DWLBC REPORT

Volumetric Conversion in the South East of South Australia: Calculation of the Delivery Component and Bridging Volume

2006/34

Government of South Australia
Department of Water, Land and Biodiversity Conservation

Volumetric Conversion in the South East of South Australia: Calculation of the Delivery Component and Bridging Volume

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Resource Allocation
Department of Water, Land and Biodiversity Conservation

September 2006

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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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ASSOCIATED REPORTS

Carruthers, R 2006, *Volumetric Conversion in the South East of South Australia: Community Consultation Processes,* DWLBC Report 2006/33, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Mount Gambier.

Carruthers, R, Latcham, B & Pudney, S 2006, *Volumetric Conversion in the South East of South Australia: Summary of the Conversion Model and Associated Conversion Rates,* DWLBC Report 2006/29, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Mount Gambier.

Carruthers, R, Skewes, M, Latcham, B & Pudney, S 2006, *Volumetric Conversion in the South East of South Australia: Calculation of the Crop Adjustment Factor,* DWLBC Report 2006/32, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Mount Gambier.

Pudney, S 2006, *Volumetric Conversion in the South East of South Australia: Validating the allocation model,* DWLBC Report 2006/30, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Mount Gambier.

Pudney, S, Latcham B & Carruthers, R 2006, *Volumetric Conversion in the South East of South Australia: Calculation of Specialised Production Requirements,* DWLBC Report 2006/31, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Mount Gambier.

Skewes, M 2006, *Definition of Net Irrigation Requirements in the South East of South Australia,* Report to Department of Water Land and Biodiversity Conservation, Irrigated Crop Management Service, Rural Solutions SA, Primary Industries and Resources South Australia.

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Under the proposed volumetric conversion model all licensees will receive a base allocation and a delivery component. The base allocation accounts for the net irrigation requirement of the existing area-based licences. The delivery component reflects the extra water that a reasonably efficient irrigator needs to extract above the net irrigation requirement to account for losses that occur through the application of irrigation water (i.e. deep drainage and evaporation).

At the 2004 irrigator workshops the term 'reasonably efficient' was agreed to be a volume that provides sufficient allocation for 3/4 of the irrigation community. Using the 75th percentile value of real-life volume pumped data to calculate delivery components has ensured at least 75% of irrigators are allocated sufficient water to continue their current practices.

The delivery component and bridging volume were calculated for each irrigation system type within separate delivery zones. Delivery zones are areas of like characteristics developed by analysing volume pumped data, soil mapping and other relevant information. Final delivery component and bridging volume values were calculated using the volume pumped records from within each delivery zone.

The bridging volume is a temporary allocation that may be granted on application (subject to eligibility criteria) where licensees pump in excess of their combined base allocation, delivery component and any other components that the licensee qualifies for. It is designed to give irrigators time to adjust their systems to their new volumetric allocation and has been calculated to account for 95% of the irrigation community.

This report summaries the methodology used to calculate volumetric allocations for the delivery component and bridging volume. Table 1 details the delivery component and bridging volume values in relation to irrigation system type and delivery zone.

Table 1. Delivery Components and Bridging Volumes*

Delivery Zone	Flood Irrigation		Spray Irrigation		Drip Irrigation	
	Delivery	*Bridging*	*Delivery*	*Bridging*	*Delivery*	*Bridging*
1	54%	54%	18%	18%	11%	11%
2	152%	103%	18%	18%	11%	11%
3	102%	136%	18%	31%	11%	11%
4	199%	114%	18%	19%	11%	11%
5	132%	145%	18%	50%	11%	11%
6	132%	145%	18%	22%	11%	11%
7	54%	54%	18%	38%	11%	11%
8	132%	104%	18%	23%	11%	11%
9	123%	156%	18%	27%	11%	11%
10	54%	54%	18%	44%	11%	11%
11	54%	54%	27%	39%	11%	11%

*(expressed as a percentage of Base Allocation)

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 may be available on application, subject to meeting eligibility criteria.

This report describes the methodology and volumetric allocations for the 'Delivery Component and Bridging Volume' (shaded portion of Fig. 1). Other reports (listed in 'Associated Reports') detail the calculation of the Base Allocation, Crop Adjustment Factor and Specialised Production Requirements. Reports has also been published on the community consultation and model validating processes used in this project.

1.2 INTRODUCTION TO DELIVERY COMPONENTS AND BRIDGING VOLUMES

Under the proposed volumetric conversion model, all licensees will receive a base allocation and a delivery component. The base allocation accounts for the net irrigation requirement of the existing area-based licences. The delivery component reflects the extra water that a reasonably efficient irrigator needs to extract above the net irrigation requirement to account for losses that occur through the application of irrigation water (i.e. deep drainage and evaporation).

No irrigation system is capable of achieving 100% application efficiency and must therefore pump more water than the crop eventually uses. The delivery component is designed to account for the inefficiencies of different irrigation systems under local conditions. Minimum

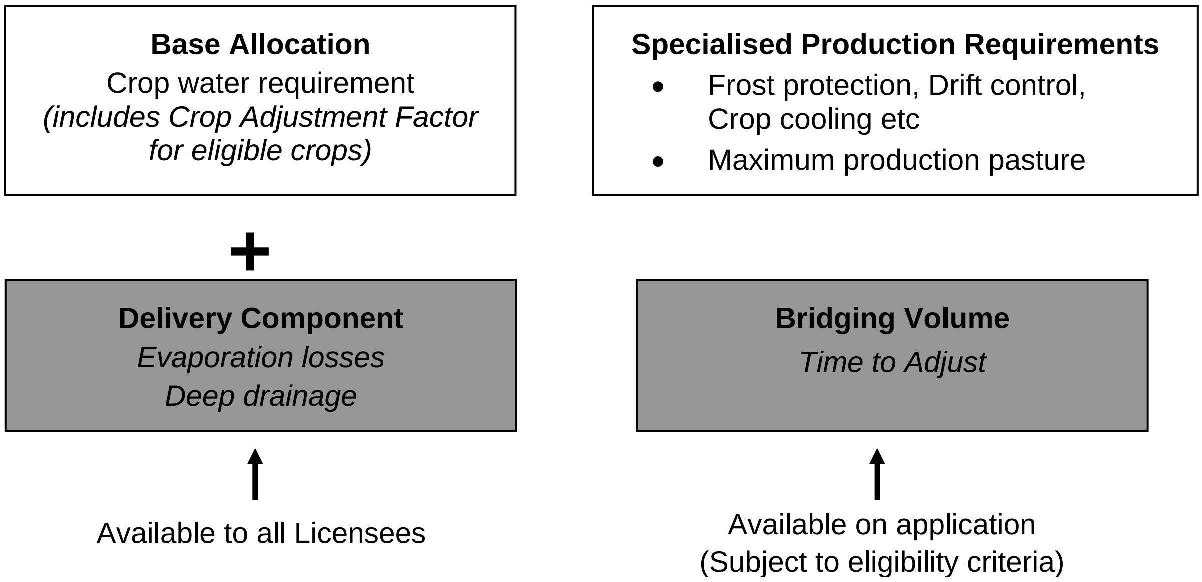

Figure 1. Proposed volumetric conversion model

delivery components can be based on globally accepted efficiencies, however data from field trials indicated that such efficiencies are hard to achieve in many areas of the SE due to the shallow porous nature of the soils. Where this is the case the delivery components have been be calculated on the requirement of a 'reasonably efficient' irrigator.

At the 2004 irrigator workshops the term 'reasonably efficient' was agreed to be a volume that provides sufficient allocation for 75% of the irrigation community to continue their current irrigation practices. To calculate the amount of water this represents it was necessary to collect real-life data on volumes pumped for irrigation. Three data collection programs were initiated to obtain information on local irrigation practices.

The delivery component and bridging volume were calculated for each irrigation system type within separate delivery zones. Delivery zones are areas of like characteristics developed by analysing volume pumped data, soil mapping and other relevant information. Within each delivery zone the 75th percentile of the data set was identified to determine the delivery component for each irrigation system type. This produces a delivery component that is tailored to each irrigation system type and location.

Using the 75th percentile value of the volume pumped data set to calculate delivery components has ensured at least 3/4 of irrigators receive sufficient allocation to continue their current practices. Final delivery component values have been determined using the 75th percentile value, or the minimum delivery component if greater.

The bridging volume is a temporary allocation that may be granted on application (subject to eligibility criteria) where licensees pump in excess of their combined base allocation, delivery component and any other components that the licensee qualifies for. It is designed to give irrigators time to adjust their systems to their new volumetric allocation, and has been calculated to account for 95% of the irrigation community.

An integral approach of the Volumetric Conversion Project was to base the conversion process on 'real-life' field data and to promote stakeholder involvement in the data collection process. This has resulted in irrigator ownership of the data, and importantly a greater understanding and acceptance of the conversion outcomes.

2. OBJECTIVES

1. To determine appropriate delivery components that allow reasonably efficient irrigators to continue their current irrigation practices.
2. To determine appropriate bridging volumes that allow irrigators pumping in excess of their new volumetric allocation time to adjust to the new volumetric system.

3. METHODOLOGY

3.1 DATA COLLECTION PROGRAMS

At the commencement of the Volumetric Conversion Project there was limited information available on the volumes pumped for irrigation in the SE. Thus, three major data collection programs were initiated to obtain detailed information on the diversity of irrigation practices across the region. The Metered Extraction Trials (MET), Field Irrigation System Trials (FIST) and Annual Water Use Return (AWUR) programs generated real-life crop type and irrigation rate (ML/ha) information from nearly 5000 data points over three irrigation seasons (2002–03, 2003–04 and 2004–05).

3.1.1 METERED EXTRACTION TRIALS – MET PROGRAM

The MET program involved supplying monetary incentives to irrigators for the purchase and installation of water meters, in return for them collecting accurate data on the volumes pumped per hectare irrigated.

Participants were required to record meter readings at the start and end of each irrigation event for all individual crops irrigated. A total of 120 irrigators participated in the trial, installing 160 water meters and generating volume pumped data from approximately 200 irrigated crop sites per annum.

3.1.2 FIELD IRRIGATION SYSTEM TRIALS – FIST PROGRAM

The Field Irrigation System Trials (FIST) program resulted in the collection of detailed information on the on-farm water balance from 36 representative farms from the MET program and other collaborative research sites. The program involved the continuous monitoring of the volume pumped, soil moisture, water table and weather-related parameters linked to calculation of evapotranspiration. Data from the FIST sites has been used to test the conversion model (Pudney 2006).

