LAND MONITOR

65 Brockway Road, Floreat WA 6014
Tel. 08-9387 0340
nicole.trudgeon@landgate.wa.gov.au
http://www.landmonitor.wa.gov.au

1.0 Product Information Sheet

Title: Land Monitor Salinity Monitoring Mosaic 1987-1992 and 1995-2000

Data Supplied	- Salt-affected land / consistently low productive land - Bush / perennial vegetation - Water
Mosaic Updated	14 February 2008, 20 February 2008
Coverage	Landsat TM scenes Fitzgerald Biosphere Region (Bremer Bay, Newdegate, Ravensthorpe), Dumbleyung, Bencubbin, Collie- Pemberton, Esperance, Jackson, Kalbarri- Geraldton, Kellerberrin, Moora, Mt Barker, Mullewa, Perth, and Southern Cross.
Format	BIL Compatible with ER Mapper and Arc View
Number of Bands	1
Grid / Pixels Size	25
Coordinate system	GDA 1994 MGA Zone 50 and Zone 51 (Ravensthorpe Esperance region)
Projection	Transverse Mercator
Rectification to roads database	Bencubbin, Bremer Bay
Rectification base Land Monitor 1994	Collie- Pemberton, Dumbleyung, Esperance, Kalbarri- Geraldton, Jackson, Kellerberrin, Moora, Mt Barker, Mullewa, Newdegate, Perth (1996 base), Ravensthorpe, Southern Cross
Calibration state spring base	Bencubbin, Bremer Bay, Collie- Pemberton, Dumbleyung, Kalbarri- Geraldton, M Barker, Newdegate, Southern Cross
Version	Version 2 This document updated 16 April 2008

Table 1.1 Legend Values and Colours

This data is classified. Data values represent:

0 White	Not mapped currently
1 Cream	Background
2 Green	Bush / perennial vegetation cover (from the relevant vegetation mask (2000) used for the salt mapping)
3 Orange	Mapped as salt-affected land in earliest time period (between 1987 and 1992)
4 Red	Mapped as additional salt-affected land in latest time period (between 1994 and 2000)
5 Cyan	Water

Table 1.2 Change in Saline Area Dates per Satellite Scene Coverage

Fitzgerald Scene	class 1	orange	salt 1990 and 1991
	class 2	red	salt increase in 1994/ 96/ 97
Dumbleyung Scene	class 1	orange	salt 1989
	class 2	red	salt increase in 1994/ 95
Bencubbin Scene	class 1	orange	salt 1987/ 88
	class 2	red	salt increase in 1994/ 95/ 96
Collie- Pemberton Scene	class 1	orange	salt 1988
	class 2	red	salt increase in 1996/ 98/ 99
Esperance Scene	class 1	orange	salt 1987/ 88/ 90
	class 2	red	salt increase in 1994/ 97/ 98 / 99/ 2000
Jackson Scene	class 1	orange	salt 1988/ 89/ 90
	class 2	red	salt increase in 1994/ 95/ 97/ 99
Kalbarri- Geraldton Scene	class 1	orange	salt 1990/ 92
	class 2	red	salt increase in 1994/ 95/ 96/ 98
Kellerberrin Scene	class 1	orange	salt 1988/ 89/ 90
	class 2	red	salt increase in 1993/ 94/ 95/ 96
Moora Scene	class 1	orange	salt 1989/ 90 /91
	class 2	red	salt increase in1993/ 94/ 95/ 97/ 99
Mt Barker Scene	class 1	orange	salt 1989/ 90
	class 2	red	salt increase in 93/ 94/ 95/ 98
Mullewa Scene	class 1	orange	salt 1990/ 91
	class 2	red	salt increase in 1993/ 94/ 95/ 97/ 98/ 99
Perth Scene	class 1	orange	salt 1986/ 87/ 91
	class 2	red	salt increase in 1995/ 96/ 97/ 98
Southern Cross Scene	class 1	orange	salt 1989/ 91/ 92
	class 2	red	salt increase in 1995/ 97/ 99/2000

2.0 Methods

This document is a summary of the accuracy of salinity monitoring for the agricultural zone in south west of Western Australia. Specific methods are described in individual scene reports. Please refer to the reference section of each scene accuracy statement. Please also refer to the paper on Salinity monitoring (below) found on the CSIRO Centre for Mathematical and Information Sciences website http://www.cmis.csiro.au/rsm/publications.htm .

References

Caccetta, P. A., Campbell, N. A., Evans, F. H., Furby, S. L., Kiiveri, H. T. and Wallace, J. F. (2000), *Mapping and monitoring land use and condition change in the South-West of Western Australia using remote sensing and other data*, (2000), Proceedings of the Europa 2000 Conference, Barcelona. Article available in full text PDF (311KB).

Evans, F. H., Allen, A., Caccetta, P. A., Furby, S. L. and Wallace, J. F. (1999), *Broad-scale land condition monitoring using Landsat TM and DEM-derived data*, Proceedings of the fourth International Symposium on Environmental Software Systems. Article available in full text PDF (1263KB)

Furby S., Evans F., Wallace J., Ferdowsian R., and Simons J. (1998) *Collecting Ground Truth Data for Salinity Mapping and Monitoring,* HTML Doc, Last updated: September 1998

Kiiveri, H. T. and Caccetta, P. A. (1998), *Image fusion with conditional probability networks for monitoring salinisation of farmland, Digital Signal Processing*, Vol. 8, No.4, pp. 225-230. Article available in full text PDF (156KB).

McFarlane, D. J., George, R. J. and Caccetta, P. A. (2004), *The Extent and Potential Area of Salt-affected Land in Western Australia Estimated Using Remote Sensing and Digital Terrain Models*, Engineering Salinity Solutions, 9-12 November, Perth, Western Australia. Article available in full text PDF (398KB)

3.0 Limitations and Liabilities

The information contained in these salinity maps is necessarily based in part upon various assumptions and predictions. The Land Monitor Project (comprising the Western Australian State Government agencies, Department of Agriculture and Food Western Australia, Department of Environment and Conservation, Department of Water, Landgate, Department for Planning and Infrastructure and The Water Corporation and the Commonwealth agencies CSIRO (Centre for Mathematical and Information Sciences) and the Australian Greenhouse Office (Department of Environment and Heritage) accepts no responsibility for any inaccuracies in these salinity maps and persons relying on these maps do so at their own risk.

Areas mapped as salt-affected are areas of persistent low productivity which may include salt-affected land, dam embankments, fire breaks and roads.

