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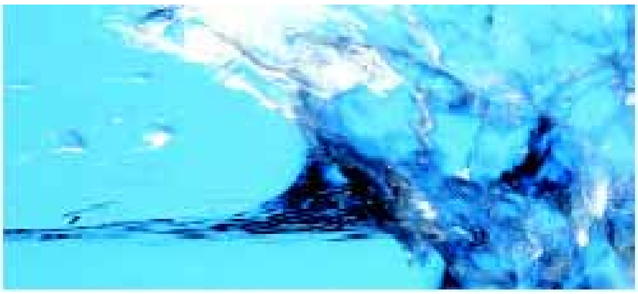

Blue Lake capture zone trial field survey

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Report DWLBC 2004/27

Government
of South Australia

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Foreword

South Australia's natural resources are fundamental to the economic and social well-being of the State. One of the State's most precious natural resources, water is a basic requirement of all living organisms and is one of the essential elements ensuring biological diversity of life at all levels. In pristine or undeveloped situations, the condition of water resources reflects the equilibrium between, rainfall, vegetation and other physical parameters. Development of these resources changes the natural balance and may cause degradation. If degradation is small, and the resource retains its utility, the community may assess these changes as being acceptable. However, significant stress will impact on the ability of the resource to continue to meet the needs of users and the environment. Understanding the cause and effect relationship between the various stresses imposed on the natural resources is paramount to developing effective management strategies. Reports of investigations into the availability and quality of water supplies throughout the State aim to build upon the existing knowledge base enabling the community to make informed decisions concerning the future management of the natural resources thus ensuring conservation of biological diversity.

Bryan Harris
Director, Knowledge and Information Division
Department of Water, Land and Biodiversity Conservation

CONTENTS

LIST OF TABLES

LIST OF FIGURES

SI UNITS COMMONLY USED WITHIN TEXT

Name of unit	Symbol	Definition in terms of other metric units	
Millimetre	mm	10^{-3} m	length
Metre	m		length
Kilometre	km	10^{3} m	length
Hectare	ha	10^{4} m^{2}	area
Microlitre	µL	10^{-9} m^{3}	volume
Millilitre	mL	10^{-6} m^{3}	volume
Litre	L	10^{-3} m^{3}	volume
Kilolitre	kL	1 m^{3}	volume
Megalitre	ML	10^{3} m^{3}	volume
Gigalitres	GL	10^{6} m^{3}	volume
Microgram	µg	10^{-6} g	mass
Milligram	mg	10^{-3} g	mass
Gram	g		mass
Kilogram	kg	10^{3} g	Mass

Abbreviations Commonly Used Within Text

Abbreviation		Name	Units of measure
TDS	=	Total Dissolved Solids *(milligrams per litre)*	mg/L
EC	=	Electrical Conductivity *(micro Siemens per centimetre)*	µS/cm
PH	=	Acidity	
δD	=	Hydrogen isotope composition	$^{o}/_{oo}$
CFC	=	Chlorofluorocarbon *(parts per trillion volume)*	pptv
δ^{18}O	=	Oxygen isotope composition	$^{o}/_{oo}$
^{14}C	=	Carbon-14 isotope *(percent modern Carbon)*	pmC
Ppm	=	Parts per million	
Ppb	=	Parts per billion	

ABSTRACT

Increased irrigation occurring in the Lower Southeast has shown the need to calculate total water use. A first step in this process has been a commitment by DWLBC through the lower southeast groundwater assessment study to calculate a water budget for the Blue Lake Capture Zone. An area was selected so that techniques could be trialled to calculate stock, domestic and irrigation water use and relate them back to various agricultural practices and land uses. A relationship seems to exists between land use and Nitrate as N.

Estimated irrigation water use was calculated using a number of methods for comparative purposes. Stock and domestic water use was then expressed as a percentage of Irrigation water use and was calculated as 8 percent. Taking into account summer to winter variations in stock numbers, this figure probably varies between 6 to 8 percent. As this was calculated in an area of fairly intense irrigation, other parts of the region could have a slightly higher figure.

Total water use was estimated at 3301.3 megalitres, which is about the same water use as the municipal area of Mount Gambier. To meet this water use for the area surveyed, around 60 mm of recharge per hectare per year is needed. This water use figure is occurring with only about 45 percent of licensed irrigation occurring. Most irrigation water is pumped through a six-month period.

An important water quality issue was the number of wells that were unequipped or abandoned, as a potential exists to contribute to point source contamination of the aquifer.

During the survey as many water samples as possible were taken and analyzed for Nitrate (As N), and Total Dissolved Salts to gain a comprehensive insight into the groundwater water quality for the area. The salinity levels for the area were of excellent quality and averaged 462 milligrams per litre and the Nitrate as N average is 6.05 milligrams per litre. For the survey area 84% of all Nitrate as N samples were below the W.H.O. limit of 10 mg/L.

1 INTRODUCTION

The Blue Lake is important to Mount Gambier as both a water supply to the city and also as a natural wonder that attracts visitors to the region. While the pumping supply rates from the Lake are well known, the amount of water pumped from the rest of the Blue Lake Capture Zone has never been calculated. This survey was conducted in a trial area to use a number of techniques to calculate stock, domestic and irrigation water use.

A more precise knowledge of the amount of water that is used for stock, domestic and irrigation practices is required within the Blue Lake Catchment zone, prior to calculation of a water budget. A further determination is the amount of stock and domestic water used, as a percentage of irrigation water usage.

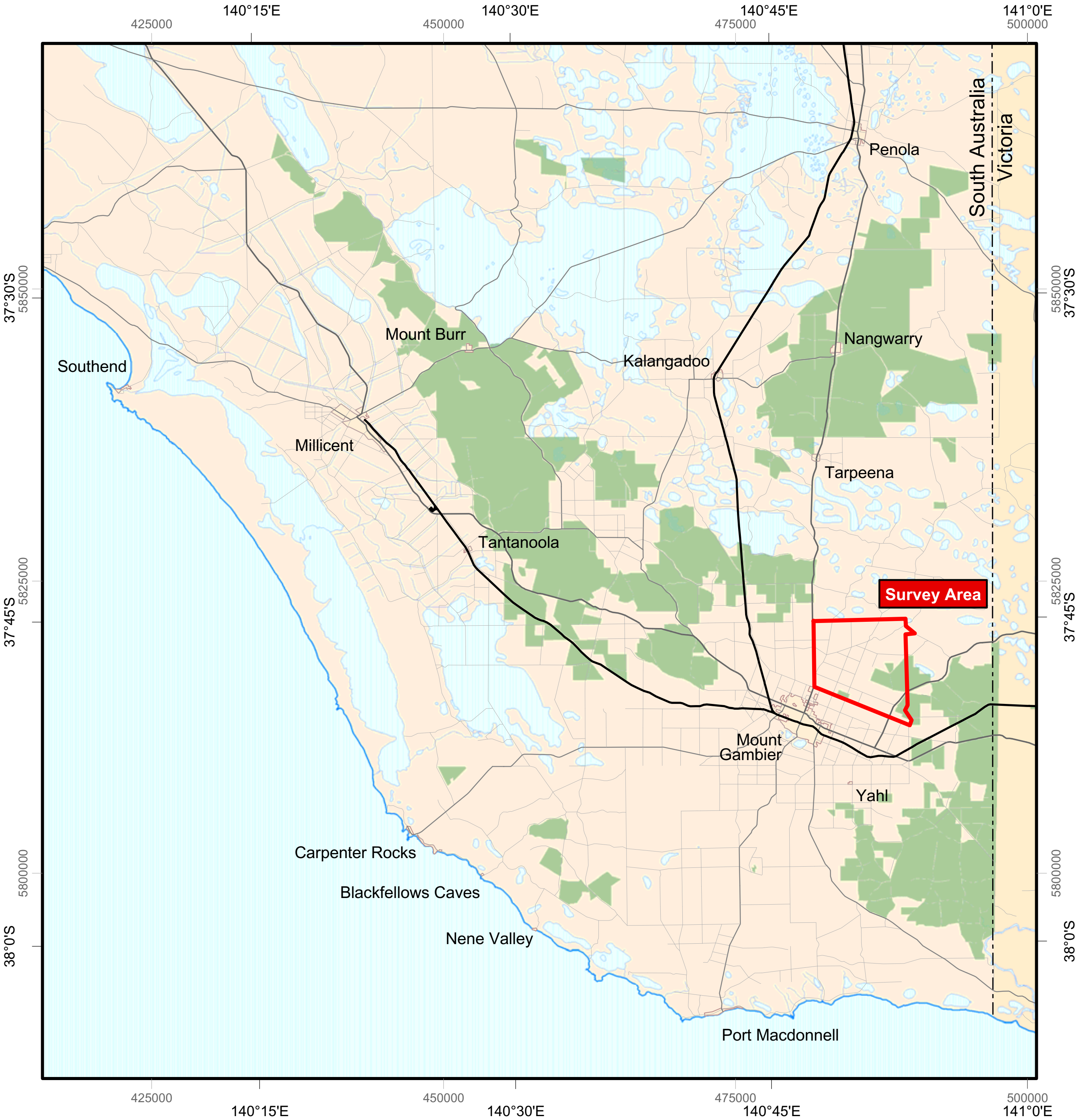
An average amount of about 3600 megalitres per year is pumped from the Blue Lake for the water consumption needs for the city of Mount Gambier. Peak values of 4300 megalitres were recorded in 1976 and 1990. This survey was conducted to estimate the water use immediately up gradient of the Lake.

The best way to begin the process was to:

- Initially survey a trial area.
- Compile the results to ascertain whether the techniques used would provide meaningful figures.
- Upscale to the whole of the catchment.

A trial area was selected that looked at as many land uses and agricultural practices as possible so that a balanced result was achieved. The trial zone is shown in Figures 1 and 2. It also included an area that had previously been surveyed in the late seventies and the early eighties so that some 20-year water quality data comparisons could be made.

The South East Catchment Water Management Board (SECWMB) was able to contribute financially to the water sample testing, so that as many samples as possible could be laboratory analyzed for oxidized nitrogen (Nitrate as N). Total dissolved salts were tested in the Mount Gambier office of the Department for Water, Land and Biodiversity Conservation.