Sites consistently pumping in excess of proposed allocations have been analysed using IRES software (developed by Irrigated Crop Management Service, Loxton) and issues that may be causing use in excess of the proposed allocation identified. This checking process has been used to verify whether reasonably efficient irrigators will have sufficient allocation continue their current irrigation practices.

3.1.3 ANNUAL WATER USE RETURNS – AWUR PROGRAM

The AWUR process requires all water license holders to report their water use activities at the completion of each season. Since 2001–02 irrigators have been asked to provide information on their annual volume pumped, either through metered measurements or by way of estimates. An information sheet was provided to growers to assist them with the calculations.

The risk of including unreliable volume pumped estimates was minimised by assigning accuracy ratings to each of the AWUR estimates, (see Table 2), followed by statistical screening (described under Data Range and Selection, Section 3.3). Of the 2500 irrigation licences, the AWUR process yielded some 1500 useable records each season, substantially increasing the range of irrigation practices included in the data set.

Table 2. Accuracy ratings used for categorising the reliability of AWUR estimates

Rating	Assessment criteria
1	Volumes assessed using meter readings for whole season
2	Volumes calculated using sound methodology (eg. time to fill container method, or using system specifications to calculate flow rate) with calculations shown on form
3	Volumes calculated using sound methodology (eg. time to fill container method, or using system specifications to calculate flow rate) but calculations not shown on form
4	Volumes calculated using ‘best estimates’ or ‘average pumping hours’
5	Questionable data – possible mathematical errors
6	Metered Extraction Trial participant – no data entry completed, will be reported through MET program

3.2 COMPARATIVE VOLUME PUMPED (CVP)

Due to the wide range of irrigation practices used across the region, it was necessary to normalise the volume pumped data in order to compare the volumes pumped between different crop types, irrigation systems and climatic locations. All volume pumped data from the MET and AWUR programs was expressed as the irrigation rate (ML/ha) and compared against the (seasonal) crop allocation volume for the respective crop type grown. The crop allocation volume represents the base allocation for each crop in each climatic band and was calculated annually to take into account the seasonal variation in the Net Irrigation Requirements of irrigated crops (NIRc).

The Comparative Volume Pumped (CVP) calculation was developed to quantify the difference between the volume pumped for irrigation and the crop allocation volume as shown in Equation 1. Seasonal NIRc values and crop allocation volumes were calculated by M. Skewes of Irrigated Crop Management Services, Loxton at the completion of each irrigation season, by the method described in Skewes (2006).

Equation 1

$$CVP\ (\%) = \left(\frac{Volume\ \ Pumped\ \ (ML\ /\ ha) - Crop\ \ Allocation\ \ Volume\ \ (ML\ /\ ha)}{Crop\ \ Allocation\ \ Volume\ \ (ML\ /\ ha)} \right) \times 100$$

Expressed as a percentage of the crop allocation volume, the CVP calculation ensures the data is normalised for climatic location, crop type grown and seasonal variability, thus providing a real-life measure of the delivery volume for each data point.

3.3 DATA RANGE AND SELECTION

The rating system used for the AWUR data was used to identify the data range limits for the volume pumped estimates. MET data and rating 1 and 2 AWUR records were combined to determine the range in which the AWUR estimates could be statistically included into the data set for each irrigation system type. This combined data set of accurate irrigation records was deemed to provide the best representation of irrigation practices across the region.

Data points at the upper and lower ends of the CVP continuum were checked for errors to ensure validity. Data that could not be verified or contained errors was removed from the data set. Sites with failed crops, system breakdowns, low-intensity irrigation and mid-season changes in management practices were also removed from the data set.

All remaining AWUR estimates that fell within the CVP range identified for each irrigation system type were included for analysis. All individual metered crop sites per property per season received were regarded as individual data points.

3.4 USING PERCENTILES TO DETERMINE THE DELIVERY COMPONENT

At the 2004 irrigator workshop series the community was asked ‘What percentage of the irrigator community should receive sufficient allocation to continue their current practices’. The community’s response was then used to identify which percentile of the CVP data set would be used to calculate the delivery component. This process was aided by presenting the CVP data from the first two seasons of collection, followed by discussions amongst small groups.

As a result of the consultation process the 75^{th} percentile has been recognised as reasonably efficient for irrigation practices across the region. The 75^{th} percentile of the CVP data (CVP_{75}) will account for 75% of irrigation practices and ultimately provide sufficient allocation for 75% of the irrigator community.

Further information on the community consultation process for the Volumetric Conversion Project is provided by Carruthers (2006).

3.5 COMPARISON OF IRRIGATION SYSTEM TYPES

A wide variety of historic and modern irrigation system types are used throughout the SE. For the purpose of calculating delivery components, three major irrigation systems types were recognised, as shown in Table 3.

Pivots, sprinklers and travellers have been grouped together (spray irrigation) as it was found there was little or no significant difference in the volumes pumped, despite differences in their application efficiencies. Figure 2 shows the box-and-whisker plot of the relative CVP distributions for all five irrigation system types using the regional data-set.

Table 3. Classification of Irrigation System Type

System Classification	Irrigation System Type
Drip Irrigation	Sub-surface drip, Micro-sprinklers, Trickle, Micro jet
Flood Irrigation	Lasered flood, Surface, Border-check
Spray Irrigation	Pivots – mobile, fixed, lateral move Sprinklers – overhead, under-tree, pop-up, fixed, portable Travellers – water winch, wheel line, mobile gun/spray

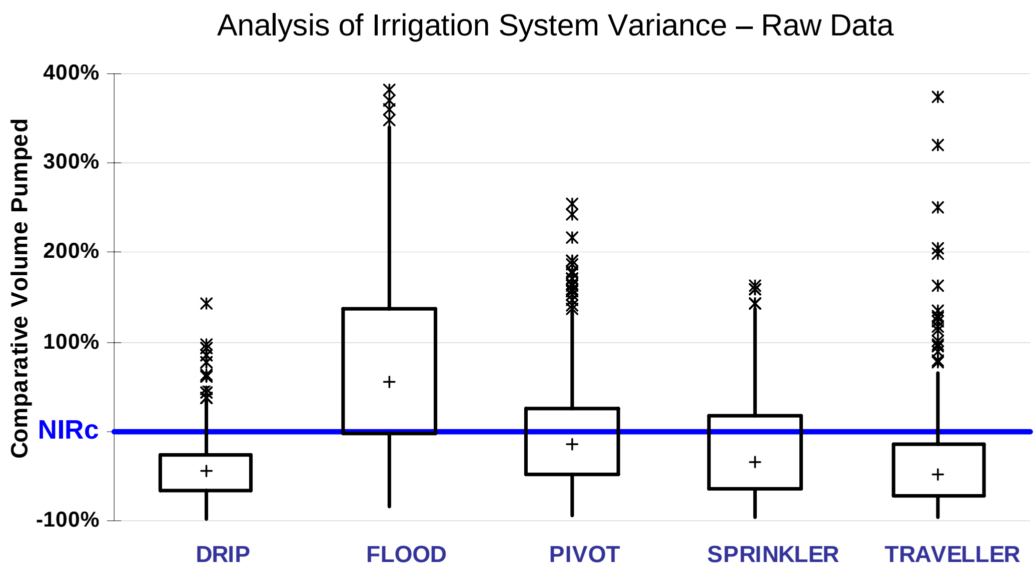

Figure 2. Comparison of CVP between irrigation system types

NOTE: The top of each box represents the 75th percentile, the bottom represents the 25th percentile, the '+' represents the 50th percentile (or median value). The upper and lower whiskers or tails represent the upper and lower 25% of the data set and the asterisk symbol represents statistical outliers.

3.6 ACCOUNTING FOR SPECIALISED PRODUCTION REQUIREMENTS (SPR'S)

Some cropping systems will received additional allocation for practices not accounted for in the Base Allocation or Delivery Component (see Specialised Production Requirements Technical Report, Pudney et al. 2006 for more information). SPR's include water for soil drift control, frost protection in vineyards, sunburn prevention in orchards and for the higher NIR associated with Maximum Production Pasture, all of which were not accounted for under the existing area-based licensing system.

In order to prevent doubling-up on allocations (with regard to delivery component and SPR's allocations), volume pumped figures for eligible SPR crops were adjusted to prevent these practices from inflating the delivery component values. Cropping systems that had SPR's subtracted from the volume pumped records, along with the conditions of the adjustments, are detailed in Table 4.

Table 4. Values and conditions for subtracting SPR's from volume pumped data.

Crop Type	SPR allocation (ML/ha)	Conditions
Fruit Trees (Apples)	0.39	Subtracted for records pumping greater than +18% above the seasonal NIRc
Maximum Production Pasture	0.60–2.87#	CVP re-calculated using NIRc for MPP for top 20% of pasture volume pumped records from delivery zones 10 and 11 (where the majority of intensive pasture irrigation is concentrated).
Olives	0.28	No adjustment made, only a small number of olive groves, all with young trees, requiring less than NIRc.
Onions	1.10* 1.47^	Subtracted for records pumping greater than +18% above the seasonal NIRc
Potatoes	1.35* 1.70^	Subtracted for records pumping greater than +18% above the seasonal NIRc
Subterranean Clover Seed	0.31* 0.38^	Subtracted for records pumping greater than +18% above the seasonal NIRc
Vines	1.55	Frost protection records were not included in volume pumped records for vine irrigation

* = South: Management areas within Climate Bands 1A-3A

^ = North: Management areas within Climate Bands 4A-9A

= Depending on management area and irrigation system type

Additional irrigation water may also be used in some circumstances for the purpose of leaching residual salts from the soil profile. This practice of applying larger irrigations to flush the root zone may be required for high value or sensitive horticultural crops and in areas using saline irrigation water. Volume pumped records used for calculating irrigation delivery components included sites practicing salt leeching and therefore final delivery components provide sufficient allocation enable this practice to continue.

3.7 DELIVERY ZONES

Delivery zones are areas of like characteristics within the SE used to calculate delivery components. Delivery zones were developed using soil mapping data, volume pumped data and other hydrogeological information sources (ie depth to water table, salinity). Figure 3 shows the delivery zones and corresponding management areas. Final delivery components have been calculated for each irrigation system type within each delivery zone using the irrigation records collected from each zone.

The existing 73 unconfined management areas have been used as the minimum building blocks for the delivery zones. The process of developing delivery zones commenced at the May 2005 irrigator workshops, with attendees using their local knowledge to identify areas with like characteristics. Adjoining management areas were grouped together where appropriate, using the parameters described below:

3.7.1 SOIL VARIABILITY AND DISTRIBUTION WITHIN THE SE

Soil type, depth and distribution is highly variable throughout the SE, having a major influence on the volumes pumped for irrigation. In order to accommodate the influence of soil at a sub-regional level, the soils of the SE were grouped into six major categories.