Areas mapped as salt-affected represent areas greater than about one hectare. Salt-affected areas smaller than this cannot be mapped reliably. The precise definition of salt-affected is dependent in part on the qualitative assessment of the ground-truthing personnel and in part on the limitations of the productivity changes that can be reliably measured by the Landsat TM instrument.

4.0 Comments on the Accuracy Assessment by Satellite Scene:

The aims was to describe the current salinity maps and their accuracy and limitations, and the salinity change maps. These are brief summaries of each scene, please refer to the scene report referenced or contact the custodian for more information.

Salinity mapping accuracy was estimated from ground truth validation data. Difficulties in obtaining historical information, and the physical expanse of the mapping, required validation to be performed on the most recent mapping.

4.1 Bremer Bay Region

Accuracy Assessment:

Table 4.1.1 Accuracy Assessment of the Salinity Maps

Region	Severely salt-affected land detected	Marginal salt-affected land detected	Non-saline land labelled as salt-affected
Upper Gairdner catchment	77%	43%	4%
Bremer Bay region	76%	63%	9%
Fitzgerald River corridor	82%	52%	1%

Comments on the Accuracy Assessment:

The biggest sources of commission errors (non-saline land labelled as salt-affected) are:

- Paddocks that have been cleared but appear never to have been cropped. The surface is uneven and the volunteer vegetation is scrappy and sparse.
- "Parkland" regions (scattered trees with grassy under storey used for pasture).

The biggest sources of omission errors (salt-affected land not detected) are:

- Sites where a saline area is detected, but the extent is underestimated (common for flat areas where the margins are still cropped).
- Narrow areas (up to 1 pixel) that are only just becoming saline (since ~1994).

Special Comments:

None

Area of Salt-affected Land (Full Scene)

The following table shows the area of salt-affected land for the local government authorities completely within the in the Bremer Bay Landsat TM scene. Since some of the local authority boundaries extend beyond the area cleared for agriculture, summary statistics are reported for the whole authority and for that part of the authority contained within the agricultural area.

Table 4.1.2 Area of salt affected land for LGA within Bremer Bay Landsat scene

Shire	Region	Total Area (ha)	Salt-affected 1990-1992 (ha)	Salt-affected 1996-97 (ha)
Jerramungup	Whole Shire	652 300	11 863	15 534

References:

The above information has been extracted from the following technical report:

Furby S. (2001) Mapping *Salinity in the Bremer Bay Landsat TM Scene*, CSIRO Mathematical and Information Sciences, www.landmonitor.wa.gov.au/reports/sm_reports/BBYsummary.doc

4.2 Dumbleyung Scene Region

Overall summary

The total area covered by the final products is 2.76 million hectares; of this 6.8% was mapped as saline in 1990, and this figure increases to 7.5% in 1998. A further 3.0% is classed as 'valley bush' in 1998; a significant proportion of this is salt-affected. In addition, 1.5% of the total area is covered by the water mask.

Accuracy Assessment: see section 5 of Wallace (2002) and notes.

Large saline areas of the Beaufort and Arthur river valleys are densely covered with samphire, salt-tolerant trees and barley grass. These areas are spectrally similar to poor condition 'non-saline' bush, and were not mapped as 'saline'; instead, they were included as an extra class – 'valley bush'. Statistical summaries of the data should take this into account.

The biggest source of omission errors (salt-affected land not detected) were:

- Areas densely covered with salt-tolerant grasses or a cover of salt-tolerant species (eg. trees, samphire, saltbush), particularly in saline river valleys. These errors are now largely accounted for in the 'valley bush' class.
- Sites where good cover of salt tolerant grasses grow successfully. These have been previously reported as omission errors. The 2002 field assessment of the final product did not report any such errors, and found that the mapping was highly accurate in one such system. Nevertheless, it is likely that some such areas have been omitted.

The biggest sources of commission errors are:

- Some sites with poor condition remnant vegetation; roadside areas not removed by the road-mask buffer; road-like areas which were not in the road mask (e.g. internal farm tracks and firebreaks) and so were not removed by the buffering

Accuracy assessment results – overall

The overall accuracy combined from records for the west, central and eastern assessment zones were 96%, 94% and 92% respectively. The errors of commission and omission are summarised in tables 1-9 in Wallace (2002) referenced below.

Area of Salt-affected Land by Shire

The following table shows the areas mapped as salt-affected land for the local government authorities completely within the Dumbleyung Landsat TM scene. Percentages of the shire area are also given.

The areas of the water mask and of the 1998 'valley bush' class are also given. Within the Dumbleyung scene, nearly all of the areas mapped as water are saline lakes or drainage channels. As noted above, in certain areas of the scene where there are broad valley systems, a large proportion of the 'valley bush' class is actually salt-affected non-agricultural land. Expert knowledge is needed in association with the maps to provide estimates of the proportion of this bush which is salt-affected in different landscape units or in different portions of the scene.

Table 4.2.1 Area mapped as saline and related classes summarised by Shire

Shire	**Total Area Processed (ha)**	**Mapped Salt 1990 (ha) [%]**	**Mapped Salt 1998 (ha) [%]**	**Valley Bush 1998 (ha) [%]**	**Water Mask 1990/98 (ha) [%]**
Dumbleyung	253 895	16 183 [6.3%]	17 778 [7.0%]	3 089 [1.2%]	4 014 [1.6%]
Wickepin	204 020	12 458 [6.1%]	14 077 [6.9%]	3 335 [1.6%]	1 001 [0.5%]
Wagin	194 755	16 697 [8.6%]	17 312 [8.9%]	8 955 [4.5%]	4 860 [2.5%]
Woodanilling	112 891	7 492 [6.6%]	7 908 [7.0%]	8 751 [7.8%]	1 042 [0.9%]
Narrogin	163 080	12 430 [7.6%]	13 153 [8.06%]	7 404 [4.5%]	695 [0.4%]
Katanning	151 805	13 892 [9.1%]	16 179 [10.7%]	9 097 [6.0%]	1 252 [0.8%]

References:

The above information has been extracted from the following technical report:

Wallace J. (2002) *Mapping Salinity in the Dumbleyung Landsat TM Scene,* CSIRO Mathematical and Information Sciences, Agriculture Western Australia, CMIS Task Report No. 2002/xxx, September 2002, http://www.landmonitor.wa.gov.au/reports/sm_reports/DUMsalinity_v2.pdf

