Sydney–South Coast Region Irrigation Profile

compiled by Meredith Hope and John O'Connor,
for the Water Use Efficiency Advisory Unit, Dubbo

The Water Use Efficiency Advisory Unit is a NSW Government joint initiative between NSW Agriculture and the Department of Sustainable Natural Resources.

This Irrigation Profile is one of a series for New South Wales catchments and regions. It was written and compiled by Meredith Hope, NSW Agriculture, for the Water Use Efficiency Advisory Unit, 37 Carrington Street, Dubbo, NSW, 2830, with assistance from John O'Connor (Resource Management Officer, Sydney-South Coast, NSW Agriculture).

ISBN 0 7347 1335 5 (individual)

ISBN 0 7347 1372 X (series)

(This reprint issued May 2003. First issued on the Internet in October 2001. Issued a second time on cd and on the Internet in November 2003)

job # 4179
Editorial assistance: Penny Marr

Cover design: Nicky Parker
Maps: Udai Pradhan

CONTENTS

List of figures

List of tables

Acknowledgments:

Thanks to the Water Management Fund for providing financial support to undertake this work.

Thanks also to:

- the Water Analysis and Audit Branch, Sustainable Water Management, Department of Land and Water Conservation (DLWC), Parramatta; and
- the Licence Administration Branch, DLWC, Parramatta
- NSW Agriculture staff, especially Nick Austin; Eddie Parr; Steve Elliott; Len Banks; Bill Yiasoumi; John Gillett; Harry Kemp; and Udai Pradhan.

for their assistance in preparing this document.

1. EXECUTIVE SUMMARY

The *Sydney–South Coast Region Irrigation Profile* was developed from a study to obtain region and industry assessments of water use and water use efficiency. The Profile details (where possible, by water source) what is known about:

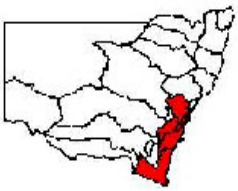
- the number of irrigators and the number of enterprises that irrigate
- the number of licences, the entitled volume or area authorised for irrigation
- the area irrigated and water used in total and by crop type
- irrigation methods
- irrigated crop yields
- the value of irrigated agriculture in the Sydney–South Coast Region

Irrigation data in the public domain were collected from State and Commonwealth sources, from published research and industry reports and from unpublished reports. These data were assigned a reliability rating using a system developed by the National Land and Water Resources Audit (1999).

Note: We do not attempt to interpret or infer water use efficiencies from the data collected in this Profile.

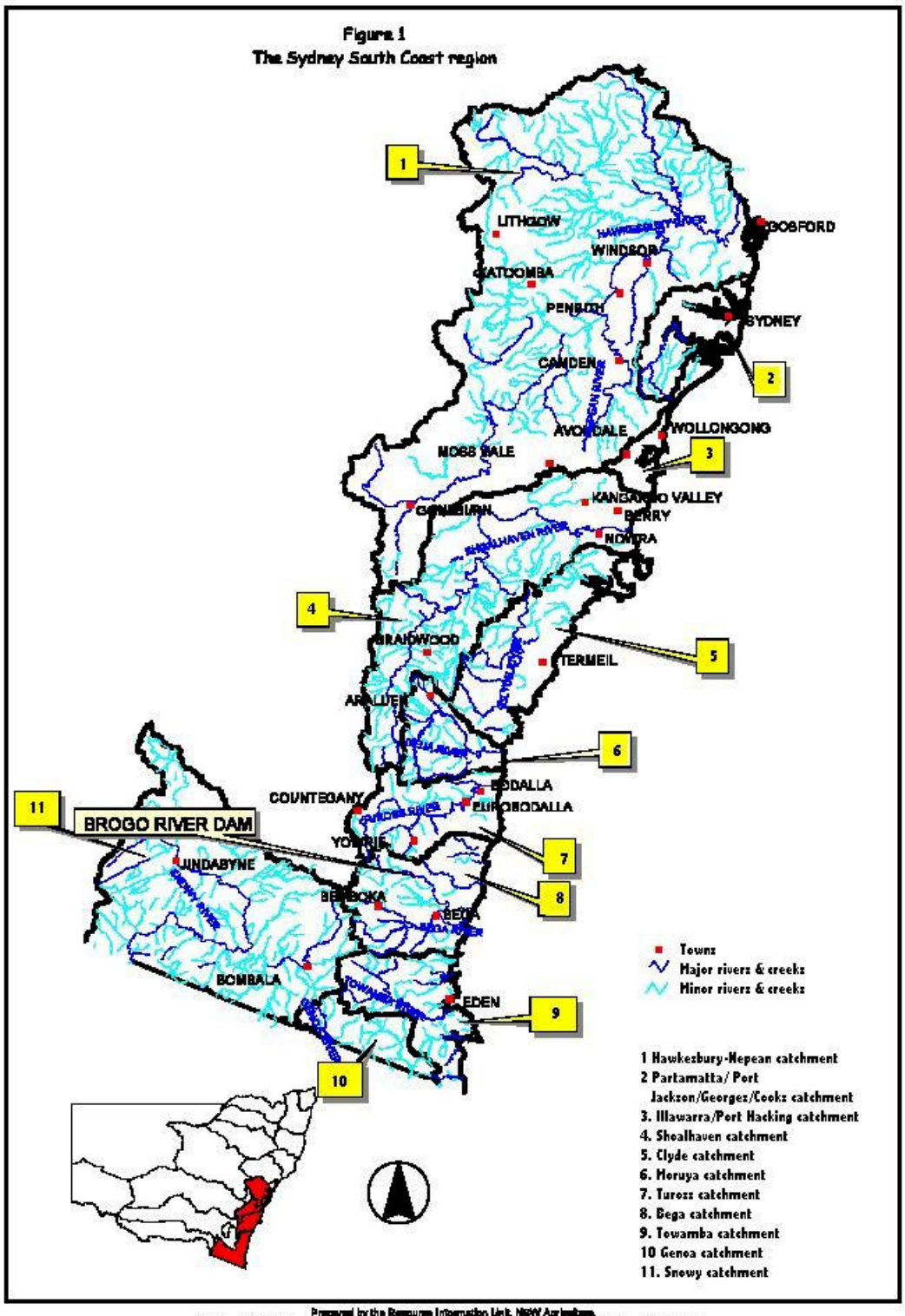
1.1 An overview of Sydney–South Coast Region irrigation

- The two main irrigation centres in Sydney and the South Coast are the Hawkesbury–Nepean and the Bega catchments. Pockets of irrigation are scattered along the coast between these centres.
- The area of land irrigated on individual farms is small compared with the rest of the State. Broadacre and dairy properties in the Sydney–South Coast Region irrigate, on average, 26 ha. Broadacre and dairy properties in the rest of the State irrigate 189 ha on average.
- In the Bega catchment the most important irrigated crop is irrigated pasture for dairy production. Pasture for dairy production, turf, vegetables, cut flowers and nurseries are important irrigated industries in the Hawkesbury–Nepean catchment.
- Of the total area irrigated in New South Wales, between 1% and 2% is in the Sydney–South Coast Region.
- Of the total number of licences in New South Wales with a purpose of irrigation, 12% are in the Sydney–South Coast Region.



- Of the total land area irrigated in the Sydney–South Coast Region, 70–80% is pasture.

Figure 1
The Sydney South Coast region



Prepared by the Resource Information Unit, NSW Agriculture.
Catchment boundaries from data provided by DLWC, topographic features from AUSLIG Topo 250K Coastdata.
November 2000

1.2 Issues in the Sydney–South Coast Region

1.2.1 How many enterprises in this region are irrigating?

There was a large discrepancy in the estimates of the number of irrigation enterprises in the Sydney–South Coast Region. Sources report either 937 or 3,213 enterprises irrigating crops.

There are believed to be 1,000 additional enterprises irrigating in the Hawkesbury–Nepean catchment that do not have a licence. It is therefore difficult to provide a reliable estimate of the volumes of water being extracted for irrigation from the catchment. This issue is being addressed by the Department of Land and Water Conservation (DLWC) in the region.

There has been an apparent decline in the number of enterprises irrigating and the area irrigated between 1993–94 and 1996–97. There was no explanation for this decline other than that the responses may have varied depending on the composition of questions in the 1993–94 and 1996–97 survey forms. In 1996–97, information on the volume of water used on crops was sought for the first time by the Australian Bureau of Statistics (ABS). Many irrigators do not know how much water they apply and this question alone may have reduced the response rate for other irrigation questions.

1.2.2 What area is irrigated?

Someone unfamiliar with the vagaries of the ABS data-set may choose the wrong data-set when determining the total area irrigated.

In 1993–94, the 'total area irrigated' could be determined in two ways:

1. Irrigators were asked to estimate the area of land they irrigated.

   The total area irrigated could be derived by summing the data from these responses for each Statistical Local Area or SLA.

2. Irrigators were asked to estimate the area irrigated from different sources of water.

   Where a single patch of land is irrigated from more than one source of water, such as from groundwater and from unregulated supplies, an irrigator might have double-counted this patch of land when responding. This may cause the total area irrigated to be overestimated (table 1).

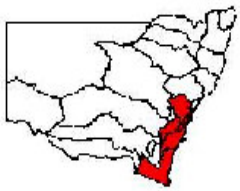


Table 1. Area irrigated from different sources of water as a percentage of the total area irrigated

	Surface	Town	Groundwater	Dam	Total
Area (ha)	23,721	550	1,904	6,983	23,251
% of total area irrigated	102%	2%	8%	30%	

Source: ABS 1998

Data from the volumetric conversion survey could not be reconciled with the ABS estimates of total area irrigated from all sources. The area irrigated as estimated from the volumetric conversion survey ranged from 91% to 171% of the area estimated by the ABS.