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Datum GDA94 – Projection MGA Zone 54

Blue Lake Capture Zone
Trial Field Survey

LOCALITY PLAN

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Figure 1

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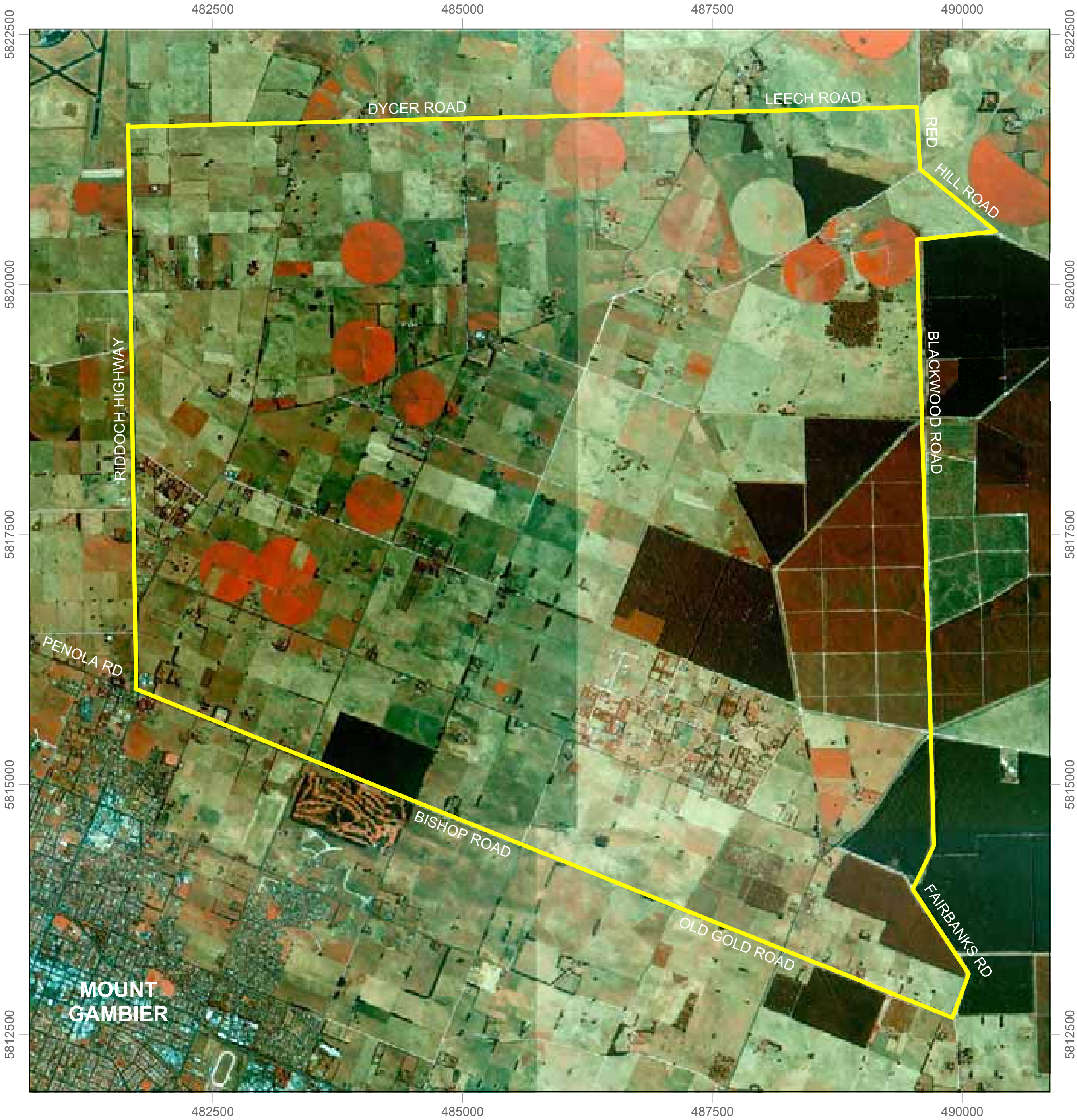

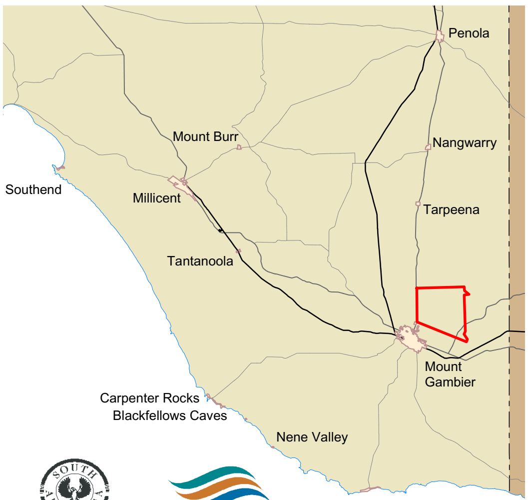

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Datum GDA94 – Projection MGA Zone 54

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Figure 2

Blue Lake Capture Zone
Trial Field Survey

TRIAL FIELD SURVEY AREA

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2 HYDROGEOLOGY

In the study area groundwater is predominantly extracted from the tertiary unconfined Gambier limestone aquifer. Across the northern part of the study area, water is also extracted from the sandstone of the overlying Bridgewater formation.

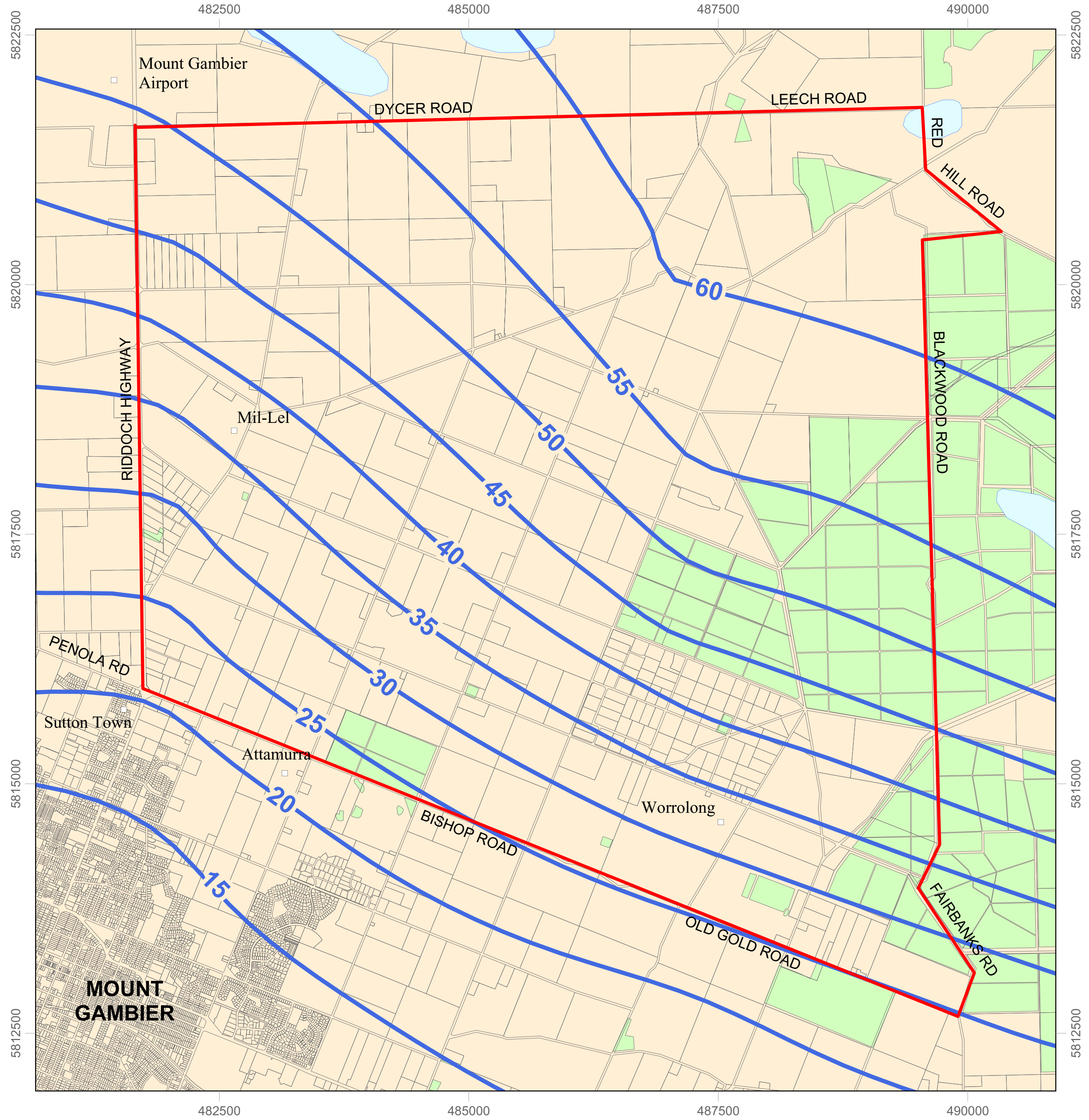
Whereas most of the lower southeast is characterized by a shallow undulating water table, the area to the north of Mount Gambier shows a gradient drop in the water table of over 40 metres in 10 kilometres.

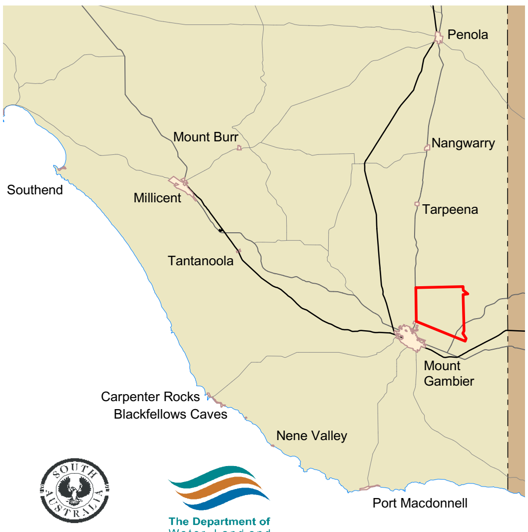
Most of the survey area is contained within this steep gradient groundwater zone, which commences just to the north of the former cheese factory at Mil-Lel, and continues southward until it reaches the northern outskirts of Mount Gambier. Water table is 60 metres above the Australian Height Datum (AHD) in the northeastern corner of the survey area and declines to about 20 metres on the northern outskirts of the city (Fig. 3).

Along the north eastern boundary the water table is flat and relatively shallow, in the range of 4 to 5 metres. Depth to water becomes increasingly deeper towards the southern boundary of the survey area, where typically it is around 26 to 27 metres.

Irrigation supplies in the region are easily obtained. In the north of the study area, yields for three existing irrigation wells, gained from original drilling data, range from 45 to 70 litres per second. An irrigation well further to the south shows a testing yield of 32 litres per second.

Two probable reasons for the steep gradient zone in the water table are lower Permeability values related to faulting or a thinning in the aquifer. In this case it is probably caused by block fault displacement, which leave different geological units facing each other across the fault, along with fault wall smearing.





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Datum GDA94 – Projection MGA Zone 54

Water table contours in metres (AHD)

- Contour interval 5m
- Cadastre boundary
- Plantations
- Lakes

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Blue Lake Capture Zone
Trial Field Survey

WATER TABLE CONTOURS (October 2003)

Figure 3

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3 CRITERIA USED TO SELECT THE TRIAL SITE

The survey area was selected based on the following criteria:

- At least some part of the area had been field surveyed before to compare the pickup rate of holes not previously in the database. If water samples had previously been taken, then a comparison of the nitrate and salinity values over time was carried out.
- To include different land uses, namely irrigated land, dry land farming, rural living and pine plantations.
- To sample as many wells as possible so that a comprehensive knowledge of the aquifer quality in the area immediately upgradient of the Blue Lake was gained.
- Include the area around the former cheese factory at Mil-Lel, so that an update of water quality within the old pollution plume could be gained, and also to observe if it has moved.
- To study the nitrate levels on both dairy and dryland farms. High nitrate ingestion can affect the health of agricultural animals.