4.3 Bencubbin Scene

The biggest sources of commission errors (non-saline land labelled as salt-affected) are:

- Dams / houses/ gravel pits
- Thin/sparse remnant vegetation
- Low lying wet areas with abundant non salt-tolerant species

The biggest sources of omission errors (salt-affected land not detected) are:

- Sites where a saline area is detected, but the extent is underestimated (common for flat areas where the margins are still cropped).
- Sites with greater than ~80% cover of salt-tolerant grasses such as barley grass
- Saline areas with a good cover of salt-bush not being labelled as salt-affected (6% of salt-affected sites)

Accuracy Assessment

Table 4.3.1 Accuracy Assessment of the Salinity Maps

Catchment	Salt-affected land detected	Non-saline land labeled as salt-affected
Ninan catchment	78%	5%
Marchagee catchment	95%	13%
Pithara – Dalwallinu region	80%	5%
Goodlands catchment	95%	15%

Special Comments:

None

References:

The above information has been extracted from the following technical report:

Furby S. (2001) *Mapping Salinity in the Bencubbin Landsat TM Scene*, CSIRO Mathematical and Information Sciences
http://www.landmonitor.wa.gov.au/reports/sm_reports/bensummary.doc

4.4 Collie- Pemberton Scene

Accuracy Assessment

Table 4.4.1 Accuracy assessment of the salinity maps in East Collie catchment

Catchment	Accuracy of Salt-affected land detected	Non-saline land labelled correctly
East Collie	99% of bare salt 70%of marginal salt	99% remnant vegetation 100% agricultural land

Comments on the Accuracy Assessment:

The biggest sources of omission errors (salt-affected land not detected) are:

- Areas with a cover of salt-tolerant grasses.

The biggest source of commission errors are:

- Sparse remnant vegetation.

Special Comments:

The mosaiced Collie - Pemberton Landsat TM scenes have been divided into five zones that broadly correspond to the major hydro geological systems of the region, as mapped by the Agriculture WA Soil Landscape zones. The salinity mapping zones are:

- Coastal zone including the coastal plains irrigation areas
- South west zone including the Margaret River vineyard areas
- Forest zone
- Eastern Zone (including a significant overlap with the Dumbleyung scene)
- Southern Zone (areas east including the upper Tone and Lake Muir catchments have been processed as part of the Mt Barker scene)

Expressions of salinity in south west and forest zones are minor and quite different to those observed in most of the wheatbelt. These zones have not been processed for this reason.

The coastal zone is known to have large areas affected by salinity. However, the salt-affected areas cannot be discriminated using Landsat TM satellite imagery. Salinity is also affecting significant areas of agricultural land in the coastal zone, but ground data in the Manjimup-Pemberton area have shown that the Land Monitor method is also unsuitable in these higher rainfall areas.

Area of Salt-affected Land

The following table shows the area of salt-affected land for the local government authorities completely within the in the Eastern zone of the Collie and Pemberton Landsat TM scenes. Such summaries can be calculated for any sub-region of interest within the scene.

Table 4.4.2: Areas of salt-affected land

Shire	Total Area(ha)	Salt-affected 1988 ha	Salt-affected 1998 ha
West Arthur	282 885	5 824	9 423
Williams	230 446	1 303	1 944

References:

The above information has been extracted from the following technical report:

Evans F. (2001*) Collie and Pemberton Landsat TM Scenes, Salinity Mapping*, CSIRO Mathematical and Information Sciences, CMIS Task Report No. 3/01, October 2001, **http://www.landmonitor.wa.gov.au/reports/sm_reports/cpfinalreport.doc**

4.5 Esperance Scene

Validation, Accuracy and Limitations

The data comprised validation of the class labels at fixed grid intervals of 250m. The process was carried out in eight sites over two zones:

At each grid location the label of the map was compared with field checks. Assessment sites in the North Zone contained few salt affected areas and statistics drawn from these areas are not practical for quantitative estimates of plotting accuracy on their own.

Different figures can be used to summarise mapping accuracy. Tables below show the accuracy and errors of commission and omission for each class.

Table 4.5.1 Percent accuracy of mapped classes (*commission errors)

		Image Classification Label	
		Salt	Non-salt
Ground state	Salt	100.0%	*8.5%
	Non-salt	*0.0%	91.5%
	Total	100.0%	100.0%

Table 4.5.2 Percent accuracy of ground classes (*omission errors)

		Image Classification Label		
		Salt	Non-salt	Total
Ground state	Salt	62.4%	*37.6%	100.0%
	Non-salt	*0.0%	100.0%	100.0%

Overall accuracy (proportion of correctly labelled sites) for the mapping is 92.6%. The amount of salt is generally underestimated, and this is most noticeable in the North Zone. Areas of salt tolerant vegetation may have been included in the classification as non-woody vegetation, and further processing focussing on identifying this marginal vegetation type may improve the classification performance.

Shire statistics

The salinity estimates may be aggregated to produce shire summaries. Table 4.5.3 below provides a summary of the salinity status for the Esperance Shire which includes the extents of the mapping. The table contains area estimates expressed in hectares (ha) as well as the percentage of processed area of the shire estimated to be saline. The Shire of Esperance covers a large area, over 60% of which lies outside the agricultural area boundary. The area of the salt affected land within the agricultural boundary is included in the table below.

Table 4.5.3 Salinity estimates summarised for shires intersecting the Esperance scene.

Esperance			
Area of Shire	4 227 146 ha		
Area processed	1 408 067 ha	33.3%	of shire area
Shire processed area salt affected 1988	23 688 ha	1.7%	of area processed
Shire processed area salt affected 1999	38 012 ha	2.7%	of area processed
Area of shire with agricultural bounds	1 603 552 ha	37.9%	of shire area
Shire agricultural bounds area processed	1 195 480 ha	74.6%	of agricultural area
Agricultural area processed salt affected 1988	12 206 ha	1.0%	of area processed
Agricultural area processed salt affected 1999	21 521 ha	1.8%	of area processed

References:

The above information has been extracted from the following technical report:

Meston J. (2001) *Mapping and Monitoring Salinity: the Esperance Landsat TM scene (108-083)*, CSIRO Mathematical and Information Sciences, 17 October 2001, CMIS Report Number: 01/162, http://www.landmonitor.wa.gov.au/reports/sm_reports/esperance_salinity.doc

4.6 Jackson Scene

Accuracy assessment

The data comprised validation of the class labels at fixed grid intervals of 1km, performed by the authors in two sub-regions.