Table 2. Area irrigated from unregulated supplies as a percentage of the total area irrigated

	1993–94	1995–96	1996–97
Volumetric conversion data (ha)[a]	22,279	23,290	23,728
ABS total area irrigated (ha)[b]	24,351	13,634	15,188
	91%	171%	156%

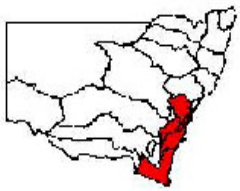
Source: [a] DLWC 2000d [b] ABS 1998

1.2.3 Knowledge gaps

- There was a large discrepancy between the estimated value of irrigated agriculture in the Sydney–South Coast Region. The reported value was either $173 million or $727 million.
- There are no data on the total amount of water used by irrigated agriculture from all sources in the Sydney–South Coast Region.
- There are gaps in knowledge regarding irrigation methods, yields from irrigated crops and the amounts of water used by irrigation from regulated rivers, unregulated rivers, groundwater, farm dams and town water supplies in the region. There are hardly any records of the volumes of water used to irrigate crops from any source in the region. Data were last collected from farms irrigating crops using regulated supplies in 1990–91 from the Bega–Brogo river system.

1.3 Conclusion

A more comprehensive and consistent approach to the collection of irrigation statistics is needed. Such an approach would help to ensure that data are comparable across different water sources and industries. Protocols for the collection, management and distribution of irrigation data are required to ensure that data are accurate and reliable. This comprehensive approach can only be developed with the full involvement and support of the many agencies and irrigator groups that require these data.



2. INTRODUCTION

During 1998, a desktop study was undertaken to develop a comprehensive database of New South Wales irrigation statistics. This was done to obtain regional and industry assessments of on-farm water use efficiency (WUE). From this study, Irrigation Profiles, or situation statements of irrigation, were developed for each of the major regions in New South Wales.

This *Profile* focuses on the Sydney–South Coast Region and attempts to document what is known about the number of irrigators, the area irrigated and water used in total and by crop, irrigated production, irrigation methods and the value of irrigated agriculture.

2.1 Background

A comprehensive assessment of irrigation was previously undertaken in New South Wales by the Water Resources Commission (McGowan International 1986). The study highlighted a lack of data on crop areas irrigated, water used, irrigated yields and financial returns.

More recently, Deborah Wilson Consulting (DWC 1990) provided a comprehensive report on crop areas, irrigated yields and the values of individual irrigated commodities between 1980 and 1989 for New South Wales.

Sloane (1993) provided an overview of the number of farms and area irrigated for four broad agricultural regions in New South Wales between 1988 and 1992.

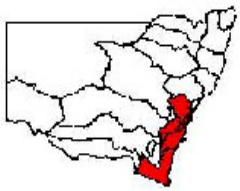
The Australian Bureau of Statistics (ABS) has been collecting information on irrigation for various years since 1986 (ABS 1998).

The Department of Land and Water Conservation (DLWC) and its predecessors have also collected information over the last 50 years on the area irrigated and water used by irrigated agriculture across New South Wales.

More recently, the Australian Bureau of Agricultural Resource Economics (ABARE 2000) completed a survey of broadacre and dairy farms that irrigate in each of the major catchments in New South Wales.

Despite the apparently ample collection of statistics in New South Wales over the last two decades, a basic description of the irrigation industry remains elusive. A review commissioned by the Murray–Darling Basin Commission (Crabb 1997a; Crabb 1997b) highlighted a lack of data on:

1. the number of irrigators
2. the area of land irrigated
3. the location of irrigated land
4. the volume of water used



Additional points that need to be covered could have been added to this list: the irrigated yields that are being obtained, the crop types being irrigated, and the irrigation methods that are being used to irrigate crops.

There is a pressing need to answer these basic questions to help strategically focus efforts to address inefficient water use, provide communities with information on irrigation to aid decision making about sharing water in New South Wales, and help agencies and communities measure change as a result of water reform.

2.2 The *Sydney–South Coast Region Irrigation Profile*

In 1998, a desktop study was undertaken by NSW Agriculture with financial assistance from the Water Management Fund to develop a comprehensive database of New South Wales irrigation statistics. This study developed into the *Sydney–South Coast Region Irrigation Profile* which provides a summary of the availability and reliability of data on irrigated activities in the Sydney–South Coast Region.

The availability and reliability of data in the Sydney–South Coast Region has been summarised for five water sources: regulated rivers; unregulated rivers; groundwater; farm dam supplies; and town water supplies. The data have been presented by water source because the availability and reliability vary markedly for different water sources. A description of these sources is provided below.

Regulated rivers[1] are those rivers that have been declared by the Minister, by order published in the *Gazette*, to be a regulated river (*Water Management Act 2000* (NSW)). Regulated rivers have their flows controlled by major government-owned rural dams. These capture water that is then released to users downstream when needed (DLWC 1999b). The Bega River and the Brogo River are the only regulated rivers in the Sydney–South Coast Region.

Unregulated rivers[1] are all other rivers that are not regulated rivers (*Water Management Act 2000* (NSW)). Many of these rivers may still have dams or weirs built on them by urban water suppliers to control water flows (DLWC 1999b).

---

[1] **Rivers:** A river includes

(a) any watercourse, whether perennial or intermittent and whether comprising a natural channel or a natural channel artificially improved;

(b) or any tributary, branch or other watercourse into or from which a watercourse referred to in paragraph (a) flows; and,

(c) anything declared by the regulations to be a river.

but does not include anything declared by the regulations not to be a river.

Groundwater is water that can be accessed from an aquifer. An aquifer is a geological structure or formation, or an artificial landfill, that is permeated with water or is capable of being permeated with water (*Water Management Act 2000* (NSW)).

Farm dam water is water from dams that are on a watercourse as defined by the *Water Management Act 2000* (NSW) or that capture water from overland run-off.

Town water supplies are those that have been reticulated for a town's or city's drinking water.

In this report, data are reported at a subcatchment, Statistical Local Area (SLA), catchment, subregion and regional scale (figure 2).

The region has been divided into the Hawkesbury-Nepean catchment and the Sydney and the South Coast subregions. The South Coast subregion has been further divided into Illawarra, Upper Shoalhaven, Lower Shoalhaven, Lower South Coast, Snowy–Genoa and Tuggerah Lakes microregions.

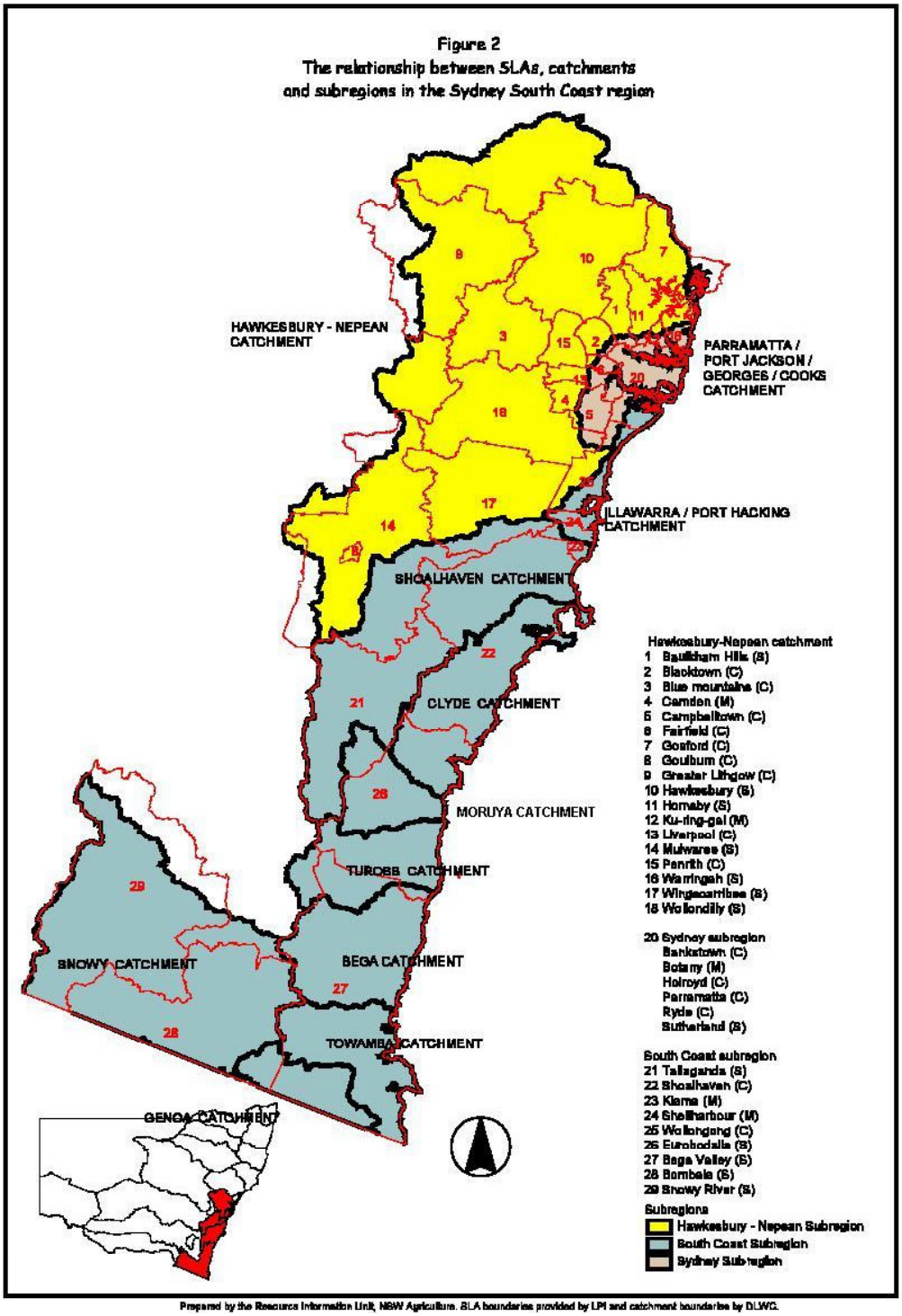
The Sydney–South Coast Region can also be divided into the major catchments: Parramatta, Port Jackson, Georges, Cooks, Port Hacking, Hawkesbury–Nepean, Illawarra, Shoalhaven, Clyde, Moruya, Tuross, Bega and Towamba.