4 STATUS PRIOR TO THE FIELD SURVEY COMMENCEMENT

Prior to starting the survey, wells contained within the trial area boundaries were examined from the Departmental database, so that an initial statistical analysis could take place.

The Departmental records showed that 597 wells with water use data existed (Fig. 4). The water uses are shown in Table 1.

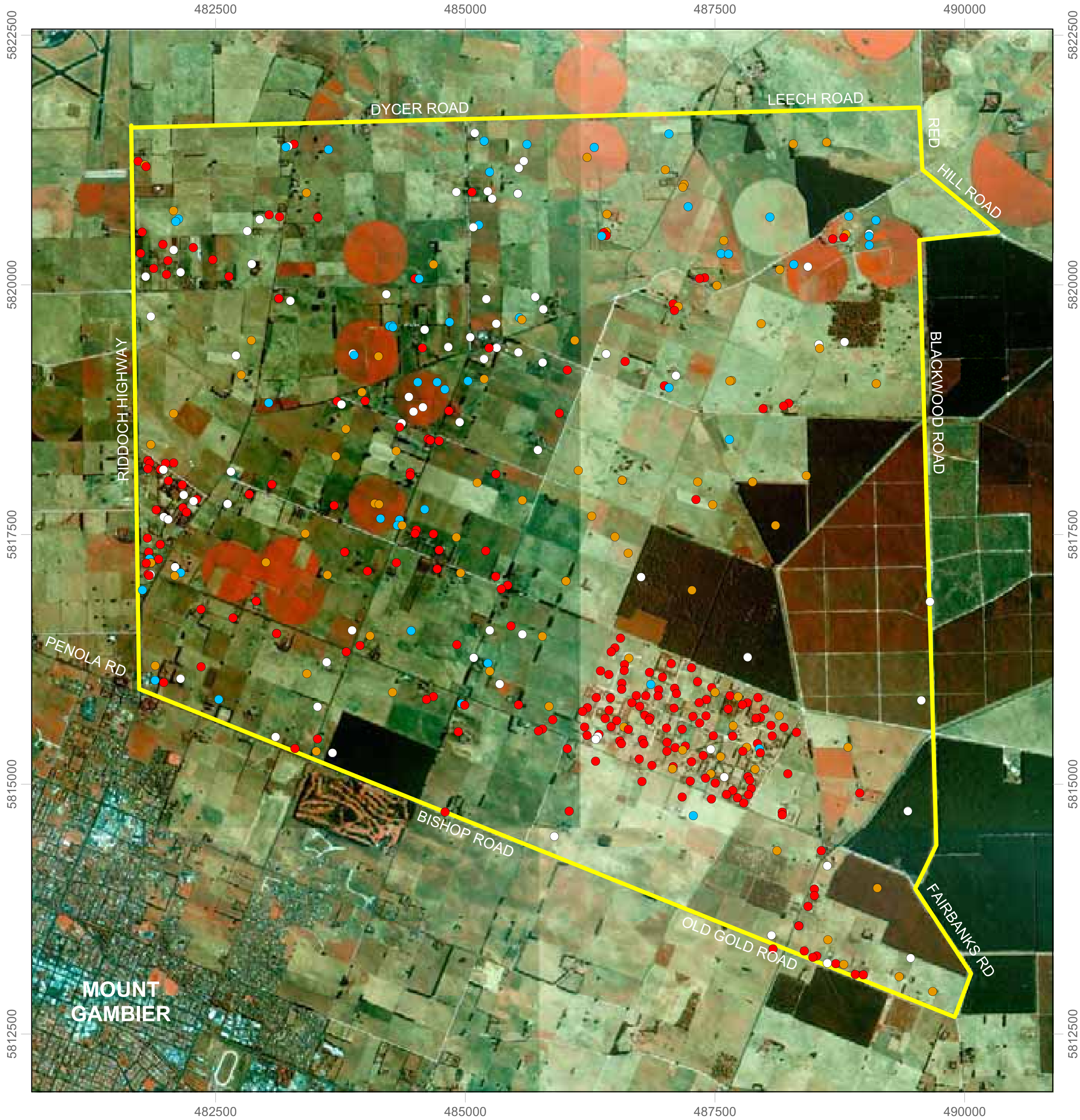
Table 1. Water Use Statistics prior to Survey Commencement

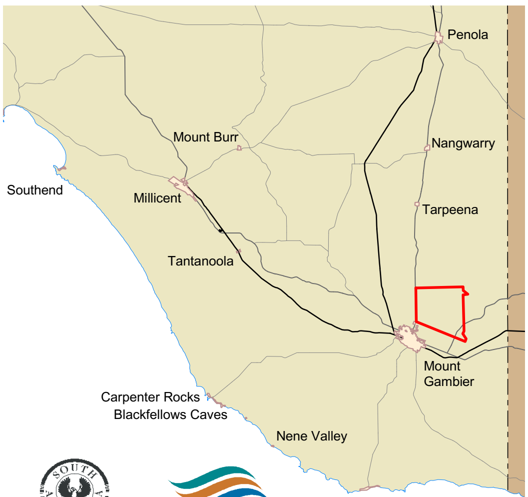
Type of Use	Percentage of the Total Wells %
Domestic	18.8
Stock	17.8
Observation	17.1
Stock and Domestic	16.7
Unknown	9.5
Irrigation	8.2
Other	8.1
Abandoned	3.8
Totals	**100.0**

It is clear from the table that stock and domestic wells were the major category being 53 percent of all holes. The irrigation figure seemed slightly inflated at 8 percent. A specific purpose of the survey was to find out the use of the 9.5 percent of wells with an unknown status. Abandoned wells also account for 4% of the total.

A high percentage of the 17% of the observation wells is related to holes drilled during the mid to late seventies, to investigate contamination around the former cheese factory at Mil-Lel.

The minor uses included drainage wells, industrial wells and backfilled holes and these are included under the title category other. The majority of the backfilled holes were comprised of power pole earthing holes, which were recorded during the mid seventies, so that the agency could quickly gather much needed geological data from the drillers' logs.





GDA

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Datum GDA94 – Projection MGA Zone 54

Major uses

Domestic	35.5%
Irrigation	8.2%
Stock	17.1%
Unknown	9.5%

Blue Lake Capture Zone
Trial Field Survey

KNOWN DATA POINTS PRIOR TO SURVEY

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Figure 4

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5 CURRENT STATISTICAL ANALYSIS

The spreadsheet compiled at the end of the survey accounted for 637 data points, which included the holes known prior to the survey plus all new wells found. Backfilled wells accounted for 130 data points.

The analysis was calculated on the percentages of the wells that exist on the ground today (Table 2). This equates to 507 wells (Fig. 5).

Table 2. Current Water Use Statistics

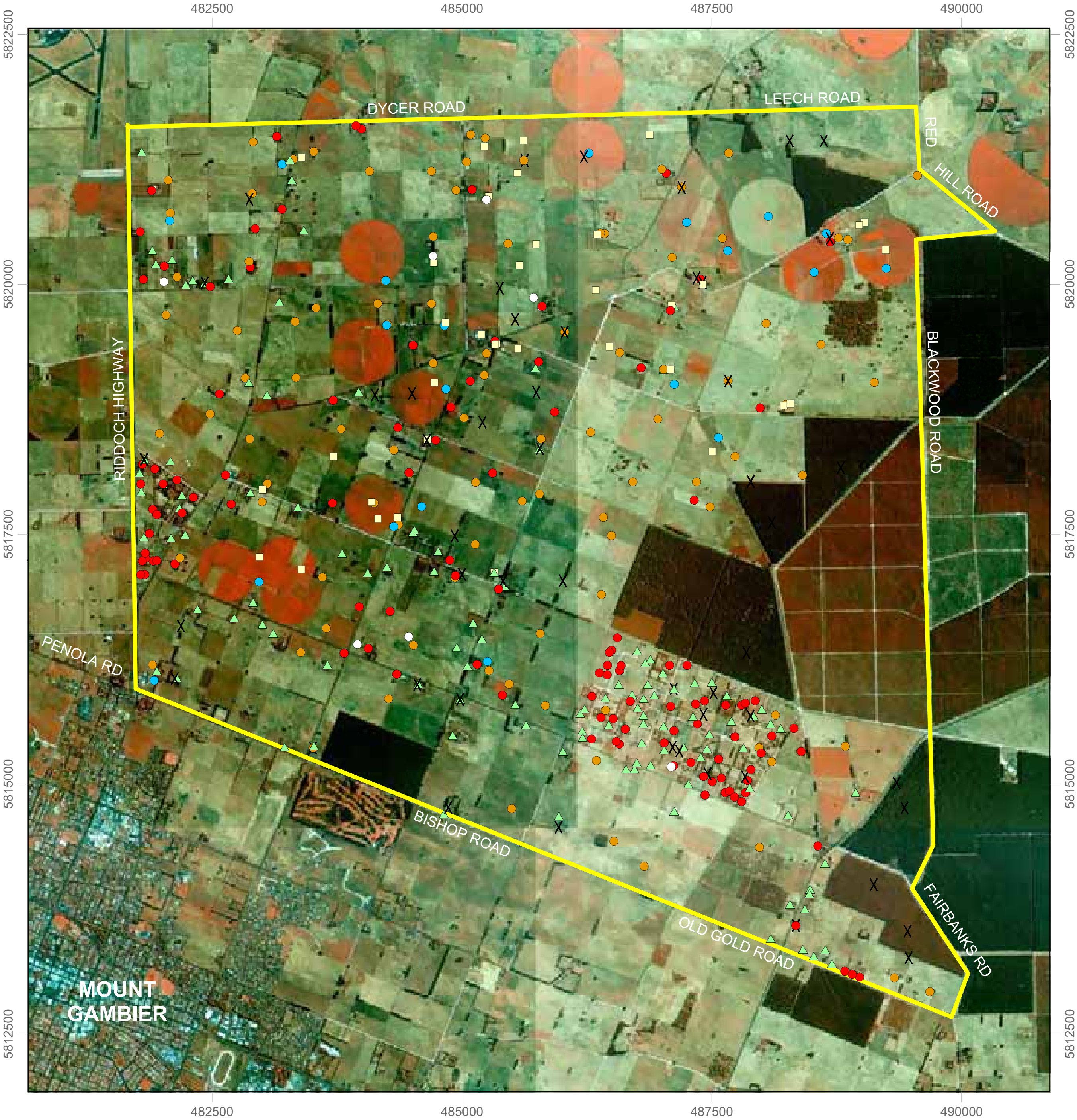
Type of Use	Percentage of Total Wells %
Stock and Domestic	24.0
Domestic	23.0
Stock	19.8
Abandoned	10.3
Unequipped	9.0
Others	6.7
Irrigation	4.0
Not in Use	3.2
Totals	**100.0**

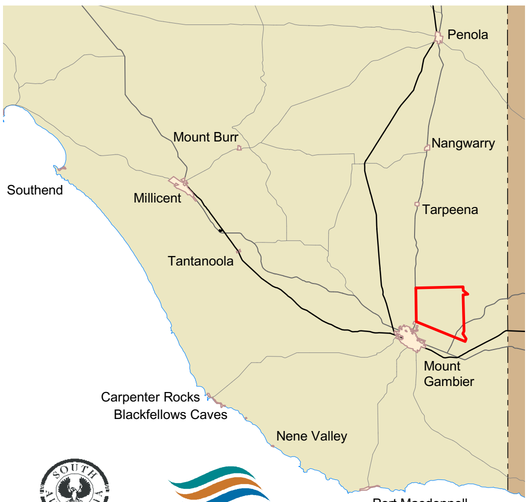
Stock, domestic and stock and domestic categories, accounted for 67 percent of all wells in the 2002 survey. The pre survey figure was 53 percent. The initial irrigation figure of 8% was considered to high and the survey confirmed that a lower figure of 4% was more realistic.