For the two regions, the overall mapping accuracy is 94% and 96% respectively, although we observe that the mapping over estimates the extent of salinity in both areas. Generally, overestimates resulted from sites such as degraded bush in low lying areas, eroded catchments, dams (dams not included in masks) and areas of low productivity being mislabelled as saline. Below, tables 4.6.1 to 4.6.6 give the results for the two validation areas.

Table 4.6.1: Area 1. Site counts obtained from field validation

		Image map label		
		Non saline	Saline	Total
Ground Label	Non saline	46	3	49
	Saline	-	2	2
	Total	46	5	51

Table 4.6.2: Area 1. Percent accuracy of mapped classes (*and errors of commission)

		Image map label	
		Non saline	Saline
Ground Label	Non saline	100	60
	Saline	0	40
	Total (%)	100	100

Table 4.6.3: Area 1. Percentage of ground classes actually mapped (*and errors of omission)

		Image map label		
		Non saline	Saline	Total (%)
Ground Label	Non saline	94	6	100
	Saline	0	100	100

Table 4.6.4: Area 2. Site counts obtained from field validation

		Image map label		
		Non saline	Saline	Total
Ground Label	Non saline	73	3	76
	Saline	0	4	4
	Total	73	7	80

Table 4.6.5: Area 2. Percent accuracy of mapped classes (*and errors of commission)

		Image map label	
		Non saline	Saline
Ground Label	Non saline	100	43
	Saline	0	57
	Total (%)	100	100

Table 4.6.6: Area 2. Percentage of ground classes actually mapped (*and errors of omission)

Image map label				
Ground Label		Non saline	Saline	Total (%)
	Non saline	96	4	100
	Saline	0	100	100

Shire statistics

No complete shires are covered by the area considered. Shires partially included in the mapping include Yilgarn, Westonia, Mukinbudin, Nungarin, Trayning, Mount Marshall, Wyalkatchem and Koorda. Statistic are obtainable by aggregating the results with those of neighbouring scenes, including Bencubbin and Kellerberrin.

References:

The above information has been extracted from the following technical report:

Caccetta P.[1], Bryant G.[1] and Beetson B. [2] (2002) *Mapping and Monitoring Salinity: the Jackson Landsat TM scene (111-081),* CSIRO Mathematical and Information Sciences, [2]AgWest, 19 September, 2002, http://www.landmonitor.wa.gov.au/reports/sm_reports/jackson_salinity.doc

4.7 Kalbarri - Geraldton Scene

Accuracy Assessment:

Table 4.7.1 summarise the accuracy assessment of the final 1996/1998 salinity map for each of the stratification zones.

Zone	Salt-affected land detected	Non-saline land labelled as salt-affected
Sandplains	85%	100%
Binnu system	66%	100%
Sandy and duplex soils	70%	99%
Gravels	NA	100%
Wet and heavy soils	NA	100%

Note: Salt-tolerant remnant vegetation with >80% cover not mapped.

Comments on the Accuracy Assessment:

The biggest sources of omission errors (salt-affected land not detected) are:

- Sites where a saline area is detected, but the extent is underestimated (common for flat areas where the margins are still cropped). The only zone in which any saline area was completely mapped as non-saline was the Binnu zone, and those sites were higher in the landscape than the landforms suggested.
- Sites with salt-tolerant grasses and greater than 60% cover of salt-tolerant species (eg. dead trees, samphire, saltbush), particularly in sandy soils.
- Narrow valleys less than one pixel wide.

These types of errors are difficult to correct using the Land Monitor methodology.

Special Comments:

Lower accuracies in the Binnu system result from local rehabilitation attempts and the occurrence of healthy salt-tolerant species on salt-affected sites. The satellite signal tends to show that these sites support a healthy cover of vegetative species.

Lower accuracies in the loams and duplex soil zones are caused by the non-specificity of the ground data provided. Cover types were not specified and hence the accuracy is averaged over all cover types, including areas supporting healthy salt-tolerant species.

References:

The above information has been extracted from the following technical report:

Evans F. (2001) *Mapping Salinity in the Kalbarri-Geraldton Landsat TM Scene*, CSIRO Mathematical and Information Sciences, CMIS Task Report No. 2/01, January 2001, www.landmonitor.wa.gov.au/reports/sm_reports/KGfinalreport.pdf

4.8 Kellerberrin Scene

The data comprised validation of the class labels at fixed grid intervals of 500m, performed by the authors in two sub-regions.

For the two regions, the overall mapping accuracy is 96.7% and 97% respectively, although we observe that the mapping over estimates the extent of salinity in area 1, and marginally overestimates the extent of salinity in area 2. Generally, overestimates resulted from sites such as degraded bush in low lying areas, eroded catchments, new dams (dams not included in dam mask) and areas of low productivity being mislabelled as saline.

Table 4.8.1: Area 1. Site counts obtained from field validation

		Image map label		
		Non saline	Saline	Total
Ground label	Non saline	158	4	162
	Saline	2	22	24
	Total	160	26	186

Table 4.8.2: Area 1. Percent accuracy of mapped classes (*and errors of commission)

		Image map label	
		Non saline	Saline
Ground label	Non saline	99	15*
	Saline	1*	85
	Total (%)	100	100

Table 4.8.3: Area 1. Percentage of ground classes actually mapped (*and errors of omission)

		Image map label		
		Non saline	Saline	Total (%)
Ground label	Non saline	98	2*	100
	Saline	8*	92	100

Table 4.8.4: Area 2. Site counts obtained from field validation

		Image map label		
		Non saline	Saline	Total
Ground label	Non saline	162	5	167
	Saline	1	35	36
	Total	163	40	203

Table 4.8.5: Area 2. Percent accuracy of mapped classes (*and errors of commission)

		Image map label	
		Non saline	Saline
Ground label	Non saline	99	13*
	Saline	1*	87
	Total (%)	100	100

Table 4.8.6: Area 2. Percentage of ground classes actually mapped (*and errors of omission)

Image map label				
Ground label		Non saline	Saline	Total (%)
	Non saline	97	3*	100
	Saline	3*	97	100

Shire statistics

The salinity estimates may be aggregated to produce shire summaries. Table 4.8.7 provides a summary of the salinity status for the shires fully contained within the extents of the mapping. The table contains area estimates expressed in hectares (ha) as well as the percentage of each shire estimated to be saline and the rate of increase of these estimates.

From the table we observe that the estimates of the extent of salinity are increasing for all shires, although at different rates.