Information on the Sydney–South Coast Region can be obtained by summing individual SLAs. (See appendix 13.1 for the definition of an SLA and the difference between SLAs and Local Government Areas.) The SLA grouping used for the *Sydney–South Coast Region Irrigation Profile* can be found in appendix 13.2. This combination is the same as that used by the DLWC to compile social and economic information for Water Management Committees in New South Wales. The Healthy Rivers Commission included more SLAs than have been used in this *Profile*: Cessnock, Crookwell, Gunning, Oberon, Rylstone, Singleton and Wollongong, but these SLAs contain very few irrigation licences and have not been included in this *Profile*.

There are six remaining SLAs in the area: Bankstown, Botany, Holroyd, Parramatta, Ryde and Sutherland and these fall into the Georges–Cooks catchment. The *Profile* refers to this grouping as the Sydney subregion. The SLAs of Campbelltown and Fairfield could align with the Georges–Cooks catchment, but, to match the DLWC SLA combination noted, they have been incorporated into the Hawkesbury-Nepean catchment. The profile has not attempted to provide an account of irrigation in the Georges–Cooks catchment.

Data on irrigation have been collected at many scales. DLWC has gathered information by licence, and these data can be aggregated to subcatchment, catchment and regional scales.

The region is also the reporting unit for the 1996–97 survey (ABARE 2000) of broadacre and dairy farms that irrigate. Unlike DLWC data, these cannot be disaggregated into smaller areas.



The ABS has collected information by SLA and, in most instances, these units can be aggregated into the Sydney–South Coast Region. However, some SLAs may overlap region borders. Because accurate information on the location of irrigated enterprises within each SLA is scanty, no attempt has been made to apportion SLA data to that which relates to the region only. In other words, even though

part of an SLA may fall outside the region, data from this portion has been included in the total area irrigated for the whole region.

This report summarises where available, by water source and by region, subregion, catchment and SLA:

1. number of licences
2. number of irrigated enterprises
3. entitled volume or area authorised for irrigation
4. area irrigated and water used in total and by crop type
5. method of irrigation
6. irrigated yield
7. value of irrigated production

2.3 Methods

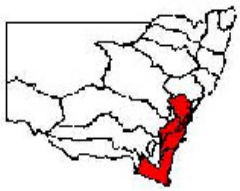
During 1998, a desktop study was undertaken to review readily accessible irrigation data from State sources including the DLWC, and from Commonwealth sources including ABARE and ABS. Electronic data collected include:

1. the ABS Irrigation Statistics Catalogue, AGSTATS (ABS 1998)
2. the 1996–97 ABARE Irrigated Farm Survey results obtained from the ABARE Survey of Primary Industry, Resources and Energy (ASPIRE) database (ABARE 2000)
3. a DLWC database of crop area and water use, developed for use by NSW Agriculture (DLWC 1998a)
4. various spreadsheets provided by the Water Analysis and Audit Branch, Sustainable Water Management, DLWC, Parramatta

Data were also obtained from relevant research and industry reports. A preliminary Irrigation Profile or situation statement of irrigated industries operating within the Sydney–South Coast Region was developed from this information. The Profile was further developed in collaboration with NSW Agriculture staff in regional offices. As these staff uncovered regional data (for example, unpublished reports), those data were incorporated into the Profile.

2.4 Rating data reliability

The reliability of these data has been described using a rating system developed by the National Land and Water Resources Audit (1999). The system rates data against four classes:



1. **Class A** - data based on reliable recorded and surveyed information. Little or no extrapolation or interpolation required.
2. **Class B** - data based on approximate analysis and limited surveys. Some measured data and some interpolation or extrapolation required to derive the data-set.
3. **Class C** - little measured data. Data based on reconnaissance survey (that is, a survey that lacks detailed investigation or modelling, a preliminary survey).
4. **Class D** - derived without investigation; figures estimated from other data in nearby catchments or extrapolated or interpolated from any available data.

In this *Profile*, the reliability rating class has been indicated with the symbols:

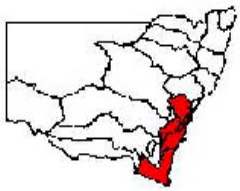
- Class A: ①
- Class B: ②
- Class C: ③
- Class D: ④

So, for example, 'the number of irrigated enterprises in the Sydney–South Coast Region was 937 (ABS 1998, ②)'.

3. REGIONAL IRRIGATION OVERVIEW

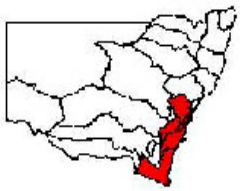
3.1 Summary

Irrigation from all sources of water; with reliability rating ① to ④		References
Total area irrigated (ha)	15,188 (②) (1996–97)	ABS 1998
	24,351 (②) (1993–94)	ABS 1998
Total water used (ML)	no data	
Number of licences with the purpose of irrigating	2,835 (①)	Determined from several sources. Unregulated and regulated licence figures from DLWC 2000d, groundwater licences from DLWC 2000a by D. McKibbin (pers. comm.)
Number of enterprises (1996–97)	937 (②)	ABS 1998
	3,213 (④)	Determined by combining sources and assumptions: DLWC 2000f; ABS 1998; B. Watt (pers. comm.); D. Dekel (pers. comm.)
Crop with greatest area irrigated (1996–97)	Pasture: 10,803 ha (②)	ABS 1998
	Pasture: 7,600 ha (③)	ABARE 2000
Crop that used the most water (ML)	Pasture: 34,960 ML in 1996–97 (③)	ABARE 2000
Value of irrigation ($ million) (1996–97)	173 (③)	Donovan 2000
	727 (④)	By summing data from Donovan 2000 and data from B. Yiasoumi (pers. comm.)



CROPS AND THEIR LOCATION		
Crop	**Location**	**Reference**
Citrus	Hawkesbury–Nepean catchment	B. Yiasoumi (pers. comm.); J. Gillett (pers. comm.)
Cut flowers	Hawkesbury–Nepean catchment	B. Gollnow (pers. comm.)
Dairy	Bega catchment, Bodalla, Kangaroo Valley	H. Kemp (pers. comm.); J. Whitely (pers. comm.)
	Hawkesbury–Nepean catchment	D. Ryan (pers. comm.)
Maize	Hawkesbury–Nepean catchment	J. Gillett (pers. comm.)
Nursery	Hawkesbury–Nepean catchment	B. Yiasoumi (pers. comm.)
Pome fruit	Hawkesbury–Nepean catchment	J. Gillett (pers. comm.)
Potatoes	Robertson	C. Beckingham (pers. comm.)
Stonefruit	Araluen, Hawkesbury–Nepean catchment	J. Gillett (pers. comm.)
Strawberries	Hawkesbury–Nepean catchment	L. Ullio (pers. comm.)
Turf	Hawkesbury–Nepean catchment	B. Yiasoumi (pers. comm.)
Vegetables	Hawkesbury–Nepean catchment	J. Gillett (pers. comm.)
Wine grapes	Hawkesbury–Nepean catchment	J. Gillett (pers. comm.)

IRRIGATION METHOD			
Method	**Crop**	**Location**	**References**
Travelling irrigators	Pasture	Hawkesbury–Nepean catchment	B. Yiasoumi (pers. comm.); J. O'Connor (pers. comm.)
	Pasture	Kangaroo Valley	J. Gillett (pers. comm.)
	Potatoes	Robertson	C. Beckingham (pers. comm.)
	Vegetables	Sydney–South Coast	J. Gillett (pers. comm.)
Lateral moves	Pasture	Berry	J Whitely (pers. comm.)
Bike shift	Pasture	Bega catchment, Berry	H. Kemp (pers. comm.); J. Whitely (pers. comm.)
Centre pivot	Pasture	Bega catchment, Berry	H. Kemp (pers. comm.); J. Whitely(pers. comm.)
Micro-irrigation	Ornamentals	Sydney–South Coast	J. Gillett (pers. comm.)
Bottom watering systems	Ornamentals	Sydney–South Coast	J. Gillett (pers. comm.)
Undertree sprinkler	Citrus, pome and stonefruit	Sydney–South Coast	J. Gillett (pers. comm.); P. Malcolm (pers. comm.)
Drip	Wine grapes, citrus, vegetables, ornamentals, strawberries, pomefruits, stonefruits	Sydney–South Coast	L. Ullio (pers. comm.); J. Gillett (pers. comm.)
Hydroponics	Vegetables, strawberries, salad crops	Sydney–South Coast	J. Gillett (pers. comm.)



IRRIGATION METHOD			
Method	**Crop**	**Location**	**References**
Semi hydroponics	Ornamentals		J. Gillett (pers. comm.)
Sprinkler	Vegetables	Hawkesbury–Nepean catchment	J. Gillett (pers. comm.)
	Cereals, pasture, vegetables	Sydney–South Coast	J. Gillett (pers. comm.)

YIELDS FROM IRRIGATED CROPS (t/ha) (④)				
Crop	**Average**	**Min – Max**	**Location**	**Reference**
Lucerne	9.8		Sydney–South Coast	ABARE 2000
Hay or silage	10.7		Sydney–South Coast	ABARE 2000
Perennial pasture	15	12–18	Berry	J. Whitely (pers. comm.)
	20		Bega	H. Kemp (pers. comm.)
Stonefruit	20	15–40	Sydney–South Coast	L. Ullio (pers. comm.)
Strawberries	30	20–40		L. Ullio (pers. comm.)
Potatoes	20	15–50	Sydney–South Coast	C. Beckingham (pers. comm.)