1. Sandy soil over calcrete or limestone shallower than 50 cm.
2. Loamy to clayey soil over calcrete or limestone shallower than 50 cm.
3. Deep sand (more than 80 cm).
4. Deep sandy loam to clay loam without clearly defined clayey subsoil, or deep clay.
5. Sandy surface soil over clayey subsoil shallower than 80 cm.
6. Sandy loam to clay loam surface soil over clayey subsoil shallower than 80 cm.

The distribution of the six soil categories is highly variable both across the region and within management areas (see Fig. 4, App. A). Given that the existing management areas would form the minimum building blocks, the dominant (and sub dominant) irrigated soil type were determined for each management area (see Fig. 5, App. A). This mapping information enabled the direct comparison of dominant irrigated soil types between adjoining management areas and was used as the first step in identifying areas of like characteristics.

3.7.2 VOLUME PUMPED DATA BY MANAGEMENT AREA

CVP data was used to view the variation in volumes pumped for each irrigation system type across the region. The CVP_{75} value for each management area was calculated to identify areas pumping similar volumes for each of the three irrigation system categories (see Figs 6–8, App. B). Statistically a minimum of 30 data points are required to be confident in the derived CVP_{75} value (Fowler and Cohen 1990; Hewa, pers. comm.).

High variation in volumes pumped were observed for flood irrigation between management areas. This variation appears to correspond closely with the dominant irrigated soil type, evident by the high values observed for the hundred of Stirling and Padthaway Management Areas 1 and 2, where shallow free draining soils are dominant. Similarly, areas with deep heavier soils such as the Naracoorte Ranges PWA and the northern half of Tatiara PWA were found to be pumping considerably lower volumes for flood irrigation.

3.7.3 FINAL DELIVERY ZONES

A total of 11 delivery zones were developed across the SE by joining management areas with like characteristics (Fig. 1). The 11 zones reflect areas within the region that have either similar irrigated soils or were found to be pumping similar volumes for irrigation.

3.7.4 COMMENTS ON DELIVERY ZONES

The major factors in developing the delivery zones were the dominant irrigated soil types along with the variations in flood CVP_{75} values in the mid and upper SE and spray CVP_{75} values in the lower SE and coastal fringe. CVP_{75} values for all management areas with drip irrigation were below the minimum delivery component and therefore were not affected by the configuration of delivery zones.

The dominant irrigated soil type can still be seen to vary within some delivery zones (see Fig. 5, App. A), however all reasonable attempts were made to ensure the shallow and free-draining soils (categories 1 to 3) were kept separate from the deeper heavier soils (categories 4 to 6).

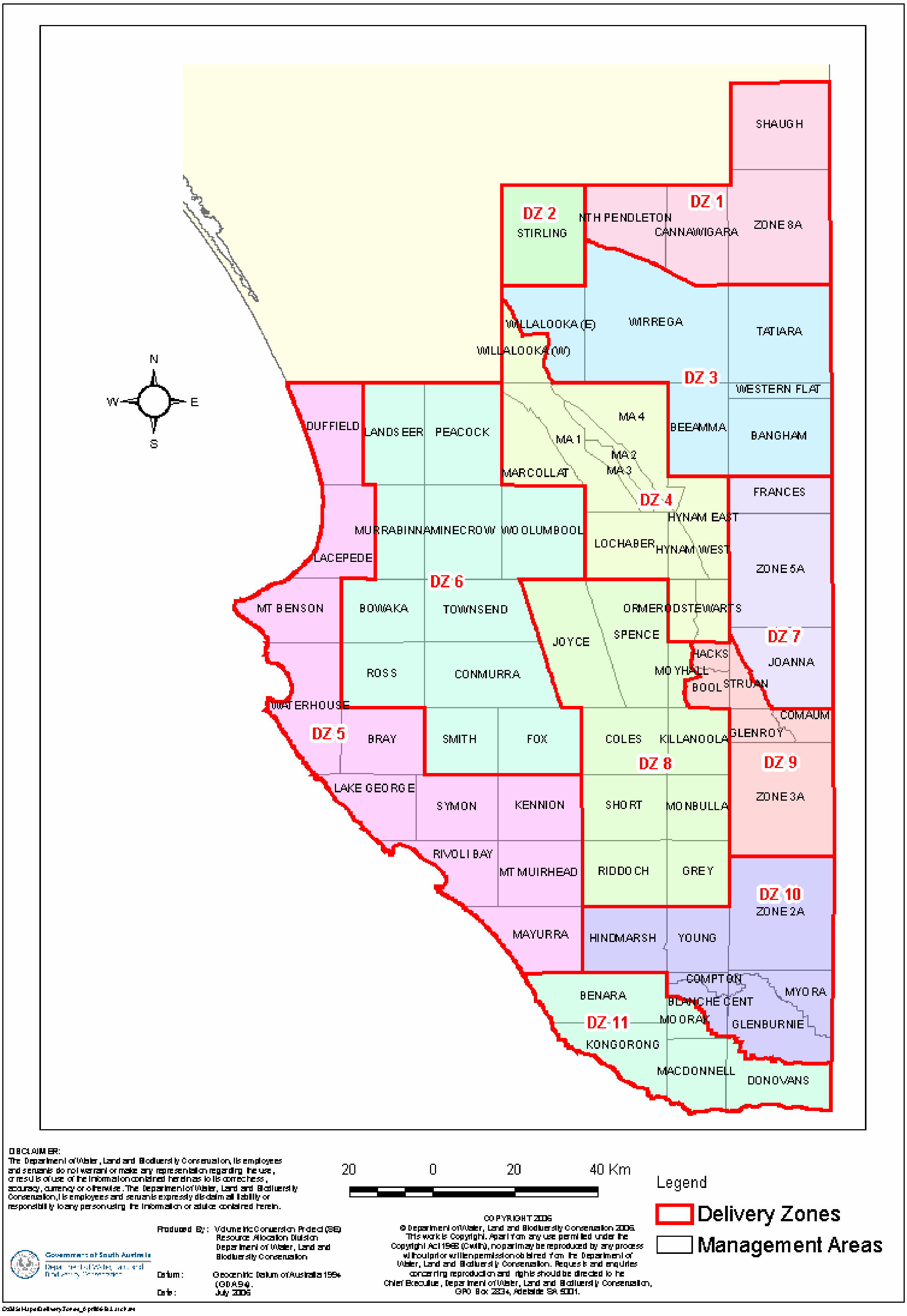

Figure 3. Delivery Zones

In cases where there is no significant difference in the CVP_{75} values between management areas of different soil types, larger delivery zones were formed (i.e. delivery zone 3). In large areas of common soil types with large differences in the CVP_{75} values between management areas, smaller delivery zones were formed to ensure appropriate outcomes (i.e. delivery zones 5 and 11). Table 5 describes the rationale behind each delivery zone.

Willalooka was the only management area to be split into two delivery zones. This occurred due to strong community input via the Project Advisory Committee, irrigator workshops and the MET program. The reasoning behind the split was due to the conditions in south-western Willalooka (soil type and volumes pumped for flood irrigation) aligning more closely with those found in the Padthaway area and along the Naracoorte plains (delivery zone 4) compared to the north-east corner of Willalooka and delivery zone 3.

3.8 CALCULATING THE DELIVERY COMPONENT

It is proposed that each licensee will receive a minimum delivery component based on globally accepted irrigation system efficiencies (Table 6). Minimum delivery components have been determined using the inverse relationship as shown in equation 2.

Equation 2

$$Minimum\ \ Delivery\ \ Component\ \ (decimal) = \left(\frac{1}{System\ \ Efficiency\ \ (decimal)} \right) - 1$$

The minimum delivery components will be insufficient for many areas of the SE due to the shallow porous nature of the soils being irrigated. Final delivery component values have been calculated using the greater of CVP_{75} value or the minimum delivery component.

3.9 CALCULATING THE BRIDGING VOLUME

Irrigation practices and efficiencies vary considerably across the SE. Given that the delivery component is designed to account for 75% of the irrigation community, up to 25% of irrigators may not receive sufficient allocation to continue their current practices. The bridging volume is intended to provide irrigators pumping in excess of their new allocation time to adjust to the volumetric licensing system. Consultative processes with the industry based Project Advisory Committee (PAC) and the South East Water Management Board (SECWMB) resulted in a recommendation that the bridging volume provide sufficient allocation for 95% of the irrigation community.

The maximum bridging volume allocation has been determined using the 95^{th} percentile of the CVP data (CVP_{95}). Bridging volumes were calculated by subtracting CVP_{75} from CVP_{95} for each irrigation system within each delivery zone. Where CVP_{95} - CVP_{75} is less than the minimum delivery component, the minimum delivery component will be used as the bridging volume. Therefore the delivery component plus bridging volume will equate to CVP_{95} or two times the minimum delivery component, whichever is greater.

Table 5. Rationale behind the Delivery Zones

Delivery Zone	Unconfined Management Areas	Description / Reasoning
1	North Pendleton, Cannawigara, Zone 8A, Shaugh,	*Upper Tatiara:* Sand over clay and deep sand, low volumes pumped for flood irrigation, deep water table
2	Stirling	*Stirling:* Very shallow loam over limestone, almost exclusively flood irrigated lucerne seed, high groundwater salinities, different management arrangements currently in place with special CAR's for lucerne seed
3	Bangham, Beeamma, Western Flat, Wirrega, Tatiara, Willalooka (east)	*Lower Tatiara:* Sand over clay and deep heavier soils, very similar volumes pumped for flood irrigation, characteristics of the north-eastern half of Willalooka more closely associated with Wirrega
4	Willalooka (west), Marcollat, Padthaway Management Areas 1, 2, 3 & 4, Lochaber, Hynam East & West, Ormerod, Stewarts	*Padthaway and Naracoorte plains:* Very shallow sand and loam over limestone along plains with deep sand along ranges, very high volumes pumped for flood irrigation, south-western half of Willalooka aligns very closely with Padthaway area.
5	Duffield, Lacepede, Mt. Benson, Waterhouse, Bray, Lake George, Symon, Rivoli Bay, Mt Muirhead, Mayurra	*Coastal fringe:* Predominately shallow loam over limestone or deep sand, little or no flood irrigation, higher volumes pumped for spray compared to inland zones.
6	Landseer, Peacock, Murrabinna, Minecrow, Woolumbool, Bowaka, Townsend, Ross, Conmurra, Smith, Fox, Kennion	*Mid SE (west):* Predominately shallow loam over limestone, incorporates flood irrigation area using confined aquifer
7	Frances, Zone 5A, Joanna	*Naracoorte Ranges*: With sand and heavy loam over clay, low volumes pumped for both flood and spray irrigation.
8	Joyce, Spence, Moyhall, Coles, Killanoola, Short, Monbulla, Riddoch, Grey	*Mid SE (east):* Predominantly sand over clay, mixture of flood and spray irrigation
9	Hacks, Bool, Struan, Glenroy, Comaum, Zone 3A	*Coonawarra:* Predominantly vine irrigation on shallow loam over limestone, encompasses Coonawarra wine district.
10	Zone 2A, Hindmarsh, Young, Compton, Blanche Central, Myora, Glenburnie	*Mt Gambier Nth:* Deep sand and loam, deep water table, spray volumes pumped less than minimum delivery component, intensive dairy region.
11	Benara, Kongorong, Moorak, MacDonnell, Donovans	*Mt Gambier Sth:* Intensive dairy region established on very shallow loam over limestone, high volumes pumped for spray irrigation.