Table 4.8.7: Salinity estimates summarised by shire

Catchment	Saline 1989 ha **(% of total)**	Saline 1995 ha **(% of total)**	Total Area ha	Area Increase ha **(% of total) (rate %)**
Merredin	7537 **(2.3)**	9138 **(2.8)**	329393	1601 **0.5** **21**
Bruce Rock	11517 **(4.2)**	12608 **(4.6)**	272516	1091 **0.4** **9.5**
Trayning	6750 **(4.1)**	7577 **(4.6)**	165196	827 **0.5** **12.3**
Kellerberrin	11580 **(6.0)**	11964 **(6.2)**	191554	384 **0.2** **3.3**
Tammin	7492 **(6.8)**	8417 **(7.6)**	110246	925 **0.8** **12.3**

References:

The above information has been extracted from the following technical report:

Caccetta P. and Beetson B. (2000) *Mapping and Monitoring Salinity:* the Kellerberrin Landsat TM scene (111-082), CSIRO Mathematical and Information Sciences, AgWest, Report Number: CMIS 2000/202, 22 November, 2000,
http://www.landmonitor.wa.gov.au/reports/sm_reports/kellerberrinsummary.pdf

4.9 Moora Scene

Validation, Accuracy and Limitations

The validation process followed the grid method used for other Land Monitor scenes. Maps of the final processed product (1997 salinity/low productivity) were produced for sample areas at 1:50000, and marked with a regular grid at 500m. Two sample areas were chosen to represent the coastal plain zone and the zone east of the scarp.

For the two regions, the overall mapping accuracy is 93.8% and 94.1% respectively. Generally, errors of commission in the coastal region were sand patches. Commission errors were also observed on firebreaks at the edges of bushland, a quarry area, and wide bare areas adjacent to roads. Errors of omission were observed in salt-affected areas with perennial vegetation cover.

Table 4.9.1: Area 1. Coastal Zone. Percent accuracy of mapped classes (*and errors of commission)

Image map label			
Ground label		Non saline	Saline
	Non saline	99	22*
	Saline	1*	78
	Total (%)	100	100

Table 4.9.2: Area 1. Coastal Zone. Percentage of ground classes actually mapped (*and errors of omission)

Image map label				
Ground label		Non saline	Saline	Total (%)
	Non saline	93	7*	100
	Saline	2*	98	100

Table 4.9.3: Area 2. Eastern Zone. Percent accuracy of mapped classes (*and errors of commission)

Image map label			
Ground label		Non saline	Saline
	Non saline	96	10*
	Saline	4*	90
	Total (%)	100	100

Table 4.9.4: Area 2. Eastern Zone. Percentage of ground classes actually mapped (*and errors of omission)

Image map label				
Ground label		Non saline	Saline	Total (%)
	Non saline	96	4*	100
	Saline	12*	88	100

Shire statistics

The salinity estimates may be aggregated to produce shire summaries. Table 4.9.5 provides a summary of the salinity status for three shires for which the majority of the shire area is contained within the extents of the mapping. The table contains area estimates expressed in hectares (ha) as well as the percentage of the processed area of each shire estimated to be saline and the rate of increase of these estimates.

Table 4.9.5: Salinity estimates summarised by shire. *Approximately 98% of the Coorow shire area lies within the processed region

Shire	Saline 1990 ha (% of total)	Saline 1997 ha (% of total)	Total Area processed ha	Area Increase ha (% of total) (rate %)
Coorow*	21770 (5.3)	25277 (6.1)	409496*	3507 0.8 16
Carnamah	11075 (3.8)	13037 (4.5)	287072	1962 0.7 18
Dandaragan	3320 (0.5)	5204 (0.7)	671276	1884 0.2 --

References:

The above information has been extracted from the following technical report:

Wallace J. F. and Bryant. G. (2001) *Mapping and Monitoring Salinity: the Moora Landsat TM scene (113-081)*, CSIRO Mathematical and Information Sciences, October 2001, Report Number: CMIS 2000/205, http://www.landmonitor.wa.gov.au/reports/sm_reports/Moora_salinity.doc

4.10 Mt Barker Scene

Comments on the Accuracy Assessment:

The biggest sources of omission errors (salt-affected land not detected) are:

- Sites where a saline area is detected, but the extent is underestimated.
- Sites with salt-tolerant grasses or a cover of salt-tolerant species (eg. trees, samphire, saltbush), particularly in sandy soils.
- Salt-affected streamlines where the stream is too narrow for the satellite sensor to detect salinity.

The biggest source of commission errors are:

- Sites with consistent waterlogging.
- Sites with poor condition remnant vegetation.
- Lunettes or dried lake systems.

Table 4.10.1: Accuracy Assessment

Catchment / Study Area	Salt-affected land detected	Non-saline land labelled as salt-affected
Ryan's Brook	72%	99%
Kent	82%	91%
South Stirlings	68%	95%
South Coast	71%	93%

Special Comments:

Lower accuracies for detecting salt-affected land are due in part to the non-specificity of the ground data provided. Cover types were not specified and hence the accuracy is averaged over all cover types, including areas supporting grasses and healthy salt-tolerant species.

Area of Salt-affected Land

The following table shows the area of salt-affected land for the local government authorities completely within the in the Mt Barker Landsat TM scene. Since some of the local authority boundaries extend beyond the area cleared for agriculture, summary statistics are reported for the whole authority and for that part of the authority contained within the agricultural area.

Table 4.10.2: Area of salt-affected land for LGA's completely within Mt Barker scene

Shire	Total Area (ha)	Salt-affected 1989 (ha)	Salt-affected 1995 (ha)
Tambellup	143 677	11 000	12 337
Cranbrook	327 512	13 995	15 012
Denmark	78 597	238	252
Plantagenet	447 382	4 415	5 100

References:

The above information has been extracted from the following technical report:

Evans F. (2001) *Mapping Salinity in the Mt Barker Landsat TM Scene,* CSIRO Mathematical and Information Sciences, CMIS Task Report No. 2/01, January 2001, http://www.landmonitor.wa.gov.au/reports/sm_reports/MTBfinalreport.pdf

4.11 Mullewa Scene

Validation, Accuracy and Limitations

The validation process followed the grid method used for other Land Monitor scenes. Maps of the final processed product (1997 salinity/low productivity) were produced for sample areas at 1:50000, and marked with a regular grid at 500m. This quantitative validation process was carried out in two sub-regions which included portions of all the three zones used.

