


Figure 72. Salting upstream of a small farm dam due to the dam acting as a hydraulic barrier near Wellington, New South Wales.

Figure 73. Salted area from the top of an ancient mound spring associated with faulting in South Australia.



Plant salt-tolerance data

The following tables (Tables 46 and 47) list salt-tolerance data for crop, pasture, vegetable, fruit and ornamental species compiled from the work of a number of researchers. The data source is indicated in the final column of the table.

1. Maas & Hoffman (1977)
2. Ayers & Westcot (1976)
3. Russell (1976)
4. Maas (1986)
5. West & Francois (1982)
6. Bresler, McNeal & Carter (1982)
7. Ayers (1977)
8. Heuer, Meiri & Shalhevet (1986)
9. Shaw et al. (1987)

Note: The data from reference 3 (Russell 1976) have been recalculated according to the method of Maas & Hoffman (1977), using a number of assumptions which may affect their accuracy. However, these data are included because Russell provides local Queensland data.

The table is provided twice for ease of access. In Table 46 the information is presented in alphabetical order by common name, divided into categories of grain, fruit, heavy vegetables, ornamental, pasture and vegetables. In Table 47 the information is listed in order of sensitivity at 90% yield (or at the end of the table by salinity threshold if productivity decrease data are not available).

When using these tables to investigate the likely effects of salinity on yield, the following points need to be considered:

- The data are not absolute and vary with the method of assessment, climate and cultural practices.
- The salt tolerance ratings in this table have been largely evaluated from experiments where the salinity was imposed after seedling establishment and thus do not necessarily apply to germination and early seedling establishment.
- The data assume that the soil is uniformly saline, which does not accurately reflect field conditions.
- The data assume that the dominant anion is chloride, so the chemical composition of salts may affect how applicable this information is in a particular field situation.
- In one or two places, two sets of data have been provided for one species. This has occurred where different researchers have established differing values, providing emphasis that the data must be considered in the light of local conditions and plant/variety differences.
- Rainfall amount and timing will have an impact. Adverse osmotic adjustment has been noted for soybeans.

The threshold values for 90%, 75% and 50% yields have been calculated from the data on salinity threshold and productivity decrease with increasing salinity in excess of the threshold. To determine the actual yield response of a plant species, the following relationship between the salinity threshold and the percentage productivity decrease per dS/m increase above this threshold value is used (from Maas & Hoffman 1977):

$$Yr = 100 - B(EC_{se} - A) \quad \text{.................. } 34$$

where

Yr	is	relative yield
EC_{se}	is	theoretical value of root zone EC_{se} resulting in relative yield Yr
B	is	percent productivity decrease per dS/m increase above the threshold value (from Table 46)
A	is	salinity threshold value of root zone EC_{se} (from Table 46).

Rearranging this equation to find the EC_{se} associated with a particular yield gives:

$$EC_{se} = A + \frac{100 - Y_r}{B} \quad \text{........................ } 35$$

To calculate an EC_{se}, for instance, which will result in approximately 90% yield (Yr = 90), this equation becomes:

$$EC_{se(90\%)} = A + \frac{100 - 90}{B} \quad \text{.................. } 36$$

Similarly, the equation for calculating ECse for approximately 75% yield is:

$$EC_{se(75\%)} = A + \frac{100 - 75}{B} \quad \text{................ } 37$$

These equations, which have been used to generate the relative yield figures in the following tables, can also be used to calculate relative yield from threshold and productivity decrease data for species not listed here.

Table 46. Plant salt-tolerance data, in alphabetical order by common name, within broad plant groups.

Common name	Scientific name	Salinity threshold (EC_{se})	Productivity decrease per dS/m increase (%)	Soil salinity EC_{se} at			Reference
				90% yield	75% yield	50% yield	
Grains							
Barley, grain	*Hordeum vulgare*	8.0	5.0	10.0	13.0	18.0	1
Corn, grain, sweet	*Zea mays*	1.7	12.0	2.5	3.8	5.9	1
Cotton	*Gossypium hirsutum*	7.7	5.2	9.6	12.5	17.3	1
Cowpea (seed)	*Vigna unguiculata*	1.6	9.0	2.7	4.4	7.2	9
Cowpea, Caloona	*Vigna unguiculata* var. *Caloona*	2.0	10.8	2.9	4.3	6.6	3
Flax/Linseed	*Linum usitatissimum*	1.7	12.0	2.5	3.8	5.9	1
Oats	*Avena sativa*	5.0	20.0	5.5	6.3	7.5	9
Peanut	*Arachis hypogaea*	3.2	29.4	3.5	4.1	4.9	2
Phasey bean, Murray	*Macroptilium lathyroides*	0.8	7.9	2.1	4.0	7.1	3
Rice, paddy	*Oryza sativa*	3.0	12.2	3.8	5.1	7.1	1
Safflower	*Carthamus tinctorius*	6.5					6
Sorghum	*Sorghum bicolor*	6.8	15.9	7.4	8.4	9.9	4
Sorghum, crooble	*Sorghum almum*	8.3	11.2	9.2	10.5	12.8	3
Soybean	*Glycine max*	5.0	20.0	5.5	6.3	7.5	1
Sugarcane	*Saccharum officinarum*	1.7	5.9	3.4	5.9	10.2	1
Sunflower	*Helianthus annuus* spp.	5.5	25.0	5.9	6.5	7.5	9
Wheat	*Triticum aestivum*	6.0	7.1	7.4	9.5	13.0	1
Wheat, durum	*Triticum turgidum*	5.7	5.4	7.6	10.3	15.0	4
Fruits							
Almond	*Prunus dulcis*	1.5	18.0	2.1	2.9	4.3	1
Apple	*Malus sylvestris*	1.0	18.0	1.6	2.4	3.8	1
Apricot	*Prunus armeniaca*	1.6	23.0	2.0	2.7	3.8	1
Avocado	*Persea americana*	1.3	21.0	1.8	2.5	3.7	7
Blackberry	*Rubus* spp.	1.5	22.2	2.0	2.6	3.8	1
Boysenberry	*Rubus ursinus*	1.5	22.2	2.0	2.6	3.8	1
Date	*Phoenix dactylifera*	4.0	3.4	6.9	11.4	18.7	1
Fig	*Ficus carica*	4.2					6
Grape	*Vitis* spp.	1.5	9.5	2.6	4.1	6.8	1
Grapefruit	*Citrus paradisi*	1.8	16.1	2.4	3.4	4.9	1
Guava, pineapple	*Feijoa sellowiana*	1.2					6
Lemon	*Citrus limon*	1.0					6
Natal plum	*Carissa macrocarpa*	6.0					6
Olive	*Olea europaea*	4.0					6
Orange	*Citrus sinensis*	1.7	15.9	2.3	3.3	4.8	1
Peach	*Prunus persica*	3.2	18.8	3.7	4.5	5.9	1
Pear	*Pyrus* spp.	1.0					6
Plum	*Prunus domestica*	1.5	18.2	2.0	2.9	4.2	1
Prune	*Prunus domestica*	1.0					6
Pomegranate	*Punica granatum*	4.0					6
Raspberry	*Rubus idaeus*	1.0					6

Common name	Scientific name	Salinity threshold (EC_{se})	Productivity decrease per dS/m increase (%)	Soil salinity EC_{se} at			Reference
				90% yield	75% yield	50% yield	
Rockmelon	*Cucumis melo*	2.2	7.3	3.6	5.6	9.0	7
Strawberry	*Fragaria*	1.0	33.3	1.3	1.8	2.5	1
Heavy vegetables							
Beet, garden	*Beta vulgaris*	4.0	9.0	5.1	6.8	9.6	1
Beet, sugar	*Beta vulgaris*	7.0	5.9	8.7	11.2	15.5	1
Onion	*Allium cepa*	1.2	16.1	1.8	2.8	4.3	1
Potato	*Solanum tuberosum*	1.7	12.0	2.5	3.8	5.9	1
Sweet potato	*Ipomoea batatas*	1.5	11.1	2.4	3.8	6.0	1
Ornamentals							
Arbor-vitae	*Thuja orientalus*	2.0					6
Algerian ivy	*Hedera canariensis*	1.0					6
Bambatsi	*Panicum coloratum*	1.5	3.2	4.6	9.3	17.1	3
Bottlebrush	*Callistemon viminalis*	1.5					6
Bougainvillea	*Bougainvillea spectabilis*	8.5					6
Boxwood	*Buxus microphylla* var. *Japonica*	1.7	10.8	2.6	4.0	6.3	1
Chinese holly	*Ilex cornuta*	1.0					6
Dracaena	*Dracaena endivisa*	4.0	9.1	5.1	6.7	9.5	1
Euonymus	*Euonymus japonica var. grandiflora*	7.0					6
Heavenly bamboo	*Nandina domestica*	1.0					6
Hibiscus	*Hibiscus rosa-sinensis* cv. *Brilliante*	1.0					6
Juniper	*Juniperus chinensis*	1.5	9.5	2.6	4.1	6.8	1
Lantana	*Lantana camara*	1.8					1
Oleander	*Nerium oleander*	2.0	21.0	2.5	3.2	4.4	1
Pittosporum	*Pittosporum tobira*	1.0					6
Privet	*Ligustrum lucidum*	2.0	9.1	3.1	4.7	7.5	1
Pyracantha	*Pyracantha braperi*	2.0	9.1	3.1	4.7	7.5	1
Rose	*Rosa* spp.	1.0					6
Star jasmine	*Trachelospermum jasminoides*	1.6					6
Viburnum	*Viburnum* spp.	1.4	13.2	2.2	3.3	5.2	1
Xylosma	*Xylosma senticosa*	1.5	13.3	2.3	3.4	5.3	1
Pastures							
Barley, forage	*Hordeum vulgare*	6.0	7.0	7.4	9.6	13.1	1
Barley, hay	*Hordeum vulgare*	6.0	7.1	7.4	9.5	13.0	2
Barrel medic, Cyprus	*Medicago truncatula*	3.0	14.6	3.7	4.7	6.4	3
Barrel medic, Jemalong	*Medicago truncatula*	1.0	7.7	2.3	4.2	7.5	3
Buffel grass, Gayndah	*Cenchrus ciliaris* var. *Gayndah*	5.5	10.3	6.5	7.9	10.4	3
Buffel grass, Nunbank	*Cenchrus ciliaris* var. *Nunbank*	6.0	6.8	7.5	9.7	13.4	3

