DWLBC REPORT

Volumetric Conversion in the South East of South Australia: Calculation of the Crop Adjustment Factor

2006/32



Government of South Australia

Department of Water, Land and Biodiversity Conservation

Volumetric Conversion in the South East of South Australia: Calculation of the Crop Adjustment Factor

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FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

The Volumetric Conversion Project was a four-year project initiated in 2002 to facilitate the process of converting the existing area based water licences in the South East of South Australia to licences with a volumetric basis for allocation. The conversion approach was developed following a comprehensive community consultation process, using the best available science and extensive field data.

The conversion approach will be implemented through the review of Water Allocation Plans for the Padthaway, Tatiara and Lower Limestone Coast Prescribed Wells Areas that is being conducted by the South East Natural Resource Management Board. The reviewed Water Allocation Plans will define the arrangements for the issue of new volumetric allocations, taking into account the recommendations of this report, the sustainability of the resource and input from the stakeholder community.

Rob Freeman CHIEF EXECUTIVE DEPARTMENT OF WATER, LAND AND BIODIVERSITY CONSERVATION

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EXECUTIVE SUMMARY

Early in the consultation process associated with volumetric conversion, licensees raised concerns about the Crop Area Ratios (CARs) of certain crops and whether they provided sufficient water to grow those crops under the crop management practices currently used. In response to these concerns a review of the net irrigation requirements of all crops irrigated in the South East has identified a number of crops where, for a range of reasons, the existing Crop Area Ratios provide insufficient water.

The Crop Adjustment Factor is a one-off adjustment to the base allocation available to licensees growing eligible crops during the period of eligibility 2002–03 to 2004–05. The Crop Adjustment Factor will provide affected licensees with sufficient allocation to continue growing these crops 'post conversion'.

This report describes the methodology used to calculate the Crop Adjustment Factors and details eligible crops and Crop Adjustment Factors that will apply for each of the 73 unconfined groundwater management areas. Table 1 below details the crops eligible for a Crop Adjustment Factor listed by Prescribed Wells Area.

Tatiara	Lower Limestone Coast	Padthaway		
Beans – Broad/Faba	Coriander	Perennial Clover Seed		
Chinese Cabbage Seed	Fruit Trees Coriander			
Perennial Clover Seed	Maize	Onions		
Coriander	Native Flowers	Grass Seed		
Fruit Trees	Native Foliage			
Maize	Onions			
Onions	Grass Seed			
Lupins				
Mustard				
Peas – Field				
Potatoes				
Native Flowers				
Native Foliage				

 Table 1.
 Crops that are eligible for the CAF (listed by Prescribed Wells Area)

1. INTRODUCTION

1.1 GENERAL INTRODUCTION

The Volumetric Conversion Project was initiated in 2002 to facilitate the process of converting 2500 area based water licences in the South East of South Australia to licences with volumetric allocations.

The volumetric conversion process will be implemented through the review of Water Allocation Plans, due for finalisation in late 2006. Over the past four years the Project has developed a model that describes the proposed process for conversion using an iterative process of consultation and amendment with input from the stakeholder community.

The proposed conversion model is shown below (Fig. 1). All licensees will receive a Base Allocation and a Delivery Component. The base allocation provides for crop irrigation requirements (Skewes 2006). Some licensees may also be eligible for a Crop Adjustment Factor that provides additional base allocation for licensees where, due to initial calculation problems, the existing area based system does not provide adequate allocation.

The delivery component is the volume of water needed in excess of the crop irrigation requirements to account for irrigation system losses (evaporation losses, deep drainage etc.). In certain crop production systems it is necessary to use water for other activities, this water will be provided through the Specialised Production Requirements model component. The Bridging volume is an additional temporary water allocation designed to give irrigators who are currently pumping in excess of their new volumetric allocation time to adjust to the new system. The Specialised Production Requirements and Bridging Volume model components will be available on application, subject to meeting eligibility criteria.



This report describes the methodology and volumetric allocations for the Crop Adjustment Factor (an element of the base allocation for licensees growing eligible crops). Other reports (listed in 'Associated Reports') detail the calculation of the base allocation, delivery component, specialised production requirements and bridging volume. A report has also been published on the community consultation processes used in this project.

1.2 INTRODUCTION TO CROP ADJUSTMENT FACTOR

As described by Skewes (2006), allocations under the area-based allocation system are based on the Irrigation Requirements (IR) of the Reference Crop. The unit of allocation is the Irrigation Equivalent (IE), defined as the IR of 1ha of Reference Crop.

Crop Area Ratios (CAR) were determined as the ratio of IR for the Reference Crop (IR_o) to IR for the range of crops being irrigated. For example, in Tatiara Prescribed Wells Area, the current Reference Crop IR is 6.34 ML/ha, and IR for Subterranean Clover is 3.61 ML/ha. The resultant CAR for Subterranean Clover is 6.34/3.61 = 1.8. This means that for each IE on a licence, the licensee can irrigate 1.8 ha of Subterranean Clover.

Early in the consultation process associated with volumetric conversion, licensees raised concerns about the CARs of certain crops and whether they provided sufficient water to continue to grow those crops following volumetric conversion. In response to these concerns and as part of the volumetric conversion process the theoretical crop water requirement of all crops grown in the South East has been re-calculated using the latest scientific methodology (Skewes, 2006). The review has identified a number of crops where, for a range of reasons, the existing Crop Area Ratios provide insufficient water.

Under the volumetric allocation system irrigators will be assessed according to the volume of water they pump, whereas under the current system they are assessed according to the area of crop they grow. Given that irrigators have put in place infrastructure to irrigate a certain area of crop under the current system, one of the principles of conversion relates to protection of water access rights. Under this principle, the allocation should be sufficient to enable the irrigator to continue to irrigate their current area of crop, rather than being penalised because the crop they grow was poorly understood when the CAR's were established.