Another factor, which reflects the value of the survey, is the percentage of wells with an unknown usage, which drops from 9.5% to zero.

For the Blue Lake Capture Zone, the most worrying statistics are the 22.5% of wells that are unequipped, not in use and abandoned. These wells represent an access point where contamination could occur via a direct conduit. Future management plans should encourage the backfilling to surface of these types of wells.

Prior to commencement of the survey it was hoped that if a pick up rate of additional wells for the trial area was calculated, then this could be used to estimate the number of extra holes in the whole Blue Lake Catchment Zones. For the area that had previously been unsurveyed, 49 new wells were located and entered into the database. This equated to a pick up rate of 16%. It was estimated at the start of the survey that the pick up rate might be about 20%. Considering the Worrolong rural living area was in the previously unsurveyed portion and about 105 wells exist and most of these have been drilled since water well permits were required, the original estimated pick up rate was probably very close.





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Datum GDA94 – Projection MGA Zone 54

Water bore use/status

X	Abandoned	10.3%
●	Domestic	23.0%
●	Irrigation	4.0%
●	Stock	19.8%
△	Stock & domestic	24.0%
○	Not in use	3.2%
□	Unequipped	9.0%

Blue Lake Capture Zone
Trial Field Survey

EXISTING DATA POINTS AFTER SURVEY

Government of South Australia

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Figure 5

PIRSA Publishing Services A8:201952_005

6 CRITERIA USED FOR TABULATION OF WATER USAGE FIGURES

Irrigation Usage

The area figures used for the irrigation usage are supplied by the Department for Water, Land and Biodiversity Conservation's 2001/2002 licence returns. A land-irrigated figure is calculated by the landowner and validated by a Departmental officer.

Further explanation of the ways the irrigation use was calculated are detailed under the water use section of this report.

Dairy Cattle

Water is without a doubt the single most important nutrient in a cow's diet. Water makes up 75% of the cows' body and 85% of the milk produced. A cow producing 20 litres of milk per day requires approximately 120 to 130 litres of water per day for body maintenance, temperature regulation, excretion of body wastes and milk production. In hot weather the requirements are higher (www.dairycorp.com.au).

A portion of the required water is sourced from the water contained in the fodder consumed, but the rest must come directly from water intake. In summer approximately 50 litres of water will come from the fodder ingested and the remainder, 70 to 80 litres, must come from water consumption.

The DairyCorp home page (www.dairycorpcom.au) shows that South Australian milk production from 1991 to 2000 has averaged 14 litres per cow per day. In the year 2000 production was even higher with an average of 19 litres per cow per day. A few local dairy farmers would indicate that some properties are now averaging around 23 litres of milk per cow per day. Conversely the Victorian dairy industry produced 6800 million litres of milk in 2001 from 1.44 million cows. This averages at 13 litres per cow per day.

However South Eastern farmers tend to milk mainly Holsteins, which produce a higher milk count, whereas their Victorian counterparts use mainly Jerseys that produce a higher quality of milk but reduced volume.

One cow in the Penola area was reputed to have milked 75 litres in one day! Other figures of 42 litres in a day have been recorded. (Personal comment Noel Stratford).

Based on this data an average dairy cow water intake of 80 litres per day, based on a production rate of 19 litres per cow per day was used for the calculation process. For ease of calculation this figure was used all year round, which would compensate for higher production rates. Young dairy calves were calculated at 40 litres per day.

It is recommended that in the future, a meter be set into a dairy cattle water supply system so that a more accurate record for water use is recorded.

Beef Cattle, Sheep and Horses

The information researched for these animals water needs comes from the www.agric.nsw.gov.au site.

Table 3. Adopted Animal Water Use figures

Animal Type	Average water use Litres/day	Adopted Value Litres/ Day
Adult dry sheep	2 to 6	5
Dry Stock	35 to 80	60
Young Stock	25 to 50	40
Horses	40 to 50	40

In summer, evaporation from open tanks and animal troughs obviously occurs, however these losses were considered to be minor and were not factored into the calculations.

It is recommended that in the future, a meter be installed on a beef cattle property and possibly even a sheep water supply system so that a more accurate record for water use is recorded.

Human Consumption

Three different consumption rates were used to compare lower, medium and higher use. These were:

- The Australian Water Resources Assessment 2000, which states that in 1996/97 each person used around 274 litres per day. Gardening is responsible for up to half of this use; flushing toilets uses approximately a quarter.
- Information supplied by SA Water for the years 99/00, 00/01 and 01/02 show an average urban consumption for Mt Gambier of 233 litres per person if a population of 23 000 people is used.
- The current Australian average for water consumption is quoted as 350 litres per person per day (farmweb.au.com).
- As a comparison people in Asia, Africa and Latin America use 50–100 litres per day; people in the USA use 400–500 litres per day.

Most of the houses visited in the survey area were equipped with rainwater tanks, but this water was generally only used for cooking purposes. In dry years, typically in the period 1993–2000 groundwater was used to supplement the rainwater at the end of summer. In most rural living situations larger lawns and gardens are common, and at least three-quarters of all water is used to service them and toilets. Some properties also had swimming pools. Children were calculated at the same rate because of these criteria plus the consideration that bathing and showers were probably similar in water use to an adult.

In summary it was considered that rural domestic water requirements would be treated as similar as to that in an urban environment.

It is recommended that in the future a meter be set into a rural domestic supply system and record water use for an average family of two adults and two children. These metering actions meet the requirements of the Blue Lake Management plan.

7 WATER USE

Irrigation usage

Currently up to 12 centre pivots are operating in the study area. Of these, 8 are for dairy pasture production, two for pasture production used for dairy calf rearing, as well as some small crop production. One pivot is on a former dairy property, which the owner is still irrigating from during summer to create feed for beef cattle. Another pivot is used for potato irrigation on a 4 or 5 years rotation cycle and was not used during the 2002 irrigation season.

Towards the end of the survey period, a new 8 span pivot was installed to service an estimated area of 55 hectares (Table 3).

The total area licensed in hectares of irrigation equivalents is 930.1 hectares (Table 3). The area irrigated after factoring in the irrigation equivalents (I.E) used for the Comaum-Caroline prescribed wells area is 416.18 haIE. However the actual on ground irrigated area is 554.43 hectares.

The ratio of irrigated IE area (as per the 2002 returns) as a percentage of total licensed IE area is about 44.8%. Irrigated land (554.43 hectares) as a percentage of the whole study area is 9.6 percent.

The estimated water usage on the annual irrigation returns from the landowners varied quite considerably for the same type of activity such as pasture production, which is by far the most common form of irrigation. To gain an initial picture of irrigated water use, the estimation of the water requirement of irrigated crops for the Comaum Caroline proclaimed area as proposed by Desmier (Desmier 1990) were used. A further comparison with Victorian dairy farmers best practice water figures indicated that Desmier was too conservative. However these calculations including a 20 percent evaporative loss factor, resulted in a total irrigation water use (including seed production figures) of 2315.2 megalitres per annum. For the dairy farms in the study area the water use is calculated as 1366 megalitres.

In 1990 when Desmier (report no 151 – 1990) compiled his report, the usual irrigation practice in the lower South East of South Australia was the use of traveling irrigators. The introduction of centre pivots has seen farmers trying to maintain optimum soil moisture conditions, and so a common practice is to rotate the pivot about every three days. Water application rates could be as high as 8 to 10 megalitres per hectare (compared to the 5.4 megalitres per hectare when using Desmier). Personal communication with some local producers indicate that even higher water application rates could be occurring. For this report it will be assumed that no excess water returns to the aquifer. This question will be reported by the Volumetric Conversion group in the future.

To take into account these higher application rates, all pasture pivot irrigation was recalculated at 8 megalitres per hectare (personal communication Gerrit Schrale 2003). This resulted in an estimate of 2041.6 megalitres used for dairy pasture production for 2001/2002. Total irrigation water use for the same period was 3052.82 megalitres (Table 4).

Table 4. Irrigation Return Statistics for the Survey Area 2001/2002.

Irrigation licence No	Allocation halE	Purpose of irrigation	Hectares irrigated	Equivalent use	Type of irrigation	Desmier with 20% evaporation	8 megs of water per Ha pasture
9490	50.0	Pasture	40.2	40.2	pivot	215.1	321.6
9461	42.3	Pasture hay	28.53	20.3	pivot	152.6	152.6
		Lucerne hay	13.5	4.6	spray	51.7	51.7
9345	0.9					0	0
9261	1.6					0	0
9297	6.5					0	0
9025	2.4					0	0
11228	1.0	Nursery	0.8	1.5	spray	0.3	0.3
9129	4.3					0	0
9010	114.0	grazing & hay	32	32	pivot	171.3	256.0
	14.0	grazing & hay	14	14	set spray	74.9	74.9
9184	44.0	Industrial				17.5	17.5
	82.4	Pasture	122.5	13.76	spray	73.5	73.5
9243	61.0	Pasture	32	32	pivot	171.3	256.0
9011	78.2	Pasture	56.5	56.5	pivot	302.4	302.4
		Maize	10	5.2	pivot	27.7	27.7
		Pasture	10	10	travellor	53.5	53.5
		Mustard	2.5	0.42	pivot	2.4	2.4
9244	26.0	Pasture	26	26	pivot	139.2	208.0
9017	10.0	Pasture	10	10	travellor	53.5	53.5
9414	75.0	Pasture	70	70	pivot	374.6	560.0
9364	20.0	Pasture	23.4	23.4	pivot	125.3	187.2
9451	7.6	Radish seed	3.5	0.9	travellor	3.3	3.3
		Pasture	4	0.4	travellor	10.7	10.7
9285	20.0					0	0
9281	0.9					0	0
9235	2.0	School		not	recorded		
9371	0.7					0	0
9199	5.0					0	0
9031	1.0					0	0
9027	20.0					0	0
11016	98.9					0	0
11018	71.0					0	0
11115	0.4					0	0
11264	2.0	vineyard	0	0		0	0
11136	12.0						
New	55.0	Pasture	55	55	pivot	294.4	440.0
Totals	**930.1**		**554.43**	**416.18**		**2315.2**	**3052.8**

Research from the Victorian EPA Internet site (www.epa.vic.gov.au) shows “The results found that in all Victorian dairy regions some farmers used three times as much water on pasture as others to produce the same amount of milk. In the northern irrigation region water use ranged from as little as 0.43 mL to produce 1000 litres of milk to 1.15 mL for 1000 litres of milk.” Using the above figures, about 968 milking cows are milked in the survey area, and were estimated to average 19 litres of milk per cow per day. At the lowest estimate of water use this equates to 1972 megalitres per year and at the highest end 5300 megalitres per year for pasture irrigation only. This calculation also assumed the cows had a one-month dry period during the year.