Table 6. Industry standard system efficiencies and minimum delivery components

Irrigation System	System Efficiency	Minimum Delivery Component Required*
Drip and Micro	90%	+11%
Flood (Surface)	65%	+54%
Pressurised Spray	85%	+18%

* Expressed as a percentage of Base Allocation

NOTE: Efficiency figures for Flood and Pressurised Spray are based on target figures in the Water Allocation Plan for the River Murray Prescribed Watercourse (River Murray Catchment Water Management Board, 2002). The drip irrigation efficiency figure of 90% is widely accepted (Brouwer, et al., 1989; Phocaides, 2001; Tanji and Yaron, 1994).

3.10 PROCESS FOR VALIDATING THE VOLUMETRIC CONVERSION MODEL

Field Irrigation System Trial (FIST) data has been used to determine whether the model will allow at least 75% of irrigators to continue their current practice (see Pudney et al. for more details). The analysis is based on three season's data (2002–03, 2003–04, and 2004–05), collected at each of the FIST trial sites.

Sites found to repeatedly exceeded the proposed allocation were analysed using IRES water balance software (developed by Irrigated Crop Management Service, Loxton), to identify possible reasons why irrigation practices at these sites would not be considered as 'reasonably efficient'.

4. RESULTS

4.1 DELIVERY COMPONENT

Almost 5000 data points were available for calculating irrigation system delivery components. A minimum of 30 data points are required to calculate the CVP_{75} for each irrigation system type and delivery zone combination (Fowler and Cohen 1990; Hewa, pers. comm.). Where insufficient data points were available, delivery components were determined either using the minimum value or by combining the data set with a neighbouring zone of like characteristics (where appropriate).

Delivery component factors for each irrigation system type within each delivery zone are shown in Table 7, with volumetric values per management area displayed in Appendix C.

Table 7. Delivery Component (as a percentage of Base Allocation)

Delivery Zone	Flood	Spray	Drip
1	54%	18%	11%
2	152%	18%	11%
3	102%	18%	11%
4	199%	18%	11%
5	132%	18%	11%
6	132%	18%	11%
7	54%	18%	11%
8	132%	18%	11%
9	123%	18%	11%
10	54%	18%	11%
11	54%	27%	11%

4.1.1 FLOOD IRRIGATION

Delivery components vary considerably for flood irrigation. The minimum delivery component of +54% was applied to 4 of the 11 zones. In delivery zones 1 and 7 the CVP_{75} value was less than the minimum value, whereas zones 10 and 11 had little or no flood irrigation records (see Table 8). Delivery zone 5 had insufficient data points to calculate a delivery component, however the individual records and irrigated soil types matched very closely with the neighbouring delivery zone 6 (see Fig. 3). In this case flood irrigation records from delivery zone 5 were combined with delivery zone 6 with no effect on the calculation of CVP_{75} for delivery zone 6.

Table 8. Number of data points used to calculate delivery component*

Delivery Zone	Flood	Spray	Drip	Total
1	52	79	7	138
2	257	11	0	268
3	357	397	31	785
4	296	147	101	544
5	10	124	133	267
6	147	81	7	235
7	24	465	171	660
8	126	295	39	460
9	53	136	348	537
10	6	664	18	688
11	2	371	6	379
Total	1330	2770	861	4961

* Each individual irrigation record received constitutes a data point

4.1.2 SPRAY IRRIGATION

Only delivery zone 11 was found to require a delivery component greater than the minimum value of +18% for spray irrigation. In delivery zone 11 the CVP_{75} value equated to +27%, even after adjusting for maximum production pasture sites. The CVP_{75} values for all remaining zones was below +18%, with the next highest value from the delivery zone 5 (the coastal fringe) at +15%.

4.1.3 DRIP IRRIGATION

All CVP_{75} values for drip irrigation were well below the minimum delivery component value of +11%. Less than 4% of drip irrigated sites across the SE were found to be pumping above the minimum delivery component, thus over 96% of drip irrigators should have sufficient allocation with a delivery component of +11%.

4.2 BRIDGING VOLUME

Bridging volumes have been calculated using the same data set as used for the delivery component calculation. The maximum bridging volume allocations are designed to account for 95% of the data, thus 95% of irrigation practices for the region. Where CVP_{95} - CVP_{75} is less than the minimum delivery component, the minimum delivery component has been used as the bridging volume.

Bridging volumes for each irrigation system type within each delivery zone are shown in Table 9, with volumetric values per management area displayed in Appendix D. The delivery component plus bridging volume equates to the greater of CVP_{95} or 2 times the minimum delivery component as seen in Table 10.

Table 9. Maximum Bridging Volume (as a percentage of Base Allocation)

Delivery Zone	Flood	Spray	Drip
1	54%	18%	11%
2	103%	18%	11%
3	136%	31%	11%
4	114%	19%	11%
5	145%	50%	11%
6	145%	22%	11%
7	54%	38%	11%
8	104%	23%	11%
9	156%	27%	11%
10	54%	44%	11%
11	54%	39%	11%

Table 10. Delivery Component plus Maximum Bridging Volume (as a percentage of Base Allocation)

Delivery Zone	Flood	Spray	Drip
1	108%	36%	22%
2	255%	36%	22%
3	238%	49%	22%
4	313%	37%	22%
5	277%	68%	22%
6	277%	40%	22%
7	108%	56%	22%
8	236%	41%	22%
9	279%	45%	22%
10	108%	62%	22%
11	108%	66%	22%

4.2.1 FLOOD IRRIGATION

Maximum bridging volumes for flood irrigation reflect the vast differences in irrigation practices and efficiencies across the region. Values ranged from +54% to +156%. Delivery zone 5 had insufficient data points to calculate a bridging volume, so the records were combined with delivery zone 6 with no effect on the outcome for delivery zone 6. Total flood allocations with a maximum bridging volume range from +108% to +313% of the base allocation.

4.2.2 SPRAY IRRIGATION

Maximum bridging volumes for spray irrigation display much higher variation than the delivery component analysis. Maximum Bridging Volume allocations range from +18% to +50%. Total spray allocations with a maximum bridging volume range from +38% to +68% of the base allocation.

4.2.3 DRIP IRRIGATION

All maximum bridging volumes for drip irrigation equated to +11%. Total drip allocations with maximum bridging volumes therefore equate to +22% of the base allocation.

4.3 OUTCOMES FROM VALIDATING THE VOLUMETRIC CONVERSION MODEL

Less than 25% of FIST sites were found to have pumped in excess of the proposed allocation. Only one flood and one spray irrigator were found to repeatedly exceed the proposed allocation (see Pudney *et al.* for more details).

The contributing factor at each site was the irrigation application depth exceeding the soil water holding capacity, resulting in excessive deep drainage per irrigation event. Estimated deep drainage over the trial period ranged from 19% (1.3 ML/ha) to 32% (3.5 ML/ha) at the spray site and 65% (8.5 ML/ha) to 68% (10.7 ML/ha) at the flood irrigation site.

5. CONCLUSION

Delivery components have been determined to allow reasonably efficient irrigators to continue their current practices (Objective 1). Through stakeholder input reasonably efficient irrigation was recognised as the 75^{th} percentile of the volume pumped data set for each irrigation system type within each delivery zone. Final delivery components have been calculated using the 75^{th} percentile or minimum value if greater and therefore provide sufficient allocation for at least 75% of irrigators.

Bridging volumes allow time to adjust by providing additional temporary allocation for irrigators pumping in excess of their new volumetric allocation (Objective 2). Maximum bridging volumes have been calculated using the 95^{th} percentile of the volume pumped data set for each irrigation system type with each delivery zone. Final allocations with maximum bridging volumes equate to the 95^{th} percentile or two times the minimum delivery component if greater, providing sufficient (temporary) allocation for up to 95% of irrigators.

The results of the FIST site analysis provide confidence that the 75^{th} percentile is a reliable cut-off point to define ‘reasonably efficient’ irrigators. In conclusion the proposed volumetric conversion model achieves the aim of providing reasonably efficient irrigators with sufficient allocation to continue their current irrigation practices.