The Crop Adjustment Factor is a one-off adjustment to the base allocation available to licensees who have grown eligible crops during the period of eligibility 2002–03 to 2004–05. The Crop Adjustment Factor will provide affected licensees with sufficient allocation to continue growing these crops 'post conversion', under the conversion principle that irrigators should be able to continue to do what they legitimately did before conversion.

2. OBJECTIVE

To develop a methodology for the determination of Crop Adjustment Factors to apply to licensees growing crops where the existing Crop Area Ratios provide insufficient allocation for the crop management practices currently being utilised.

3. METHODOLOGY

3.1 CALCULATION OF NET IRRIGATION REQUIREMENTS

Eighteen workshops were conducted in August/September 2002 at various venues throughout the South East to collect data on crop calendars for the range of crops grown in the Region as part of the process of reviewing crop water requirements. The crop calendars provided data on the crop management practices being utilised at that time, the timing of crops events and the development of ground cover across the season (Skewes, 2006). Summary crop calendars were derived for each distinct crop and displayed for 'checking' at 18 workshops held at similar venues in 2003.

Skewes (2006) used the methodology of Allen et al. (1998) to calculate net irrigation requirement for the reference crop (NIRo) and net irrigation requirement for each crop grown (NIRc) for each of the 10 climatic bands that have been developed to represent the range of evapotranspiration and rainfall across the South East. Results are shown in Table 2.

3.2 CALCULATION OF CROP ADJUSTMENT FACTOR

To determine whether a Crop Adjustment Factor should apply to a particular crop it is necessary to calculate the difference between the ratio of new NIR_o and NIR_c values as determined by Skewes (2006) and the existing Irrigation Equivalent and Crop Area Ratio system. An example of this calculation using Perennial Clover Seed in Padthaway is shown in Appendix A.

Table 3 shows the results of this calculation for all crops grown in the South East averaged across Prescribed Wells Areas. Values near or below zero indicate that the ratio of NIR_o:NIR_c is similar to or less than the ratio of IR_o:IR_c (represented by the current CAR) and therefore conversion of IE's to NIR_o will provide sufficient water to meet NIR for these crops. Values above zero indicate that the ratio of NIR_o:NIR_c is lower than the ratio of IR_o:IR_c, and these crops, on average, require more water than indicated by the current CAR, and provided by the conversion of IE's to NIR_o.

It has been determined that Crop Adjustment Factors should apply where the comparison between the NIR₀:NIR_c and IR₀:IR_c is such that a proportional increase of greater than a nominal 5% in the base allocation is required for the licensees to continue to meet the NIR of the crop in the future. The Crop Adjustment Factor will also only apply where the licensee has grown the crops over the period 2002–03 to 2004–05. Table 4 details crops eligible for a crop adjustment factor that have been grown in the respective Prescribed Wells Area within the period of eligibility together with the Crop Adjustment Factor that would apply per hectare of crop grown averaged over the Prescribed Wells Area.

There are 73 unconfined groundwater management areas that are used as the basis for groundwater management arrangements in the South East. CARs often differ from management area to management area for the same crop. This has come about as a result of the method of determination of CARs and IEs as each new Prescribed Wells Area came into existence and the gradual refinement of methodology over time. Consequently Crop Adjustment Factors may also differ from management area to management area.

Сгор	Band 1A	Band 2A	Band 3A	Band 4A	Band 5A	Band 6A/1	Band 6A/2	Band 7A	Band 8A	Band 9A
Reference crop*	490	508	549	584	615	640	670	726	766	818
Beans – Broad/Faba	97	102	109	120	131	133	142	151	161	180
Canola*	43	49	61	23	34	40	49	62	75	92
Carrot Seed**	200	209	225	241	256	263	281	306	325	353
Cereals*	57	62	71	84	97	99	109	118	130	152
Chinese Cabbage Seed	113	118	125	136	148	150	160	169	178	198
Clover Seed – Annual	162	168	179	193	207	209	223	237	250	277
Clover Seed – Perennial	320	334	363	390	421	437	465	508	541	583
Clover Seed – Subterranean	177	183	194	208	223	225	240	260	276	304
Coriander	171	177	189	203	217	221	236	256	271	301
Fruit Trees*	396	413	450	476	496	514	537	573	595	629
Grass Seed	309	316	334	352	368	373	394	420	441	477
Lucerne Hay/Graze*	340	352	384	408	428	443	463	494	515	550
Lucerne Seed*	248	259	286	309	329	338	357	381	402	438
Lupins	98	103	110	121	132	134	143	152	161	181
Maize	480	487	516	533	544	561	576	604	619	647
Mustard	115	119	126	133	142	141	151	161	169	189
Native Flowers*	202	210	235	252	265	275	288	306	318	341
Native Foliage*	84	90	108	123	135	145	155	172	183	199
Olive – Fresh*	261	277	309	333	355	370	389	420	442	477
Olive – Oil*	226	241	271	293	312	325	343	369	390	422
Onion	482	492	524	547	564	582	599	630	649	683
Onion Seed	309	316	338	355	371	378	396	420	438	471
Pasture	453	468	501	528	550	566	588	620	644	679
Pasture – Half	174	180	193	207	220	222	237	252	268	294
Pasture – Starter/Finisher	25	29	36	45	54	55	63	74	86	103
Pasture – Max. Production	603	619	657	686	711	731	756	800	827	869
Peas – Field	77	81	88	98	109	110	119	127	134	152
Potatoes	416	423	449	468	483	494	512	538	554	589
Potatoes – Seed	283	287	306	316	323	333	341	360	368	386
Radish Seed	110	115	126	139	152	153	165	180	194	217
Summer Fodder	244	254	279	295	307	319	331	351	365	383
Sunflower	301	308	331	343	351	365	373	394	404	422
Sweetcorn	321	325	346	357	363	376	383	403	412	430
Winegrape*	156	165	189	205	218	226	242	261	274	296

Table 2. NIR_o and NIR_c values for each of the 10 climatic bands

* = Allowance of 50 mm stored soil water (Wb), and Effective Rainfall calculated for 50 mm RAW – applicable to deeper rooted perennial crops (Reference Crop, Fruit Trees, Lucerne, Native Flowers and Foliage, Olives and Winegrapes) as well as Canola and Cereals. All other crops calculated using Wb = 20 mm and Effective Rainfall calculated for 20 mm RAW.