Common name	Scientific name	Salinity threshold (EC_{se})	Productivity decrease per dS/m increase (%)	Soil salinity EC_{se} at			Reference
				90% yield	75% yield	50% yield	
Clover, alsike, ladino, red	*Trifolium* spp.	1.5	12.0	2.3	3.6	5.7	1
Clover, berseem	*Trifolium alexandrinum*	2.0	10.3	3.0	4.4	6.9	3
Clover, berseem (USA)	*Trifolium alexandrinum*	1.5	5.8	3.2	5.8	10.1	1
Clover, rose (Kondinin)	*Trifolium hirtum*	1.0	8.9	2.1	3.8	6.6	3
Clover, strawberry (Palestine)	*Trifolium fragiferum*	1.6	10.3	2.6	4.0	6.5	3
Clover, white (New Zealand)	*Trifolium repens*	1.0	9.6	2.0	3.6	6.2	3
Clover, white (Safari)	*Trifolium semipilosum*	1.5	12.1	2.3	3.6	5.6	3
Corn, forage	*Zea mays*	1.8	7.4	3.2	5.2	8.6	1
Couch grass	*Cynodon dactylon*	6.9	6.4	8.5	10.8	14.7	1
Cowpea (vegetative)	*Vigna unguiculata*	1.3	14.3	2.0	3.0	4.8	1
Desmodium, green leaf	*Desmodium intortum*	2.1	14.9	2.8	3.8	5.5	3
Desmodium, silverleaf	*Desmodium uncinatum*	1.0	22.7	1.4	2.1	3.2	3
Dodonea	*Dodonea viscosa*	1.0	7.8	2.3	4.2	7.4	1
Dolichos Rongai	*Lablab purpureus*	1.0	15.6	1.6	2.6	4.2	3
Fescue	*Festuca elatior*	3.9	5.3	5.8	8.6	13.3	1
Glycine tinaroo	*Glycine wightii*	1.8	9.9	2.8	4.3	6.9	3
Green panic, Petri	*Panicum maximum*	3.0	6.9	4.4	6.6	10.2	3
Kikuku grass, Whittet	*Pennisetum clandestinum*	3.0	3.0	6.3	11.3	19.7	3
Leichhardt	*Macrotyloma uniflorum*	3.0	15.6	3.6	4.6	6.2	3
Lotononis, Miles	*Lotononis bainesii*	1.0	12.2	1.8	3.1	5.1	3
Lovegrass	*Eragrostis* spp.	2.0	8.5	3.2	4.9	7.9	1
Lucerne, Hunter River	*Medicago sativa*	2.0	6.0	3.7	6.2	10.3	3
Lucerne, Hunter River (temperate)	*Medicago sativa*	1.5	6.9	2.9	5.1	8.7	3
Lucerne (USA)	*Medicago sativa*	2.0	7.3	3.4	5.4	8.8	1
Meadow foxtail	*Alopecurus pratensis*	1.5	9.7	2.5	4.1	6.7	1
Orchard grass	*Dactylis glomerata*	1.5	6.2	3.1	5.5	9.6	1
Pangola grass	*Digitaria decumbens (pentzii)*	2.0	4.0	4.5	8.3	14.5	3
Paspalum	*Paspalum dilatatum*	1.8	9.0	2.9	4.6	7.4	3
Phalaris	*Phalaris tuberosa (aquatica)*	4.2					6
Rhodes grass, Pioneer	*Chloris gayana*	7.0	3.2	10.1	14.8	22.6	3
Sesbania	*Sesbania exaltata*	2.3	7.0	3.7	5.9	9.4	1
Setaria, Nandi	*Setaria sphacelata* var. *sericea*	2.4	12.2	3.2	4.5	6.5	3
Siratro	*Macroptilium atropurpureum*	2.0	7.9	3.3	5.2	8.3	3
Snail medic	*Medicago scutellata*	1.5	12.9	2.3	3.4	5.4	3

Common name	Scientific name	Salinity threshold (EC_{se})	Productivity decrease per dS/m increase (%)	Soil salinity EC_{se} at			Reference
				90% yield	75% yield	50% yield	
Strand medic	*Medicago littoralis*	1.5	11.6	2.4	3.7	5.8	3
Sudan grass	*Sorghum sudanense*	2.8	4.3	5.1	8.6	14.4	1
Townsville stylo	*Stylosanthes humilis*	2.4	20.4	2.9	3.6	4.9	3
Trefoil, big	*Lotus uliginosus*	3.0	11.1	3.9	5.3	7.5	1
Trefoil, birdsfoot	*Lotus corniculatus*	5.0	10.0	6.0	7.5	10.0	1
Urochloa	*Urochloa mosambicensis*	8.5	12.4	9.3	10.5	12.5	3
Wheatgrass, crested	*Agropyron desertorum*	3.5	4.0	6.0	9.8	16.0	1
Wheatgrass, fairway	*Agropyron cristatum*	7.5	6.9	8.9	11.1	14.7	1
Wheatgrass, tall	*Agropyron elongatum*	7.5	4.2	9.9	13.5	19.4	1
Vegetables							
Bean	*Phaseolus vulgaris*	1.0	18.9	1.5	2.3	3.6	1
Broadbean	*Vicia faba*	1.6	9.6	2.6	4.2	6.8	1
Broccoli	*Brassica oleracea*	2.8	9.1	3.9	5.5	8.3	1
Cabbage	*Brassica oleracea* var. *Capitata*	1.8	9.7	2.8	4.4	7.0	1
Carrot	*Daucus carota*	1.0	14.1	1.7	2.8	4.5	1
Cauliflower	*Brassica oleracea*	2.5					6
Celery	*Apium graveolens*	1.8	6.2	3.4	5.8	9.9	4
Cucumber	*Cucumis sativus*	2.5	13.0	3.3	4.4	6.3	1
Eggplant	*Solanum melongena*	1.1	6.9	2.5	4.7	8.3	8
Kale	*Brassica campestris*	6.5					6
Lettuce	*Latuca sativa*	1.3	13.0	2.1	3.2	5.1	1
Pea	*Pisum sativum L.*	2.5					6
Pepper	*Capsicum annum*	1.5	14.1	2.2	3.3	5.0	9
Rosemary	*Rosmarinus lockwoodii*	4.5					6
Spinach	*Spinacia oleracea*	2.0	7.6	3.3	5.3	8.6	1
Squash	*Cucurbita maxima*	2.5					6
Squash, scallop	*Cucurbita pepo melopepo*	3.2	16.0	3.8	4.8	6.3	4
Tomato	*Lycopersicon esculentum*	2.3	18.9	2.8	3.6	4.9	1
Turnip	*Brassica rapa*	0.9	9.0	2.0	3.7	6.5	4
Zucchini	*Cucurbita pepo melopepo*	4.7	9.4	5.8	7.4	10.0	4

Table 47. Plant salt-tolerance data, in numerical order by sensitivity at 90% yield (or at the end of the table by salinity threshold if productivity decreases data not available). (* indices data not available.)

Common name	Scientific name	Salinity threshold EC_{se}	Productivity decrease per dS/m increase (%)	Soil salinity EC_{se} at			Reference
				90% yield	75% yield	50% yield	
Strawberry	*Fragaria*	1.0	33.3	1.3	1.8	2.5	1
Desmodium, silverleaf	*Desmodium uncinatum*	1.0	22.7	1.4	2.1	3.2	3
Bean	*Phaseolus vulgaris*	1.0	18.9	1.5	2.3	3.6	1
Apple	*Malus sylvestris*	1.0	18.0	1.6	2.4	3.8	1
Dolichos Rongai	*Lablab purpureus*	1.0	15.6	1.6	2.6	4.2	3
Carrot	*Daucus carota*	1.0	14.1	1.7	2.8	4.5	1
Lotononis, Miles	*Lotononis bainesii*	1.0	12.2	1.8	3.1	5.1	3
Onion	*Allium cepa*	1.2	16.1	1.8	2.8	4.3	1
Avocado	*Persea americana*	1.3	21.0	1.8	2.5	3.7	7
Turnip	*Brassica rapa*	0.9	9.0	2.0	3.7	6.5	4
Clover, white (New Zealand)	*Trifolium repens*	1.0	9.6	2.0	3.6	6.2	3
Cowpea (vegetative)	*Vigna unguiculata*	1.3	14.3	2.0	3.0	4.8	1
Blackberry	*Rubus* spp.	1.5	22.2	2.0	2.6	3.8	1
Boysenberry	*Rubus ursinus*	1.5	22.2	2.0	2.6	3.8	1
Plum	*Prunus domestica*	1.5	18.2	2.0	2.9	4.2	1
Apricot	*Prunus armeniaca*	1.6	23.0	2.0	2.7	3.8	1
Phasey bean, Murray	*Macroptilium lathyroides*	0.8	7.9	2.1	4.0	7.1	3
Clover, rose (Kondinin)	*Trifolium hirtum*	1.0	8.9	2.1	3.8	6.6	3
Lettuce	*Latuca sativa*	1.3	13.0	2.1	3.2	5.1	1
Almond	*Prunus dulcis*	1.5	18.0	2.1	2.9	4.3	1
Viburnum	*Viburnum* spp.	1.4	13.2	2.2	3.3	5.2	1
Pepper	*Capsicum annum*	1.5	14.1	2.2	3.3	5.0	9
Barrel medic, Jemalong	*Medicago truncatula*	1.0	7.7	2.3	4.2	7.5	3
Dodonea	*Dodonea viscosa*	1.0	7.8	2.3	4.2	7.4	1
Clover, white (Safari)	*Trifolium semipilosum*	1.5	12.1	2.3	3.6	5.6	3
Clover, alsike, ladino, red	*Trifolium* spp.	1.5	12.0	2.3	3.6	5.7	1
Snail medic	*Medicago scutellata*	1.5	12.9	2.3	3.4	5.4	3
Xylosma	*Xylosma senticosa*	1.5	13.3	2.3	3.4	5.3	1
Orange	*Citrus sinensis*	1.7	15.9	2.3	3.3	4.8	1
Strand medic	*Medicago littoralis*	1.5	11.6	2.4	3.7	5.8	3
Sweet potato	*Ipomoea batatas*	1.5	11.0	2.4	3.8	6.0	7
Grapefruit	*Citrus paradisi*	1.8	16.1	2.4	3.4	4.9	1
Eggplant	*Solanum melongena*	1.1	6.9	2.5	4.7	8.3	8
Meadow foxtail	*Alopecurus pratensis*	1.5	9.7	2.5	4.1	6.7	1
Corn, grain, sweet	*Zea mays*	1.7	12.0	2.5	3.8	5.9	1
Flax/Linseed	*Linum usitatissimum*	1.7	12.0	2.5	3.8	5.9	1

Common name	Scientific name	Salinity threshold EC_{se}	Productivity decrease per dS/m increase (%)	Soil salinity EC_{se} at			Reference
				90% yield	75% yield	50% yield	
Potato	*Solanum tuberosum*	1.7	12.0	2.5	3.8	5.9	1
Oleander	*Nerium oleander*	2.0	21.0	2.5	3.2	4.4	1
Grape	*Vitis* spp.	1.5	9.5	2.6	4.1	6.8	1
Juniper	*Juniperus chinensis*	1.5	9.5	2.6	4.1	6.8	1
Broadbean	*Vicia faba*	1.6	9.6	2.6	4.2	6.8	1
Clover, strawberry (Palestine)	*Trifolium fragiferum*	1.6	10.3	2.6	4.0	6.5	3
Boxwood	*Buxus microphylla* var. *Japonica*	1.7	10.8	2.6	4.0	6.3	1
Cowpea (seed)	*Vigna unguiculata*	1.6	9.0	2.7	4.4	7.2	9
Cabbage	*Brassica oleracea* var. *Capitata*	1.8	9.7	2.8	4.4	7.0	1
Glycine tinaroo	*Glycine wightii*	1.8	9.9	2.8	4.3	6.9	3
Desmodium, green leaf	*Desmodium intortum*	2.1	14.9	2.8	3.8	5.5	3
Tomato	*Lycopersicon esculentum*	2.3	18.9	2.8	3.6	4.9	1
Paspalum	*Paspalum dilatatum*	1.8	9.0	2.9	4.6	7.4	3
Cowpea, Caloona	*Vigna unguiculata* var. *Caloona*	2.0	10.8	2.9	4.3	6.6	3
Townsville stylo	*Stylosanthes humilis*	2.4	20.4	2.9	3.6	4.9	3
Lucerne, Hunter River (temperate)	*Medicago sativa*	1.5	6.9	2.9	5.1	8.7	3
Clover, berseem	*Trifolium alexandrinum*	2.0	10.3	3.0	4.4	6.9	3
Orchard grass	*Dactylis glomerata*	1.5	6.2	3.1	5.5	9.6	1
Privet	*Ligustrum lucidum*	2.0	9.1	3.1	4.7	7.5	1
Pyracantha	*Pyracantha braperi*	2.0	9.1	3.1	4.7	7.5	1
Clover, berseem (USA)	*Trifolium alexandrinum*	1.5	5.8	3.2	5.8	10.1	1
Corn, forage	*Zea mays*	1.8	7.4	3.2	5.2	8.6	1
Lovegrass	*Eragrostis* spp.	2.0	8.5	3.2	4.9	7.9	1
Setaria, Nandi	*Setaria sphacelata var. sericea*	2.4	12.2	3.2	4.5	6.5	3
Siratro	*Macroptilium atropurpureum*	2.0	7.9	3.3	5.2	8.3	3
Spinach	*Spinacia oleracea*	2.0	7.6	3.3	5.3	8.6	1
Cucumber	*Cucumis sativus*	2.5	13.0	3.3	4.4	6.3	1
Sugarcane	*Saccharum officinarum*	1.7	5.9	3.4	5.9	10.2	1
Celery	*Apium graveolens*	1.8	6.2	3.4	5.8	9.9	4
Lucerne (USA)	*Medicago sativa*	2.0	7.3	3.4	5.4	8.8	1
Peanut	*Arachis hypogaea*	3.2	29.4	3.5	4.1	4.9	2
Rockmelon	*Cucumis melo*	2.2	7.3	3.6	5.6	9.0	7
Leichhardt	*Macrotyloma uniflorum*	3.0	15.6	3.6	4.6	6.2	3
Lucerne, Hunter River	*Medicago sativa*	2.0	6.0	3.7	6.2	10.3	3
Sesbania	*Sesbania exaltata*	2.3	7.0	3.7	5.9	9.4	1
Barrel medic, Cyprus	*Medicago truncatula*	3.0	14.6	3.7	4.7	6.4	3
Peach	*Prunus persica*	3.2	18.8	3.7	4.5	5.9	1
Rice, paddy	*Oryza sativa*	3.0	12.2	3.8	5.1	7.1	1
Squash, scallop	*Cucurbita pepo melopepo*	4.8	6.3	3.2	16.0	3.8	4