APPENDICES

A. SOIL MAPS

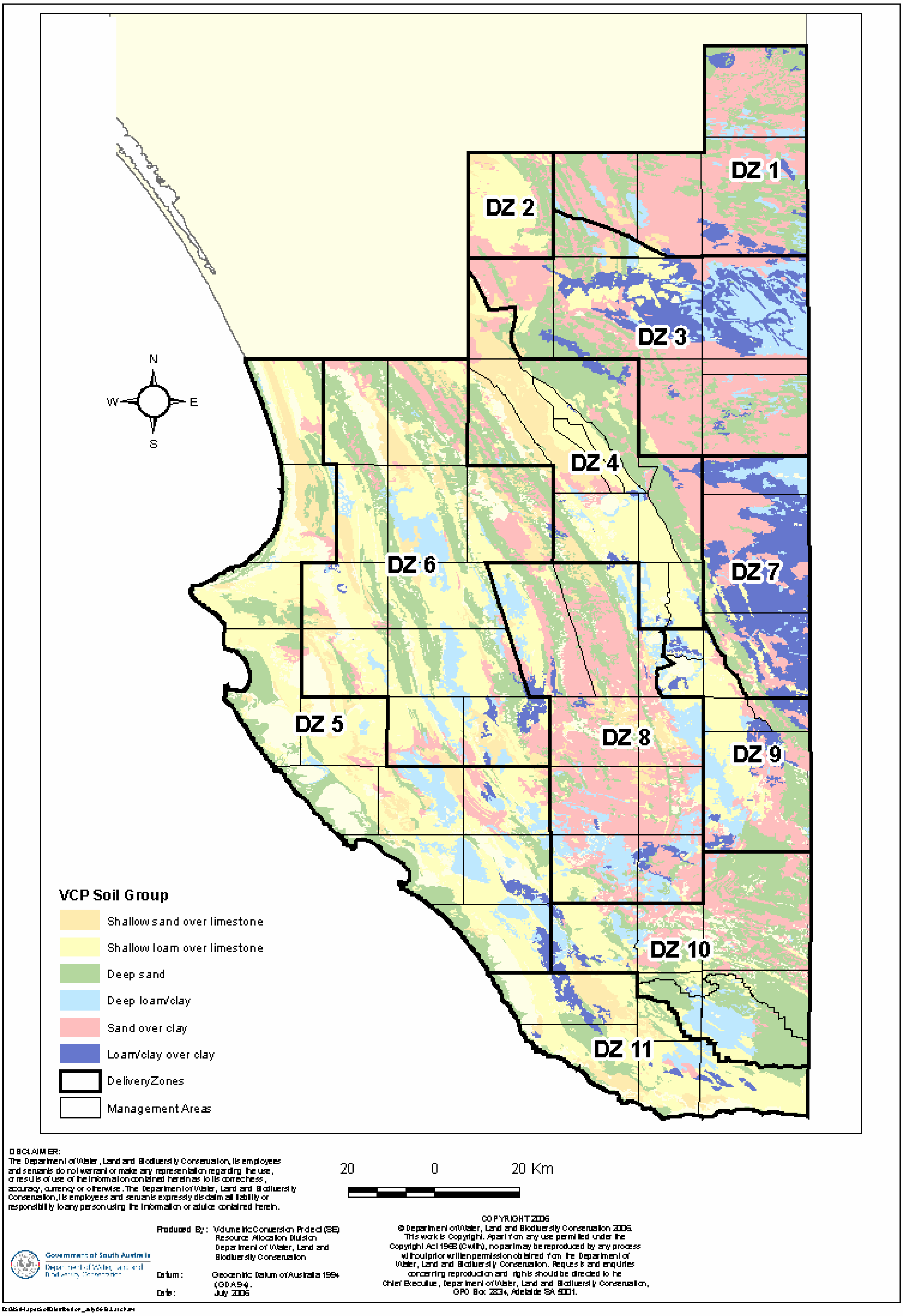

Figure 4. Soil Distribution of the SE – Using the Volumetric Conversion Soil Categories

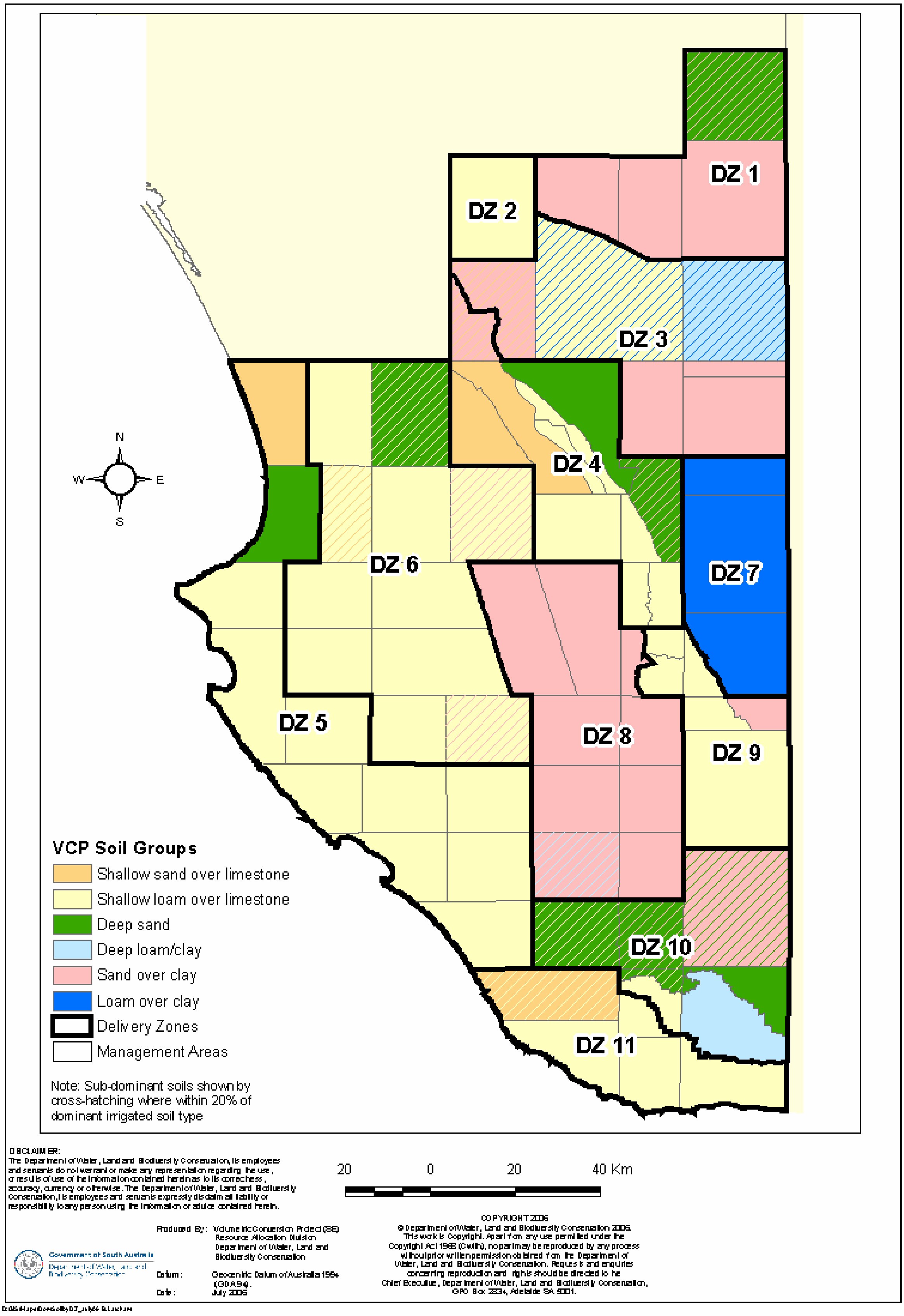

Figure 5. Dominant Irrigated Soils – Using the Volumetric Conversion Soil Categories