Finally using the Australian Water Use Statistics for 2003 (www.cse.csiro.au/futures/) lends the following figure. It is estimated that about 6.1 megalitres of water per hectare for pasture use is used as an average across the country. This equates to a pasture irrigation estimate for the Trial area of 1700 mL and is considered to be the least reliable estimate because it is averaged over so many different environments.

Conclusions

All of the figures contained below are calculating water use for dairy pasture irrigation for the field survey area only.

- Survey area Desmier, 1990 — 1366 mL
- Survey area @ 8 mL per hectare — 2042 mL
- Victorian Dairy Best Practice — 1972 mL
- Victorian Dairy Worst Practice — 5300 mL
- Australian Water Use Figures — 1700 mL

The above figures show the variability when attempting to calculate pasture irrigation. The most realistic values are based on using 8 mL per hectare water use and also the Victorian best and worst practice values. A best estimate will be between 2000 and 5000 mL per annum. For the purposes of this report the estimate using 8 mL per hectare will be used. The large differences in this estimating will be eliminated by the introduction of irrigation meters. This is currently occurring.

Stock Usage

As is the case in all agricultural areas, stock numbers vary from summer to winter depending on available feed and market price. However, the figures were calculated on the numbers on the ground during the survey, which, because it was conducted during winter, would have seen higher numbers.

The types of animals catered for in the calculations were dairy cattle, dairy calves, beef cattle, sheep and horses.

Total water use estimated for dry land stock usage was 131.2 megalitres per annum (Table 4).

Three sites rear dairy calves. One property rears them for two years before they go back to the originating farms, whilst the other two sites hold the calves for periods of about 6 and 12 months before sending them on to feed lotting. One of these farms rears about 1500 calves per annum. Due to difficulty calculating water use for this intense rearing of calves, and the varying stock numbers for the rest of the study area from summer to winter, it is believed that total stock water consumption could vary by about 10 to 15%.

Dairy Industry Water Use

Because of the intensity of animals on the ground, the dairy farms are probably the farming practice of most interest. Water use for dairy cattle was estimated at 29.9 megalitres per annum. This means the dairying in the study area accounted for about 18.6% of stock water usage.

In addition water is also used in dairy sheds, both for the milking of the cow and also as wash down water at the completion of operations. Water estimates for this function can vary considerably, and so research for details led to the EPA Internet site in Victoria (www.epa.vic.gov.au). Quoting from this site “in the South West, the most efficient dairies used under 2000 litres per cow each year. At the other end of the scale, the most water used was 38000 litres per cow each year. The average for the region was 9600 litres per cow each year”.

From this, the figure of 9600 litres per cow each year was used. With 968 dairy cows in the study area, water use for this activity is calculated at 9.3 megalitres.

Human Consumption

For the purposes of calculating the total survey area water use, the current Australian average was used, because it is perhaps more useful to consider the highest possible water use.

To gain a range of human water use, consumption was calculated at three varying rates.

Using the average Mount Gambier consumption figures for the last three years (233 L/day/person) calculated 51.9 megalitres per year. The Australian 1996/97 average of 274 L/d/p added up to 60.8 megalitres per year and the current Australian average, which is 350 L/d/p computes to 78.1 megalitres per year.

Discussion

Table 5 summarizes the total estimated water usage for the survey area as 3301.3 megalitres for 2001/2002. In comparison residential water use for the city of Mount Gambier for the July 2001 – June 2002 period was 1861 megalitres.

Comparing Stock and Domestic water use as a percentage of Irrigation water use is about 8.1%.

If the stock water use was overestimated by 15% (taking into account shifting stock numbers) and the domestic water was calculated at the lower estimate of 233 litres per person (Mount Gambier three year average) to give a best-case scenario, stock and domestic water use as a percentage of irrigation use is 6.6 percent.

So irrespective of the figures used, it is clear that the percentage will average in the range of 6 to 8.

These calculations should be revisited after water meters are installed so that accurate figures from irrigation well pumping can be used.

It must be stressed that these figures are not representative of the whole Blue Lake Catchment area. These figures are valid for the survey area only. It is the intention of this study to now apply these techniques to gain a water use estimate for the whole of the Catchment area.

Total water use as stated above is 3301.3 megalitres for 2001/2002. The area contained within the study boundaries is about 5796 hectares. This equates to a groundwater discharge rate of 57 mm per hectare per year. If the pine trees and small blue gum and natural vegetation are removed from the potential recharge/usage an area of 4852 hectares is left which calculates to discharge rate of 68 mm per hectare per year.

Table 5. Total Water Usages for the Study Area

Water Use	2002 Estimated Water Use Megalitres per Annum
Irrigated Land	3052.8
Stock Water Use	131.2
Dairy Water Use	29.9
Dairy Shed Use	9.3
Domestic Water Use	78.1
Total	**3301.3**

The major water use for the study area is irrigation, and as a soil moisture deficit occurs in summer, most of the water is pumped out of the aquifer over a six-month period. The aquifer is stressed through the summer period. Figure 6 below demonstrates the steep cumulative curve during the summer months. In comparison is a cumulative graph of an average Blue Lake pumping season, with a steep curve through the early part of the year but then fairly gentle for the rest of the year.

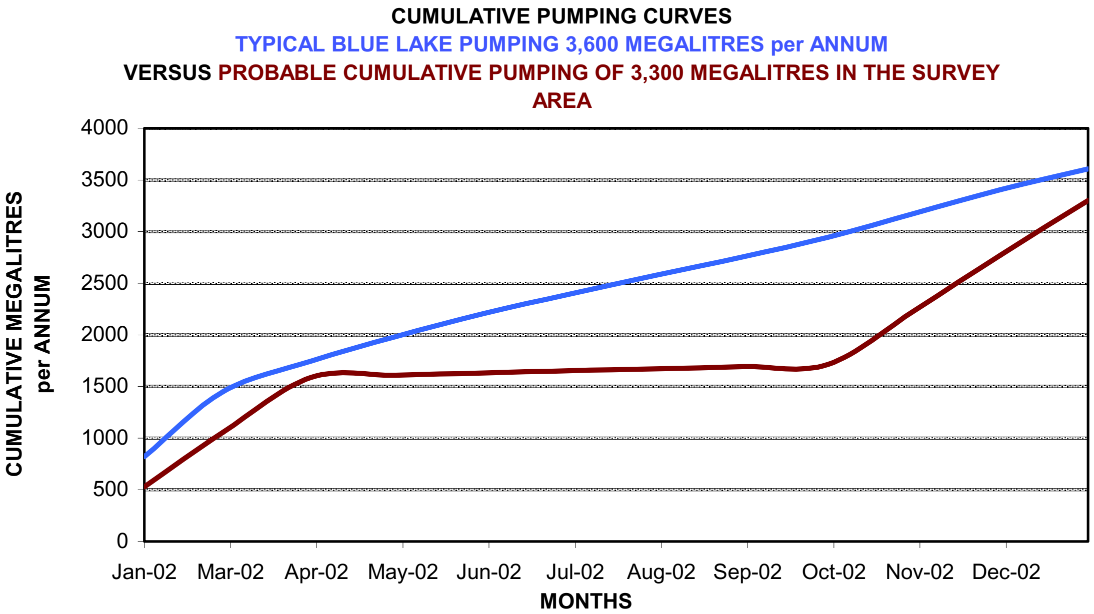


Figure 6. Cumulative pumping rate

8 WATER QUALITY

Historical Nitrates

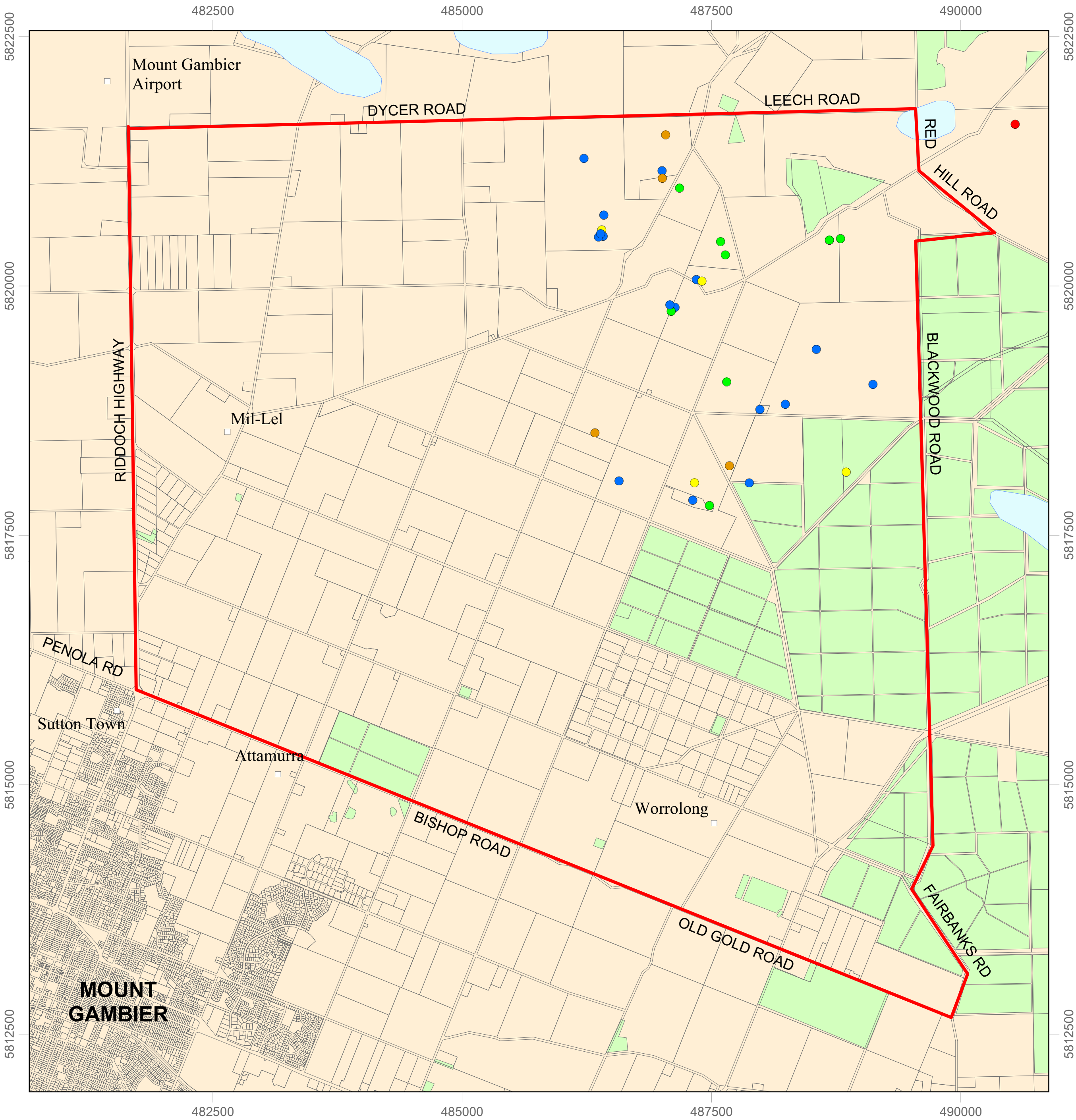
In 1981 the former E & WS Department (now SA Water) conducted a feasibility study as to whether the water quality in the Mingbool area would meet drinking guidelines, and to establish if it could be pumped to Mt Gambier as a standby town water supply. This contingency plan was devised in the event of the Blue Lake no longer being used as a municipal supply, due to contamination. Part of this area falls within the northeastern corner of the survey area and was deliberately selected so that a twenty-year comparison of the water quality could be observed. The values obtained in 1981 are shown in Figure 7.