Common name	Scientific name	Salinity threshold EC_{se}	Productivity decrease per dS/m increase (%)	Soil salinity EC_{se} at 90% yield	75% yield	50% yield	Reference
Broccoli	*Brassica oleracea*	5.5	8.3	2.8	9.1	3.9	1
Trefoil, big	*Lotus uliginosus*	5.3	7.5	3.0	11.1	3.9	1
Green panic, Petri	*Panicum maximum*	6.6	10.2	3.0	6.9	4.4	3
Pangola grass	*Digitaria decumbens (pentzii)*	8.3	14.5	2.0	4.0	4.5	3
Bambatsi	*Panicum coloratum*	9.3	17.1	1.5	3.2	4.6	3
Sudan grass	*Sorghum sudanense*	8.6	14.4	2.8	4.3	5.1	1
Beet, garden	*Beta vulgaris*	6.8	9.6	4.0	9.0	5.1	1
Dracaena	*Dracaena endivisa*	6.7	9.5	4.0	9.1	5.1	1
Oats	*Avena sativa*	6.3	7.5	5.0	20.0	5.5	9
Soybean	*Glycine max*	6.3	7.5	5.0	20.0	5.5	1
Fescue	*Festuca elatior*	8.6	13.3	3.9	5.3	5.8	1
Zucchini	*Cucurbita pepo melopepo*	7.4	10.0	4.7	9.4	5.8	4
Sunflower	*Helianthus annuus* spp.	6.5	7.5	5.5	25.0	5.9	9
Wheatgrass, crested	*Agropyron desertorum*	9.8	16.0	3.5	4.0	6.0	1
Trefoil, birdsfoot	*Lotus corniculatus*	7.5	10.0	5.0	10.0	6.0	1
Kikuyu grass, Whittet	*Pennisetum clandestinum*	11.3	19.7	3.0	3.0	6.3	3
Buffel grass, Gayndah	*Cenchrus ciliaris* var. *Gayndah*	7.9	10.4	5.5	10.3	6.5	3
Date	*Phoenix dactylifera*	11.4	18.7	4.0	3.4	6.9	1
Barley, hay	*Hordeum vulgare*	9.5	13.0	6.0	7.1	7.4	2
Barley, forage	*Hordeum vulgare*	9.6	13.1	6.0	7.0	7.4	1
Wheat	*Triticum aestivum*	9.5	13.0	6.0	7.1	7.4	1
Sorghum	*Sorghum bicolor*	8.4	9.9	6.8	15.9	7.4	4
Buffel grass, Nunbank	*Cenchrus ciliaris* var. *Nunbank*	9.7	13.4	6.0	6.8	7.5	3
Wheat, durum	*Triticum turgidum*	10.3	15.0	5.7	5.4	7.6	4
Couch grass	*Cynodon dactylon*	10.8	14.7	6.9	6.4	8.5	1
Beet, sugar	*Beta vulgaris*	11.2	15.5	7.0	5.9	8.7	1
Wheatgrass, fairway	*Agropyron cristatum*	11.1	14.7	7.5	6.9	8.9	1
Sorghum, crooble	*Sorghum almum*	10.5	12.8	8.3	11.2	9.2	3
Urochloa	*Urochloa mosambicensis*	10.5	12.5	8.5	12.4	9.3	3
Cotton	*Gossypium hirsutum*	12.5	17.3	7.7	5.2	9.6	1
Wheatgrass, tall	*Agropyron elongatum*	13.5	19.4	7.5	4.2	9.9	1
Barley, grain	*Hordeum vulgare*	13.0	18.0	8.0	5.0	10.0	1
Rhodes grass, Pioneer	*Chloris gayana*	14.8	22.6	7.0	3.2	10.1	3
Algerian ivy	*Hedera canariensis*			1.0	*		6
Chinese holly	*Ilex cornuta*			1.0	*		6
Heavenly bamboo	*Nandina domestica*			1.0	*		6
Hibiscus	*Hibiscus rosa-sinensis* cv. *Brilliante*			1.0	*		6
Lemon	*Citrus limon*			1.0	*		6
Pear	*Pyrus* spp.			1.0	*		6
Pittosporum	*Pittosporum tobira*			1.0	*		6

Common name	Scientific name	Salinity threshold EC_{se}	Productivity decrease per dS/m increase (%)	Soil salinity EC_{se} at 90% yield	75% yield	50% yield	Reference
Prune	*Prunus domestica*		1.0	6	*		6
Raspberry	*Rubus idaeus*		1.0	6	*		6
Rose	*Rosa* spp.		1.0	6	*		6
Guava, pineapple	*Feijoa sellowiana*		1.2	6	*		6
Bottlebrush	*Callistemon viminalis*		1.5	6	*		6
Star jasmine	*Trachelospermum jasminoides*		1.6	6	*		6
Lantana	*Lantana camara*		1.8	1	*		1
Arbor-vitae	*Thuja orientalus*		2.0	6	*		6
Cauliflower	*Brassica oleracea*		2.5	6	*		6
Pea	*Pisum sativum L.*		2.5	6	*		6
Squash	*Cucurbita maxima*		2.5	6	*		6
Olive	*Olea europaea*		4.0	6	*		6
Pomegranate	*Punica granatum*		4.0	6	*		6
Fig	*Ficus carica*		4.2	6	*		6
Phalaris	*Phalaris tuberosa (aquatica)*		4.2	6	*		6
Rosemary	*Rosmarinus lockwoodii*		4.5	6	*		6
Natal plum	*Carissa macrocarpa*		6.0	6	*		6
Kale	*Brassica campestris*		6.5	6	*		6
Safflower	*Carthamus tinctorius*		6.5	6	*		6
Euonymus	*Euonymus japonica* var. *grandiflora*		7.0	6	*		6
Bougainvillea	*Bougainvillea spectabilis*		8.5	6	*		6

Pasture species for saline soils

The following table (Table 48) lists plants considered suitable for planting on saline soils in Queensland (I. Christiansen, pers. comm.; Townson & Roberts 1992). Information is included on growth habit, propagation, tolerance to waterlogging and salinity, and pasture characteristics. The species are divided into four groups:

- grasses for severely saline soils
- grasses for highly saline soils
- grasses for less saline soils (such as the periphery of saline areas)
- other plants for saline soils.

Grazing management is particularly important in saline areas. Natural regeneration after stock have been excluded or stocking rates decreased is often significant. When salt-tolerant pastures are planted, stock should ideally be excluded for an initial period—generally one to two years depending on conditions—to allow pasture species to establish and achieve satisfactory growth.

Notes on saltbush and samphire species

Atriplex (saltbush) shrubs enhance nutrient cycling, increasing fertility in the mounds under individual bushes and creating favourable microniches for other species. Pasture production beneath the shrubs is greater than in the surrounding area (Mott & McComb 1974). Growth of ephemerals is also promoted under *Atriplex* shrubs (Wilcox 1979). When sown, saltbush plants should be spaced to allow other pasture species to establish in the intervening area.

Saltbush is best regarded as a protein supplement to dry grasses or cereal stubbles. For instance, sheep fed on saltbush alone are likely to lose weight (Warren et al. 1990). Provided a plentiful supply of fresh water is available, cattle productivity on (supplemented) saltbush pasture is similar to that of sheep (Wilson & Graetz 1980).

Because samphires are high in soluble salts, these species are more suitable for grazing by sheep than by cattle or other stock. Samphire grazing should be diluted with alternative fodder such as crop stubble, grass or hay, and a plentiful supply of fresh water should be available. Samphire stands do not tolerate heavy grazing (Malcolm & Cooper 1974). Grazing on samphires is best restricted to late summer and autumn so that the plants can maintain normal summer growth and set seed.

Table 48. Plants considered suitable for saline conditions in Queensland (I. Christiansen, pers. comm.; Townson & Roberts 1992).

Grasses for severely saline soils

Species	Growth habit	Waterlogging and salinity tolerance	Pasture features	Propagation
Brown beetle grass *Diplachne fusca*	Tufted, semiaquatic grass up to 1.5 m high. Leaves are soft and succulent. Forms a dense mat. Generally found growing only in patches.	Often found in flooded depressions or in areas where the watertable is close to the surface. Very high salt tolerance. Tolerates drought and fire.	Highly palatable and nutritious. (Regarded as a weed of rice crops and waterways.)	Does not set viable seed; best established from rooted slips. Active growth in summer.
Salt-water couch *Paspalum distichum* (formerly *P. vaginatum*)	Slow growing, mat forming.	Very resistant to high salt concentrations. Suitable for drainage lines or areas where continuous salty seepage keeps the ground moist most of the time. Fairly resistant to frost and high temperatures	Palatable, readily grazed. Tolerates strategic grazing once established.	Seed viability very low and not available commercially; all plantings to date have used rooted clumps, runners and cuttings. Has been observed to spread and stabilise a salt-affected waterway near Monto and Kingaroy, and to spread slowly downstream.
Marine couch *Sporobolus virginicus*	Fine-leaved, mat forming grass, 5–40 cm high.	Establishes and spreads well on highly saline soils with high watertables. Tolerates extremely high salt levels. Found naturally in areas where the watertable is high or which are subject to periodic flooding or marine inundation. Responds well to controlled burning.	Considered a valuable pasture for fattening cattle. Palatable and nutritious. Tolerates strategic grazing once established.	Establishes well from rooted clumps. Needs plentiful moisture for good growth but is able to survive dry periods. Seeds do not germinate readily
Buffalo grass *Stenotaphrum secundatum*	Hardy perennial grass. Spreads vigorously by runners; roots readily at stem joints.	Tolerates high salinity in moist, swampy soils. Tolerates frost, short dry periods, flooding and shade.	Palatable when young; can be made into useful silage. Best grazed every second week to 6 cm; recovery is slow if grazed shorter than this.	Plant from rooted runners, dig or disc harrow then roll into the soil. Does not set seed.