B. MAPS OF VOLUMES PUMPED

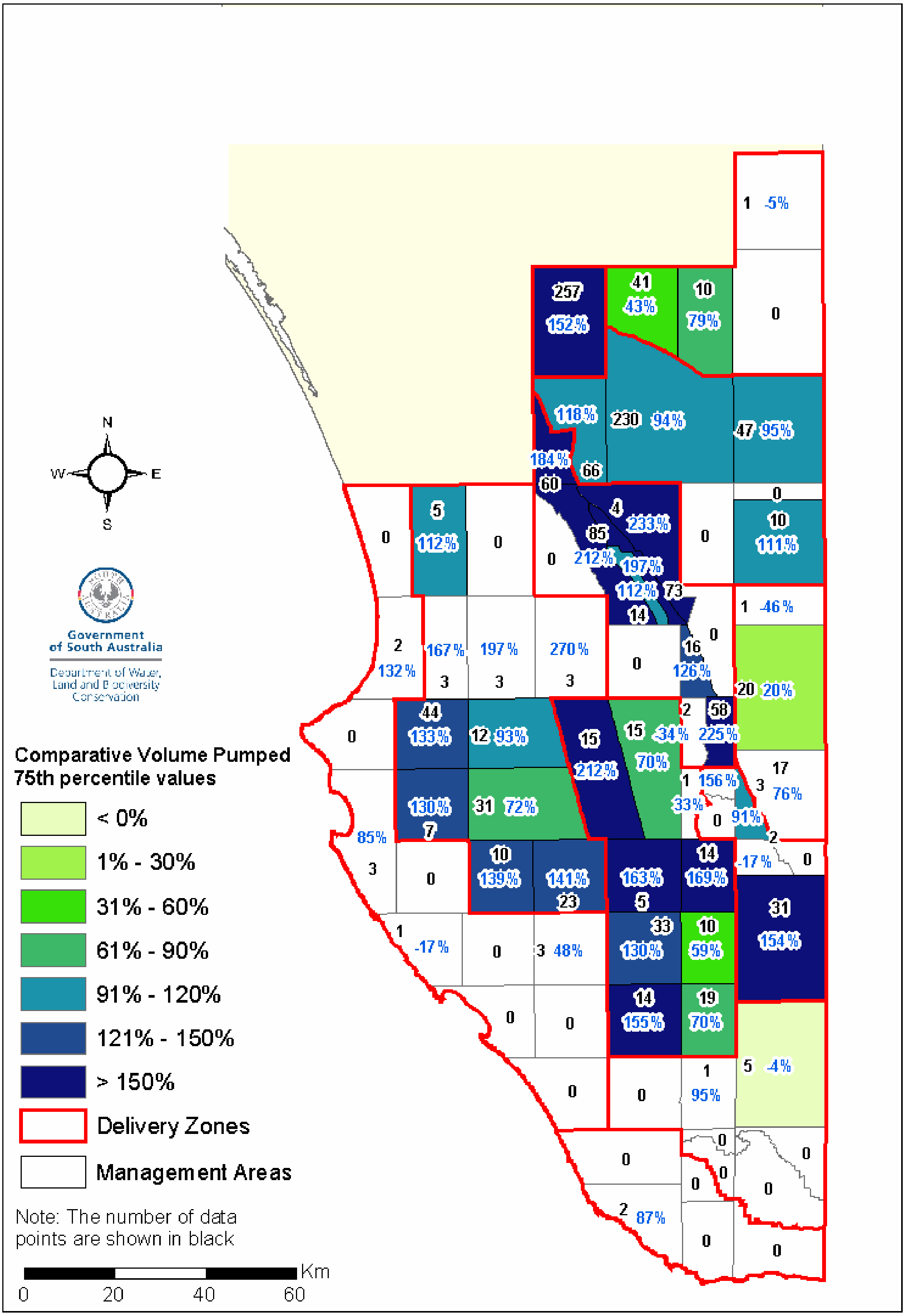

Figure 6. **Volumes Pumped for Flood Irrigation**

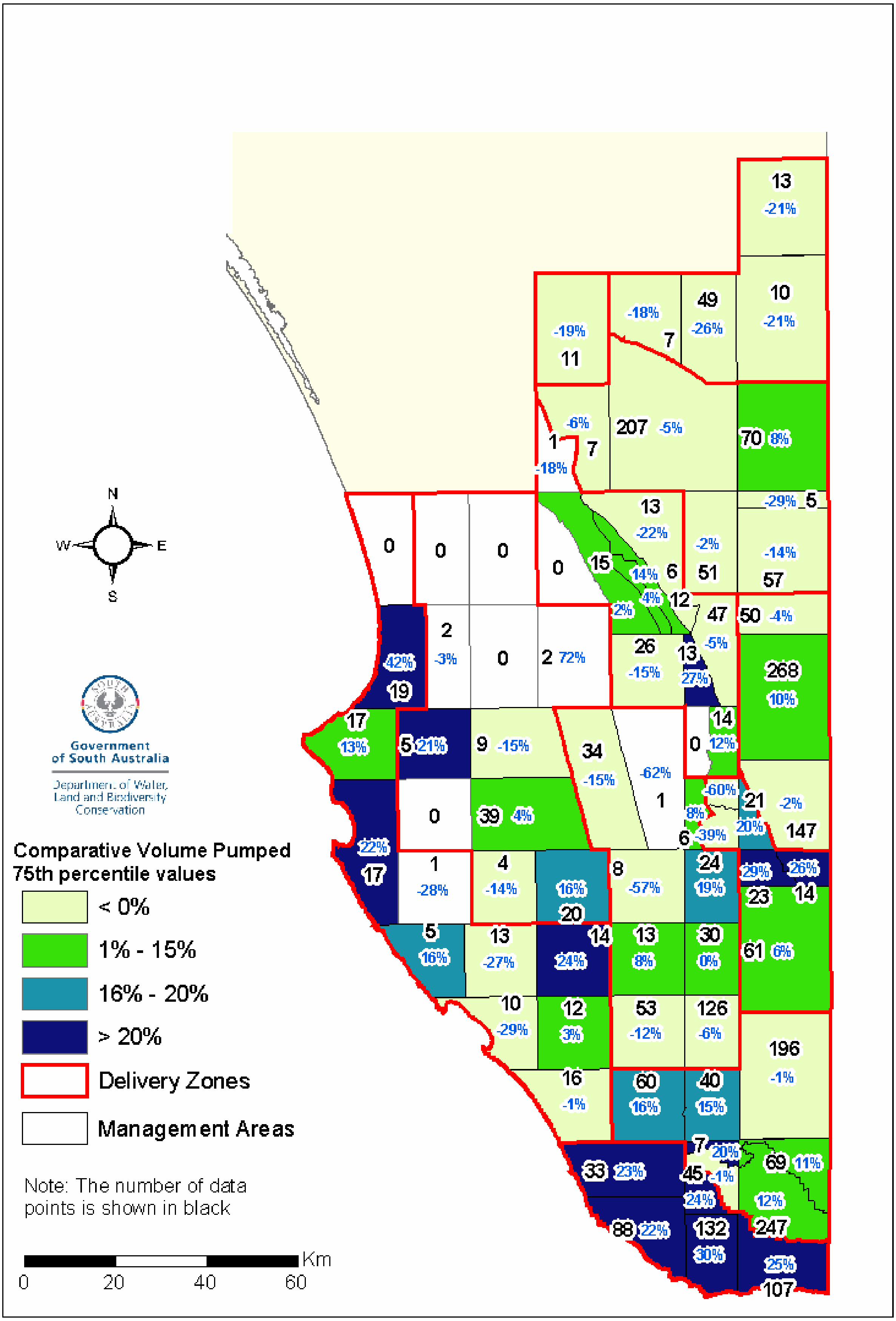

Figure 7. Volumes Pumped for Spray Irrigation

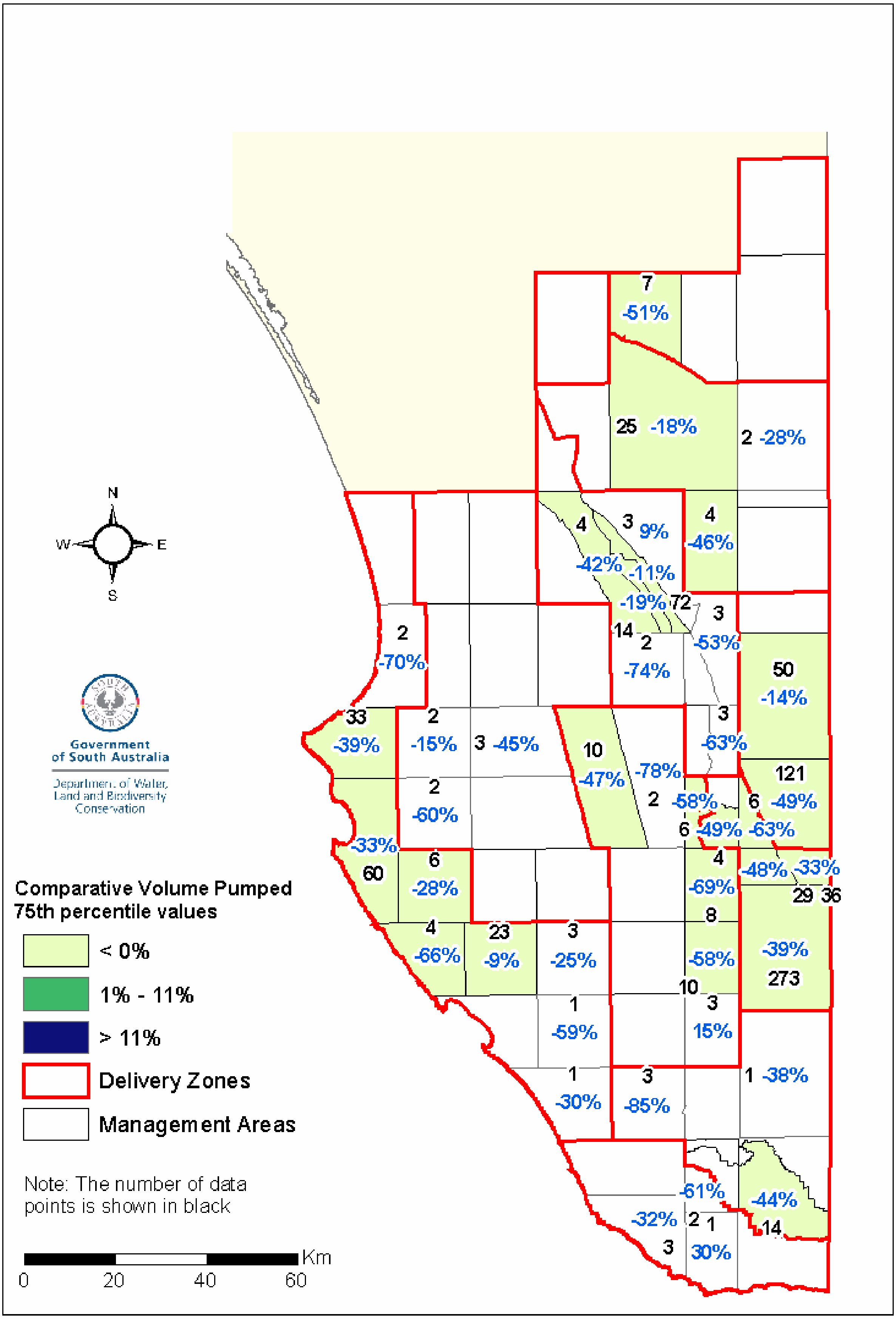

Figure 8. Volumes Pumped for Drip Irrigation

C. DELIVERY COMPONENT VOLUMES

Management Area*	Base Value (ML/haIE)	Delivery Zone	Drip Delivery Component		Flood Delivery Component		Spray Delivery Component	
			Factor (%)	*Volume (ML/haIE)*	*Factor (%)*	*Volume (ML/haIE)*	*Factor (%)*	*Volume (ML/haIE)*
Bangham	6.70	DZ 3	0.11	0.74	1.02	6.83	0.18	1.21
Beeamma	6.70	DZ 3	0.11	0.74	1.02	6.83	0.18	1.21
Benara	4.90	DZ 11	0.11	0.54	0.54	2.65	0.27	1.32
Blanche Central	4.90	DZ 10	0.11	0.54	0.54	2.65	0.18	0.88
Bool	6.15	DZ 9	0.11	0.68	1.23	7.56	0.18	1.11
Bowaka	6.15	DZ 6	0.11	0.68	1.32	8.12	0.18	1.11
Bray	5.49	DZ 5	0.11	0.60	1.32	7.25	0.18	0.99
Cannawigara	7.66	DZ 1	0.11	0.84	0.54	4.14	0.18	1.38
Coles	5.84	DZ 8	0.11	0.64	1.32	7.71	0.18	1.05
Comaum	5.84	DZ 9	0.11	0.64	1.23	7.18	0.18	1.05
Compton	4.90	DZ 10	0.11	0.54	0.54	2.65	0.18	0.88
Conmurra	5.84	DZ 6	0.11	0.64	1.32	7.71	0.18	1.05
Donovans	4.90	DZ 11	0.11	0.54	0.54	2.65	0.27	1.32
Duffield	6.70	DZ 5	0.11	0.74	1.32	8.84	0.18	1.21
Fox	5.84	DZ 6	0.11	0.64	1.32	7.71	0.18	1.05
Frances	6.40	DZ 7	0.11	0.70	0.54	3.46	0.18	1.15
Glenburnie	4.90	DZ 10	0.11	0.54	0.54	2.65	0.18	0.88
Glenroy	5.84	DZ 9	0.11	0.64	1.23	7.18	0.18	1.05
Grey	5.08	DZ 8	0.11	0.56	1.32	6.71	0.18	0.91
Hacks	6.15	DZ 9	0.11	0.68	1.23	7.56	0.18	1.11
Hindmarsh	4.90	DZ 10	0.11	0.54	0.54	2.65	0.18	0.88
Hynam East	6.40	DZ 4	0.11	0.70	1.99	12.74	0.18	1.15
Hynam West	6.40	DZ 4	0.11	0.70	1.99	12.74	0.18	1.15
Joanna	5.84	DZ 7	0.11	0.64	0.54	3.15	0.18	1.05
Joyce	6.15	DZ 8	0.11	0.68	1.32	8.12	0.18	1.11
Kennion	5.49	DZ 5	0.11	0.60	1.32	7.25	0.18	0.99
Killanoola	5.84	DZ 8	0.11	0.64	1.32	7.71	0.18	1.05
Kongorong	4.90	DZ 11	0.11	0.54	0.54	2.65	0.27	1.32
Lacepede	6.15	DZ 5	0.11	0.68	1.32	8.12	0.18	1.11
Lake george	5.49	DZ 5	0.11	0.60	1.32	7.25	0.18	0.99
Landseer	6.70	DZ 6	0.11	0.74	1.32	8.84	0.18	1.21
Lochaber	6.40	DZ 4	0.11	0.70	1.99	12.74	0.18	1.15
Macdonnell	4.90	DZ 11	0.11	0.54	0.54	2.65	0.27	1.32
Management Area 1 (MA1)	6.70	DZ 4	0.11	0.74	1.99	13.33	0.18	1.21
Management Area 2 (MA2)	6.70	DZ 4	0.11	0.74	1.99	13.33	0.18	1.21
Management Area 3 (MA3)	6.70	DZ 4	0.11	0.74	1.99	13.33	0.18	1.21