Note: Full details of **personal communications** are listed in the References.

3.2 Region description

The Sydney–South Coast Region is a long, thin area of land on the east coast of New South Wales. The region is bordered in the north by the southern borders of the Macquarie-Tuggerah Lakes catchment and the Hunter catchment and extends southwards to the Victorian border (figure 1). It is bordered in the west by the Great Dividing Range and by the Pacific Ocean in the east. The catchment covers an area of 43,581 km² and has extensive forested headwaters, World Heritage listing in the Blue Mountains, large areas of National Park and State forest, important wetlands, river estuaries and freshwater swamps (EPA 1997) interspersed by pockets of rural land.

The following section provides a description of each of the catchments and is presented in sequence from north to south. It should be noted that there are many small subcatchments that discharge directly to the sea or into lakes and these smaller catchments are grouped into the major catchments shown in figure 1.

3.2.1 Hawkesbury–Nepean catchment

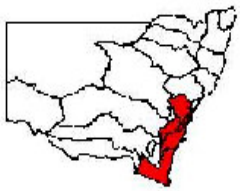
The Hawkesbury–Nepean catchment[2] is 20,810 km² and is flanked in the west by the Blue Mountains and the Macquarie and Lachlan river catchments, in the south by the Shoalhaven River catchment, in the north by the Hunter River catchment and in the east by Sydney and the Pacific Ocean (WRC 1980).

The Hawkesbury–Nepean river system is the largest watercourse in the Sydney–South Coast Region and provides water to industry and irrigated agriculture and drinking water to Sydney's population. The catchment has an average annual discharge of 3,010,000 ML (appendix 13.3), which is the second largest average annual discharge of any river on the New South Wales coast. (The Clarence catchment has the largest annual discharge with 4,920,000,000 ML (WRC 1980)). Approximately 88% of the water flowing into the Hawkesbury–Nepean river system is used by Sydney Water for urban water supply.

There are 19 major water storages in the catchment: Warragamba Dam, which contains 2,000,000 ML, and the rest, which together hold 857,561 ML. River flows in the Hawkesbury–Nepean river system are bolstered by water from sewerage treatment plants. Approximately 137.8 ML/d of treated effluent water enter the lower reaches of the river (DLWC 1998b). Major towns include Gosford, Richmond, Lithgow, Katoomba, Windsor, Penrith, Camden, Picton, Mittagong, Moss Vale and Goulburn (EPA 1997).

---

[2] The figure 20,810 km² was determined by subtracting the areas of Port Hacking and Illawarra catchments from the area of the Hawkesbury–Nepean catchment as estimated by the WRC (1980) (21,730 km²). The WRC (1980) report includes the catchments of Port Hacking and Illawarra in the Hawkesbury–Nepean catchment whereas this *Profile* does not.



3.2.2 Urban catchments – Parramatta to Illawarra

The catchments of Parramatta (520 km²), Cooks (100 km²), Georges (920 km²), Port Hacking (220 km²) and Illawarra (700 km²) have a combined total of 2,460 km². The first four catchments are all heavily urbanised and industrialised (EPA 1997). The area is bordered in the north, west and south by the Hawkesbury–Nepean catchment. Most of the urban streams in these catchments are perennial, with low flow periods occurring about 20% of the time in summer or late winter (EPA 1997). Some streams cease to flow altogether. In wet years, the flows rarely fall to low flow levels, whereas in dry years, flows in some streams may cease for months on end. Major suburbs include Frenchs Forest, Ku-ring-gai, Lane Cove, North Sydney, Ryde, Parramatta, Drummoyne, Sydney, Leichhardt, Strathfield and Randwick.

3.2.3 Shoalhaven catchment

The Shoalhaven catchment is 7,300 km² and is bounded in the north by Lake Illawarra catchment and in the north-west and west by the Hawkesbury–Nepean catchment (figure 2). The Murrumbidgee catchment also lies to the west. The catchment's southern borders are bounded by the Clyde and Moruya river catchments. The Shoalhaven catchment is hilly and heavily forested (WRC 1980) and drains the mountainous country of the Southern Tablelands (EPA 1997). The Shoalhaven River winds through steeper sections of the catchment and then across a broad fertile floodplain before emptying into the sea at Crookhaven Heads (EPA 1997). After the Hawkesbury–Nepean river system, the Shoalhaven River is the second largest river in the region with an annual average discharge of 1,788,000 ML (appendix 13.3). Major population centres include Nowra–Bomaderry (25,000), Culburra–Crookhaven (3,700), Shoalhaven Heads (2,500), Berry (1,800) and Braidwood (1,100) (EPA 1997).

3.2.4 Clyde catchment

The Clyde catchment is 3,300 km² and is bounded to the north and west by the Shoalhaven catchment (figure 2). The Moruya catchment lies to the south. The Clyde catchment has an annual average discharge of 932,000 ML, and empties into the sea at Batemans Bay (appendix 13.3). The Buckenbowra River, which also empties into the sea at Batemans Bay, may cease to flow between 2% and 4% of the time (EPA 1997). Major towns in the catchment include Jervis Bay and Sussex Inlet in the north, Ulladulla, and Batemans Bay in the south.

3.2.5 Moruya catchment

The Moruya catchment is 1,550 km² and is bounded in the north by the Clyde and the Shoalhaven catchments (figure 2). The Shoalhaven catchment also bounds the Moruya catchment in the west: the Tuross catchment is in the south. The Moruya catchment has a very small coastal strip with most of the landmass extending inland to the west. About 80% of the catchment is steep and mountainous (15 degrees or more) (WRC 1980). The Moruya catchment has a

small annual average discharge of 379,000 ML (appendix 13.3), with the major river, the Deua, collecting water from the steep ranges to the west. The major population centre is Moruya.

3.2.6 Tuross catchment

The Tuross catchment is 2,200 km² and is mostly covered in national parks, nature reserves, State forests and timber reserves. The catchment is bounded to the north by the Moruya catchment and by the Bega catchment in the south (figure 2). The Murrumbidgee catchment lies to the west. The catchment is characterised by a 'drowned' coastline to the east. There are a series of lakes and lagoons that include Coila, Tuross, Brou, Mummaga, Corunna and Tilba Tilba lakes. It has been estimated that 85% of the catchment is rugged or mountainous (WRC 1980). The major river is the Tuross River and the catchment has an annual discharge of 495,000 ML (appendix 13.3). The Tuross River may cease to flow between 2% and 4% of the time and Wandella Creek may cease to flow 10% of the time (EPA 1997). The major population centres are Tuross Head and Narooma.

3.2.7 Bega catchment

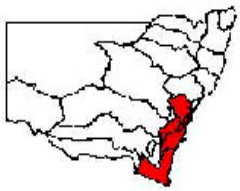
The Bega catchment is 2,850 km² and is bordered in the east by the Pacific Ocean and a series of coastal lakes that include Wallaga, Cuttagee, Wapengo, Nelson and Wallagoot. The catchment extends inland towards Bemboka and south towards Wolumla. The area is bounded by Tuross catchment in the north, Towamba catchment in the south and the Snowy catchment to the west (figure 2). Approximately 85% of the region is mountainous or rugged. Mixed-use rural land exists down the Bemboka and the Brogo rivers and also around Quaama, Cobargo and Tilba Tilba (EPA 1997). The major rivers are the Brogo, the Bemboka and the Bega, and the catchment has an annual average discharge of 570,000 ML (appendix 13.3).

The Bega catchment contains the only regulated river in the Sydney–South Coast Region. The Brogo River becomes regulated after Brogo Dam (capacity 9,800 ML) (EPA 1997; Healthy Rivers Commission 1999a) (①). The Bega River becomes regulated after the confluence with the Brogo River.

The Bega catchment has a second water body called Cochrane Dam which lies near the top of Bemboka River. This dam is used primarily to generate electricity. It is also used by the power generation company in regulating river flows for downstream irrigators. Technically, the dam is not considered to be a regulating structure as defined by the DLWC (see section 2.2 for a definition of a regulated river). If river regulation reduces the power generation capacity, irrigators have agreed to pay for any lost income.

3.2.8 Towamba catchment

The Towamba catchment is 2,200 km² and is bounded in the north by the Bega catchment and by the Genoa catchment to the south and the Snowy catchment to



the west (figure 2). The catchment is mostly mountainous and forested, although there are strips of mixed-use rural land along the Towamba River, Pambula River and Mataganah River near Wyndham (EPA 1997). The catchment has an average annual discharge of 484,000 ML. Towamba River and Pambula River may stop flowing between 2% and 4% of the time, and Merimbula Creek may cease to flow 10% of the time (EPA 1997). The major population centres are Merimbula, Wyndham and Pambula in the north, Burragate in the centre of the catchment and Towamba.

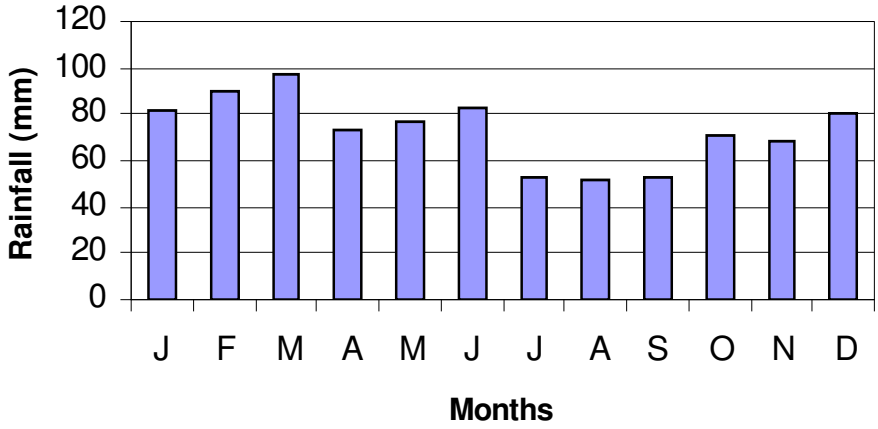
3.2.9 Snowy–Genoa catchments

Less than 20% of the Genoa catchment and roughly 58% of the Snowy catchment lie inside New South Wales – the rest lies in Victoria. The total area inside New South Wales is 15,100 km^2 (WRC 1980). Genoa catchment is bordered by the Towamba catchment in the north and by the Snowy catchment to the west. The Snowy catchment is bordered by the Murrumbidgee catchment to the north and by the Murray catchment to the west (figure 2). Both catchments are divided in two by the New South Wales–Victorian border. The major river in the Genoa catchment is the Genoa River which drains towards Mallacoota in Victoria. The major river in the Snowy catchment is the Snowy River. Population centres in the Genoa catchment include Platts and Rockton. The major towns in the Snowy catchment are Eucumbene, Nimmitabel, Bombala, Jindabyne and Dalgety (WRC 1980).