Grasses for highly saline soils

Species	Growth habit	Waterlogging and salinity tolerance	Pasture features	Propagation
Rhodes grass *Chloris gayana*	Perennial, tufted grass up to 1 m high. Tough, wiry, leafy runners root and shoot readily at the nodes	Most salt-tolerant pasture species available commercially. Suggested for erosion and watertable salting areas on a wide range of soils. Tolerates frost and drought. Can extract water to 4.25 m.	Highly valued as a pasture species. Cultivar Pioneer is the most salt tolerant but the least palatable when mature; produces abundant seed. Some Katamboora cultivars are salt tolerant and palatable.	By seed.
Common or green couch *Cynodon dactylon*	Perennial grass which forms a tough mat.	Tolerates moderate to high levels of soil salinity, particularly in subtropical conditions. Can be highly productive on very saline soils. Tolerates drought. Recovers from frost.	Very palatable and nutritious if fertilised and growth kept short. Good soil binder to prevent erosion. Resistant to heavy grazing.	Can be included in the seed mixture under most conditions except in low rainfall and very salty areas. Once established, spreads quickly by rhizomes and stolons.
Curly windmill grass *Enteropogon acicularis*	Tufted perennial grass up to 1 m high, but usually less. Grows in clumps up to 30 cm wide with a strong, fibrous root system.	Tolerates extreme soil salinity. Tolerates drought.	Varieties found on heavy soils are valuable fodder; taller, coarser variety found on sandy soils is only moderately palatable, but is useful when other feeds become scarce. Does not tolerate heavy grazing.	Readily establishes (naturally) on bare ground and in waterways.

Grasses for less saline soils (such as the periphery of saline areas)

Species	Growth habit	Waterlogging and salinity tolerance	Pasture features	Propagation
Pangola *Digitaria decumbens*	Stoloniferous; summer growing.	Does not tolerate extreme salinity but is useful for less saline margins. Tolerates temporary flooding only. Susceptible to frost but recovers well when weather warms. Will survive drought once established.	Highly palatable and nutritious when young. Makes good silage if cut before it becomes stemmy.	By sprigs or roots from which it spreads rapidly. Does not set viable seed.
Tall fescue grass *Festuca arundinacea*	Winter growing grass. Will gradually colonise surrounding area.	Good for margins of saline areas and wet toeslopes.	Good pasture species.	Vegetative or seed. Sets viable seed.
Para grass *Brachiaria mutica*	Perennial grass up to 2 m tall with long, hairy leaf blades.	Commonly found in swampy areas. Grows well in areas that are flooded occasionally or in seepage areas. Often found on deep loams over saline clays and on marine floodplains. Can be used in high rainfall areas (more than 800 mm/year).	Sensitive to frost. Young grass is very palatable. Valuable as feed in the dry season.	Set seed not generally viable, so vegetative planting is usually necessary. Planting material should be reduced to 20–30 cm lengths, spread over the area and disced into the soil. Irrigation after planting, if available, is most beneficial.

Other plants for saline soils

Species	Growth habit	Waterlogging and salinity tolerance	Pasture features	Propagation
River saltbush *Atriplex amnicola*	Bushy, perennial shrub.	Grows vigorously in extremely saline areas provided sufficient moisture is available. Tolerates waterlogging.	Good forage, recovers well from grazing. High protein, low carbohydrate.	Best established from seedlings or cuttings.
Wavy leaf saltbush *Atriplex undulata*	Bushy, low-growing shrub.	Grows well on drier sites. Not recommended for waterlogged areas.	Generally not as productive as *A.-amnicola*. Recovers well from grazing. Readily grazed by sheep. High protein.	Establishes well from seed. Susceptible to dieback disease.
Old man saltbush *Atriplex nummularia*	Upright growth habit. Leafy.	Tolerates very high salinity. Not tolerant of prolonged waterlogging. Tolerates drought.	Less palatable than *A.-amnicola* and *A.-undulata*. High protein.	Grows rapidly from seedlings even in low rainfall conditions. Seeds should be washed with running water for 2 to 4 hours before sowing to leach out germination inhibitors. Susceptible to Phytopthera (root rot).
Grey saltbush *Atriplex cinerea*	Both prostrate and upright forms.	Tolerates moderate waterlogging.	Variable palatability. High protein.	Spreads rapidly.
Queensland bluebush *Chenopodium auricomum*	Upright, open shrub.	No information available.	Useful as a drought-resistant fodder.	Volunteers readily in areas spelled from stock.
Ruby saltbush *Enchylaena tomentosa*	Dense, rounded bushy shrub with short, succulent leaves, up to 1.5 m high. Flowers and fruits during most of the year.	Grows well on highly saline soils. Tolerates moderate waterlogging.	Readily grazed with very high digestibility. Does not withstand continuous, heavy grazing. Sweet berries are edible.	Volunteers readily after grazing pressures have been removed. Fresh seed (encased in pink berry) germinates well.
Coastal pigface *Sesuvium portulacastrum*	Succulent, prostrate, perennial herb. Spreads by long stems flat on the ground.	Good coloniser of severely saline, bare ground, creating more favourable niches in which other plants can establish. Tolerates waterlogging.	A good pioneer of severely saline areas, paving the way for other species to become established.	Establishes by plant pieces. Once established, spreads well by runners. Does not compete well with other species, but will re-establish if competing species fail.
Samphire *Halosarcia* spp.	Low-growing, leafless shrub. May cover considerable ground area.	Colonises severely affected areas well, and can improve soil conditions for other species to establish. Tolerates extreme waterlogging.	High protein content. Readily grazed provided sufficient other, less saline feeds are also available.	Establishes well from surface-sown seed; plant pieces that hold seed can be spread.
Swamp rat-tail grass *Sporobolus mitchelli*	Spreads rapidly over bare ground by means of long runners.	Grows well in saline seepages.	Good early coloniser but takes some time to produce good ground cover. Tolerates strategic grazing once established.	Plant as rooted clumps or runners.

Note: Refer to notes on saltbush and samphire species at the beginning of this section.

Tree species for salinity management

The information in Table 49 has been collated from the results of research trials conducted in Queensland and other States, supported by information based on the experience of Forestry officers and researchers in establishing and observing tree planting projects around Queensland (Hinchley 1994). (Further information on selecting, establishing and maintaining trees is provided in Tree planting page 104.)

This information, along with more detailed information on tree species, is now available on the Internet. The Queensland Tree Selector ‹www.dpi.qld.gov.au› is a computer program that selects the most suitable trees and shrubs for the site conditions entered by the user.

Notes for Table 49

1. Salinity, waterlogging and sodicity tolerance:
   - VH very high tolerance
   - H high tolerance
   - M moderate tolerance
   - L low tolerance
   - ? tolerance unknown
2. Frost tolerance:
   - H tolerates heavy frost
   - L tolerates light frost
   - N intolerant of frost
   - ? frost tolerance unknown
3. Suitability for saline discharge sites.
4. Rainfall zone:
   - VH very high (› 1250 mm/yr)
   - H high (1000–1250 mm/yr)
   - M medium (750–1000 mm/yr)
   - L low (500–750 mm/yr)
   - VL very low (‹ 500 mm/yr)
5. Potential uses:
   - s/s shade/shelter
   - fge forage
   - wbk windbreaks
   - frm farm timber
   - cbt cabinet or craft timber
   - pol poles/sawlogs
   - oil oil/tannin/chemicals
   - hny honey
6. Approximate maximum mature height (m).
7. Origin:
   - Q natural range includes Queensland
   - A Australian native, not from Queensland
   - NQ Australian native, suitable for North Queensland only
   - WA Western Australian species
   - E exotic species
8. Origin of information for this table:
   - F field trialled in Queensland
   - G glasshouse or interstate trials
   - E expert information, Queensland source
9. Potential weed.
10. Potential weed on floodplain.

Table 49. Trees suitable for growing in saline and waterlogged conditions and for use in salinity management (Hinchley 1994).

Scientific name	Tolerance						Potential uses[5]	Height[6] (m)	Origin[7]	Info origin[8]
	Salinity[1]	Water-logging[1]	Sodicity[1]	Frost[2]	Suit SDS[3]	Rainfall zone[4]				
Acacia aulacocarpa	M	L	L	L		M	frm, cbt, pol, hny	28	Q	F,G,E
Acacia auriculiformis	H	L	H	N	✓	H	fge, frm, cbt, pol, oil	20	Q	F,G,E
Acacia crassicarpa	L	L	M	L	✗	H	frm, cbt, pol	12	Q	F,E
Acacia leptocarpa	L	L	?	N	✗	M	fge, frm, cbt	7	Q	F,G,E
Acacia mangium	L	L	L	L	✗	H	s/s, wbk, cbt, pol	25	Q	G,E
Acacia melanoxylon	M	M	L	H		H	s/s, wbk, cbt, pol	25	Q	F,G,E
Acacia pendula	L	M	M	H		L	s/s, fge, cbt	6	Q	G,E
Acacia salicina	H	L	H	H	✓	L	fge, wbk, cbt, pol	12	Q	G,E
Acacia saligna	M	L	L	H		L	fge, wbk	4	A	G,E
Acacia stenophylla	H	M	H	H	✓	L	s/s, fge, frm, cbt	8	Q	G,E
Atriplex spp.	H	L	M	H	✓	L	fge	2	Q	E
Callistemon linearis	H	M	L	H	✓	H	wbk	4	A	E
Callistemon montanus	H	M	L	L	✓	M	wbk	2	Q	E
Callistemon phoenicius	H	M	L	H	✓	H	wbk	3	A	E
Callistemon rigidus	H	M	L	H	✓	H	wbk	3	Q	E
Cassia brewsteri	M	L	M	H		M	s/s	8	Q	G,E
Casuarina cristata	H	M	M	H	✓	L	s/s, wbk	20	Q	E
Casuarina cunninghamiana	H	H	L	H	✓✓	H	s/s, fge, wbk, cbt	30	Q	F,G,E
Casuarina equisetifolia	M	M	H	L	✓	H	s/s, fge	15	Q	G,E
Casuarina glauca	VH	H	M	H	✓✓	M	s/s, wbk	20	Q	F,G,E
Eucalytpus argophloia	H	M	M	H	✓	L	s/s, frm, pol	25	Q	G,E
Eucalyptus brassiana	H	L	H	M	✓	H	s/s	20	Q	F,E
Eucalyptus brockwayii	M	M	?	H		VL	s/s, frm	15	WA	G,E
Eucalyptus camaldulensis	H	H	H	H	✓✓	VL	s/s, fge, wbk, frm, pol, hny	30	Q	F,G,E
Eucalyptus citriodora	M	L	L	L		M	s/s, frm, pol	30	Q	F,G,E
Eucalyptus cloeziana	L	L	L	L	✗	H	s/s, frm, pol	35	Q	G,E
Eucalyptus curtisii	H	L	H	H	✓	L	s/s, pol	6	Q	E

Scientific name	Tolerance						Potential uses[5]	Height[6] (m)	Origin[7]	Info origin[8]
	Salinity[1]	Water-logging[1]	Sodicity[1]	Frost[2]	Suit SDS[3]	Rainfall zone[4]				
Eucalyptus grandis	M	L	L	H	✗	H	s/s, pol	35	Q	F,G,E
Eucalyptus intermedia	L	L	L	L	✗	H	s/s, frm, hny	30		F,E
Eucalyptus largiflorens	M	H	?	H		L	s/s, hny	20	Q	G,E
Eucalyptus leucoxylon	M	L	L	H		L	hny	20	A	G,E
Eucalyptus longicornis	H	M	M	H	✓	L	s/s, hny	20	A	E
Eucalyptus maculata	H	L	M	L		H	pol, hny	30	Q	G,E
Eucalyptus melliodora	M	M	M	H	✓	L	s/s, wbk, frm, pol, hny	25	Q	F,E
Eucalyptus microtheca	H	L	H	H	✓	VL	s/s, frm, pol, hny	25	Q	F,G,E
Eucalyptus moluccana	H	M	M	H	✓✓	H	s/s, wbk, pol, hny	20	Q	F,G,E
Eucalyptus paniculata	L	L	?	L	✗	H	wbk, frm, hny	30	NQ	E
Eucalyptus pellita	M	M	L	L		H	s/s, pol, hny	30	NQ	G,E
Eucalyptus pilularis	L	L	L	L	✗	H	s/s, wbk, frm, cbt, pol	35	Q	G,E
Eucalyptus platypus var.	M	M	?	H		L	hny	6	WA	G,E
Eucalyptus raveretiana	H	M	?	H	✓	L	s/s, frm	20	Q	F,G
Eucalyptus robusta	H	H	L	L	✓	VH	s/s, wbk, frm, cbt, pol, hny	25	Q	F,G,E
Eucalyptus saligna	L	L	L	L	✗	VH	s/s, wbk, pol, hny	30	Q	G,E
Eucalyptus sideroxylon	H	L	M	H	✓	L	s/s, frm, pol, oil, hny	30	Q	F,E
Eucalyptus spathulata	M	M	?	H		L	s/s, wbk, oil	6	A	G,E
Eucalyptus tereticornis	H	H	H	H	✓✓	M	frm, pol, hny	30	Q	F,G,E
Eucalyptus tessellaris	H	L	H	H		M	frm	25	Q	E
Grevillea robusta	M	L	L	L	✗	M	s/s, cbt, pol	25	Q	G,E
Leptospermum petersonii	L	L	L	L	✗	M	wbk	3		G,E
Leptospermum polygalifolium	H	H	L	H	✓✓	L	wbk	2	Q	E
Leucaena leucocephala	M	L	L	L		M	fge	6	E	F,E
Lophostemon confertus	L	L	L	L	✗	H	s/s, wbk, frm, cbt, pol, hny	30	Q	G,E