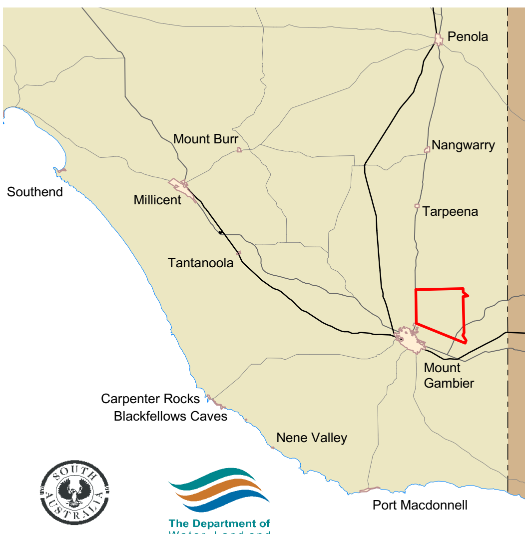
Overall, little change has occurred over the twenty year period; in fact the average value through this zone is a little lower in 2002 at 3.43 mg/l NO3-N compared to 4.90 mg/l NO3-N in 1981. These differences probably relate to sampling of different wells, and also through technological changes. During the survey, by using a 12-volt marine pump, more wells with a variety of land uses could be pumped (rather than bailed). The pumped samples in1981 were more likely to be windmills, which are biased toward higher nitrate values because of animal congregation at the drinking/extraction point.

In addition, as part of the survey, any wells that had previously been tested for nitrate analysis (1972 to 2002) and recorded on the agency database were noted and the results can be seen in Figure 8. It is difficult to assess what has occurred when compared to the 2002 results as in comparative holes some levels have dropped and some have increased. Overall the levels have not changed by any significant amount that cannot be explained by land use changes or differences in laboratory testing. The average Nitrate as N for this historical data set is 7.08 mg/l.

2002 Nitrates

The ALS Laboratory in Melbourne carried out the oxidized nitrogen testing for the survey. The samples were tested for Oxidized Nitrogen (expressed in the sample results as Nitrite and Nitrate as N). This technique proved to be a slightly cheaper analysis method and helped to test more samples in the survey area. The final batch of samples sent to the laboratory, were tested for Nitrite as N and Nitrate as N as well as the normal oxidized nitrogen to compare how closely the results matched. Table 5 below compares the values and shows that the results obtained during the survey compare favourably when plotted against Nitrate as N plus Nitrite as N. The two techniques when compared to each other plot on the same line. For the purposes of talking about the water quality in this report, it will now consider all values to be Nitrate as N.





0 0.5 1 1.5 2 Kilometres

Datum GDA94 – Projection MGA Zone 54

NO3-N

●	0 to 2 mg/L	11 wells
●	2 to 5 mg/L	9 wells
●	5 to 8 mg/L	4 wells
●	8 to 10 mg/L	4 wells
●	10 to 22 mg/L	1 well

- Cadastre boundary
- Plantations
- Lakes

Blue Lake Capture Zone
Trial Field Survey

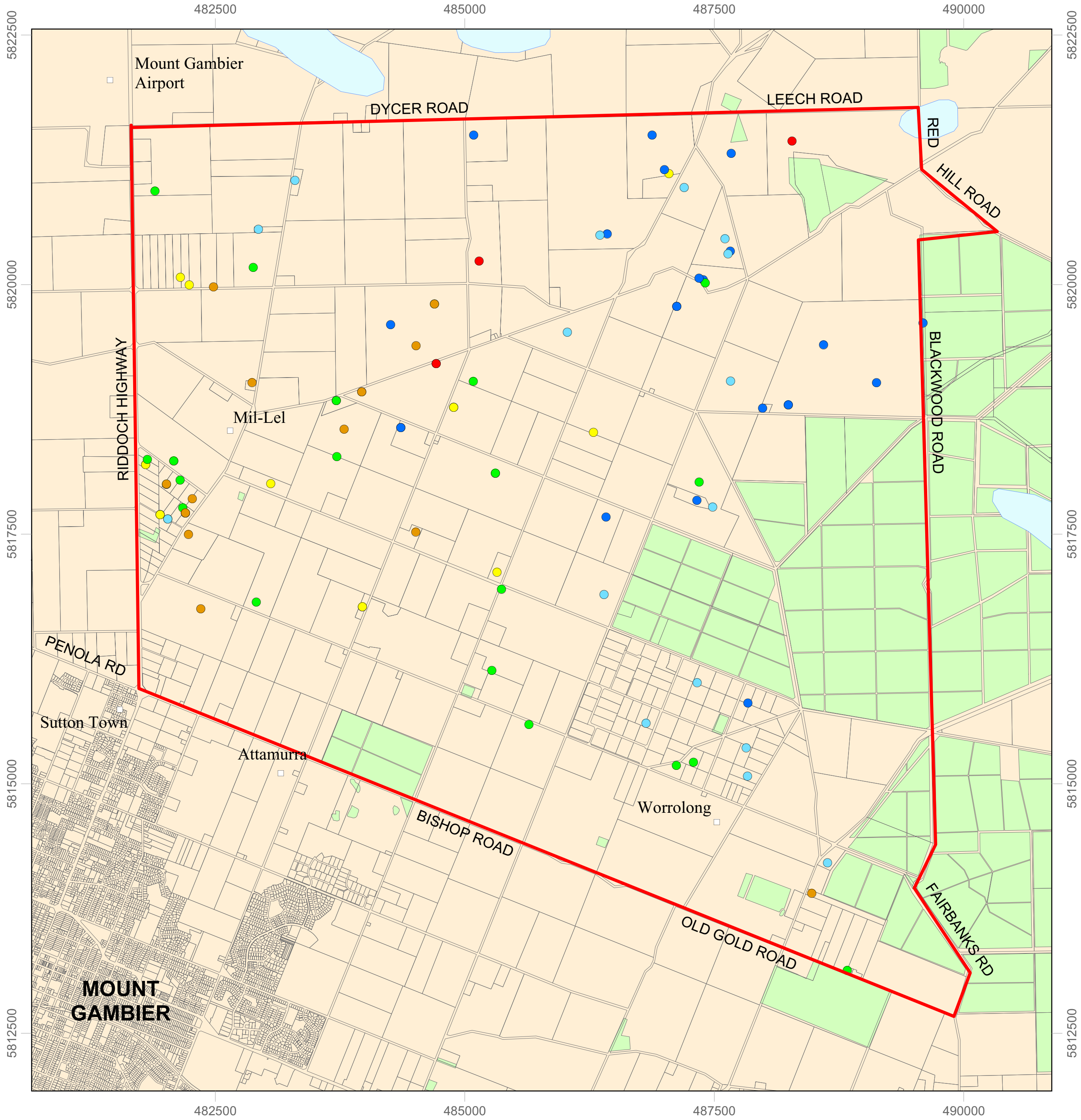
1981 NITRATE AS N VALUES

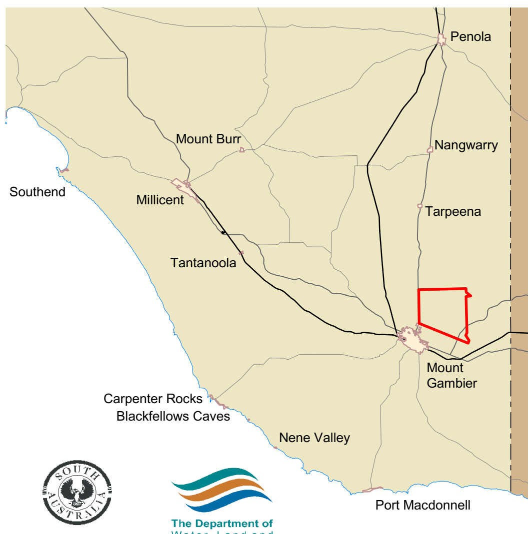
Government of South Australia

The Department of Water, Land and Biodiversity Conservation

Figure 7

PIRSA Publishing Services A8:201952_007





GDA

0 0.5 1 1.5 2 Kilometres

Datum GDA94 – Projection MGA Zone 54

NO3-N

●	0 to 2 mg/L	19 wells
●	2 to 5 mg/L	16 wells
●	5 to 8 mg/L	25 wells
●	8 to 10 mg/L	15 wells
●	10 to 22 mg/L	16 wells
●	22 to 40 mg/L	4 wells

Cadastre boundary

Plantations

Lakes

Blue Lake Capture Zone
Trial Field Survey

HISTORICAL NITRATE AS N VALUES

Government of South Australia

The Department of Water, Land and Biodiversity Conservation

Figure 8

PIRSA Publishing Services A8:201952_008

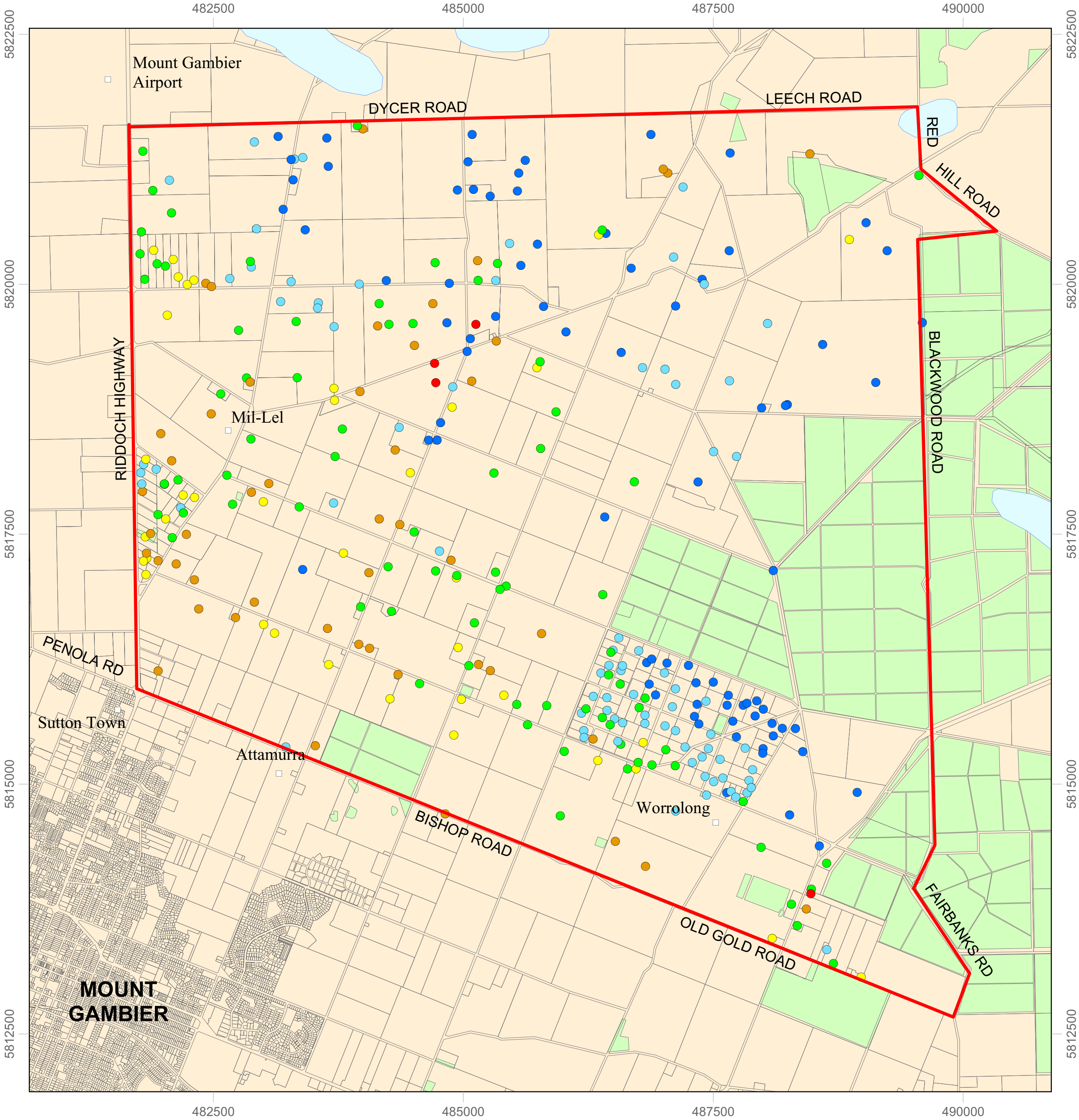
Table 6. A Comparison of Nitrite+Nitrate as N and Oxidized Nitrogen