3.3 Climate

The rainfall pattern in the Sydney–South Coast Region is distributed more uniformly throughout the year than on the rest of New South Wales' coastline, but, as in the north, summer rains dominate, with drier periods occurring in winter and early spring (figure 3).

Figure 3. Monthly average rainfall at Bega



Source: Bureau of Meteorology 2000

The average annual rainfall varies from 850 mm in the Tuross catchment to 1,300 mm in the Wollongong catchment[3] (appendix 13.3). Annual rainfall varies considerably within some catchments. For example, rainfall[4] across the Hawkesbury–Nepean catchment has ranged from 640–1,300 mm and in the Shoalhaven catchment from 700–1,640 mm (appendix 13.3). The region has experienced drought 23 years out the 103 years between 1898 and 2000 (Clewett et al. 1999).

[3] Note that the Wollongong catchment referred to in appendix 13.3 (WRC 1980) is the same as the Illawarra–Port Hacking catchment in figure 2.

[4] Effective rainfall is the rainfall useful for meeting crop water requirements (Doorenbos and Pruitt 1977), or, the portion of total precipitation that is available for plant growth (Alexander and Foley 1998); it excludes deep percolation, surface run-off and interception. Mean and median rainfall, mean number of rain days and the number of years that data were collected is available for 79 stations in the region (Clewett *et al.* 1999).

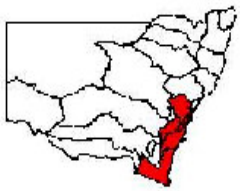
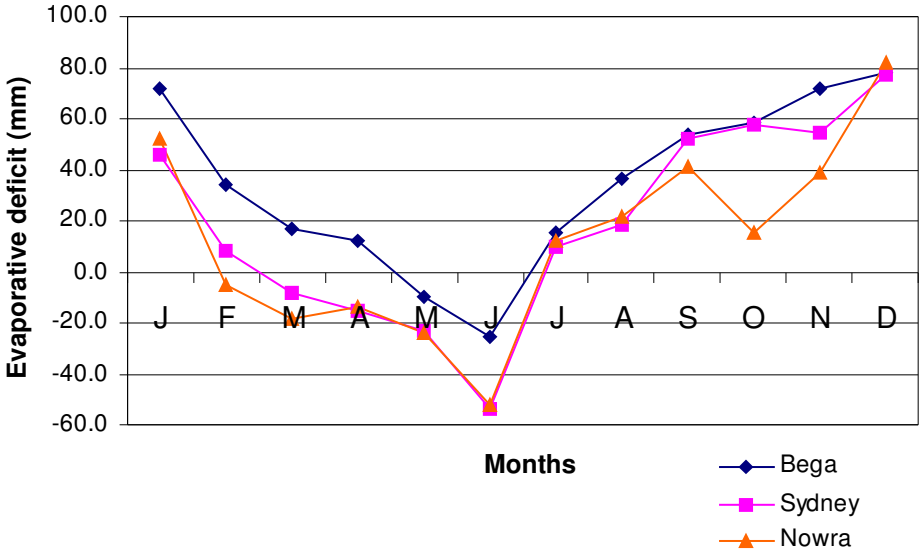


Figure 4. Evaporative deficit at Sydney, Nowra and Bega

Evaporative deficit = monthly reference evapotranspiration[5] – monthly average rainfall



Source: Climatic data were obtained from the Bureau of Meteorology (2000).

Evaporation in the Sydney–South Coast Region is between 800 mm and 1,250 mm. Reference evapotranspiration[5] generally exceeds rainfall during spring and summer (figure 4) from the Hawkesbury–Nepean catchment in the north to the Towamba catchment in the south. Irrigation water is generally needed during the summer months to meet the water demands of crops after rainfall in the Sydney–South Coast Region. The Bega region exhibited a greater need for irrigation water throughout the year when compared with Sydney and Nowra (figure 4). Daily temperatures range from a mean minimum of 7–13°C to a mean maximum of 20–22 °C (appendix 13.4). In extreme conditions, temperatures may reach 38–45°C.

3.4 Population and ethnicity

There are 4.1 million people in the Sydney–South Coast Region and nearly half of these (1.8 million) are in the Hawkesbury–Nepean catchment (ABS 2000). The South Coast subregion has a population of 0.41 million with the greatest number of people in Wollongong. There are approximately 1.9 million people in the Sydney subregion (see figure 2 for the area this covers).

[5] Reference evapotranspiration is the evapotranspiration from a clipped grass surface. Reference evapotranspiration was determined using the FAO 56 methodology (Allen et al. 1998).

3.4.1 Diversity in the Hawkesbury-Nepean catchment

The Hawkesbury–Nepean catchment is culturally diverse: approximately 4.6% of the people in the Hawkesbury–Nepean catchment were born outside Australia (ABS 2000), and there are many farmers from non-English-speaking backgrounds (NESB) (NSW Agriculture 1998).

- Half of the horticultural industries in the LGAs[6] of Camden, Campbelltown, Wollondilly, outer south-western Sydney, Blue Mountains, Hawkesbury, Penrith, outer western Sydney, Baulkham Hills, and Blacktown are managed by people from NESB (data in DLWC 1998b from ABS 2000, ②).
- Around 70% of the vegetable growers in the Hawkesbury–Nepean catchment are of ethnic origin (ABS 1991, in NSW Government 1998, ④). Nationalities include Maltese, Italian, Chinese, people from former Yugoslavia, Lebanese and German (NSW Government 1998, ②).
- Approximately 90% of cutflower growers are from NESB, and most are Italian (D. Trewin, pers. comm.).

Because of the many farmers from NESB in the Hawkesbury–Nepean catchment, there are likely to be people who find it difficult to complete written surveys of the kind used by ABS. This group often has very poor literacy skills in both English and in their native language (DLWC 1998b), a factor that was, for example, found to limit the uptake of information about safe use of herbicides and pesticides in the area (NSW Government 1998): that study recommended that training courses needed to be developed that specifically target people from NESB (NSW Government 1998).

In a report on market gardeners from NESB (NSW Government 1998), difficulty with understanding and completing written surveys in English was highlighted as a factor that may limit the quality of ABS census information (see also, in this *Profile*, sections 4.3 and 4.4). In recognition of these language and literacy barriers, the DLWC are implementing a multilingual communications campaign called the Hawkesbury–Nepean Communication Strategy (DLWC 1998b). This strategy aims to license NESB irrigators who do not have a licence.

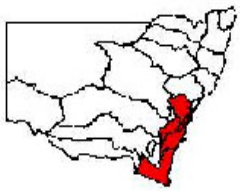
3.4.2 Homogeneity in the South Coast subregion

The South Coast subregion is less culturally diverse than the Hawkesbury–Nepean catchment and there are fewer people from NESB. About 2% of the people in the region were born in a country other than Australia (ABS 2000).

There is a long history of family farming in the Bega catchment. For example, 65% of dairy farms in the Bega and Eurobodalla shires were held by the previous generation and on average these farms were held in the family for 92 years (EBC 1999).

---

[6] See appendix 13.1 for the definition of LGAs.



4. IRRIGATION FROM ALL SOURCES

4.1 Introduction

Irrigated agriculture occurs mainly in the Hawkesbury–Nepean and Bega catchments but pockets of irrigation occur all along the coast between these two areas. Nearly half of the agricultural enterprises in the Sydney–South Coast Region are small: approximately 48% of enterprises in the South Coast subregion have a property size of between 10 and 25 ha (DLWC 1998b). The average area irrigated for broadacre and dairy farms in New South Wales in 1996–97 was 189 ha, whereas the Sydney–South Coast Region has an average of 26 ha (ABARE 2000).

Most irrigated enterprises rely on water from unregulated rivers and farm dams. Only a small number rely on regulated rivers, town water supplies and groundwater supplies (ABS 1998). Irrigation water is generally needed in spring and summer when rainfall is insufficent to meet crop demand.

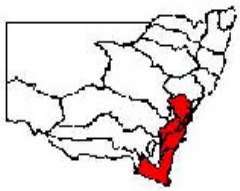
On average, unregulated rivers in the South Coast subregion experience low flows 20% of the time and these flows usually occur during springtime. In wet years, flows in most rivers rarely reach low-flow levels, whereas in dry years, rivers may cease to flow for months. By comparison, the Hawkesbury–Nepean river system experiences regular flows from the input of water from more than 20 sewage treatment plants (A. Senn, pers. comm.). Demand for water by irrigated agriculture increases during these drier periods. In some cases, there is sufficient irrigation, riparian and urban extraction of water to reduce flows in rivers substantially. This can occur in Currumbene, Conjola, Araluen, Wandella and Narira creeks and the Murrah and the Bemboka rivers (EPA 1997). About 40% of the irrigation water on the Sydney–South Coast Region is extracted from streams that cease to flow naturally every year and about 70% of licence-holders are prohibited from taking water during low flow periods (EPA 1997).