Scientific name	Tolerance						Potential uses[5]	Height[6] (m)	Origin[7]	Info origin[8]
	Salinity[1]	Water-logging[1]	Sodicity[1]	Frost[2]	Suit SDS[3]	Rainfall zone[4]				
Melaleuca alternifolia	M	H	L	L	✓	H	s/s, wbk, oil	7	Q	G,E
Melaleuca arcana	H	?	?	N		M	s/s, wbk, hny	8		F
Melaleuca argentea	M	M	?	N		M	s/s, wbk, hny	8	Q	G,E
Melaleuca armillaris	M	L	M	L		M	s/s, wbk, hny	6	Q	G,E
Melaleuca bracteata	H	VH	M	H	✓✓	M	s/s, wbk, oil, hny	8	Q	F,G,E
Melaleuca cajeputi	H	?	?	N		M	s/s, wbk, oil	8	Q	F,G
Melaleuca dealbata	L	M	?	?	✗	H	s/s, wbk	8	A	F,G,E
Melaleuca decussata	H	H	L	L	✓✓	M	wbk	2	A	E
Melaleuca lanceolata	L	M	?	H		M	s/s, wbk, hny	4	Q	G,E
Melaleuca lateritia	H	L	L	L		H		2	A	G,E
Melaleuca leucadendra	H	H	M	L	✓✓	H	s/s, wbk, frm, pol, oil, hny	20	Q	F,G,E
Melaleuca linariifolia	M	H	M	H	✓	H	s/s, wbk, oil, hny	10	Q	G,E
Melaleuca nodosa	M	VH	M	H	✓✓	M	hny	3	Q	F,E
Melaleuca quinquenervia	M	H	M	L	✓✓	M	s/s, wbk, oil, hny	20	Q	F,G,E
Melaleuca thymifolia	H	H	L	H	✓✓	H	hny	1	Q	G,E
Melaleuca viridiflora	L	H	L	L		H	hny	15	Q	E
Melia azedarach	M	L	M	H	✓	M	s/s, pol, hny	25	Q	E
Metrosideros queenslandica	M	L	?	L		VH	pol	20	Q	G,E
Pinus caribaea var. *hondure* [9]	L	L	M	L	✗	H	s/s, wbk, pol	30	E	G,E
Pittosporum phylliraeoides	M	L	M	H		M	s/s, fge	6	Q	E
Syzygium forte spp. *forte*	M	M	?	N	✓	VH	s/s	20	Q	E
Tamarix aphylla [10]	H	L	?	?	✗	L	s/s, wbk	20	E	G
Tipuana tipu [9]	L	L	L	H	✗	M	s/s, fge	15	E	F,E

Useful software packages

Table 50. Summary listing of software packages relevant to salinity investigations and property management decisions.

Software package	Product and features	Sources and contacts
Climate/rainfall information		
AUSTRALIAN RAINMAN	Provides and can analyse rainfall information for nearly 4-000 locations throughout Australia, incorporating the likely effects of the Southern Oscillation Index (SOI) and of Sea Surface Temperatures (SST) in the Indian Ocean on rainfall predictions. Package includes a book, Will It Rain?, which explains how the SOI and Indian Ocean SST influence weather in Australia, and how farm and pastoral managers can use this information to make informed decisions.	DEEDI book sales
Salinity-related calculations		
SALF–SALFCALC	Designed to 'make sense' of soil salinity data. Using soil profile data, measures of root zone salinity, leaching fraction and relative crop yield can be calculated. Also converts between salinity measurements at different water contents ($EC_{1:5}$, EC_{se} and EC_{s}). Output can be stored in files for use with other packages.	DERM
Catchment hydrology		
TOPOG-IRM	Combines information about soils and vegetation with contour maps to predict how and where water flows through a catchment. Can be used to predict the effects of tree clearing or planting or changes to farm plans on a flow of groundwater, on a catchment scale. Results are presented three-dimensionally. Requires detailed data inputs.	CSIRO Land and Water
SWAGSIM	Links above-ground processes with subsurface processes. Simulates recharge and watertable response across a region having a patchwork of crops and water-use patterns. Models regional watertable fluctuations, locates recharge and discharge zones, and calculates the rates of these processes; can also be used to plan pumping for salinity control and to estimate groundwater discharge into streams.	CSIRO Land and Water
Groundwater modelling		
MODFLOW	Can be used to model groundwater systems and to explore the effect of changes to the groundwater (for instance, resulting from the extraction of water through pumping, or increased recharge through tree clearing). Requires input of detailed data on the catchment under study.	United States Geological Survey (source code) Various distributors (compiled and enhanced versions)
Crop water balance		
PERFECT (Productivity, Erosion, Run-off Functions to Evaluate Conservation Techniques)	Can be used to examine how crop water use matches available water and to provide information for planning future cropping programs. Compares the water use of alternative cropping strategies, assessing the productivity and economic performance of each strategy. Uses a cropping system simulation model to analyse the risks that soil erosion poses for long-term crop production under different conditions.	DERM DEEDI book sales

Software package	Product and features	Sources and contacts
Irrigation management and crop selection		
SALF–SALFPREDICT	Designed for predicting the effects of different irrigation regimes on a number of crop and other plant species. From information about water quality, soil properties and rainfall, the program estimates leaching fraction (the amount of water draining below the root zone) and salinity in the root zone, and then predicts the likely effect on crops grown under these conditions. Output can be stored in files for use with other packages.	DERM
SODICS	Models solute dynamics in irrigated clay soils. Can be used to assess the potential salinity hazard of soils in a range of dryland and irrigated situations and to assess the impact of tree clearing on deep drainage. Calculates deep drainage between two times in a soil profile from soil salinity data. Future changes in soil salinity with time in the profile can then also be calculated.	DERM
MEDLI (Model for Effluent Disposal using Land Irrigation)	Uses a number of models to consider the range of factors involved in designing and operating sustainable land disposal systems for effluent from a range of intensive rural industries (such as piggeries, cattle feedlots, abattoirs, dairy sheds and sewage treatment plants). Supports decision making from a range of options.	DERM
SWAGMAN WHATIF (Salt, Water and Groundwater Management)	Education package. Develops an understanding of the interactions between shallow watertables, crops, irrigation and salinisation. Package includes a booklet, Understanding Salt and Sodium in Soils, Irrigation Water and Shallow Groundwaters.	CSIRO Land and Water
SWAGMAN OPTIONS	Uses a framework of submodels (hydrogeology, soils, irrigation, soils, agronomy and economics) to evaluate cost-effective partial solutions on a number of scales (farm, sub-catchment and regional) for managing watertable rise and salinisation in irrigated areas (particularly in relation to growing rice). Gross margins are maximised and recharge minimised while maintaining soil salinity below critical levels, using a series of optimisation routines and a groundwater simulation routine.	CSIRO Land and Water
SIRAG	Irrigation decision support for deciding how much water to apply and when. Component versions deal with irrigation scheduling for annual field crops and for orchard crops. Can be used to forecast irrigations in the current season or to evaluate irrigation management in past seasons.	CSIRO Land and Water
RUSTIC (Runoff, Storage and Irrigation Calculator)	Tool for designing farm dams and water harvesting equipment, preparing irrigation management plants, selecting cropping strategies and assessing existing irrigation/cropping systems. Can be used to calculate runoff values, performance of storage or water harvesting installations, size of land and balancing storage necessary for land disposal of effluent, reliability of irrigating from a number of sources, and to compare the performance of crops under irrigation and not under irrigation.	DERM
WATERSCHED	An irrigation management aid for field crops for predicting future irrigation dates and amounts to apply, according to crop water use.	DEEDI book sales
Pumping options		
Pump it	Interactive spreadsheet program designed for land use planners and advisers that allows the user to select the best pumping strategy to reduce rising water levels (if enhanced discharge is the optimal salinity management solution). Provides information on effects of windmill pumping, siting pumping wells, pump and windmill size, optimum pumping rates and times and disposal options for pumped saline effluent.	CSIRO Land and Water

SALF

The SALF for Windows software package incorporates the models SALFPREDICT and SALFCALC. This version of the software has several useful features:

- Data manipulation functions simplify the export and import of data in various formats. For instance, SALF can generate Excel spreadsheet formatted files which enables data to be exchanged with other applications with ease.
- SALF integrates database management tools for project and site evaluations based on SITES (Soil Information Transfer and Evaluation System) consistent with a national standard for soil database design. This ensures that data entered into the SALF database will be in a form suitable for future data transfer.
- SALF incorporates a graph package for graphical presentations of calculated data and illustrating EC and Cl versus depth over the root zone.

The minimum system requirements for SALF for Windows are:

- Intel 386-based PC or higher, with 4Mb of RAM
- Microsoft Windows 3.1, Windows NT, or Windows 95
- hard disk with at least 3Mb free
- mouse or pointing device.

SALFPREDICT

SALFPREDICT is used to predict the effects of irrigation on soil root zone salinity, leaching fraction and plant salinity response, based on soil properties and salt balance.

The model used by SALFPREDICT, described and developed in Shaw and Thorburn (1985a, 1985b), is a long-term steady state prediction of the potential change in root zone salinity and leaching fraction with changes in water inputs. The model incorporates soil particle packing theory, rainfall amount, the role of exchangeable sodium and electrolyte content on soil permeability, and the influence of clay content and mineralogy on soil behaviour. Over 700 soil profiles from a wide range of rainfalls were used to drive the relationships which were validated in three irrigated areas in Queensland.

For the development of the model, refer to Shaw and Thorburn (1985a) and Shaw and Thorburn (1985b). The plant salt-tolerance data used in SALFPREDICT are taken from published relationships and recalculated in some cases. These data are presented in Shaw et al. (1987).

To operate SALFPREDICT, the following information is required:

- annual rainfall (in mm)
- EC of the water to be used for irrigation (in an irrigation situation) (in dS/m)
- cation exchange capacity of the soil (in $cmole_c$ /kg, equivalent to meq/100 g)
- clay content of the soil (as a percentage)
- exchangeable sodium in the soil at 0.9 m depth (nominal bottom of the root zone) (in $cmole_c$ /kg or meq/100 g).

Data entered into SALFPREDICT and results generated by the program can be stored in associated files for further reference.