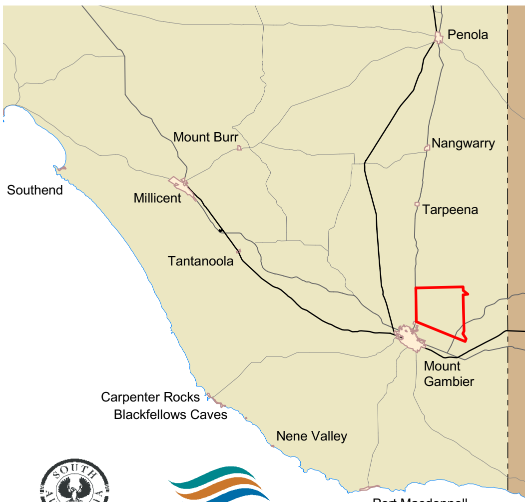
Nitrite+Nitrate as N	Oxidized Nitrogen	Nitrite+Nitrate as N	Oxidized Nitrogen
0.03	0.02	5.07	5.07
0.05	0.06	5.13	5.16
0.09	0.07	5.22	5.25
0.55	0.55	5.26	5.28
0.96	0.99	5.31	5.33
1.11	1.12	5.57	5.59
1.46	1.48	5.70	5.72
2.07	2.08	5.86	5.86
2.53	2.53	6.20	6.23
2.60	2.59	7.12	7.11
2.74	2.74	7.17	7.16
2.85	2.87	7.25	7.25
3.35	3.35	7.47	7.46
3.82	3.83	8.43	8.45
3.98	4.00	8.50	8.53
4.10	4.10	9.18	9.21
4.45	4.47	10.81	10.80
4.50	4.49	14.23	14.20
4.53	4.54	15.91	16.00
4.73	4.76	16.73	16.70
4.80	4.82	37.58	37.50

A spatial distribution of the nitrate results is shown in Figure 9. In total, 320 samples were analyzed and divided into the categories shown in Table 5.

Table 7. Nitrate (As N) Concentrations expressed as a Percentage

Nitrate (As N) concentration	Percentage of Total samples
0 to 2 mg/l	22.8%
2 to 5 mg/l	24.7%
5 to 8 mg/l	24.7%
8 to 10 mg/l	11.6%
10 to 22 mg/l	15.0%
22 to 40 mg/l	1.20%





GDA

0 0.5 1 1.5 2 Kilometres

Datum GDA94 – Projection MGA Zone 54

NO3-N

●	0 to 2 mg/L	22.8% of wells
●	2 to 5 mg/L	24.7% of wells
●	5 to 8 mg/L	24.7% of wells
●	8 to 10 mg/L	11.6% of wells
●	10 to 22 mg/L	15% of wells
●	22 to 40 mg/L	1.2% of wells

Cadastre boundary
Plantations
Lakes

Blue Lake Capture Zone
Trial Field Survey
2002 NITRATE AS N VALUES

Government of South Australia

The Department of Water, Land and Biodiversity Conservation

Figure 9

PIRSA Publishing Services A8:201952_009

Values of Nitrate as N of less than 2 milligrams per litre are commonly found as background levels in shallow groundwater (Hallberg 1989), and this suggests that there is no contamination due to human activity.

The percentage of water below the World Health Organization (W.H.O) drinking guidelines of 10 mg/l Nitrate as N is 84 percent. It can be concluded that the aquifer is in a relatively healthy condition. Wells in the range of 8–10 mg/l total 11.6% along with 15% of wells in the 10–22 mg/l range. About a quarter of all holes are either at or close to the W.H.O organizations upper limit for human consumption.

If the Australian Drinking Water Guidelines, and the South Australian Health Commission's drinking standard of up to 22 mg/l Nitrate as N is accepted for adult human consumption, only 1% of the wells are above the standards.

During the survey, two people raised the fact that they felt cancer rates might have been higher in the general Mil-Lel area than was acceptable. This information including a list of names was passed on to the Human Services Department, who were able to report back that, based on State wide figures, the incidence of cancer was no higher than any other region of South Australia.

Text on nitrate in drinking water, suggests some epidemiological evidence indicates a relationship between nitrate and gastric cancer in humans, but this has not been confirmed in more definitive analytical studies. Conversely a recent book titled "Nitrate and Man" tends to indicate that nitrate in drinking water is not as dangerous to humans and animals as have previously been felt. (L'hirondel et al 2002).

Nitrate and Animal Health

At the start of the field survey, a discussion was held with Noel Stratford from the Warrnambool Cheese and Butter Factory, who has a great interest in animal health with regard to nitrate contamination. Information was supplied that shows high nitrate levels can affect the health of animals.

Some pertinent points are:

- Water containing nitrate is beneficial to a degree in crop fertilization but has no benefit to a living animal.
- High nitrate levels can affect animals, resulting in early births, along with the mothering instincts not being fully developed.
- There is concern that nitrite may react with foods rich with secondary amines to form N-nitroso compounds in the stomach; many of these compounds are known to be carcinogenic in animals.
- Nitrate levels can be potentially risky in animals if the water values are high, or water values combined with a feed high in nitrate.

A guide for animal use for Nitrate as N in mg/L is as follows;

- Less than 10 — Generally safe
- 10–20 — Safe for livestock unless feed also has high levels
- 20–40 — Might cause problems for livestock. If ration contains more than 1000 mg/L nitrate nitrogen and the water contains 20 mg/L, the total NO3-N is apt to exceed safe levels.
- 40–100 — Risky for livestock.
- 100–200 — Dangerous and should not be used.
- Over 200 — Don't use.

Because of the importance of animal agriculture in the South East of South Australia both Noel Stratford and the author's believe that work should be carried out to investigate the levels of nitrate as N being ingested by cattle and sheep.

In the study area 4 sample results were greater than 20 mg/L NO3-N. One of these wells was a windmill supply to dairy cattle. Another well was an unequipped irrigation well and the final two holes were observation wells that had been contaminated with irrigation wastewater. Approximately 14 other wells fall into the 10–20 mg/L NO3-N category, which carry a level of risk.

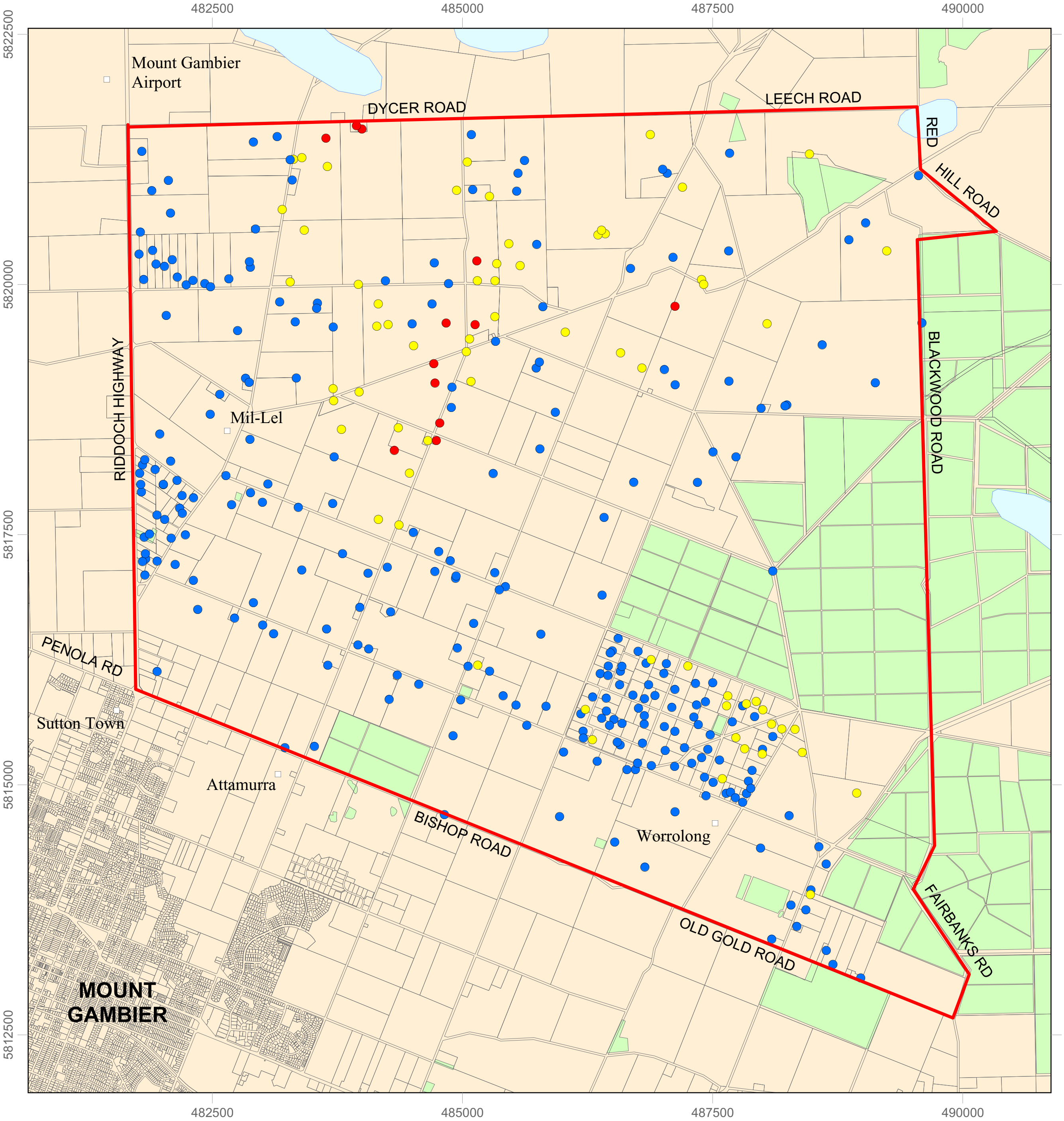
2002 Salinities

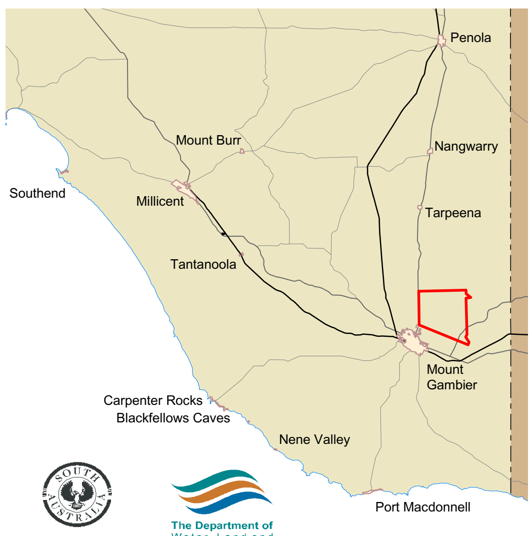
The Australian Drinking Water Guidelines give an upper limit of 1000 milligrams per litre for human consumption.