** = Carrot seed is grown over two irrigation seasons, with some overlap between harvest of one crop and the sowing of the next crop. As a result, the water requirement for a crop of carrot seed is spread over two irrigation seasons. The NIR figures here represent 70% of the total NIR for a carrot seed crop, which is sufficient to cover the irrigation requirements in the second season, and more than enough for the first season.

Average CAF (extra IE's per licensed IE)	Lower Limestone Coast PWA	Padthaway PWA	Tatiara PWA
Beans – Broad/Faba	-0.10	-0.11	0.34
Canola	-0.62	-0.69	-0.14
Carrot Seed	-0.05	0.72	-0.02
Cereals	-0.40	-0.33	-0.19
Chinese Cabbage Seed	-0.12	0.00	1.05
Clover Seed – Annual	-0.07	-0.03	-0.21
Clover Seed – Perennial	-0.02	0.11	0.13
Clover Seed – Subterranean	-0.02	-0.14	-0.35
Coriander	0.81	0.06	2.12
Fruit Trees	0.32	0.44	0.40
Grass Seed	0.02	0.12	-0.07
Lucerne Hay/Graze	-0.12	-0.31	-0.26
Lucerne Seed	-0.21	-0.31	-0.37
Lupins	-0.09	-0.10	0.35
Maize	0.66	0.55	0.78
Mustard	0.19	-0.05	0.95
Native Flowers	1.66	1.58	1.47
Native Foliage	0.30	0.39	0.41
Olive – Fresh	-0.17	-0.13	-0.13
Olive – Oil	-0.27	-0.23	-0.23
Onion	0.17	0.16	0.53
Onion Seed	-0.11	-0.23	0.04
Pasture	-0.10	-0.12	-0.07
Pasture – Half	-0.29	-0.29	-0.26
Pasture – Starter/Finisher	-0.39	-0.30	-0.29
Pasture – Maximum Production	0.17	0.13	0.19
Peas – Field	-0.26	-0.25	0.12
Potatoes	-0.05	-0.01	0.24
Potatoes – Seed	-0.36	-0.34	-0.18
Radish Seed	-0.06	0.03	0.30
Summer Fodder	-0.09	-0.11	-0.19
Sunflower	-0.02	-0.11	-0.05
Sweetcorn	-0.13	-0.03	-0.24
Winegrape	-0.09	-0.02	-0.21

Table 3.	Calculated difference between the ratio of NIR _o :NIR _c in comparison to IR _o :	IR _c
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Average CAF (extra IE's per IE of crop grown)	Lower Limestone Coast PWA	Padthaway PWA	Tatiara PWA
Beans – Broad/Faba			0.34
Carrot Seed		0.72	
Chinese Cabbage Seed			1.05
Clover Seed – Perennial		0.11	0.13
Coriander	0.81	0.06	2.12
Fruit Trees	0.32	0.44	0.40
Grass Seed		0.12	
Lupins			0.35
Maize	0.66	0.55	0.78
Mustard	0.19		0.95
Native Flowers	1.66	1.58	1.47
Native Foliage	0.30	0.39	0.41
Onion	0.17	0.16	0.53
Peas – Field			0.12
Potatoes			0.24
Radish Seed			0.30

Table 4. Crop Adjustment Factor per IE of Crop Grown Averaged over Prescribed Wells Areas

It should be noted that the data in Table 3 and Table 4 provides average values only across each of the Prescribed Wells Areas and should not be used to calculate Crop Adjustment Factors to apply to individual licenses or individual management areas. Crop Adjustment Factors (extra IEs per HaIE of crop grown) that are applicable for each eligible crop for each of the 73 management areas are tabulated in Appendix B.

It is also possible to calculate the Crop Adjustment Factor in megalitres (ML) per hectare of crop grown. Crop Adjustment Factors (extra MLs per Ha of crop grown) that are applicable for each eligible crop for each of the 73 management areas are tabulated in Appendix C.

Licensees with confined aquifer licenses will be assigned to applicable unconfined groundwater management areas according to the location of their licence centroid point.

4. REASONS FOR APPLICATION OF CAF

For each of the crops in Table 4 there are different issues leading to the need for a CAF. These issues are summarised below.

4.1 BEANS – BROAD/FABA, CHINESE CABBAGE SEED, LUPINS, PEAS – FIELD, POTATOES AND RADISH SEED

For a number of crops there is a CAF available in Tatiara PWA only. This reflects a significant difference in the current CAR's for these crops between Tatiara and the other PWA's. This reflects a low Irrigation Requirement calculated for these crops when Tatiara PWA was prescribed, and results in insufficient water when IE's are converted at the base NIR₀ for Climatic Bands 7A–9A, whereas the CAR's in the other PWA's provide sufficient water when converted.

The CAR's for these crops in the different PWA's are set out in Table 5. The differences reflect the development in understanding of crop water requirements for these crops in the time between prescription of Tatiara PWA (the first PWA prescribed), and prescription of the other PWA's.

Although there is a CAF for Radish Seed, there are no records of Radish Seed being grown in Tatiara PWA in the Annual Water Use Returns (AWUR's) during the three year eligibility period, and therefore it is not expected that any CAF for Radish Seed will be issued.