Limitations of SALFPREDICT

In developing the SALFPREDICT model, some assumptions had to be made. SALFPREDICT is not reliable for data that do not agree with these assumptions. The following riders need to be considered when using SALFPREDICT:

- *Climate and rainfall*—The model is based on steady state conditions and requires the entry of average rainfall data. Thus the model predicts average values that correspond to steady state conditions. The model does not accommodate short-term rainfall fluctuations, and is not appropriate for changes over periods of less than 10 years. In addition, SALFPREDICT was developed using data for conditions receiving average annual rainfall of 200 to 2 000 mm. The model will not provide reliable estimates for average annual rainfall values outside this range. SALFPREDICT is based on conditions in summer rainfall areas, and will underestimate the leaching fraction in winter rainfall areas.
- *Local conditions*—SALFPREDICT inputs are depth weighted averages of rainfall and irrigation on an annual basis. For some crops and conditions, short-term salinity problems may become apparent, particularly in dry years, in response to seasonal variations in crop growth, rainfall and irrigation application. This is not accounted for. A rough estimate can be made by changing the irrigation–rainfall data to reflect the dry year. Plant varieties and local conditions, particularly evaporative demand, may result in plant responses that differ from those incorporated into SALFPREDICT.
- *Soil properties*—Relationships for some clay and CEC/clay ratio groups are not provided in SALFPREDICT because of the limited occurrences of these soils in Queensland. If the user selects one of these soils, SALFPREDICT will use an algorithm to select a soil group with similar characteristics, so these results must be considered as

approximations only. SALFPREDICT states the clay/CCR group used in the calculation. If the CEC/clay ratio is less than 0.25, a soil will most likely be acid. These soils are under-represented in the soil groups used in deriving the relationships for the model. For these soils, SALFPREDICT will underestimate leaching and overestimate root zone salinity.

- *Leaching fraction*—The leaching fraction is calculated at field water content, which is calculated as 2.2 times drier than saturation. This is based on the essential cessation of downward flux of water at 'field capacity'. The program converts EC_s to EC_{se}. More accurate methods are being developed.
- *Measure of salinity*—Because the sum of all salts present has an effect on soil permeability, electrical conductivity has been used to represent salinity rather than chloride. If an irrigation water contains significant calcium associated with sulfate (SO_4) and/or bicarbonate (HCO_3) or sodium as bicarbonate or carbonate (CO_3), SALFPREDICT will overestimate the root zone salinity. This is because the model assumes no precipitation of salts as the soil dries.
- *Root zone characteristics*—The model assumes average soil properties in a root zone with a depth of 0.9 m. For soils with strong texture contrast and deep sandy A horizons, SALFPREDICT will provide less reliable results.
- *pH*—The model was derived mainly for soils in the semiarid areas, which are dominantly neutral to alkaline in pH. For soils with pH less than 4.5, SALFPREDICT results will underestimate deep drainage due to the increased soil stability resulting from exchangeable aluminium under these conditions offsetting the effects of exchangeable sodium.
- *A non-linear correction* has been applied to address the effect of increasing EC on soil leaching, based on field work in the Lockyer Valley. This is not necessarily applicable to all soils.

SALFCALC

SALFCALC has been designed to help 'make sense' of soil salinity data. SALFCALC can be used to convert raw data to measures of salinity that have direct relationships with plant yield data and soil leaching processes. Leaching fraction and relative plant yield can be estimated.

To operate SALFCALC, the following information is required for each site:

- name of the crop to be grown (to be selected from a list supplied by the program)
- root zone depth for the crop (in cm)
- $EC_{1:5}$ data for the soil profile, at sampled depth intervals (in dS/m)
- $Cl_{1:5}$ data for the soil profile, at sampled depth intervals (as % by weight, or in mg/kg)
- air dry water content, or clay content, or CEC, or −33 kPa water content, or −1500 kPa water content (or soil texture, although this is less accurate).

From this initial information, SALFCALC will calculate:

- conversions between salinity measurements (EC) at different water contents—$EC_{1:5}$, EC_{se} and EC_s
- average and water uptake weighted root zone salinity
- leaching fraction (fraction of applied water and rainfall moving below the root zone)
- plant-available water capacity of the soil
- relative yield for a crop (selected from a list provided by the package).

Limitations of SALFCALC

Because the method of measuring saturation percentage is prone to inaccuracy, SALFCALC uses surrogate estimates of saturation percentage. Considering the errors introduced by these estimates and the method of determining plant salt tolerance, SALFCALC's predictions will not be precise and should be considered ± 20% at best.

Salinity publications for further reference

Salinity investigations in Queensland past and present

This list is intended only as an initial guide to known regional investigations and salinity research work in Queensland. All too often, relevant information is not published in a form that is widely available, and subsequent researchers, being unaware of the previous work, are unable to take advantage of it. Much of the information listed here may be available only from libraries or from the authors themselves.

In general, the reports are divided into localities which are listed in geographical order, progressing approximately from south to north and from east to west. Within each locality, reports are listed in alphabetical order by the surname of the first author. Where possible, authors' first names have been provided to facilitate personal contact.

State-wide or multiple areas

Beetson, Trevor & Gordon, Ian 1991, 'Role of trees in alleviating secondary salinity: The current position in Queensland', *The role of trees in sustainable agriculture—A National Conference*, 30 September–3 October 1991, Albury Convention Centre, National Agroforestry Working Group.

Bevin, Peter & Shaw, Roger 1980, 'Queensland salinity problems in irrigation areas', *Bulletin*, Australian National Committee for Irrigation and Drainage, Special Issue, August 1980.

Brebber, Lindsay 1991, *Saltwatch '91: Summary of collected data*, Project Report QO92005, Natural Resource Management Unit, Department of Primary Industries, Queensland.

Gill, Jill 1986, 'Water quality for agriculture in Queensland: A review of methods of interpretation of water analysis results and a survey of the geographical distribution of agricultural water quality in Queensland', *Bulletin* QB86004, Agricultural Chemistry Branch, Department of Primary Industries, Queensland.

Gill, Jill 1985, 'Queensland water quality survey', in *Landscape, soil and water salinity*, Proceedings of Lockyer Moreton Regional Workshop, Ipswich, June 1985, Conference and Workshop Series QC85004, pp. C1-1 to C1-12, Department of Primary Industries, Queensland.

Gill, Jill 1984, *Determining the quality of water for irrigation in Queensland*, Department of Primary Industries, Queensland, Ref. note R1, January 1984.

Gill, Jill 1979, *Assessment of water analysis results for irrigation in Queensland*, Department of Primary Industries, Queensland, Ref. note R37, July 1979.

Gordon, Ian (ed.) 1991, *A survey of dryland and irrigation salinity in Queensland*, Information Series QI91034, Land Management Research Branch, Department of Primary Industries, Queensland.

Hughes, Keith 1979, *Assessment of dryland salinity in Queensland*, Division of Land Utilisation Report 79/7, Department of Primary Industries, Queensland.

Saltwatch '91–'93, summary report 1994, Natural Resource Management Unit, Department of Primary Industries, Queensland, joint initiative with Department of Education, Queensland.

Shaw, Roger 1988, 'Predicting deep drainage in the soil from soil properties and rainfall', *Soil Use and Management*, **4**:120–123.

Shaw, Roger & Thorburn, Peter 1985, 'Prediction of leaching fraction from soil properties, irrigation water and rainfall', *Irrigation Science*, **6**:73–83.

Thorburn, Peter, Rose, Calvin, Shaw, Roger & Yule, Don 1990, 'Interpreting solute dynamics in irrigated soils, I. Mass balance approaches', *Irrigation Science*, **11**:199–207.

Wreczycki, R.J. 1968, 'Findings on boron content of Queensland waters', *Queensland Agricultural Journal*, **94**:331.

Inglewood

Gordon, Ian 1994, 'Terrica: Salt at faults and folds', Case study in *Saltwatch Activity Book*, Training Series QE94003, Land Conservation, Department of Primary Industries, Queensland, pp. 43–45.

Harris, Graham 1986, 'Salinity in the Inglewood Shire', in *Landscape, soil and water salinity*, Proceedings of the Darling Downs Regional Workshop, Toowoomba, March 1986, Conference and Workshop Series QC86001, pp. B3-1 to B3-13, Department of Primary Industries, Queensland.

Thorburn, Peter, Shaw, Roger & Gordon, Ian 1992, 'Modelling salt transport in the landscape', in *Modeling Chemical Transport in Soils*, ed. H. Ghadiri & C.W. Rose, Chapter 4, pp. 145–190, Lewis Publishers, CRC Press Inc., Florida.

Lockyer—Ipswich

Ahern, Col, Shaw, Roger & Thorburn, Peter 1984 'Differences in chemical and physical properties between soil layers of black earths on alluvia in the Lockyer Valley, Queensland', Abstract of conference presentation, in *Proceedings of the National Soils Conference*, Brisbane, May 1984, Australian Society of Soil Science, Brisbane, p. 180.

Christiansen, Ingrid 1993, Distribution and growth of plants in relation to soil salinity in south-east Queensland, BSc (Honours thesis), Department of Botany, University of Queensland, St Lucia.

Doherty, John 1992, *Some aspects of small-catchment groundwater hydrology*, Project Report QO92001, Department of Primary Industries, Queensland.

Gardner, E. (Ted) 1985, 'Hydro-salinity problems in the Lockyer Valley—real and perceived', in *Landscape, soil and water salinity*, Proceedings of the Lockyer–Moreton Regional Workshop, Ipswich, June 1985, Conference and Workshop Series QC85004, pages D1-1 to D1-9, Department of Primary Industries, Queensland.

Hughes, Keith 1985, 'Notes on seepage salting at Queensland Agricultural College Darbalara Farm', in *Landscape, soil and water salinity*, Proceedings of the Lockyer–Moreton Regional Workshop, Ipswich, June 1985, Conference and Workshop Series QC85004, pp. D2-1 to D2-5, Department of Primary Industries, Queensland.

Hughes, Keith 1982, Summary report on salinity in the Kalbar Area, unpublished internal report, Division of Land Utilisation, Department of Primary Industries, Queensland.

Hunt, Keryn 1994, 'Boonah: The outfield's fast', Case study in *Saltwatch Activity Book*, Training Series QE94003, Land Conservation, Department of Primary Industries, Queensland, p. 35.

McNeil, Vivienne, Poplawski, Wojciech & Gardner, E. (Ted) 1991, *Salinity problems affecting irrigation in the Lockyer Valley, Queensland, Australia*, presented at the conference on Irrigated induced physical and chemical changes in groundwater and surface water, Vienna, Austria.

Powell, Bernie, Shaw, Roger & Roberts, Max 1985, 'Factors for evaluation of land for sustainable irrigation in the Lockyer Valley', *in Proceedings Fourth Australian Soil Conservation Conference*, Part 1, ed. I.F. Fergus Maroochydore, Queensland, October 1985, pp. 296–297, Standing Committee on Soil Conservation.

Talbot, R. (Bob), Roberts, Max, McMahon, C. (Ron) & Shaw, Roger 1981, *Irrigation quality of Lockyer Valley alluvia bores during the 1980 drought*, Technical publication No. 5, Department of Biology, Queensland Agricultural College.

Thorburn, Peter, Shaw, Roger & Ahern, Col 1984, 'A comparison of leaching estimates in irrigated soils in the Lockyer Valley, Queensland', *Proceedings of the National Soils Conference*, Brisbane, May 1984, Australian Society of Soil Science, Brisbane, p. 286.

Truong, Paul, Gordon, Ian & McDowell, Murray 1991, *Effects of soil salinity on the establishment and growth of Vetiver zizanioides (L.)*, World Bank Special Publication.

Zinn, Peter 1985, 'Development of groundwater in the Lockyer Valley', *in Landscape, soil and water salinity*, Proceedings of the Lockyer–Moreton Regional Workshop, Ipswich, June 1985, Conference and Workshop Series QC85004, pp. D3-1 to D3-5, Department of Primary Industries, Queensland.

Darling Downs

Doherty, John & Stallman, Adrian 1994, *Pump test and soil profile analyses for the Brymaroo Catchment*, Project Report Series QO94007, Natural Resource Management Unit, Department of Primary Industries, Queensland.

Doherty, John & Stallman, Adrian 1992, *Land management options for a salt-affected catchment on the Darling Downs*, Project Report QO92010, Division of Land Management, Department of Primary Industries, Queensland.