In relation to the overall scene, these areas contained a relatively high proportion of land mapped as salt-affected.

For the two regions, the overall mapping accuracy is 96.3% and 97.1% respectively. Generally, errors of commission were noted in areas such as degraded bush in low lying areas, and in some highly reflective soils in the Irwin catchment. Errors of omission were observed at edges of mapped saline areas, or points mapped as thin bush due to their apparent cover of perennial vegetation.

Table 4.11.1: Area 1. Percent accuracy of mapped classes (*and errors of commission).

Image map label			
Ground label		Non saline	Saline
	Non saline	97	6*
	Saline	3*	94
	Total (%)	100	100

Table 4.11.2: Area 1. Percentage of ground classes actually mapped (*and errors of omission).

Image map label				
Ground label		Non saline	Saline	Total (%)
	Non saline	98	2*	100
	Saline	10*	90	100

Table 4.11.3: Area 2. Percent accuracy of mapped classes (*and errors of commission).

Image map label			
Ground label		Non saline	Saline
	Non saline	99	5*
	Saline	2*	95
	Total (%)	100	100

Table 4.11.4: Area 2. Percentage of ground classes actually mapped (*and errors of omission).

Image map label				
Ground label		Non saline	Saline	Total (%)
	Non saline	98	2*	100
	Saline	3*	97	100

Shire statistics

The salinity estimates may be aggregated to produce shire summaries. Table 4.11.5 provides a summary of the salinity status for the shires contained within the extents of the mapping. The table contains area estimates expressed in hectares (ha) as well as the percentage of each shire estimated to be saline and the rate of increase of these estimates. Note that the pastoral zone area has not been included in the mapping. Morawa and Mullewa shires have areas beyond the agricultural zone which are excluded from the area and percentage summaries in the table. Note that the entire agricultural area of these shires has been covered by the processed area

From the table we observe that the estimates of the extent of salinity are increasing for all shires, although at different rates.

Table 4.11.5: Salinity estimates summarised by shire for areas within the agricultural zone. Water mask areas are generally saline lakebeds. For Morawa and Mullewa shires, the processed area is the complete agricultural area within the shire boundaries.

Shire	Water mask ha (% of total processed area)	Saline 1991 ha (% of total processed area)	Saline 1997 ha (% of total processed area)	Total Area processed ha (% of total shire area)	Area Increase ha (% of total) (rate %)
Morawa	3816 (1.1)	20495 (6.7)	21573 (7.1)	304430 (87%)	1078 0.4 6.0
Mingenew	258 (0.1)	5247 (2.7)	5364 (2.8)	193606 (100%)	117 0.1 2.2
Mullewa	526 (0.1)	23456 (4.7)	24349 (4.9)	496264 (46%)	893 0.2 3.8

References:

The above information has been extracted from the following technical report:

Wallace J. F. and Bebbington D. (2001) *Mapping and Monitoring Salinity: the Mullewa Landsat TM scene (113-080)*, CSIRO Mathematical and Information Sciences, September 2001, Report Number: CMIS 2001/152,
http://www.landmonitor.wa.gov.au/reports/sm_reports/mullewa_salinity.doc

4.12 Newdegate (Lake Grace) Scene

Validation, Accuracy and Limitations

A quantitative assessment of the salinity maps for four test areas was performed. The accuracy assessments are based on a vehicle survey of sample points in the assessment areas. Assessment points were located using hardcopy 1:50,000 maps with a regular (500m) grid and a GPS.

Tables below summarize the rates of omission and commission for the western and eastern zones.

Assessment results for the western zone (test areas 1 and 2)

Table 4.12.1 : Site counts for assessment area 1 (Lake Bryde).

		Ground Label		
		Saline	Non-saline	Total
Image Map Label	Saline	12	1	13
	Non-saline	6	130	136
	Total	18	131	149

Table 4.12.2: Site counts for assessment area 2.

		Ground Label		
		Saline	Non-saline	Total
Image Map Label	Saline	60	1	61
	Non-saline	1	158	159
	Total	61	159	220

Table 4.12.3: Percentage accuracy and rates of omission for the western zone (combined from assessment areas 1 and 2).

		Ground Label	
		Saline	Non-saline
Image Map Label	Saline	91%	1%
	Non-saline	9%	99%
	Total	100%	100%

Table 4.12.4: Percentage accuracy and rates of commission for the western zone (combined from assessment areas 1 and 2).

		Ground Label		
		Saline	Non-saline	Total
Image Map Label	Saline	97%	3%	100%
	Non-saline	2%	98%	100%

Assessment results for the eastern zone (test areas 3 and 4)

Table 4.12.5: Site counts for assessment area 3

		Ground Label		
		Saline	Non-saline	Total
Image Map Label	Saline	10	8	18
	Non-saline	2	80	82
	Total	12	88	100

Table 4.12.6: Site counts for assessment area 4.

		Ground Label		
		Saline	Non-saline	Total
Image Map Label	Saline	102	6	108
	Non-saline	1	163	164
	Total	103	169	272

Table 4.12.7: Percentage accuracy and rates of commission for the eastern zone (combined from assessment areas 3 and 4).

		Ground Label		
		Saline	Non-saline	Total
Image Map Label	Saline	89%	11%	100%
	Non-saline	1%	99%	100%

Table 4.12.8: Percentage accuracy and rates of omission for the eastern zone (combined from assessment areas 3 and 4).

		Ground Label	
		Saline	Non-saline
Image Map Label	Saline	97%	5%
	Non-saline	3%	95%
	Total	100%	100%

Commission errors (non-saline land labelled as salt-affected) include the following:

- dam catchments. No dam mask was available for the assessment areas of the eastern zone (areas 3 and 4). Consequently many dam catchments have been classified as saline. These are typically small in area (1 - 2 pixels), and represent a small area in total;
- houses;
- gravel pits and
- some fence lines.

Sources of omission errors (salt-affected land not detected) are:

- sites where a saline area is detected, but the extent is underestimated (e.g. in flat areas where the salt-affected margins still support crop or pasture growth);
- sites with greater than 80% cover of salt-tolerant grasses such as barley grass;
- saline areas with a good cover of saltbush are not being labelled as salt-affected.

In addition, during the final assessment it was found that in the eastern zone light bush with patches of bare sandy soil were being classified as salt. This was only at a small number of points in the assessment areas 3 and 4. However, while the errors associated with dams were generally a few pixels in size, those associated with poor bush were sometimes much larger. In order to fix this a bush mask was used to mask out saline areas for the final product. This is described in a task reports held by CSIRO Mathematical and Information Sciences.