	Tatiara PWA	Padthaway PWA	Lower Limestone Coast PWA
Beans – Broad/Faba	6.3	4.2	3.9–5.0
Chinese Cabbage Seed	8.7	4.2	3.5–4.1
Lupins	6.3	4.2	3.9–5.0
Peas – Field	6.3	4.2	3.9–5.0
Potatoes	1.7	1.3	1.1–1.3
Radish Seed	5.1	4.2	3.6-4.2

Table 5.Comparison of Crop Area Ratios for Selected Crops across the
Prescribed Wells Area.

4.2 CARROT SEED

The CAF for Carrot Seed in Padthaway reflects a very high CAR in Padthaway PWA (4.1, compared to 2.3 in all other PWA's). However, there are no records in the AWUR's during the three year eligibility period of Carrot Seed being grown in Padthaway PWA, so it is not expected that any CAF for Carrot Seed will be issued.

4.3 CLOVER SEED – PERENNIAL

A CAF is available for Perennial Clover Seed in both Tatiara and Padthaway PWA's. Although the difference in CAR between the three PWA's is minor (1.6 in Tatiara and Padthaway, 1.4–1.5 in Lower Limestone Coast), it is enough to result in a requirement for additional water in the former two PWA's, albeit a small amount (11 and 13% respectively).

4.4 CORIANDER

A CAF is available for Coriander across all three PWA's. The amount of CAF varies between PWA's, as a result of different CAR's (8.7 in Tatiara, 3.0 in Padthaway, and 4.5–5.9 in Lower Limestone Coast). This variation reflects different understanding of the irrigation requirements of this crop at the time each PWA was prescribed. When the crop calendar and irrigation requirements for Coriander were reviewed for volumetric conversion, they were found to be most like the original figures for Padthaway.

4.5 FRUIT TREES

The initial CAR's for fruit trees were derived for the varieties present at the time of prescription. Since then, there have been additional varieties planted, in some cases with higher water requirements. In order to cover the range of fruit trees irrigated, the crop calendar used to calculate NIR_c reflects the longest growing season likely, and the crop coefficients are based on Pomefruit, the highest fruit tree category.

No reports of Fruit Tree irrigation have been received from Padthaway PWA in the AWUR's during the three year eligibility period, and it is not expected that any CAF for Fruit Trees will be issued in that PWA.

4.6 GRASS SEED

The Grass Seed CAF is again the result of differences in CAR. The CAR for Padthaway (1.9) is higher than in the other PWA's (1.6 in Tatiara, 1.7 in Lower Limestone Coast). The difference in CAR is small, and the resultant CAF is also small (12%).

4.7 MAIZE

The CAF for Maize reflects a small change in crop calendar for Maize, as well as a revision of crop coefficients used. The initial calculation of CAR's at prescription of the PWA's utilised crop coefficients from (Doorenbos and Pruitt, 1977). (Allen, Pereira, Raes, and Smith, 1998) reviewed these coefficients, and it was these revised coefficients that were used in the volumetric conversion project. The crop coefficients for Maize changed slightly between (Doorenbos and Pruitt, 1977) and (Allen et al., 1998), and combined with the modified calendar, this resulted in an increase in irrigation requirement.

No reports of Maize irrigation in Padthaway in the AWUR's during the three year eligibility period suggest that no CAF for Maize will be issued in that PWA.

4.8 MUSTARD

The current CAR for Mustard in Tatiara PWA (8.7) is much higher than in Padthaway (4.2), while the CAR's in the Lower Limestone Coast PWA are between these two extremes (4.5–5.9), resulting in a CAF for Tatiara, and a smaller CAF for some areas of Lower Limestone Coast, although there are no current records of Mustard irrigation in that region.

4.9 NATIVE FLOWERS AND NATIVE FOLIAGE

Very little information about irrigation requirements of native Australian plants was available when the CAR's were calculated. The information that was available indicated that these plants are very hardy, and will survive with very little irrigation, and so the CAR's were set very high (5.9–7.4). These CAR's reflect an estimated Irrigation Requirement of 70 mm per year (in the original PWA's of Naracoorte Ranges and Comaum Caroline, now part of Lower Limestone Coast).

More recently, the Western Australian Department of Agriculture has carried out research into the irrigation requirements of native plants, and has published crop factors (similar to crop coefficients) for a range of native plant families. This research has shown that although native plants can survive on very small amounts of irrigation, they produce optimum marketable product (flowers, fruit or vegetative growth) when much more water is applied.

Irrigators growing native plants in the South East PWA's are doing so in order to produce and sell marketable produce, and therefore need access to more water than minimum survival requirements. The published crop factors were used to derive crop coefficients for Native Flower production and Native Foliage production, from which NIR_c for these two crops was calculated.

The lack of any reports of Native Flower or Foliage irrigation in the Padthaway PWA suggest that no CAF for will be issued for these crops in that PWA.

4.10 ONION

The CAR's for Onion irrigation vary, with Tatiara (1.8) again being higher than the other PWA's (1.2 in Padthaway, 1.2–1.3 in Lower Limestone Coast). However, when crop calendars were derived for the volumetric conversion, it was found that there was a range in planting dates, resulting in a range in NIR_c for Onions. In order to provide sufficient water to all irrigators, a calendar producing higher NIR_c figures has been adopted, resulting in a CAF being made available to all Onion irrigators.

4.11 OTHER CROPS

One crop not represented in Table 4 is Pasture – Maximum Production. This crop is not recognised under Crop Adjustment Factors, it is dealt with under Specialised Production Requirements (Pudney, 2006?). One of the definitions of Specialised Production Requirements is "Water that is required in addition to base allocation due to significant changes in the crop production system (as recognised by FAO 56)".

FAO 56 (Allen et al., 1998) introduces a broader definition of Pasture crops, which includes definition between Extensive Grazing and Rotated Grazing, along with a range of water use within Rotated Grazing, the upper limit of which is beyond the water use of the Pasture category in (Doorenbos and Pruitt, 1977). This then represents a "Significant change in the crop production system", and for this reason the additional water required by Pasture – Maximum Production will be allocated as a Specialised Production Requirement, not as a Crop Adjustment Factor.