Gordon, Ian & Shaw, Roger 1994, 'Brymaroo: Salinity and recycling', Case study in *Saltwatch Activity Book*, Training Series QE94003, Land Conservation, Department of Primary Industries, Queensland, pp. 36–40.

Hughes, Keith 1986, 'Dryland salting overview—Darling Downs area', in *Landscape, soil and water salinity*, Proceedings of the Darling Downs Regional Workshop, Toowoomba, March 1986, Conference and Workshop Series QC86001, pp. B8-1 to B8-10, Department of Primary Industries, Queensland.

Huxley, Bill 1986, 'Regional hydrology and water quality characteristics of the Darling Downs', in *Landscape, soil and water salinity*, Proceedings of the Darling Downs Regional Workshop, Toowoomba, March 1986, Conference and Workshop Series QC86001, pp. B11-1 to B11-10, Department of Primary Industries, Queensland.

Kalma, Steve 1995, *An evaluation of airborne geophysics for salinity assessment in Property Management Planning: Pittsworth Airborne Geophysical Survey*, Project Report Series QO95003, Department of Primary Industries, Queensland.

Knowles-Jackson, Clive 1987, 'The occurrence of seepage salting in the Oakey soil conservation district', in *Landscape, soil and water salinity*, Proceedings of the Brisbane Regional Salinity Workshop, Brisbane, May 1987, Conference and Workshop Series QC87003, pp. B1-1 to B1-4, Department of Primary Industries, Queensland.

Molloy (Daly), Jenny & McIntyre, Geoff 1986, 'Soil and water salinity in the Dalby District', in *Landscape, soil and water salinity*, Proceedings of the Darling Downs Regional Workshop, Toowoomba, March 1986, Conference and Workshop Series QC86001, pp. B2-1 to B2-3, Department of Primary Industries, Queensland.

Stallman, Adrian 1992, *Irrigation as a land management option for a salt-affected catchment*, Natural Resource Management Unit, Department of Primary Industries, Queensland, (poster paper).

Thorburn, Peter 1991, 'Occurrence and management of dryland salting on the Darling Downs, Queensland', *Australian Journal of Soil and Water Conservation*, **4**:26–32.

Thorburn, Peter 1989, 'Dryland salinity on the Darling Downs', *Queensland Agricultural Journal*, **115**:217–224.

Thorburn, Peter, Geritz, Alan & Shaw, Roger 1986, 'Causes and managements of dryland salting: A case study', in *Landscape, soil and water salinity*, Proceedings of the Darling Downs Regional Workshop, Toowoomba, March 1986, Conference and Workshop Series QC86001, pp. B9-1 to B9-16, Department of Primary Industries, Queensland.

West, Dave, Geritz, Alan & Thorburn, Peter 1987, 'Revegetation of a dryland salting outbreak: a progress report', in *Landscape, soil and water salinity*, Proceedings of the Brisbane Regional Salinity Workshop, Brisbane, May 1987, Conference and Workshop Series QC87003, pp. B5-1 to B5-10, Department of Primary Industries, Queensland.

West, Dave 1986, 'Tree planting on the Darling Downs', in *Landscape, soil and water salinity*, Proceedings of the Darling Downs Regional Workshop, Toowoomba, March 1986, Conference and Workshop Series QC86001, pp. B7-1 to B7-5, Department of Primary Industries, Queensland.

Pumicestone Passage

Shaw, Roger 1978, *Suitability of a low lying coastal area for small crop farming and suggested drainage and reclamation measures required*, Final Report, Department of Primary Industries, Queensland.

Condamine—Miles

Dalal, Ram 1986, 'Salinity trends in Brigalow soils', in *Landscape, soil and water salinity*, Proceedings of the Darling Downs Regional Workshop, Toowoomba, March 1986, Conference and Workshop Series QC86001, pp. B5-1 to B5-5, Department of Primary Industries, Queensland.

Free, Dave 1986, 'Irrigation development and groundwater salinity in the upper Condamine River Catchment', in *Landscape, soil and water salinity*, Proceedings of the Darling Downs Regional Workshop, Toowoomba, March 1986, Conference and Workshop Series QC86001, pp. B12-1 to B12-6, Department of Primary Industries, Queensland.

Orange, Denis & Smith, George 1986, 'A case study of salinity: Effect on a Brigalow grey clay at Drillham', in *Landscape, soil and water salinity*, Proceedings of the Darling Downs Regional Workshop, Toowoomba, March 1986, Conference and Workshop Series QC86001, pp. B6-1 to B6-5, Department of Primary Industries, Queensland.

Shaw, Roger, Gardner, E. (Ted), Brebber, Lindsay, Gordon, Ian, Thorburn, Peter & Littleboy, Mark 1989, *Current approaches to estimating and predicting groundwater recharge in Queensland with reference to the Darling Basin*, Presented to the Murray Darling Basin Commission Recharge Workshop, Melbourne, November 1989.

South Burnett—Kingaroy

Dickenson, John & Kent, David 1989, *Seepage and salty outbreaks in red soil areas around Kingaroy*, Farm Note SC8901003, Soil Conservation Services Branch/Land Resources Branch, Department of Primary Industries, Queensland.

Kent, David, 1986, 'Salinity in the south Burnett', in *Landscape, soil and water salinity*, Proceedings of the Darling Downs Regional Workshop, Toowoomba, March 1986, Conference and Workshop Series QC86001, pp. B1-1 to B1-3. Department of Primary Industries, Queensland.

Reid, Bob, Shaw, Roger & Baker, Dennis 1979, *Soils and irrigation potential of the alluvial flats of the Byee Area, Barambah Creek, Murgon, Queensland*, Agricultural Chemistry Branch Technical Report No. 14, Department of Primary Industries, Queensland.

Maryborough

Brown, M. D. & Simpson, John 1987, 'Salinity and forestry in the Maryborough region', in *Landscape, soil and water salinity*, Proceedings of the Bundaberg Regional Salinity Workshop, Bundaberg, April 1987, Conference and Workshop Series QC87001, pp. B7-1 to B7-3, Department of Primary Industries, Queensland.

Collings, A. (Steve) 1987, 'Effect of Caribbean pine plantation establishment on water table levels at Wongi, Queensland', in *Landscape, soil and water salinity*, Proceedings of the Bundaberg Regional Salinity Workshop, Bundaberg, April 1987, Conference and Workshop Series QC87001, pp. B6-1 to B6-9, Department of Primary Industries, Queensland.

Hughes, Keith 1987, 'Assessment of salinity hazards in vacant Crown lands in the Maryborough area', in *Landscape, soil and water salinity*, Proceedings of the Bundaberg Regional Salinity Workshop, Bundaberg, April 1987, Conference and Workshop Series QC87001, pp. B3-1 to B3-16, Department of Primary Industries, Queensland.

Rolfe, Dennis 1987, 'Seepage salting in Wongi State Forest', in *Landscape, soil and water salinity*, Proceedings of the Bundaberg Regional Salinity Workshop, Bundaberg, April 1987, Conference and Workshop Series QC87001, pp. B5-1 to B5-4. Department of Primary Industries, Queensland.

Bundaberg

Cantor, John 1987, 'A methodology for maintenance or restoration of water quality in small farm storages', in *Landscape, soil and water salinity*, Proceedings of the Bundaberg Regional Salinity Workshop, Bundaberg, April 1987, Conference and Workshop Series QC87001, pp. B9-1 to B9-12, Department of Primary Industries, Queensland.

Forster, Bruce & Macnish, Stuart 1987, 'Field evaluation of the suitability for irrigation of caneland in the Isis mill area with particular emphasis on salinity and drainage hazard', in *Landscape, soil and water salinity*, Proceedings of the Bundaberg Regional Salinity Workshop, Bundaberg, April 1987, Conference and Workshop Series QC87001, pp. B2-1 to B2-10, Department of Primary Industries, Queensland.

Glanville, Trevor & Leverington, Andrea 1987, 'The reclamation of a saline area at the Woongarra balancing storage, Bundaberg', in *Landscape, soil and water salinity*, Proceedings of the Bundaberg Regional Salinity Workshop, Bundaberg, April 1987, Conference and Workshop Series QC87001, pp. B10-1 to B10-7, Department of Primary Industries, Queensland.

Kingston, Graham 1993, Geo-hydrology of soil and water salinity in the Maryborough Basin, thesis submitted for PhD in Environmental Management, Griffith University.

Kingston, Graham 1987, 'Application of electromagnetic induction instruments to investigation of soil salinity', in *Landscape, soil and water salinity*, Proceedings of the Bundaberg Regional Salinity Workshop, Bundaberg, April 1987, Conference and Workshop Series QC87001, pp. B4-1 to B4-13, Department of Primary Industries, Queensland.

Kingston, Graham 1985, 'Soil salinity a hazard to productivity in southern areas', BSES Bulletin, 12:14–17.

Macnish, Stuart 1985, 'The Port Curtis–Wide Bay Land Resource Survey—salinity and land use aspects', in *Landscape, soil and water salinity*, Proceedings of the Rockhampton Regional Workshop, Rockhampton, May 1985, Conference and Workshop Series QC85002, pp. C2-1 to C2-3, Department of Primary Industries, Queensland.

Smith, Geoff 1987, 'An overview of salinity in the upper and central Burnett and recent developments in the south Burnett', in *Landscape, soil and water salinity*, Proceedings of the Bundaberg Regional Salinity Workshop, Bundaberg, April 1987, Conference and Workshop Series QC87001, pp. B13-1 to B13-7, Department of Primary Industries, Queensland.

Sunners, Frank 1993, Nitrate contamination—a study of Bundaberg's groundwater, thesis for Master of Natural Resources, University of New England.

Gladstone

Plenderleigh, Rob & Hartigan, Roger 1987, 'Vegetative colonisation of saline coal ash at Gladstone, central Queensland', in *Landscape, soil and water salinity*, Proceedings of the Brisbane Regional Salinity Workshop, Brisbane, May 1987, Conference and Workshop Series QC87003, pp. B2-1 to B2-4, Department of Primary Industries, Queensland.

Callide—Biloela—Moura

Dowling, A. (Tony) & Gardner, E. (Ted) 1988, 'Spatial variation in salinity of some alluvial aquifers in central Queensland—a steady state analysis', *Australian Journal of Soil Research*, 26:583–593.

Dowling, A. (Tony) & Gardner, E. (Ted) 1985, 'Alluvial groundwater salinity in the Callide Valley, central Queensland', in *Landscape, soil and water salinity*, Proceedings of the Rockhampton Regional Workshop, Rockhampton, May 1985, Conference and Workshop Series QC85002, pp. D1-1 to D1-8, Department of Primary Industries, Queensland.

Lawrence, Peter, Thorburn, Peter & Littleboy, Mark 1991, 'Changes in surface and subsurface hydrology after clearing brigalow (*Acacia harpophylla*) forest in a semi-arid climate: Measurements and modelling', in *International Hydrology and Water Resources Symposium 1991*, Perth 2–4 October 1991, Preprints vol. 2, pp. 374–380, The Institution of Engineers, Australia, National Conference Publication No. 91/22.

Standley, John 1989, *Reclamation studies on an area of dryland salting near Thangool, central Queensland*, Bulletin Series QB89006, Agricultural Chemistry Branch, Department of Primary Industries, Queensland.

Standley, John, Cowie, Bruce & Larsen, Arnie 1987, 'Studies on an area of dryland salting near Thangool, central Queensland; Part 5—Survival of trees, 1984–1987', in *Landscape, soil and water salinity*, Proceedings of the Brisbane Regional Salinity Workshop, Brisbane, May 1987, Conference and Workshop Series QC87003, pp. B4-1 to B4-18, Department of Primary Industries, Queensland.

Standley, John, Cowie, Bruce & Larsen, Arnie 1987, 'Studies on an area of dryland salting near Thangool, central Queensland; Part 4—Drainage and salinity in the tree study area', in *Landscape, soil and water salinity*, Proceedings of the Brisbane Regional Salinity Workshop, Brisbane, May 1987, Conference and Workshop Series QC87003, pp. B3-1 to B3-10, Department of Primary Industries, Queensland.