Area of Salt-affected Land

The table below shows the area of salt-affected land for the local government authority "Lake Grace," which is largely within the Newdegate Landsat TM scene. Such summaries can be calculated for any sub-region of interest within the scene.

Table 4.12.9: Percentage accuracy and rates of omission for the eastern zone (combined from assessment areas 3 and 4).

	Area in Pixels	Area in Hectares	Percentage of processed area
total	16354599	1022162	100
bush	3612979	225811	22
salt/low productive land 1991	1019095	63693	6.2
salt/low productive land 1997	1123295	69507	6.8
water	616697	38543	4.0

References:

The above information has been extracted from the following technical report:

Dunne R. and Beetson B. (2001) *Mapping and Monitoring Salinity: The Newdegate (Lake Grace) Landsat TM Scene (110/83)*, CSIRO Mathematical and Information Sciences, Agriculture Western Australia, Report Number: CMIS 2001/54, March 2001, www.landmonitor.wa.gov.au/reports/sm_reports/Newdegate_report.pdf

4.13 Perth Scene

Validation, Accuracy and Limitation

The data comprised validation of the class labels at fixed grid intervals of 500m. Two regions were considered.

For the two regions, the overall mapping accuracy is 95% and 98% respectively, although we observe that the mapping underestimates the extent of salinity. Generally, errors of commission include sites such as degraded bush in low lying areas, eroded catchments and new dams (dams not included in dam mask). Errors of omission include underestimates of the extent of hillside seeps, and sites which support productive plant growth.

Table 4.13.1: Area 1. Site counts obtained from field validation

		Image map label		
		Non saline	Saline	Total
Ground label	Non saline	98	1	99
	Saline	6	26	32
	Total	104	27	131

Table 4.13.2: Area 1. Percent accuracy of mapped classes (*and errors of commission).

		Image map label	
		Non saline	Saline
Ground label	Non saline	94	4*
	Saline	6*	96
	Total (%)	100	100

Table 4.13.3: Area 1. Percentage of ground classes actually mapped (*and errors of omission).

		Image map label		
		Non saline	Saline	Total (%)
Ground label	Non saline	99	1*	100
	Saline	19*	81	100

Table 4.13.4: Area 2. Site counts obtained from field validation.

		Image map label		
		Non saline	Saline	Total
Ground label	Non saline	864	6	870
	Saline	17	98	115
	Total	881	104	985

Table 4.13.5: Area 2. Percent accuracy of mapped classes (*and errors of commission).

		Image map label	
		Non saline	Saline
Ground label	Non saline	98	6*
	Saline	2*	94
	Total (%)	100	100

Table 4.13.6: Area 2. Percentage of ground classes actually mapped (*and errors of omission).

		Image map label		
		Non saline	Saline	Total (%)
Ground label	Non saline	99	1*	100
	Saline	15*	85	100

Shire statistics
The salinity estimates may be aggregated to produce shire summaries. Table 8 provides a summary of the salinity status for the shires fully contained within the extents of the mapping. The table contains area estimates expressed in hectares (ha) as well as the percentage of each shire estimated to be saline and the rate of increase of these estimates.

From the table we observe that the estimates of the extent of salinity are increasing for all shires, although at different rates.

It is also observed that the highest rate of increase is reported for the catchment with the lowest percentage of salinity (Chittering). The limited accuracy of the mapping and the relatively small area of salinity mapped in this (and like) catchment may combine to artificially inflate rates of change in these areas. The rate of change figures for such catchments should be used cautiously.

Table 4.13.7. Salinity estimates summarised by shire.

Catchment	Saline 1987 ha **(% of total)**	Saline 1995 ha **(% of total)**	Total Area ha	Area Increase ha **(% of total) (rate %)**
Cunderdin	13032 **(7.0)**	13395 **(7.2)**	186234	363 **0.2** **2.9**
Northam	2606 **(1.8)**	2732 **(1.9)**	143127	126 **0.08** **4.8**
York	4537 **(2.1)**	4736 **(2.2)**	213080	199 **0.09** **4.4**
Beverley	6296 **(2.7)**	6663 **(2.8)**	237118	367 **0.15** **5.8**
Chittering	538 **(0.4)**	702 **(0.6)**	121874	164 **0.13** **30.5**
Tooday	832 **(0.5)**	917 **(0.5)**	169285	85 **0.05** **10.2**

References:
The above information has been extracted from the following technical report:

Caccetta P. A.[1], Wallace[1] J.F., Beetson B. [2] and N. Crossley[2] (2002*) Mapping Salinity in the Perth Landsat TM scene (112-082)*, *Version 1.0,* CSIRO Mathematical and Information Sciences, [2]AgWest*,* 18 December 2000, CMIS Report Number 2000/203, http://www.landmonitor.wa.gov.au/reports/sm_reports/perthsummaryV1.0.pdf

4.14 Southern Cross Scene

Overall summary

The total area covered by the final products is 956,500 hectares. Of this, 2.03% was mapped as saline in 1991, and this figure increases to 2.35% in 1999. Some of the west and south of this area is overlapped by the salinity mapping products of the Kellerberrin and Newdegate scenes.

Accuracy Assessment

The overall accuracy according to comparison with field data is 96%. The commission error for the saline class was 11%, while omission errors were very low. Comments on the accuracy assessment and the recorded mapping errors are found in section 4 and 5 of this report. The field survey reported that extensive areas of samphire-covered land were correctly mapped as salt-affected.

Area of Salt-affected Land

It is usual in Land Monitor reports of this kind to report areas mapped as saline by Shire. However, no shires have a significant proportion of their area within the processed area. Hence a single table is provided for the area as a whole. Note that the 'mapped salt area' includes the water-covered areas, so no separate water figure is provided.

References:

The above information has been extracted from the following technical report:

Wallace J. (2003*) Mapping Salinity in the Southern Cross Landsat Scene*, CSIRO Mathematical and Information Sciences, CMIS Task Report No. 2003/15, February 2003, http://www.landmonitor.wa.gov.au/reports/sm_reports/SCR_salinity_monitoring.doc

4.15 **Ravensthorpe Scene**

Validation, Accuracy and Limitations

Salinity mapping accuracy was estimated from ground truth validation data.

The data comprised validation of the class labels at fixed grid intervals of 500m. The process was carried out in two sub-regions.