Management Area*	Base Value (ML/haIE)	Delivery Zone	Drip Delivery Component		Flood Delivery Component		Spray Delivery Component	
			Factor (%)	*Volume (ML/haIE)*	*Factor (%)*	*Volume (ML/haIE)*	*Factor (%)*	*Volume (ML/haIE)*
Management Area 4 (MA4)	6.70	DZ 4	0.11	0.74	1.99	13.33	0.18	1.21
Marcollat	6.70	DZ 4	0.11	0.74	1.99	13.33	0.18	1.21
Mayurra	5.08	DZ 5	0.11	0.56	1.32	6.71	0.18	0.91
Minecrow	6.15	DZ 6	0.11	0.68	1.32	8.12	0.18	1.11
Monbulla	5.49	DZ 8	0.11	0.60	1.32	7.25	0.18	0.99
Moorak	4.90	DZ 11	0.11	0.54	0.54	2.65	0.27	1.32
Mount Benson	6.15	DZ 5	0.11	0.68	1.32	8.12	0.18	1.11
Mount Muirhead	5.08	DZ 5	0.11	0.56	1.32	6.71	0.18	0.91
Moyhall	6.15	DZ 8	0.11	0.68	1.32	8.12	0.18	1.11
Murrabinna	6.15	DZ 6	0.11	0.68	1.32	8.12	0.18	1.11
Myora	4.90	DZ 10	0.11	0.54	0.54	2.65	0.18	0.88
North Pendleton	7.66	DZ 1	0.11	0.84	0.54	4.14	0.18	1.38
Ormerod	6.15	DZ 4	0.11	0.68	1.99	12.24	0.18	1.11
Peacock	6.70	DZ 6	0.11	0.74	1.32	8.84	0.18	1.21
Riddoch	5.08	DZ 8	0.11	0.56	1.32	6.71	0.18	0.91
Rivoli bay	5.08	DZ 5	0.11	0.56	1.32	6.71	0.18	0.91
Ross	5.84	DZ 6	0.11	0.64	1.32	7.71	0.18	1.05
Shaugh	8.18	DZ 1	0.11	0.90	0.54	4.42	0.18	1.47
Short	5.49	DZ 8	0.11	0.60	1.32	7.25	0.18	0.99
Smith	5.49	DZ 6	0.11	0.60	1.32	7.25	0.18	0.99
Spence	6.15	DZ 8	0.11	0.68	1.32	8.12	0.18	1.11
Stewarts	6.15	DZ 4	0.11	0.68	1.99	12.24	0.18	1.11
Stirling	7.66	DZ 2	0.11	0.84	1.52	11.64	0.18	1.38
Struan	5.84	DZ 9	0.11	0.64	1.23	7.18	0.18	1.05
Symon	5.08	DZ 5	0.11	0.56	1.32	6.71	0.18	0.91
Tatiara	7.26	DZ 3	0.11	0.80	1.02	7.41	0.18	1.31
Townsend	6.15	DZ 6	0.11	0.68	1.32	8.12	0.18	1.11
Waterhouse	5.84	DZ 5	0.11	0.64	1.32	7.71	0.18	1.05
Western Flat	7.26	DZ 3	0.11	0.80	1.02	7.41	0.18	1.31
Willalooka (east)	7.26	DZ 3	0.11	0.80	1.02	7.41	0.18	1.31
Willalooka (west)	7.26	DZ 4	0.11	0.80	1.99	14.45	0.18	1.31
Wirrega (south)	7.26	DZ 3	0.11	0.80	1.02	7.41	0.18	1.31
Wirrega (north)	7.66	DZ 3	0.11	0.84	1.02	7.81	0.18	1.38
Woolumbool	6.40	DZ 6	0.11	0.70	1.32	8.45	0.18	1.15
Young	4.90	DZ 10	0.11	0.54	0.54	2.65	0.18	0.88
Zone 2A	5.08	DZ 10	0.11	0.56	0.54	2.74	0.18	0.91
Zone 3A	5.49	DZ 9	0.11	0.60	1.23	6.75	0.18	0.99
Zone 5A	6.15	DZ 7	0.11	0.68	0.54	3.32	0.18	1.11
Zone 8A	7.66	DZ 1	0.11	0.84	0.54	4.14	0.18	1.38

* See Figure 9, Appendix E for location of Management Areas

D. BRIDGING VOLUMES

Management Area*	Base Value (ML/haIE)	Delivery Zone	Drip Bridging Volume		Flood Bridging Volume		Spray Bridging Volume	
			Factor (%)	*Volume (ML/haIE)*	*Factor (%)*	*Volume (ML/haIE)*	*Factor (%)*	*Volume (ML/haIE)*
Bangham	6.70	DZ 3	0.11	0.74	1.36	9.11	0.31	2.08
Beeamma	6.70	DZ 3	0.11	0.74	1.36	9.11	0.31	2.08
Benara	4.90	DZ 11	0.11	0.54	0.54	2.65	0.39	1.91
Blanche Central	4.90	DZ 10	0.11	0.54	0.54	2.65	0.44	2.16
Bool	6.15	DZ 9	0.11	0.68	1.56	9.59	0.27	1.66
Bowaka	6.15	DZ 6	0.11	0.68	1.45	8.92	0.22	1.35
Bray	5.49	DZ 5	0.11	0.60	1.45	7.96	0.50	2.75
Cannawigara	7.66	DZ 1	0.11	0.84	0.54	4.14	0.18	1.38
Coles	5.84	DZ 8	0.11	0.64	1.04	6.07	0.23	1.34
Comaum	5.84	DZ 9	0.11	0.64	1.56	9.11	0.27	1.58
Compton	4.90	DZ 10	0.11	0.54	0.54	2.65	0.44	2.16
Conmurra	5.84	DZ 6	0.11	0.64	1.45	8.47	0.22	1.28
Donovans	4.90	DZ 11	0.11	0.54	0.54	2.65	0.39	1.91
Duffield	6.70	DZ 5	0.11	0.74	1.45	9.72	0.50	3.35
Fox	5.84	DZ 6	0.11	0.64	1.45	8.47	0.22	1.28
Frances	6.40	DZ 7	0.11	0.70	0.54	3.46	0.38	2.43
Glenburnie	4.90	DZ 10	0.11	0.54	0.54	2.65	0.44	2.16
Glenroy	5.84	DZ 9	0.11	0.64	1.56	9.11	0.27	1.58
Grey	5.08	DZ 8	0.11	0.56	1.04	5.28	0.23	1.17
Hacks	6.15	DZ 9	0.11	0.68	1.56	9.59	0.27	1.66
Hindmarsh	4.90	DZ 10	0.11	0.54	0.54	2.65	0.44	2.16
Hynam east	6.40	DZ 4	0.11	0.70	1.14	7.30	0.19	1.22
Hynam west	6.40	DZ 4	0.11	0.70	1.14	7.30	0.19	1.22
Joanna	5.84	DZ 7	0.11	0.64	0.54	3.15	0.38	2.22
Joyce	6.15	DZ 8	0.11	0.68	1.04	6.40	0.23	1.41
Kennion	5.49	DZ 5	0.11	0.60	1.45	7.96	0.50	2.75
Killanoola	5.84	DZ 8	0.11	0.64	1.04	6.07	0.23	1.34
Kongorong	4.90	DZ 11	0.11	0.54	0.54	2.65	0.39	1.91
Lacepede	6.15	DZ 5	0.11	0.68	1.45	8.92	0.50	3.08
Lake george	5.49	DZ 5	0.11	0.60	1.45	7.96	0.50	2.75
Landseer	6.70	DZ 6	0.11	0.74	1.45	9.72	0.22	1.47
Lochaber	6.40	DZ 4	0.11	0.70	1.14	7.30	0.19	1.22
Macdonnell	4.90	DZ 11	0.11	0.54	0.54	2.65	0.39	1.91
Management Area 1 (MA1)	6.70	DZ 4	0.11	0.74	1.14	7.64	0.19	1.27
Management Area 2 (MA2)	6.70	DZ 4	0.11	0.74	1.14	7.64	0.19	1.27
Management Area 3 (MA3)	6.70	DZ 4	0.11	0.74	1.14	7.64	0.19	1.27