Standley, John & Cowie, Bruce 1985, 'Studies on an area of dryland salting near Thangool, central Queensland; Part 3—Information from piezometer records and water analyses', in *Landscape, soil and water salinity*, Proceedings of the Rockhampton Regional Workshop, Rockhampton, May 1985, Conference and Workshop Series QC85002, pp. C6-12 to C6-19, Department of Primary Industries, Queensland.

Standley, John & Cowie, Bruce 1985, 'Studies on an area of dryland salting near Thangool, central Queensland; Part 2—Establishment of trees in the saline area', in *Landscape, soil and water salinity*, Proceedings of the Rockhampton Regional Workshop, Rockhampton, May 1985, Conference and Workshop Series QC85002, pp. C6-6 to C6-11, Department of Primary Industries, Queensland.

Standley, John & Cowie, Bruce 1985, 'Studies on an area of dryland salting near Thangool, central Queensland; Part 1—Description and drainage', in *Landscape, soil and water salinity*, Proceedings of the Rockhampton Regional Workshop, Rockhampton, May 1985, Conference and Workshop Series QC85002, pp. C6-1 to C6-5, Department of Primary Industries, Queensland.

Dee and Don River Valleys

Lloyd, John & Murphy, Greg 1985, 'Irrigation salinity in the Dee and Don River Valleys', in *Landscape, soil and water salinity*, Proceedings of the Rockhampton Regional Workshop, Rockhampton, May 1985, Conference and Workshop Series QC85002, pp. D2-1 to D2-4, Department of Primary Industries, Queensland.

Thorburn, Peter, Cowie, Bruce & Hunter, Heather 1985, 'Salinity in irrigated soils of the Wowan area, Dee River Valley', in *Landscape, soil and water salinity*, Proceedings of the Rockhampton Regional Workshop, Rockhampton, May 1985, Conference and Workshop Series QC85002, pp. D3-1 to D3-9, Department of Primary Industries, Queensland.

Rockhampton

Chapman, David 1985, 'Dryland salting at Tanby (field site)', field notes accompanying *Landscape, soil and water salinity*, Proceedings of the Rockhampton Regional Workshop, Rockhampton, May 1985, Conference and Workshop Series QC85002, Department of Primary Industries, Queensland.

Cummins, Vic 1985, 'Dryland salting in Granodiorites (field site)', field notes accompanying *Landscape, soil and water salinity*, Proceedings of the Rockhampton Regional Workshop, Rockhampton, May 1985, Conference and Workshop Series QC85002, Department of Primary Industries, Queensland.

Hill, Clem 1994, 'Ohio: Planting trees for feed', Case study in *Saltwatch Activity Book*, Training Series QE94003, Land Conservation, Department of Primary Industries, Queensland, pp. 41–42.

Hughes, Keith 1985, 'Dryland salting overview—Rockhampton and Biloela', in *Landscape, soil and water salinity*, Proceedings of the Rockhampton Regional Workshop, Rockhampton, May 1985, Conference and Workshop Series QC85002, pp. C1-1 to C1-5, Department of Primary Industries, Queensland.

Hughes, Keith 1985, 'Dryland salting at Barmoya (field site)', field notes accompanying *Landscape, soil and water salinity*, Proceedings of the Rockhampton Regional Workshop, Rockhampton, May 1985, Conference and Workshop Series QC85002, Department of Primary Industries, Queensland.

Simpson, John 1985, 'Salinity in forestry areas with particular reference to the Rockhampton district', in *Landscape, soil and water salinity*, Proceedings of the Rockhampton Regional Workshop, Rockhampton, May 1985, Conference and Workshop Series QC85002, pp. C3-1 to C3-3, Department of Primary Industries, Queensland.

Emerald

Gardner, E. (Ted) 1979, *The utility of plant measurements in assessing the irrigation suitability of cracking clay soils in the Emerald Irrigation Area*, final report on ACL–50.

Gardner, E. (Ted) 1978, Techniques for evaluating suitability for irrigation of cracking clay soils in the Emerald Irrigation Area, Master of Agricultural Science Thesis, University of Queensland, Brisbane.

Shaw, Roger & Gordon, Ian 1994, Salinity in cotton areas, in *Proceedings of the Seventh Australian Cotton Conference*, Gold Coast, August 1994.

Shaw, Roger & Yule, Don 1978, *'Assessment of soils for irrigation, Emerald, Queensland'*, Agricultural Chemistry Branch Technical Report No. 13, Department of Primary Industries, Queensland.

Shaw, Roger 1974, 'Soil water relations of cracking clay soils in the Emerald Irrigation Area', in *Proceedings of Central Queensland Soil Moisture Workshop*, pp. 36–41, Department of Primary Industries, Queensland.

Mackay

Shaw, Roger, Gordon, Ian, Brebber, Lindsay & Stallman, Adrian 1992, The potential for development of salinity and watertable problems affecting sustainable irrigation in the Pioneer Valley area, Mackay, consultancy report prepared for Water Resources, December 1992.

Proserpine

Gordon, Ian & Shaw, Roger 1992, The potential for development of salinity and watertable problems under irrigation in the Koolachu area, Proserpine, consultancy report prepared for Water Resources.

Bowen

Maltby, John, Wright, Ross & McShane, Tom 1986, 'Quality of irrigation water in the Bowen area, north Queensland', in *Landscape, soil and water salinity*, Proceedings of the Burdekin Regional Salinity Workshop, Ayr, April 1986, Conference and Workshop Series QC86003, pp. B9-1 to B9-11, Department of Primary Industries, Queensland.

Burdekin

Ahern, Col, Shaw, Roger & Eldershaw, Val 1988, Predicted deep drainage loss for Burdekin soils, in *Interpretation by landscape units and agronomic groups*, Part A, Publication QB88004, Department of Primary Industries, Queensland.

Day, Ken & McShane, Tom 1986, 'Predicting potential toposequence salinisation—lower Burdekin', in *Landscape, soil and water salinity*, Proceedings of the Burdekin Regional Salinity Workshop, Ayr, April 1986, Conference and Workshop Series QC86003, pp. B5-1 to B5-12, Department of Primary Industries, Queensland.

Doherty, John 1989, *Leichardt Downs electromagnetic survey*, ACTFR Report 89/09.

Doherty, John 1988, 1989, 1990, *Salt and water movement in hillslope soil toposequences in the Burdekin River Irrigation Area*, Progress reports, ACTFR Reports 88/09, 88/13, 89/01, 89/02, 89/08, 89/10, 90/4, Final report ACTFR Report 90/13.

Doherty, John 1987, *Leichardt Downs resistivity survey*, ACTFR Report 87/01.

Dowling, A. (Tony), Elliot, Peter, Ross, Peter & Thorburn, Peter 1988, 'Salt and water movement in a furrow irrigated sodic duplex soil from the Burdekin River Irrigation Area', in *Proceedings of the National Soils Conference*, Canberra, May 1988, p. 241, Soil Science Society of Australia.

Dowling, A. (Tony), Elliot, Peter, Thorburn, Peter, Ross, Peter & Hunt, Steve 1988, 'Chloride and water movement in a furrow irrigated sodic duplex soil from the Burdekin River Irrigation Area', in R. J. Smith and A. J. Rixon (eds), *'Soil Management 88'*, Proceedings of a symposium, Toowoomba, September 1988, pp. 321–335, Darling Downs Institute of Advanced Education.

Gardner, E. (Ted), Shaw, Roger, McShane, Tom & Brebber, Lindsay 1989, *Leichhardt hydro-salinity project*, final report, submitted to Water Resources Commission, September 1989.

Gardner, E. (Ted) & Coughlan, Kep 1982, *Physical factors determining soil suitability for irrigated crop production in the Burdekin-Elliot River area*, Technical Report No. 20, Agricultural Chemistry Branch, Department of Primary Industries, Queensland.

Maltby, John & McShane, Tom 1986, 'Quality of underground water and related effects on rice growth in the lower Burdekin area, north Queensland', in *Landscape, soil and water salinity*, Proceedings of the Burdekin Regional Salinity Workshop, Ayr, April 1986, Conference and Workshop Series QC86003, pp. B3-1 to B3-6, Department of Primary Industries, Queensland.

McClurg, Jim, Ahern, Col & Donnollan, Terry 1986, 'Characteristics of inherently saline and sodic soils of the lower Burdekin', in *Landscape, soil and water salinity*, Proceedings of the Burdekin Regional Salinity Workshop, Ayr, April 1986, Conference and Workshop Series QC86003, pp. B7-1 to B7-12, Department of Primary Industries, Queensland.

McShane, Tom 1986, 'A review of salinity in the Burdekin', in *Landscape, soil and water salinity*, Proceedings of the Burdekin Regional Salinity Workshop, Ayr, April 1986, Conference and Workshop Series QC86003, pp. B1-1 to B1-8, Department of Primary Industries, Queensland.

Shaw, Roger 1989, 'Predicted deep drainage loss under dryland and irrigation managements for Burdekin soils', in G.E. Rayment and V.E. Eldershaw, *Soils of the Burdekin River Irrigation Area, Workshop Proceedings*, Ayr, QC89003 pp. 37–48, Department of Primary Industries, Queensland.

Shaw, Roger 1986, 'Predicted hydrology, salinity and sodicity changes under irrigation development in the lower Burdekin right bank', in *Landscape, soil and water salinity*, Proceedings of the Burdekin Regional Salinity Workshop, Ayr, April 1986, Conference and Workshop Series QC86003, pp. B8-1 to B8-16, Department of Primary Industries, Queensland.

Shaw, Roger, Eldershaw, Val, Thompson, W. (Bill) & Smith, George 1984, *Hydrology and salinity changes under irrigation—Lower Burdekin right bank (Fort site)*, Bulletin QB84004, Department of Primary Industries, Queensland.

Shaw, Roger, Thorburn, Peter, McShane, Tom, Maltby, John & Robson, Chris 1983, 'The effectiveness of drainage in a region of variable aquifer hydraulic conductivity in the Lower Burdekin region, north Queensland', in R.J. Smith and A.J. Rixon (eds), *Proceedings of Symposium, Rural Drainage in Northern Australia*, pp. 129–142, Darling Downs Institute of Advanced Education.

Thorburn, Peter, Rose, Calvin, Shaw, Roger & Yule, Don 1990, 'Predictions of deep drainage below the root zone under irrigation from soil properties and a simple salt balance model', *Proceedings, Management of Salinity in South-eastern Australia*, Albury, September 1989, Australian Society of Soil Science Incorporated, Riverina Branch.

Williams, John, Bui, Elizabeth, Gardner, E. (Ted), Littleboy, Mark & Probert, Merv 1997, 'Tree clearing and dryland salinity hazard in the upper Burdekin catchment of north Queensland', *Australian Journal of Soil Research*, 35:785–801.

Collinsville

Thompson, W. (Bill), Cannon, Mike, Shaw, Roger & Clem, R. (Bob) 1982, *Soils and special land use assessment of a mining lease area, Collinsville, North Queensland*, Agricultural Chemistry Branch Technical Report No. 19, Department of Primary Industries, Queensland.

Ingham

Wilson, Peter 1986, 'Hydrology and sodicity of the soloths, solodic soils and solodised solonetz soils in the Ingham area', in *Landscape, soil and water salinity*, Proceedings of the Burdekin Regional Salinity Workshop, Ayr, April 1986, Conference and Workshop Series QC86003, pp. B6-1 to B6-5, Department of Primary Industries, Queensland.

Northern tablelands

Grundy, Mike 1986, 'Salinity in the Tablelands and northern semi-arid tropics', in *Landscape, soil and water salinity*, Proceedings of the Burdekin Regional Salinity Workshop, Ayr, April 1986, Conference and Workshop Series QC86003, p. B2-1, Department of Primary Industries, Queensland.