A. CALCULATION AND APPLICATION OF THE CROP ADJUSTMENT FACTOR USING PERENNIAL CLOVER SEED IN PADTHAWAY PRESCRIBED WELLS AREA AS AN EXAMPLE

Area-Based Prescription	Volumetric Conversion
Crop Adjustment Factor for P	erennial Clover Seed in Padthaway PWA
IE (or IRo) = 5.92 ML/ha	NIRo = 6.70 ML/ha
IRc = 3.71 ML/ha	NIRc = 4.65 ML/ha
Let $A = IRo/IRc = 1.60$	Let B = NIRo/NIRc = 1.44
It means that 1.6 ha of perennial clover seed can be grown with area-based prescription	It means that 1.4 ha of perennial clover seed can be grown with volumetric conversion
Therefore CAF	= ((A - B)/B)
	= ((1.6 - 1.44)/1.44)
	= 0.11 or 11%

B. CROP ADJUSTMENT FACTOR BY MANAGEMENT AREA (EXTRA IES PER HAIE OF CROP GROWN)

Management Area*	Beans broad/ faba	Carrot seed	Chinese cabbage seed	Clover seed perrennial	Coriander	Grass seed	Fruit trees	Lupins	Maize	Mustard	Native flowers	Native foliage	Onion	Peas field	Potatoes
Bangham					0.59		0.44		0.46		2.18	0.71	0.16		
Beeamma					0.59		0.44		0.46		2.18	0.71	0.16		
Benara					1.06	0.07	0.21		0.96	0.38	1.43		0.18		
Blanche Central					1.06	0.07	0.21		0.96	0.38	1.43		0.18		
Bool					0.59		0.45		0.50		2.19	0.62	0.19		
Bowaka					0.87		0.13		0.68	0.22	1.54	0.30	0.10		
Bray					0.96		0.23		0.79	0.31	1.53	0.16	0.15		
Cannawigara	0.32		1.02	0.13	2.08		0.40	0.32	0.78	0.92	1.45	0.41	0.53	0.10	0.23
Coles					0.84		0.14		0.73	0.21	1.55	0.24	0.12		
Comaum					0.95		0.22		0.73	0.28	1.55	0.24	0.22		
Compton					1.06	0.07	0.21		0.96	0.38	1.43		0.18		
conmurra					0.84		0.14		0.73	0.21	1.55	0.24	0.12		
Donovans					0.95	0.07	0.21		0.86	0.31	1.43		0.28		
Duffield					0.66		0.44		0.46	0.06	1.54	0.36	0.07		
Fox					0.84		0.14		0.73	0.21	1.55	0.24	0.12		
Frances					0.55		0.45		0.49		2.18	0.68	0.18		
Glenburnie					0.95	0.07	0.21		0.86	0.31	1.43		0.28		
Glenroy					0.95		0.22		0.73	0.28	1.55	0.24	0.22		
Grey					0.99	0.06	0.22		0.82	0.34	1.44		0.16		
Hacks					0.59		0.45		0.50		2.19	0.62	0.19		
Hindmarsh					1.06	0.07	0.21		0.96	0.38	1.43		0.18		
Hynam East					0.55		0.45		0.49		2.18	0.68	0.18		
Hynam West					0.55		0.45		0.49		2.18	0.68	0.18		
Joanna					0.56		0.47		0.55		2.19	0.56	0.22		
Joyce					0.76		0.45		0.50	0.15	1.54	0.30	0.19		
Kennion					0.96		0.23		0.79	0.31	1.53	0.16	0.15		
Killanoola					0.84		0.14		0.73	0.21	1.55	0.24	0.12		
Kongorong					1.06	0.07	0.21		0.96	0.38	1.43		0.18		
Lacepede					0.76		0.45		0.50	0.15	1.54	0.30	0.19		
Lake George					1.03		0.23		0.88	0.35	1.53	0.16	0.15		
Landseer					0.66		0.44		0.46	0.06	1.54	0.36	0.07		
Lochaber					0.62		0.45		0.49		1.54	0.34	0.09		
Macdonnell					1.06	0.07	0.21		0.96	0.38	1.43		0.18		
Management Area 1 (MA1)		0.72		0.11	0.06	0.12	0.44		0.55		1.58	0.39	0.16		
Management Area 2 (MA2)		0.72		0.11	0.06	0.12	0.44		0.55		1.58	0.39	0.16		