The following section provides a description of irrigation in each of the catchments and is presented in sequence from north to south.

4.1.1 Hawkesbury–Nepean catchment

The major irrigated commodities in the Hawkesbury–Nepean catchment are turf, vegetables, cut flowers and nurseries. The main irrigation areas are:

- along Mt Hunter Rivulet, Matahill Creek and Navigation Creek, which are tributaries of the Nepean River
- around Ellis Lane, Theresa Park and Cobbitty adjacent to the Nepean River



- on the northern side of Bents Basin
- on the alluvial flats between Yarramundi Bridge and Cattai Creek
- along South Creek and Kemps Creek
- along the upper reaches of Berowra, Cattai and Mangrove creeks (B. Yiasoumi, pers. comm.)

The catchment has a mixture of very small area enterprises and larger enterprises. Of the farms in the area, 27.5% of farms have a property size of less than 10 ha, 38% have a property size of between 10 and 100 ha, while a further 31% of farms have property sizes of between 100 and 1,000 ha (DLWC 1998b, ②). Approximately 3.5% of properties have a size of greater than 1,000 ha (DLWC 1998b, ②).

The catchment provides a range of irrigated produce, such as **vegetables,** to the Sydney markets. Because it is close to the city, the vegetable industry incurs very low freight costs.

- According to the Wollondilly Shire Council (1993, in NSW Agriculture 1998), in 1993 the Hawkesbury–Nepean catchment supplied 85% of Sydney's mushrooms, 70% of its tomatoes and 95% of its spring onions.
- NSW Agriculture horticulturalists estimate that at least 40% of the value (but not the volume) of New South Wales vegetable production comes from the Hawkesbury–Nepean catchment (A. Senn and A. Jones, pers. comm.).
- Vegetable enterprises are mostly concentrated around the outer western and south-western LGAs of Liverpool, Hawkesbury, Blacktown, Penrith, Baulkham Hills and Fairfield (NSW Government 1998).
- The Hawkesbury–Nepean catchment is one of the largest producers of fresh sweet corn (400 ha).
- The area is the largest outdoor hydroponic lettuce producer in Australia.
- The 1998 report (NSW Government 1998) estimated that the Sydney Basin produces 17% of the State's vegetables and 90% of perishable vegetables (leafy green vegetables, as distinct from vegetables with a longer shelf life).

The Hawkesbury–Nepean catchment contains 60–70% of the State's **ornamental** production (B. Yiasoumi, pers. comm.). The area also has a significant **cut flower** industry.

Turf and **pasture or lucerne for dairy** enterprises are some of the enterprises most reliant on irrigation in the catchment.

The **equine** industry depends heavily on fodder from the Hunter and Murrumbidgee catchments and is therefore far less dependent on irrigated agriculture within the Hawkesbury–Nepean catchment (H. Doughty, pers. comm.).

The **fruit** industry is smaller than the dairy and turf industries, but irrigated apples from Bilpin and stonefruit are still a significant industry in the catchment.

Agriculture in the Hawkesbury-Nepean catchment is a mix of extensive and intensive industries. The intensive vegetable industry might grow crops on the same plot of land for between 20 and 30 years. A few farmers growing vegetables on leased land shift operations every couple of years to avoid soil infertility problems and pests and diseases (A. Senn, pers. comm.). Dairy farmers irrigate improved pasture and fodder crops, and may use one site for many years.

The Hawkesbury-Nepean catchment is changing rapidly as residential areas encroach onto rural and agricultural lands. This factor, in combination with current water reforms, is increasing competition for water between irrigated agriculture and other water users. Urban encroachment is forcing irrigated agriculture into one of four changes:

1. moving to increasingly high value, small area enterprises (Mason nd)
2. moving further out within the catchment
3. setting up irrigation enterprises in other catchments, or
4. leaving the industry.

4.1.2 Urban catchments – Parramatta to Illawarra

The urban catchments of Parramatta, Cooks, Georges, Hacking and Illawarra are all heavily urbanised, but there are still some irrigated agriculture enterprises.

There are irrigated **horticultural** enterprises on the fringe of urban areas around Campbelltown, Liverpool and Fairfield (EPA 1997) in the Georges and Hacking catchments.

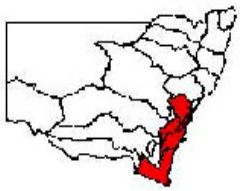
Nurseries and **cut flowers** are located in the Illawarra catchment (B. Yiasoumi, pers. comm.; C. Rolfe, pers. comm.).

There are also market gardens in the Botany Sands area. These market gardens grow **Chinese vegetables** on estuarine lowlands around Sydney Airport and at Matraville. Growers dig shallow wells into the sand and then pump water from these wells to supply their crops (D. McKibbin, pers. comm.).

4.1.3 Shoalhaven catchment

The major irrigated commodities in the Shoalhaven catchment are **stonefruit**, and **pasture for dairy** cows. **Nurseries** are also located in this catchment (C. Rolfe, pers. comm.). Irrigated activities are located at:

- Kangaroo Valley (EPA 1997)
- Berry (EPA 1997)
- Robertson (C. Beckingham, pers. comm.)



- Nowra (B. Yiasoumi, pers. comm.)
- Kiama (B. Yiasoumi, pers. comm.)

Approximately 20% of the 224 dairy farmers irrigate pasture (EPA 1997): these farms are located at Kangaroo Valley and Berry (Healthy Rivers Commission 1999b). The dairy industry tends to be located on the alluvial flats, coastal plains and the better upland soils, while pasture production for beef is located on the poorer soils in the region. The Shoalhaven dairy industry produces 13% of the State's milk, contributes around half of all the agricultural production in the catchment and is worth $130 million (EPA 1997). Pasture requires irrigation water mostly during the spring and summer months.

Irrigated **wine grapes** are increasing in area between Nowra and Kiama (B. Yiasoumi, pers. comm.), **stonefruit** is grown in the Shoalhaven microregion (DLWC 2000b) and **potatoes** are grown at Robertson in the Wingecarribee SLA (C. Beckingham, pers. comm.). For the higher value **horticultural** crops, constant amounts of water are needed to keep plantings alive during the year (Healthy Rivers Commission 1999b).

4.1.4 Clyde catchment

The major irrigated crop in the Clyde catchment is **pasture for dairy** cows. Irrigated agriculture is located:

- around Jervis Bay
- along the Currambene Creek
- on the tributaries emptying into St George's Basin
- between Lake Conjola and Milton
- around Ulladulla
- on streams near Termeil
- along the Clyde River (EPA 1997)

4.1.5 Moruya catchment

The major irrigated commodities in the Moruya catchment are **stonefruit**, and **pasture for dairy** cows. Most of the agricultural land exists along Araluen Creek, Moodang Creek and most of the Deua River. Stonefruit is grown in the Araluen Valley west of Moruya and dairy farming occurs on the river flats (DLWC 1999c).

4.1.6 Tuross catchment

The major irrigated commodity in the Tuross catchment is **pasture for dairy** cows (EPA 1997; H. Kemp, pers. comm.). Irrigated dairy farms can be found

along the Tuross River around Eurobodalla, at Corunna Lake and Tilba Tilba Lake and around Bodalla (H. Kemp, pers. comm.).

4.1.7 Bega catchment

The major irrigated commodity in the Bega catchment is **pasture for dairy** cows. **Nurseries** are also located in this catchment (C. Rolfe, pers. comm.).

The Bega catchment is one of the most agriculturally developed regions in the South Coast subregion. Approximately half of the Bega catchment is occupied by agriculture and grazing (irrigated and dryland) (EPA 1997, ③).

Dairy enterprises that irrigate pasture are located along three rivers within the Bega catchment: the Tantawangalo, the Bemboka and the Brogo rivers (Lim-Applegate and McClintock 1999). Dairy enterprises are also located around Wallaga, Wapengo and Narira lakes. Most dairy farms in the Bega catchment are of a similar size, have a similar irrigated area and have similar pasture types. On average, farms have 280 ha of improved pasture, of which there are 72 ha of irrigated white clover, ryegrass, kikuyu and sorghum (Lim-Applegate and McClintock 1999) (appendix 13.5).

4.1.8 Towamba catchment

There are no irrigated enterprises in the catchment (EPA 1997).

4.1.9 Snowy–Genoa catchments

The major irrigated commodities in the NSW part of the Snowy–Genoa catchments are **pasture for dairy** cows and **stonefruit** (ABS 1998).

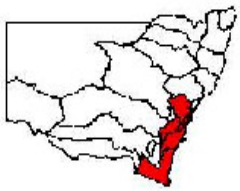
4.2 Number of licences with a purpose of irrigating (all sources)

The number of licences with the purpose of irrigating was 2,835 in 2000. This value was determined by summing:

1. licences with an authorised area: 2,304 (appendix 13.6) (DLWC 2000f)
2. licences with a volumetric entitlement: 79 (DLWC 2000f)
3. groundwater licences with the purpose of irrigating: 452. This figure was obtained from D. McKibbin (pers. comm., ①).

4.3 Number of enterprises using irrigation (all sources)

Estimates of the number of enterprises in the Sydney–South Coast Region using irrigation have ranged from as low as 937 (ABS 1998, ②) (appendix 13.2) to as



high as 3,213 (④), a figure calculated using the assumptions shown in table 3. The latter figure does not account for the number of enterprises that may have both a groundwater and a surface water licence, but the number of enterprises that do is thought to be small (B. Watt, pers. comm.) and would have little impact on the total figure.