Management Area*	Base Value (ML/haIE)	Delivery Zone	Drip Bridging Volume		Flood Bridging Volume		Spray Bridging Volume	
			Factor (%)	*Volume (ML/haIE)*	*Factor (%)*	*Volume (ML/haIE)*	*Factor (%)*	*Volume (ML/haIE)*
Management Area 4 (MA4)	6.70	DZ 4	0.11	0.74	1.14	7.64	0.19	1.27
Marcollat	6.70	DZ 4	0.11	0.74	1.14	7.64	0.19	1.27
Mayurra	5.08	DZ 5	0.11	0.56	1.45	7.37	0.50	2.54
Minecrow	6.15	DZ 6	0.11	0.68	1.45	8.92	0.22	1.35
Monbulla	5.49	DZ 8	0.11	0.60	1.04	5.71	0.23	1.26
Moorak	4.90	DZ 11	0.11	0.54	0.54	2.65	0.39	1.91
Mount Benson	6.15	DZ 5	0.11	0.68	1.45	8.92	0.50	3.08
Mount Muirhead	5.08	DZ 5	0.11	0.56	1.45	7.37	0.50	2.54
Moyhall	6.15	DZ 8	0.11	0.68	1.04	6.40	0.23	1.41
Murrabinna	6.15	DZ 6	0.11	0.68	1.45	8.92	0.22	1.35
Myora	4.90	DZ 10	0.11	0.54	0.54	2.65	0.44	2.16
North Pendleton	7.66	DZ 1	0.11	0.84	0.54	4.14	0.18	1.38
Ormerod	6.15	DZ 4	0.11	0.68	1.14	7.01	0.19	1.17
Peacock	6.70	DZ 6	0.11	0.74	1.45	9.72	0.22	1.47
Riddoch	5.08	DZ 8	0.11	0.56	1.04	5.28	0.23	1.17
Rivoli Bay	5.08	DZ 5	0.11	0.56	1.45	7.37	0.50	2.54
Ross	5.84	DZ 6	0.11	0.64	1.45	8.47	0.22	1.28
Shaugh	8.18	DZ 1	0.11	0.90	0.54	4.42	0.18	1.47
Short	5.49	DZ 8	0.11	0.60	1.04	5.71	0.23	1.26
Smith	5.49	DZ 6	0.11	0.60	1.45	7.96	0.22	1.21
Spence	6.15	DZ 8	0.11	0.68	1.04	6.40	0.23	1.41
Stewarts	6.15	DZ 4	0.11	0.68	1.14	7.01	0.19	1.17
Stirling	7.66	DZ 2	0.11	0.84	1.03	7.89	0.18	1.38
Struan	5.84	DZ 9	0.11	0.64	1.56	9.11	0.27	1.58
Symon	5.08	DZ 5	0.11	0.56	1.45	7.37	0.50	2.54
Tatiara	7.26	DZ 3	0.11	0.80	1.36	9.87	0.31	2.25
Townsend	6.15	DZ 6	0.11	0.68	1.45	8.92	0.22	1.35
Waterhouse	5.84	DZ 5	0.11	0.64	1.45	8.47	0.50	2.92
Western Flat	7.26	DZ 3	0.11	0.80	1.36	9.87	0.31	2.25
Willalooka (east)	7.26	DZ 3	0.11	0.80	1.36	9.87	0.31	2.25
Willalooka (west)	7.26	DZ 4	0.11	0.80	1.14	8.28	0.19	1.38
Wirrega (south)	7.26	DZ 3	0.11	0.80	1.36	9.87	0.31	2.25
Wirrega (north)	7.66	DZ 3	0.11	0.84	1.36	10.42	0.31	2.37
Woolumbool	6.40	DZ 6	0.11	0.70	1.45	9.28	0.22	1.41
Young	4.90	DZ 10	0.11	0.54	0.54	2.65	0.44	2.16
Zone 2A	5.08	DZ 10	0.11	0.56	0.54	2.74	0.44	2.24
Zone 3A	5.49	DZ 9	0.11	0.60	1.56	8.56	0.27	1.48
Zone 5A	6.15	DZ 7	0.11	0.68	0.54	3.32	0.38	2.34
Zone 8A	7.66	DZ 1	0.11	0.84	0.54	4.14	0.18	1.38

* See Figure 9, Appendix E for location of Management Areas

E. LOCATION OF MANAGEMENT AREAS

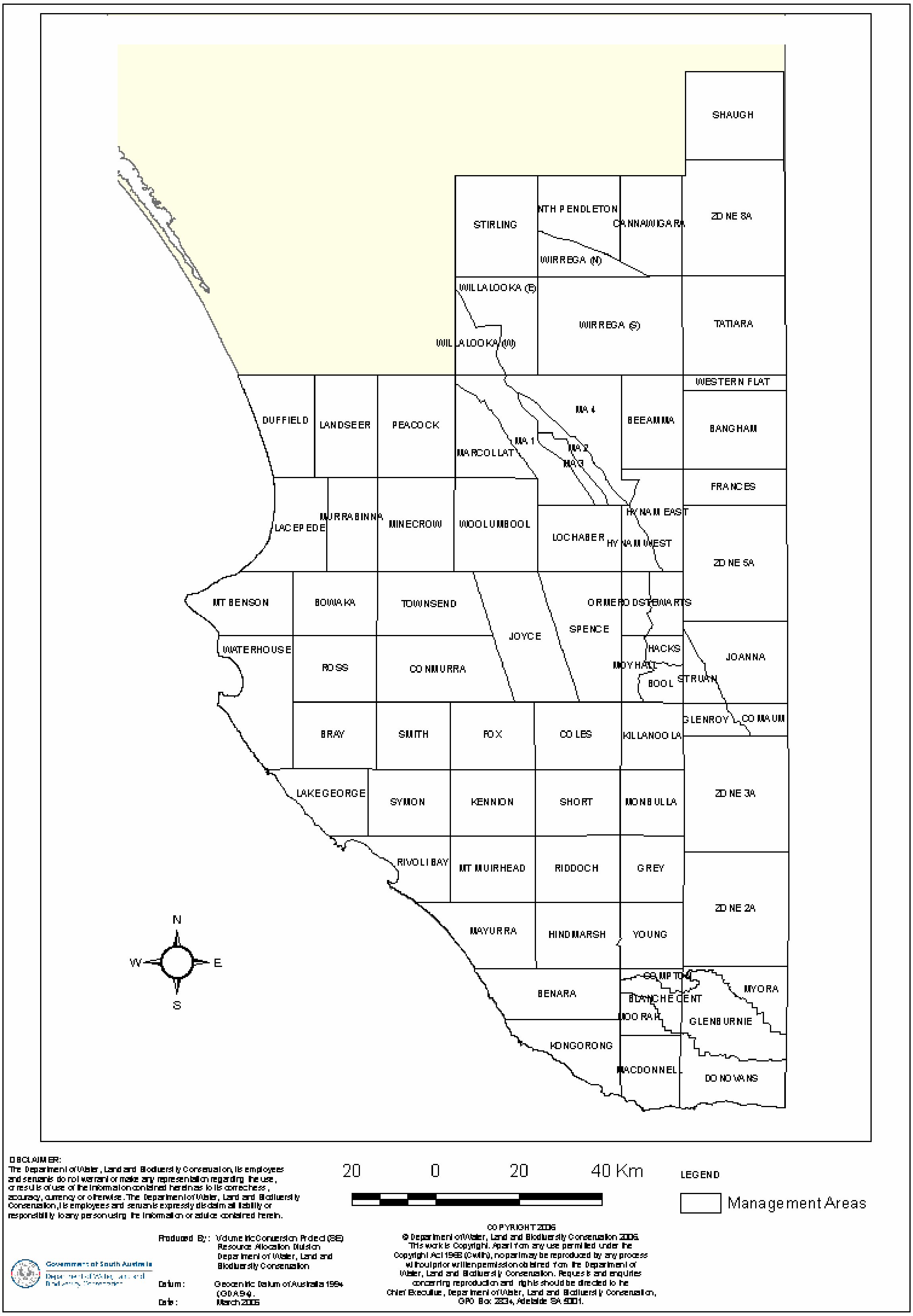

Figure 9. Location of Management Areas

UNITS OF MEASUREMENT

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

Name of unit	Symbol	Definition in terms of other metric units	Quantity
centimetre	cm	mm x 10	length
comparative volume pumped	CVP (%)	percent, decimal	proportion
hectare	ha	10^4 m^2	area
irrigation rate/requirement	ML/ha	mm depth	rate
megalitre	ML	10^3 m^3	volume
percent	%	fractions, decimal	proportion
percentile	$X_{\%}$	median (50th percentile)	Frequency distribution
year	y	365 or 366 days	time interval

GLOSSARY

Annual Water Use Returns (AWUR's). End of season reporting process whereby water license holders detail their water use activities for the given season. The details required include areas of crop types grown and assessments of volumes pumped.

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 (haIE). 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 (haIE).

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

Bridging Volume (BV). The bridging volume is an additional temporary allocation that may be granted on application subject to eligibility criteria. 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.

Comparative Volume Pumped (CVP). The difference between the seasonal volume pumped for irrigation and the seasonal NIRc, expressed as a percentage of NIRc, i.e. CVP = (volume pumped – NIRc)/NIRc.

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 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 (i.e. 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.

Drip Irrigation. High precision irrigation where water is delivered via emitters (drip, trickle, micro-spray) spaced evenly along a supply line, usually located along each crop row.

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.*

Field Irrigation System Trials (FIST Program). Field trial sites equipped with monitoring equipment to collect detailed information on the on-farm irrigation water balance.

Flood/Surface Irrigation. Non-pressurised gravity feed irrigation, whereby water is delivered from the pump via channels to fields constructed to form rectangular bays using parallel check banks. Water flows down the bay's slope as a sheet guided by the check banks.

Frost Protection. Water applied to the crop canopy using fixed overhead sprinklers to prevent frost damage to the crop.

haIE. 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 haIE 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).

Leaching. The application of irrigation water to minimise the built up of salts from the crop root zone.

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.

Metered Extraction Trials (MET Program). A field trial program aimed at generating accurate 'real-life' volume pumped data representative of irrigation practices in the region.

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 (NIR_0). 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).

Percentile. Increments of 1% that divides a distribution into 100 groups of equal frequency. For example the 50^{th} percentile is a point where 50% of the data below this point and 50% is above.

Post-Harvest Cover Crop. A crop sown after the harvest of annual crops to stabilise and retain the bare soil.

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.

Project Advisory Committee (PAC). A community-based committee made up of industry representatives from major commodity groups to provide advice to the PMC on the implementation of the Volumetric Conversion Project.

Project Management Committee (PMC). Representatives from the key water management agencies associated with and responsible for implementing volumetric conversion in the region.

Reference Crop Evapotranspiration (ET_0). Rate of evapotranspiration from an extended surface of 8 to 15cm tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of water (Doorenbos and Pruitt, 1977).

Soil Drift Control. The application of irrigation water to a bare field or emergent crop for the purpose of preventing soil from being lost or causing crop damage due wind drift.

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.

Spray Irrigation. Pressurised irrigation systems with water applied through some form of sprinkler/s. Water is delivered from the pump to the sprinkler through pipe works. Includes centre pivots, fixed sprinklers and travelling irrigators.

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

Brouwer, C, Prins, K & Heibloem, M 1989, *Irrigation Scheduling*, FAO Irrigation Water Management Training Manual No. 4, Food and Agriculture Organization of the United Nations, Rome.

Fowler, J & Cohen, L. (1990). *Practical Statistics for Field Biology.* John Wiley and Sons, England.

Phocaides, A 2001, *Handbook on Pressurized Irrigation Techniques*, Food and Agriculture Organization of the United Nations, Rome.

Pudney, S, Latcham B & Carruthers, R 2006, *Volumetric Conversion in the South East of South Australia: Calculation of Specialised Production Requirements,* DWLBC Report 2006/31, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Mount Gambier.

Pudney, S 2006, *Volumetric Conversion in the South East of South Australia: Validating the allocation model,* DWLBC Report 2006/30, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Mount Gambier.

River Murray Catchment Water Management Board 2002, *Water Allocation Plan for the River Murray Prescribed Watercourse*, River Murray Catchment Water Management Board, Berri, South Australia.

Skewes, M 2006, *Definition of Net Irrigation Requirements in the South East of South Australia,* Report to Department of Water Land and Biodiversity Conservation, Irrigated Crop Management Service, Rural Solutions SA, Primary Industries and Resources South Australia.

Tanji, KK & Yaron, B, eds 1994, *Management of Water Use in Agriculture*, Advanced Series in Agricultural Sciences 22, Springer-Verlag, Berlin.