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Management Area*	Beans broad/ faba	Carrot seed	Chinese cabbage seed	Clover seed perrennial	Coriander	Grass seed	Fruit trees	Lupins	Maize	Mustard	Native flowers	Native foliage	Onion	Peas field	Potatoes
Management Area 3 (MA3)		0.72		0.11	0.06	0.12	0.44		0.55		1.58	0.39	0.16		
Management Area 4 (MA4)		0.72		0.11	0.06	0.12	0.44		0.55		1.58	0.39	0.16		
Marcollat					0.66		0.44		0.46	0.06	1.54	0.36	0.07		
Mayurra					1.06	0.06	0.22		0.92	0.38	1.44		0.16		
Minecrow					0.76		0.45		0.50	0.15	1.54	0.30	0.19		
Monbulla					0.96		0.23		0.79	0.31	1.53	0.16	0.15		
Moorak					1.06	0.07	0.21		0.96	0.38	1.43		0.18		
Mount Benson					0.87		0.13		0.68	0.22	1.54	0.30	0.10		
Mount Muirhead					1.06	0.06	0.22		0.92	0.38	1.44		0.16		
Moyhall					0.59		0.45		0.50		2.19	0.62	0.19		
Murrabinna					0.76		0.45		0.50	0.15	1.54	0.30	0.19		
Myora					0.95	0.07	0.21		0.86	0.31	1.43		0.28		
North Pendleton	0.32		1.02	0.13	2.08		0.40	0.32	0.78	0.92	1.45	0.41	0.53	0.10	0.23
Ormerod					0.59		0.45		0.50		2.19	0.62	0.19		
Peacock					0.62		0.45		0.49		1.54	0.34	0.09		
Riddoch					1.06	0.06	0.22		0.92	0.38	1.44		0.16		
Rivoli Bay					1.06	0.06	0.22		0.92	0.38	1.44		0.16		
Ross					0.98		0.22		0.73	0.30	1.55	0.24	0.12		
Shaugh	0.39		1.11	0.14	2.20		0.38	0.39	0.74	1.01	1.46	0.44	0.50	0.17	0.22
Short					0.96		0.23		0.79	0.31	1.53	0.16	0.15		
Smith					0.96		0.23		0.79	0.31	1.53	0.16	0.15		
Spence					0.66		0.45		0.50	0.09	1.54	0.30	0.10		
Stewarts					0.59		0.45		0.50		2.19	0.62	0.19		
Stirling	0.32		1.02	0.13	2.08		0.40	0.32	0.78	0.92	1.45	0.41	0.53	0.10	0.23
Struan					0.56		0.47		0.55		2.19	0.56	0.22		
Symon					1.06	0.06	0.22		0.92	0.38	1.44		0.16		
Tatiara	0.31		1.03	0.12	2.07		0.42	0.32	0.83	0.93	1.49	0.40	0.56	0.10	0.26
Townsend					0.87		0.13		0.68	0.22	1.54	0.30	0.10		
Waterhouse					0.98		0.22		0.73	0.30	1.55	0.24	0.12		
Western Flat					0.59		0.42		0.41		2.12	0.75	0.13		
Willalooka (east)	0.31		1.03	0.12	2.07		0.42	0.32	0.83	0.93	1.49	0.40	0.56	0.10	0.26
Willalooka (west)	0.31		1.03	0.12	2.07		0.42	0.32	0.83	0.93	1.49	0.40	0.56	0.10	0.26
Wirrega (south)	0.31		1.03	0.12	2.07		0.42	0.32	0.83	0.93	1.49	0.40	0.56	0.10	0.26
Wirrega (north)	0.32		1.02	0.13	2.08		0.40	0.32	0.78	0.92	1.45	0.41	0.53	0.10	0.23
Woolumbool					0.73		0.45		0.49	0.10	1.54	0.34	0.18		
Young					1.06	0.07	0.21		0.96	0.38	1.43		0.18		

Management Area*	Beans broad/ faba	Carrot seed	Chinese cabbage seed	Clover seed perrennial	Coriander	Grass seed	Fruit trees	Lupins	Maize	Mustard	Native flowers	Native foliage	Onion	Peas field	Potatoes
Zone 2A					0.95	0.06	0.22		0.82	0.31	1.44		0.26		
Zone 3A					0.93		0.23		0.79	0.29	1.53	0.16	0.24		
Zone 5A					0.59		0.45		0.50		2.19	0.62	0.19		
Zone 8A	0.32		1.02	0.13	2.08		0.40	0.32	0.78	0.92	1.45	0.41	0.53	0.10	0.23

* Note – See Figure 2 in Appendix D for location of Management Areas

C. CROP ADJUSTMENT FACTOR BY MANAGEMENT AREA (EXTRA ML PER HA OF CROP GROWN)

Management Area*	Beans broad/ faba	Carrot seed	Chinese cabbage seed	Clover seed perrennial	Coriander	Fruit trees	Grass seed	Lupins	Maize	Mustard	Native flowers	Native foliage	Onion	Peas field	Potatoes
Bangham					0.87	1.65			1.82		1.97	0.64	0.84		
Beeamma					0.87	1.65			1.82		1.97	0.64	0.84		
Benara					0.88	0.55	0.21		2.35	0.32	1.19		0.74		
Blanche Central					0.88	0.55	0.21		2.35	0.32	1.19		0.74		
Bool					0.80	1.54			1.82		1.82	0.52	0.91		
Bowaka					1.01	0.44			2.20	0.26	1.61	0.31	0.52		
Bray					0.93	0.70			2.27	0.30	1.42	0.15	0.67		
Cannawigara	0.39		0.90	0.62	1.83	1.69		0.39	2.71	0.81	1.88	0.53	2.23	0.12	1.03
Coles					0.93	0.46			2.26	0.23	1.53	0.24	0.60		
Comaum					0.99	0.72			2.26	0.29	1.53	0.24	0.98		
Compton					0.88	0.55	0.21		2.35	0.32	1.19		0.74		
Conmurra					0.93	0.46			2.26	0.23	1.53	0.24	0.60		
Donovans					0.84	0.58	0.21		2.22	0.28	1.19		1.05		
Duffield					0.93	1.65			1.82	0.08	1.74	0.41	0.41		
Fox					0.93	0.46			2.26	0.23	1.53	0.24	0.60		
Frances					0.79	1.58			1.85		1.89	0.59	0.90		
Glenburnie					0.84	0.58	0.21		2.22	0.28	1.19		1.05		
Glenroy					0.99	0.72			2.26	0.29	1.53	0.24	0.98		
Grey					0.88	0.62	0.17		2.20	0.30	1.24		0.69		
Hacks					0.80	1.54			1.82		1.82	0.52	0.91		
Hindmarsh					0.88	0.55	0.21		2.35	0.32	1.19		0.74		
Hynam East					0.79	1.58			1.85		1.89	0.59	0.90		
Hynam West					0.79	1.58			1.85		1.89	0.59	0.90		
Joanna					0.73	1.52			1.89		1.73	0.44	0.98		
Joyce					0.94	1.54			1.82	0.19	1.61	0.31	0.91		
Kennion					0.93	0.70			2.27	0.30	1.42	0.15	0.67		
Killanoola					0.93	0.46			2.26	0.23	1.53	0.24	0.60		
Kongorong					0.88	0.55	0.21		2.35	0.32	1.19		0.74		
Lacepede					0.94	1.54			1.82	0.19	1.61	0.31	0.91		
Lake george					0.96	0.66			2.42	0.33	1.42	0.15	0.67		
Landseer					0.93	1.65			1.82	0.08	1.74	0.41	0.41		
Lochaber					0.85	1.58			1.85		1.67	0.37	0.49		
Macdonnell					0.88	0.55	0.21		2.35	0.32	1.19		0.74		
Management Area 1 (MA1)		1.18		0.46	0.13	1.65	0.41		2.04		1.76	0.43	0.84		
Management Area 2 (MA2)		1.18		0.46	0.13	1.65	0.41		2.04		1.76	0.43	0.84		
Management Area 3 (MA3)		1.18		0.46	0.13	1.65	0.41		2.04		1.76	0.43	0.84		