Table 3. Assumptions used to estimate the number of irrigation enteprises in the Sydney–South Coast Region

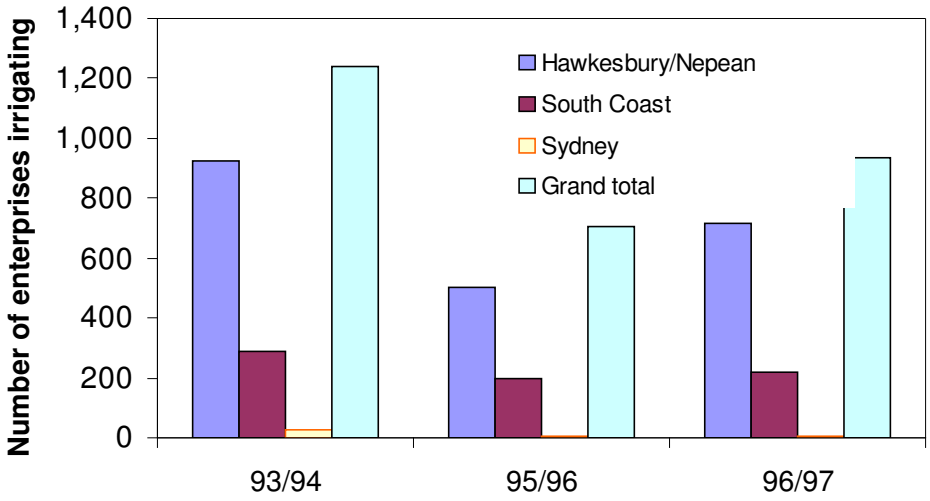
Water source	Number of enterprises	Assumptions and references
Unregulated	765 (③)	ABS 1998. This figure attracts a lower reliability rating as it was determined by subtracting the number of enterprises estimated to be using water from regulated rivers from the total number of enterprises estimated to be using water from all surface supplies (regulated and unregulated). See section 6.4 for more details.
Groundwater	89 (②)	ABS 1998
Regulated	79 (④)	DLWC 2000f. All the licences using water from regulated streams for irrigation were assumed to be active; and one licence was assumed to equal one irrigation enterprise (D. Barma, pers comm.).
Farm dams	533 (②)	ABS 1998
Town water supplies	192 (②)	The number of enterprises irrigating from town water supplies in 1993–94 (ABS 1998).
Amnesty	555(④)	There were 930 licence applications through the periods of amnesty in the Sydney–South Coast Region and 925 represent new licence applications (B. Watt, pers. comm.) It has been assumed that 60% of the new licences will actively irrigate.
Unlicensed irrigators	1,000 (④)	It is believed that there are 1,000 extra enterprises in the Hawkesbury–Nepean catchment using irrigation that do not have an irrigation licence (D. Dekel, pers. comm.).
Total	**3,213 (④)**	

The gap between ABS figures and those reported in table 3 might be explained by a survey response rate that changed depending on the group being surveyed (M. Raine, pers. comm.). ABS figures compared reasonably well with information from the Bega catchment (H. Kemp, pers. comm.) [7].

In the Hawkesbury-Nepean catchment, there appear to be many more enterprises than the ABS suggests. The number of enterprises in the Hawkesbury–Nepean may be under-reported because of difficulties for NESB irrigators in completing ABS surveys (see section 3.4).

According to ABS figures, there has been a drop in the Sydney–South Coast Region in the area irrigated and the number of enterprises (figures 5 and 6, ②) over the last seven years. There were large decreases in the number of irrigation enterprises in the SLAs of Mulwaree, Greater Lithgow and Wollondilly. Overall the number of irrigators in the Wollondilly SLA nearly halved between 1993–94 and 1996–97 (appendix 13.2) (②). The same decline was experienced in most SLAs across the State and for most crop groups reported by ABS (1998).

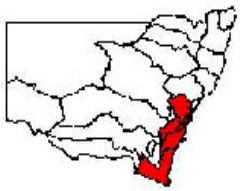
Figure 5. Number of enterprises in the Sydney–South Coast Region using irrigation in 1993–94, 1995–96 and 1996–97



Source: ABS 1998, ②

The DLWC figures show the opposite to those of the ABS: that the area irrigated increased over the period between 1993–94 and 1996–97 (D. Barma, pers. comm.). There are no explanations for the ABS trend (B. Yiasoumi, pers. comm.) apart from the possibility that the 1996–97 irrigation season was the first year

[7] The number of irrigated enterprises in the Bega, Pambula and Tuross catchments was estimated to be 84 in 2000 (H. Kemp, pers. comm., ①). This figure attracts the highest reliability rating because the data were determined by geographically locating enterprises in the region. There were between 34 and 60 enterprises between 1993-94 and 1996-97 (ABS 1998, ②).



that information on the volume of water used was sought by ABS. Many irrigators do not know how much water they apply and this question alone may have reduced the response rate to other irrigation questions generally (M. Raine, pers. comm., July 2000).

Climatic factors could not be used to explain the drop in the number of enterprises irrigating in the Sydney–South Coast Region.

- The number of enterprises in the Bega catchment decreased despite the fact that spring rainfall was lower in 1993–94 than in 1996–97 (appendix 13.7).
- In the Bega catchment, the allocation from the Brogo Dam was similar for all three seasons. If anything, there appeared to be less water available in 1996–97 in the dam (appendix 13.8).

Of the number of irrigation enterprises in the Sydney–South Coast Region (937), there were 336 irrigating pasture, 246 irrigating 'other crops', 204 vegetable enterprises and 200 fruit and nut enterprises (ABS 1998, ②). Do not attempt to sum the number of enterprises irrigating each commodity type. Most grow more than one commodity type and consequently double counting will occur. Of the 764 New South Wales production and wholesale businesses (Atkinson 1998), it is believed that a quarter of these nurseries are in the Sydney–South Coast Region (R. Stephens, pers. comm., ④).

4.4 Area irrigated and water used (all sources)

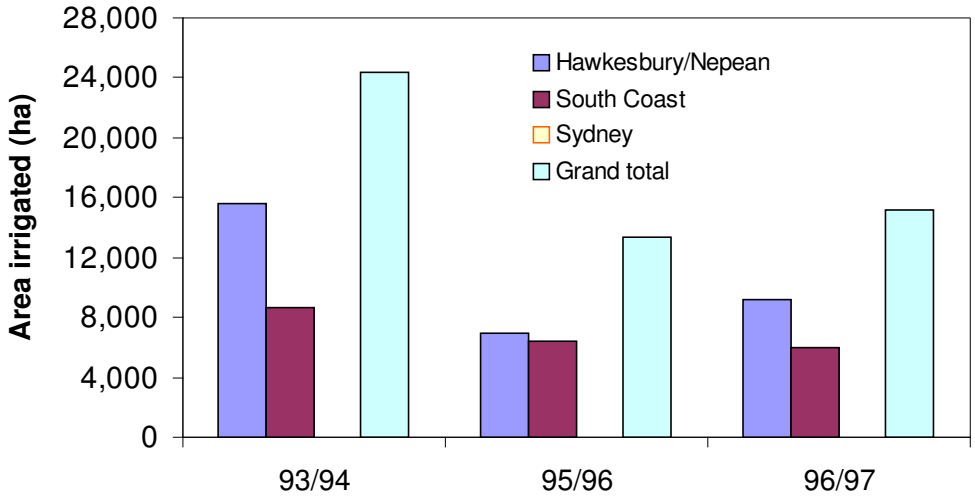
The total area irrigated in the Sydney–South Coast Region in 1996–97 was reported by the ABS (1998, ②) as being 15,188 ha, but this may be too little.

For the Hawkesbury–Nepean catchment, the ABS (1998, ②) estimates that 9,156 ha are irrigated. Another estimate (Webb, McKeown & Associates 1996, ③) gives double this, at 19,245 ha, although this area was determined using Landsat imagery that was not properly ground-truthed (hence the lower reliability rating).

Again, the area in the Hawkesbury–Nepean may be under-reported because of difficulties for NESB irrigators in completing ABS surveys.

The area of land irrigated in the Sydney–South Coast Region appeared to decrease from 24,351 ha in 1993–94 to 15,188 ha in 1996–97 (ABS 1998, ②) (figure 6). See section 4.3 for possible explanations.

Figure 6. Area irrigated in the Sydney–South Coast Region between 1993–94, 1995–96 and 1996–97



Source: ABS 1998, ②

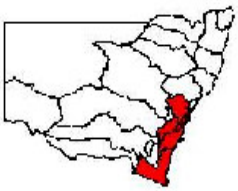
There were massive decreases in the area irrigated in some SLAs. See, for example, the drop in area irrigated (appendix 13.2) (②) in