As can be seen from Figure 10, about 77 percent of all the samples tested were less than 500 mg/L. Salinity in the survey area is considered to be excellent.

The only areas where the values tended to be elevated were in the former cheese factory plume and in the irrigated area north of the factory.

Two properties on the northern boundary of the study area demonstrated elevated salinity and nitrate. One property had a salinity of 920 mg/l and a Nitrate as N value of 18 mg/L, which is probably localized contamination.





0 0.5 1 1.5 2 Kilometres

Datum GDA94 – Projection MGA Zone 54

TDS

●	< 500 mg/L	76.5% of wells
●	500 - 750 mg/L	20% of wells
●	750 - 1000 mg/L	3.5% of wells

Cadastre boundary
Plantations
Lakes

Government of South Australia

The Department of Water, Land and Biodiversity Conservation

Blue Lake Capture Zone
Trial Field Survey

2002 TOTAL DISSOLVED SOLIDS (TDS)

Figure 10

PIRSA Publishing Services A8:201952_010

9 LAND USE COMPARED TO WATER QUALITY

Nitrates

A relationship between land use type and nitrate concentration was established.

The area where it is most obvious is south and south west of the former Kraft cheese factory. This site had prior to the introduction of the Water Resources Act in 1976 disposed of the whey waste down a well. Two values on the section immediately to the south west of the factory show values of 29.7 and 27.3 mg/L of Nitrate as N. Nitrate values were previously much lower. Close to the source point the nitrogen mostly will be in an Ammonia form. As the contaminated ground water moves away from the source it will mix with more oxygenated water, which will produce Nitrate as N gradually increasing as the contamination plume has increased groundwater residence time while also moving to the southwest.

Irrigated dairy land shows a nitrate average of about 9.14 mg/L Nitrate as N. If the two high values on the piece of land referred to above, attributed to the former cheese factory are not considered, a new average of 7.71 mg/l of Nitrate as N is obtained. Unfortunately the number of wells used to establish the average is less than for the other categories. Also the Fiander Moor property has had over twenty years of whey irrigation spraying, which may also slightly bias the result. Interestingly on this property there have been 4 wells drilled for observation purposes, with completions that would stop any surface contamination accessing the groundwater. The results in these holes show variability with values of 4.7, 9.1, 17 and 3.34 mg/L with an average of 8.53 mg/L NO3 – N. The conclusions from this are that irrigating wastewater, combined with high stocking rates can raise the Nitrate as N levels.

On irrigated land it is feasible that the concentrations could be higher and with potential to increase. With the advent of centre pivot irrigation along with changes in the dairy industry, most herd sizes have increased significantly, which will indicate increased nitrogen loading on the land. Combined with this is the requirement for dairy waste to be irrigated over the land surface. Over time and using the former cheese factories land as an example, it is probable that nitrate concentrations would increase.

Domestic along with stock and domestic wells were considered together. The reason for this is because in most cases stock and domestic wells are located on rural living blocks running a few horses, cattle or sheep. Overall the average nitrate concentrations were 5.63 mg/L Nitrate as N. Interestingly the Worrolong rural living sub division had a lower average of only 3.5 mg/L as N. Historical practices have probably contributed to any higher levels in this area, as in the locations of a former piggery, and two former dairy farms the levels are higher than the average.

For stock wells (non dairy) Nitrate as N was between 0.04 and 17 mg/L. Overall the dataset average was 6.64 mg/L Nitrate as N. This may show a bias because of what can happen at a windmill with cattle and sheep congregating in the one location with the subsequent higher nutrient loading.

The average for Nitrate as N for the spray waste discharge area to the north of the former Mil-Lel cheese factory is 4.41 mg/L. Two higher values of 28.2 and 21.3 were sampled, but not used in the calculations, due to the fact that direct infiltration of the irrigated water into the water table has occurred.

For the Pine forest plantations the data set was so small that no comment on water quality is possible.

Overall the Nitrate as N level for all the study area is 6.05 mg/l Nitrate as N. At some locations point values are higher than the surrounding results. These are most probably a reflection of past practices, which may now be impossible to identify. In some areas such as at Worrolong, local/historical knowledge can explain some elevated results.

Salinities

The salinities for the various land uses show similar trends to the nitrates (Fig. 10). An average of all the dairy land salinity samples show an average of 550 mg/L. In comparison, the stock or dryland farming samples show an average of 440 mg/L. Domestic salinities averaged the same at 445 mg/L. This time however, the Worrolong rural living area has a slightly higher average of 460 mg/L.

The land to the north of the former cheese factory at Mil-Lel shows an average salinity of 675 mg/L. This higher salinity is attributable to 25 years of the spraying of a water/whey mix (ratio about 7:1) over the land. In the initial phases of this then new technique in 1976, application rates were probably too high for the amount of land available. Over time more land became available which has helped to lower the application rates.

10 CONCLUDING STATISTICS

Approximate number of people in the survey area:	
Adults	462, and
Children	147
Irrigated land as a percentage of Licensed Irrigation:	
Actual Irrigation versus Licensed Irrigation	59.6%
Equivalent Irrigation versus Licensed Irrigation	44.7%
Actual Irrigated area versus Total Area	9.6%
Licensed Irrigation Area versus Total area	16.1% of the total area
Pine Forest Plantation	15.1% (Calculated from GIS)
Native vegetation	0.4%
Blue Gums	0.8%
Total theoretical rechargeable land (for the ease of calculation ignore all pine forest, native vegetation and Blue gums)	4852 hectares

For the season 2001/02 water extracted from each hectare of land was about 680 400 litres, which equates to a **groundwater discharge rate of 68 mm per hectare per annum.**

Discharge rate for the total survey area (5796 hectares) for 2001/02 is 57 mm per hectare per annum.

Total Study Area	5796 Hectares (Calculated from GIS)
Total Estimated water use	3301.3 megalitres
Total Estimated Irrigation water use	3052.8 megalitres
Total Estimated Stock water use	131.2 megalitres
Total Estimated Dairy Cow Usage	29.9 megalitres
Total Estimated Dairy Shed Usage	9.3 megalitres
Total Estimated Domestic water use	78.1 megalitres
Average Nitrate as N value	6.05 mg/l
Maximum value	29.7 mg/l
Minimum value	<0.01 mg/l
Average Total Dissolved solids	460 mg/l
Maximum value	920 mg/l
Minimum value	290 mg/l
Stock & Domestic water use as a percentage of Irrigation water use	6.5 to 8 percent

11 CONCLUSIONS

From the all the information contained in this report the following conclusions are made:

- Irrigation is the major water user in the survey area.
- Stock and Domestic water usage is about 6 to 8 percent of the total water use.
- Overall Nitrate as N water quality is acceptable with 84% of all wells under the W.H.O guideline of 10 mg/L.
- Groundwater salinity through the study area is very good quality, averaging about 460 mg/L.
- Overall, groundwater quality in the study area is in a healthy state.
- A relationship seems to exist between land use and Nitrate as N.
- Through education, farmers should be encouraged to backfill any well either not in use or not to be used in the near future.
- Total water use is calculated as being 3301.3 megalitres for 2001/2002.
- This is about the same amount of water as that pumped from the Blue Lake for the same time period.
- To meet this water use, between 57 and 68 mm of groundwater recharge is required per hectare per annum.
- That this water recharge requirement is occurring with about 45 percent of the potential irrigation being used.
- The great majority of the irrigation water is pumped through the six month summer period when pasture for dairy cows is required.
- That statistically a higher cancer average does not seem to exist in the study area.

12 RECOMMENDATIONS

A number of issues have been raised as a result of this study. The following are our recommendations.

- Irrigation and Industrial water usage be recalculated after metering has been installed.
- Groundwater recharge figures be calculated, and compared to discharge.
- Long term monitoring of nitrate values be carried out on selected wells on irrigated land.
- The current state of the Mil-Lel Cheese contamination plume be reported on so that the public can be assured it is not a threat to the Blue Lake water quality.
- The total water use and recharge figure for the Blue Lake capture zone be calculated, based on the standards developed in this study but also including any metering data.
- A network of additional observation wells is monitored in the short term to establish recharge values over different hydrogeological conditions.
- Geophysical logging takes place using observation and unequipped wells to establish porosity values through the study area so that an extra technique in recharge assessment can be used.
- A program is developed with Noel Stratford from Warrnambool Cheese and Butter group to sample nitrate levels on a number of dairy properties to establish if a relationship exists between land use and dairy farms.
- Establish metering on selected domestic wells and windmills to better estimate stock and domestic water use.

13 REFERENCES

Australian Bureau of Statistics. Year Book Australia 2002 Agriculture Special Article – The Victorian Dairy Industry. 1998

www.cse.csiro.au/futures/ Australian Water Use Statistics

Australian Drinking Water Guidelines 1996. Fact Sheet No 61 Nitrate and Nitrite

www.dairycorp.com.au Dairy Corporation Home Page

Desmier, R.E., 1990. Estimation of the Water Requirements of Irrigated Crops in the Comaum Caroline Proclaimed Region. Department of Agriculture South Australia Technical Report No 151.

http://www.farmweb.au.com/ Water Resources and Use in Australia.

Hallberg, G.R (1989). Nitrate in Ground Water in the United States in 'Nitrogen Management and Ground Water Protection', R.F. Follett (ed). Developments in Agriculture and Managed-Forest Ecology21, Elsevier.

L'hirondel, J and L'hirondel, J.-L, 2002. Nitrate and Man. CABI puiblishing. p168.

www.agric.nsw.gov.au New South Wales Agriculture

Dan Undersander, Dave Combs, Terry Howard, Randy Shaver, Mike Siemens and Dave Thomas. University of Wisconsin. Nitrate Poisoning in Cattle, Sheep, and Goats.

www.epa.vic.gov.au Victorian EPA Internet site