Management Area*	Beans broad/ faba	Carrot seed	Chinese cabbage seed	Clover seed perrennial	Coriander	Fruit trees	Grass seed	Lupins	Maize	Mustard	Native flowers	Native foliage	Onion	Peas field	Potatoes
Management Area 4 (MA4)		1.18		0.46	0.13	1.65	0.41		2.04		1.76	0.43	0.84		
Marcollat					0.93	1 65			1 82	0.08	1 74	0 41	0 41		
Mavurra					0.91	0.59	0.17		2.33	0.33	1.24	0.11	0.69		
Minecrow					0.94	1.54	0		1.82	0.19	1.61	0.31	0.91		
Monbulla					0.93	0.70			2.27	0.30	1.42	0.15	0.67		
Moorak					0.88	0.55	0.21		2.35	0.32	1.19	00	0.74		
Mount Benson					1.01	0.44	0		2.20	0.26	1.61	0.31	0.52		
Mount Muirhead					0.91	0.59	0.17		2.33	0.33	1.24	0.0.	0.69		
Movhall					0.80	1.54	0111		1.82	0.00	1.82	0.52	0.91		
Murrabinna					0.94	1.54			1.82	0.19	1.61	0.31	0.91		
Mvora					0.84	0.58	0.21		2.22	0.28	1.19		1.05		
North Pendleton	0.39		0.90	0.62	1.83	1.69		0.39	2.71	0.81	1.88	0.53	2.23	0.12	1.03
Ormerod					0.80	1.54			1.82		1.82	0.52	0.91	-	
Peacock					0.89	1.66			1.93		1.74	0.38	0.51		
Riddoch					0.91	0.59	0.17		2.33	0.33	1.24		0.69		
Rivoli Bay					0.91	0.59	0.17		2.33	0.33	1.24		0.69		
Ross					1.01	0.72			2.26	0.31	1.53	0.24	0.60		
Shaugh	0.50		1.04	0.72	2.07	1.75		0.51	2.75	0.95	2.02	0.60	2.29	0.22	1.08
Short					0.93	0.70			2.27	0.30	1.42	0.15	0.67		
Smith					0.93	0.70			2.27	0.30	1.42	0.15	0.67		
Spence					0.86	1.54			1.82	0.11	1.61	0.31	0.52		
Stewarts					0.80	1.54			1.82		1.82	0.52	0.91		
Stirling	0.39		0.90	0.62	1.83	1.69		0.39	2.71	0.81	1.88	0.53	2.23	0.12	1.03
Struan					0.73	1.52			1.89		1.73	0.44	0.98		
Symon					0.91	0.59	0.17		2.33	0.33	1.24		0.69		
Tatiara	0.36		0.86	0.54	1.73	1.70		0.37	2.74	0.78	1.83	0.49	2.27	0.12	1.11
Townsend					1.01	0.44			2.20	0.26	1.61	0.31	0.52		
Waterhouse					1.01	0.72			2.26	0.31	1.53	0.24	0.60		
Western Flat					0.95	1.70			1.77		2.08	0.74	0.72		
Willalooka (east)	0.36		0.86	0.54	1.73	1.70		0.37	2.74	0.78	1.83	0.49	2.27	0.12	1.11
Willalooka (west)	0.36		0.86	0.54	1.73	1.70		0.37	2.74	0.78	1.83	0.49	2.27	0.12	1.11
Wirrega (south)	0.36		0.86	0.54	1.73	1.70		0.37	2.74	0.78	1.83	0.49	2.27	0.12	1.11
Wirrega (north)	0.39		0.90	0.62	1.83	1.69		0.39	2.71	0.81	1.88	0.53	2.23	0.12	1.03
Woolumbool					0.93	1.58			1.85	0.13	1.67	0.37	0.90		
Young					0.88	0.55	0.21		2.35	0.32	1.19		0.74		
Zone 2A					0.86	0.62	0.17		2.20	0.28	1.24		1.01		
Zone 3A					0.91	0.70			2.27	0.28	1.42	0.15	1.02		
Zone 5A					0.80	1.54			1.82		1.82	0.52	0.91		
Zone 8A	0.39		0.90	0.62	1.83	1.69		0.39	2.71	0.81	1.88	0.53	2.23	0.12	1.03

APPENDICES

* Note – See Figure 2 in Appendix D for location of Management Areas



D. LOCATION OF MANAGEMENT AREAS

Figure 2. Location of Management Areas

UNITS OF MEASUREMENT

Name of unit	Symbol	Definition in terms of other metric units	Quantity
hectare	ha	$10^4 m^2$	area
Irrigation rate/requirement	ML/ha	mm depth	rate
megalitre	ML	10 ³ m ³	volume
millimetre	mm	10 ⁻³ m	length
percent	%	fractions, decimal	proportion
year	У	365 or 366 days	time interval

Units of measurement commonly used (SI and non-SI Australian legal)

GLOSSARY

Application Losses. Water delivered to the border of the field, which is lost during application to the field and therefore not made available to the crop. Includes evaporation, run-off, deep drainage and drift.