At each grid location the label of the map was compared with field checks. The two regions included in Area 1 are characterized by low occurrence of salt outbreaks, while in Area 2 the frequency of observed salt is higher. In order to calculate error rate statistics the counts for all areas were combined.

Different figures can be used to summarise mapping accuracy. The tables below show the accuracy and errors of commission and omission for each class.

Table 4.15.1: Area 1 site counts obtained from validation

		Image Classification Label		
		Salt	Non-salt	Total
Ground state	Salt	10	2	12
	Non-salt	5	282	287
	Total	15	284	299

Table 4.15.2: Area 2 site counts obtained from validation

		Image Classification Label		
		Salt	Non-salt	Total
Ground state	Salt	44	13	57
	Non-salt	1	400	401
	Total	45	413	458

Table 4.15.3: Combined site counts obtained from validation

		Image Classification Label		
		Salt	Non-salt	Total
Ground state	Salt	54	15	69
	Non-salt	6	682	688
	Total	60	697	757

Table 4.15.4: Percent accuracy of mapped classes (*commission errors)

		Image Classification Label	
		Salt	Non-salt
Ground state	Salt	90.00%	*2.15%
	Non-salt	*10.00%	97.85%
	Total	100.00%	100.00%

Table 4.15.5: Percent accuracy of ground classes (*omission errors)

		Image Classification Label		
		Salt	Non-salt	Total
Ground state	Salt	78.26%	*21.74%	100.00%
	Non-salt	*0.87%	99.13%	100.00%

Area 1 has very little saline land and only small areas are mapped. Area 2 has a higher proportion of salt. Taken together, the two areas are reasonably representative of the agricultural areas in the scene. The overall mapping accuracy is 97.7% in Area 1, 96.9% in Area 2, which when combined indicate 97.2% accuracy. When considered as a whole, the area of mapped salt has been slightly underestimated in the assessment areas. Generally, commission errors resulted from sites such as degraded bush in low lying areas, eroded catchments, new dams (dams not included in dam mask), and areas of low productivity being mislabelled as saline.

Shire statistics

The salinity estimates may be aggregated to produce shire summaries. Table 7 provides a summary of the salinity status for the shires intersected by the extents of the mapping. The table contains area estimates expressed in hectares (ha) as well as the percentage of each shire estimated to be saline.

From the table we observe that the estimates of the extent of salinity are increasing for both shires, although at different rates.

Table 4.15.6: Salinity estimates summarised for shires intersecting the Ravensthorpe scene.

Ravensthorpe			
Area of Shire	1 354 335.2 ha		
Area processed	489 850.7 ha	36.17%	of shire area
Shire processed area salt affected 1989	1 769.1 ha	0.36%	of area processed
Shire processed area salt affected 1997	3 684.3 ha	0.75%	of area processed
Agricultural area of shire	864 911.3 ha	63.86%	of shire area
Agricultural area processed	475 268.1 ha	54.95%	of agricultural area
Agricultural area processed salt affected 1989	1 740.1 ha	0.37%	of area processed
Agricultural area processed salt affected 1997	3 653.6 ha	0.77%	of area processed

References:

The above information has been extracted from the following technical report:
Meston J., (2001*) Mapping and Monitoring Salinity: the Ravensthorpe Landsat TM scene (109-083,* CSIRO Mathematical and Information Sciences, CMIS Report Number: 01/111, 6 July 2001, http://www.landmonitor.wa.gov.au/reports/sm_reports/ravsummary.doc

Summary of Image Dates Used

All data were rectified to the Land Monitor 1994 summer base created in April 1999.

Scene	Sensor	Date of capture (satellite overpass)
Fitzgerald Biosphere		
Bremer Bay Scene	TM	22 August 1990
	TM	12 September 1992
	TM	1 August 1994
	TM	22 August 1996
	TM	25 August 1997
Newdegate Scene	TM	22 August 1990
	TM	10 September 1991
	TM	1 August 1994
	TM	22 August 1996
	TM	25 August 1997
Ravensthorpe Scene	TM	31 August 1990
	TM	13 September 1989
	TM	26 August 1994
	TM	14 September 1995
Dumbleyung Scene		
	TM	10 August 1989
	TM	14 September 1990
	TM	8 September 1993
	TM	22 August 1994
	TM	14 October 1995
Bencubbin Scene		
	TM	29 September 1987
	TM	15 September 1988
	TM	20 August 1990
	TM	23 October 1990
	TM	23 August 1991
	TM	26 September 1992 (some cloud cover)
	TM	28 August 1993
	TM	15 August 1994
	TM	18 August 1995
	TM	21 September 1996
Collie – Pemberton Scene	TM	September 1996
	TM	September 1988
	TM	August 1998
	TM	August 1999
Esperance Scene		19 October 1987
		5 October 1988
		25 September 1990
		20 September 1994
		12 September 1997
		14 August 1998 30 August 1998
		18 September 1999
		12 September 2000
Jackson Scene	TM	23 August 1988
	TM	11 September 1989
	TM	14 September 1990
	TM	09 September 1994
	TM	27 August1995
	TM	1 September 1997
	TM	1 October 1999
Kalbarri-Geraldton Scene		September 1990
		August 1992
		August 1994
		September 1995

		August 1996
		August 1998
Kelleberrin Scene	TM	23 August 1988
	TM	10 August 1989
	TM	14 September 1990
	TM	23 September 1993
	TM	8 August1994
	TM	27 August 1995
	TM	29 August 1996
Moora Scene	TM	8 August 1989
	TM	12 September 1990
	TM	30 August 1991
	TM	19 August 1993
	TM	6 August 1994
	TM	10 September 1995
	TM	30 August 1997
	TM	20 August 1999
Mt Barker Scene	TM	10 August 1989
	TM	14 September 1990
	TM	22 September 1993
	TM	8 August 1994
	TM	14 October 1995
	TM	20 September 1998
Mullewa Scene	TM	12 September 1990
	TM	30 August 1991
	TM	19 August 1993
	TM	6 August 1994
	TM	25 August1995
	TM	30 August 1997
	TM	18 September 1998
	TM	12 August 1999
Perth Scene		
	MSS	9 August 1986
	MSS	28 August 1987
	TM	23 August 1991
	TM	2 August 1995
	TM	5 September 1996
	TM	22 July 1997
	TM	26 August 1998
Southern Cross Scene	TM	4 September 1989
	TM	25 August 1992
	TM	4 August 1995
	TM	25 August 1997
	TM	7 August 1999
	TM	10 September 2000
	TM	10 September 1991