Area-Based Licensing System (halE). Existing water access entitlements to irrigate a given area of crop per annum, with no restrictions on the volume of water applied to the crop. Measured in terms of hectares of irrigation equivalents (halE).

Base Allocation (BA). The crop water requirement component of the proposed volumetric licenses. Base Allocation (ML) = halE x NIRo

Bridging Volume (BV). The bridging volume is an additional temporary allocation that may be granted on application. The bridging volume is designed to give irrigators who are pumping in excess of their new volumetric allocation time to adjust to the new system.

Crop Adjustment Factor (CAF). The Crop Adjustment Factor provides additional base allocation for licensees where, due to initial calculations problems, the existing area-based licensing system does not provide adequate allocation.

Crop Area Ratio (CAR). Used in the existing area-based licensing system to determine area of crops that may be grown in relation to the theoretical irrigation requirement.

Crop Calendar. Representation of the critical periods of crop growth and development for a crop in a particular geographical location, under certain management practices. Used to assign crop coefficients to months of the year to represent the crop water requirements of the crop at that location under those management practices.

Crop Water Requirement. Depth of water required by a crop for evapotranspiration (ET_c) during a given period (Doorenbos and Pruitt, 1977).

Deep Drainage. Water that percolates past the crop root zone and is no longer available to the crop for transpiration.

Delivery Component (DC). The volume of water that a reasonably efficient irrigator needs to extract in excess of the crop water requirement to irrigate and grow the crop to account for application and distribution losses.

Delivery Zones (DZ). Areas of like characteristics within the SE. They were used to calculate delivery components and have been developed using soil mapping data, volume pumped data and other hydrogeological information sources (ie depth to water table, salinity).

Distribution Losses. Water pumped from the aquifer or from storage, which is lost during the delivery of water to the border of the field. May include evaporation and seepage from channel delivery systems, and leakage from piped delivery systems.

Effective Rainfall (Pe). Rainfall useful for meeting crop water requirement, it excludes deep percolation, surface runoff and interception (Doorenbos and Pruitt, 1977). Calculated by the method of Dastane (1974), using the metricated algorithm of Cuenca (1989).

Evapotranspiration (ET). Rate of water loss through transpiration from vegetation plus evaporation from the soil (Doorenbos and Pruitt, 1977).

FAO 56. Food and Agriculture Organization of the United Nations. FAO Irrigation and Drainage Paper, 56 (1998) - *Crop Evapotranspiration; Guidelines for Computing Crop Water Requirements.*

halE. The number of hectares of irrigation equivalents endorsed on an existing area-based water licence.

Irrigation Equivalents (IE's). The current area-based water licensing system shown in hectares, where 1 halE is equivalent to the evapotranspiration minus contribution by effective precipitation from one hectare of reference crop under the average climatic conditions for that region.

Irrigation Rate (ML/ha). The annual volume pumped for irrigation expressed in Megalitres (ML) divided by the area irrigated in hectares (ha).

Management Area (unconfined). Part of a Prescribed Wells Area used for groundwater management.

Maximum Production Pasture (MPP). A category of pasture that has been recognised as having increased NIRc due to significant changes in pasture management systems.

Megalitre (ML). One ML equal one million litres or one thousand Kilolitres.

Net Irrigation Requirement – Crop (NIR_c**).** Net irrigation requirement for a specific crop, grown according to a defined crop calendar, calculated according to the FAO 56 method (Allen et al., 1998).

Net Irrigation Requirement – Reference Crop (NIR₀). Net irrigation requirement for the reference crop, reflecting the evapotranspiration demand at a certain location, according to climatic conditions in that location, calculated according to the FAO 56 method (Allen et al., 1998).

Net Irrigation Requirement (NIR). Depth of water required for meeting evapotranspiration minus contribution by effective precipitation, ground water, stored soil water; does not include operational losses and leaching requirements (Doorenbos and Pruitt, 1977).

Prescribed Wells Area (PWA). A water resource declared by the Governor to be prescribed under the Water Resources Act 1997, and includes underground water to which access is obtained by prescribed wells.

Reference Crop Evapotranspiration (ET₀). Rate of evapotranspiration from an extended surface of 8–15 cm tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of water (Doorenbos and Pruitt, 1977).

South East Natural Resource Management Board (SENRMB). Responsible for natural resources planning, public consultation and education and in advising the Minister for Environment and Conservation on various natural resource management issues and policies.

Specialised Production Requirements (SPR). (1) Water that is necessarily applied as a part of the crop production process that does not contribute to crop water use and is not included in the delivery component (e.g. to prevent soil drift or to protect against frost damage). (2) Water that is required in addition to base allocation due to significant changes in the crop production system (as recognised by FAO 56). For example Maximum Production Pasture.

Transpiration. Rate of water loss through the plant which is regulated by physical and physiological processes (Doorenbos and Pruitt, 1977).

Volumetric Conversion Model. Describes the components and methodologies for the conversion of existing area-based allocations to volumetric allocations.

Volumetric Licensing System. Licensees are entitled to pump a certain volume of water per annum, but are not restricted by the area of crop/s grown.

Water Allocation Plan (WAP). A plan prepared by a Natural Resource Management Board or water resource planning committee and adopted by the Minister in accordance with Division 3 Part 7 of the Water Resources Act 1997.

REFERENCES

- Allen, RG, Pereira, LS, Raes, D & Smith, M 1998, Crop Evapotranspiration; Guidelines for Computing Crop Water Requirements, FAO Irrigation and Drainage Paper, 56, Food and Agriculture Organization of the United Nations, Rome.
- Doorenbos, J & Pruitt, WO 1977, *Crop Water Requirements*, FAO Irrigation and Drainage Paper, 24, Food and Agriculture Organization of the United Nations, Rome.
- Skewes, MA 2006, *Definition of Net Irrigation Requirements in the South East of South Australia,* Government of South Australia, Adelaide, ISBN 0 7590 1373 X.