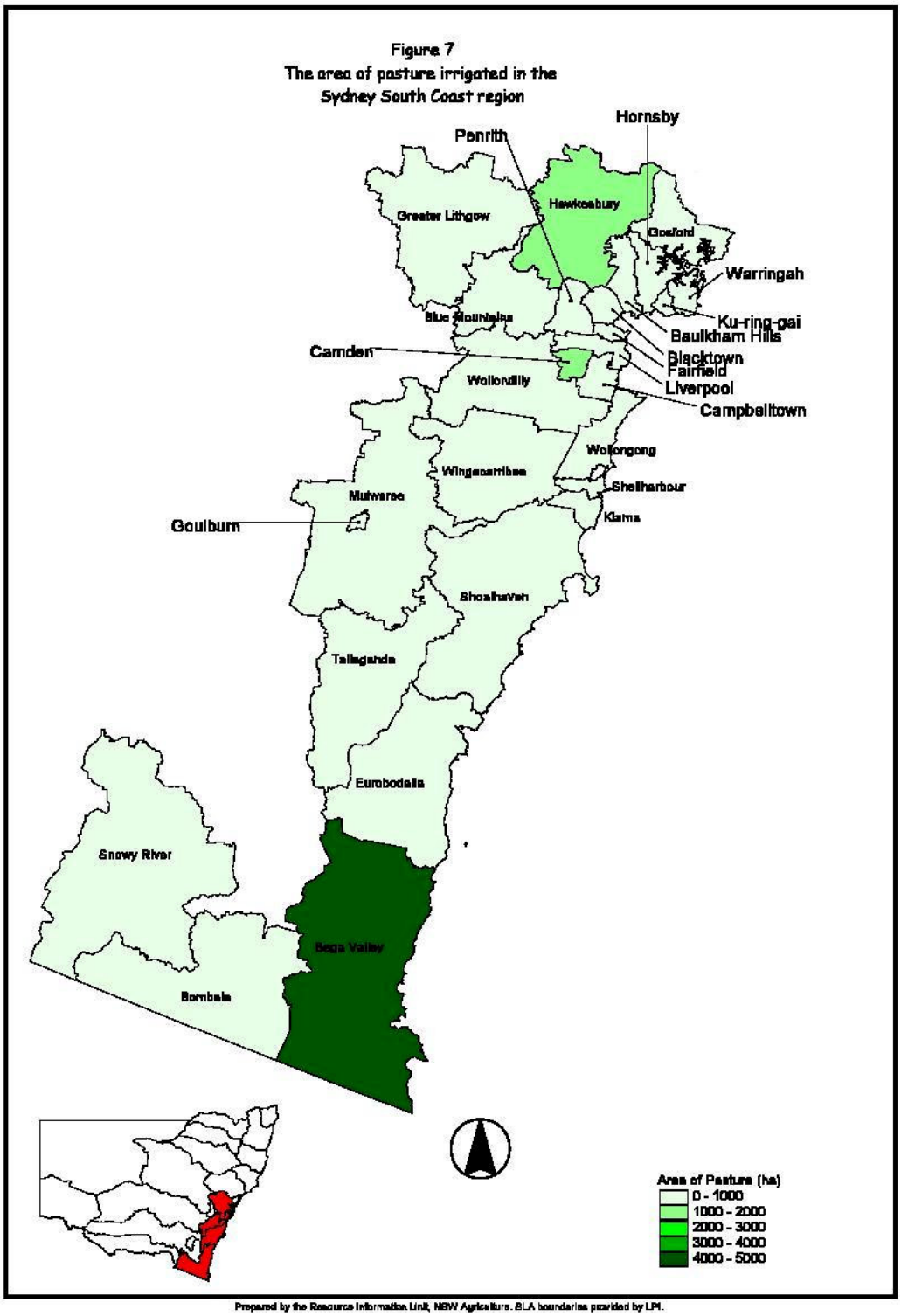
- Goulburn (3%)
- Greater Lithgow (3%)
- Blue Mountains (25%)
- Mulwaree (12%)
- Shoalhaven (43%)
- Eurobodalla 27%)

Again, one explanation for these changes (B. Yiasoumi, pers. comm.) is given in section 4.3.

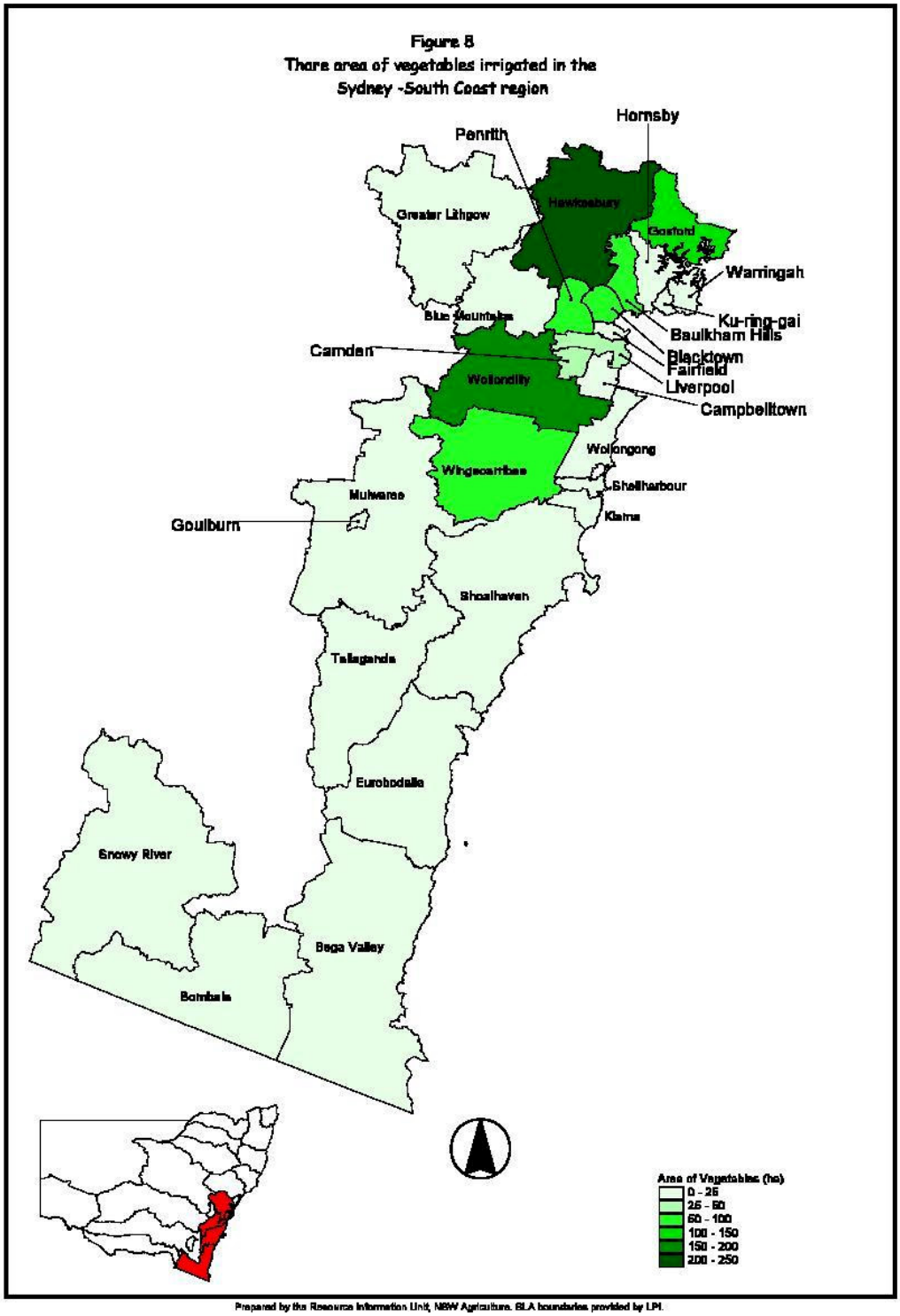
The major irrigated crops in the Sydney–South Coast Region include pasture for dairy enterprises in the Bega catchment (figure 7) and turf, cut flowers, nurseries and vegetables (figure 8) in the Hawkesbury–Nepean catchment.

Approximately half of this irrigated pasture land was located in the Hawkesbury–Nepean catchment and the other half was located in the South Coast subregion and more specifically in the Bega Valley SLA (appendix 13.9). Approximately 97% of the irrigated land in the Bega catchment was irrigated pasture in 1993–94 (②). This area increased to 98% in 1996–97 (②).

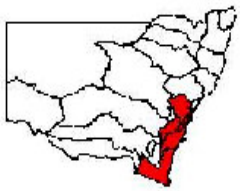




At the same time, the number of enterprises irrigating pasture fell (appendix 13.9). These data suggests that fewer farms are irrigating more land and this is a trend that has been observed in this area (H. Kemp, pers. comm., ④).



Around 95% of the vegetables grown in the Sydney–South Coast Region are grown in the Hawkesbury–Nepean catchment (figure 8). There were between 987 ha (ABS 1998) (②) and 3,500 ha (B. Yiasoumi, pers. comm., ④) of vegetables irrigated in the subregion. The second figure was determined for the portion of the subregion comprising Goulburn, Camden, Wallacia, Windsor, Glenorie and



Penrith. These data provide further evidence that the ABS data may underestimate the amount of irrigation in the subregion.

Again, ABS data suggest that there has been a decline in the vegetable area irrigated (appendix 13.9) (②). An explanation for this apparent decrease is provided in section 4.3. Data from volumetric conversions suggest that there has been a slight increase in the vegetable area irrigated between 1993–94 and 1996–97 (DLWC 2000d, ②). Between 1993–94 and 1996–97, area data from unregulated streams alone (DLWC 2000d) (②) shows the following:

- citrus – decreased 9%
- cutflowers – static
- lucerne – decreased by 7%
- nurseries – increased by 8%
- summer cereal – increased by 23%
- orchards – decreased by 6%
- turf – increased 12%
- wine grapes – increased 16%
- winter cereals – increased by 63%

There are no data on the total volume of water used on all crops from all sources in the Sydney–South Coast Region. In 1996–97, the total water used by broadacre and dairy farms that irrigate crops was 34,656 ML (table 4, ③) (ABARE 2000)[8]. The reliability of these data may be affected by the number of enterprises that were surveyed (see, for example, table 4).

[8] These data cannot be disaggregated into catchments or microregions due to a paucity of survey sample points.

Table 4. Total water used by broadacre and dairy farms that irrigated from all sources of water in 1996–97

Sydney–South Coast Region	Average farm volume (ML)	Total volume by water source (ML) [a]	RSE (%)[c]
Regulated	na	na	
Groundwater	na	na	
Unregulated supplies	106	32,224	48
Farm dams	na	na	
Total volume	**114**	**34,656** [b]	**31**

Source: ABARE 2000, ③

[a] Average farm volume multiplied by the total number of irrigators (304) (③).

na means there were insufficient sample points to provide reliable estimates of use from regulated, groundwater and farm dams.

[b] The total volume is different from the sum of each source. This is because the total source is estimated using all sample points.

[c] RSE = Relative Standard Error. The Relative Standard Error or RSE is the standard error divided by the actual data value. The result is dimensionless. The RSE shows how big the standard error is as a proportion of the actual data value.

Actual crop water use information is virtually non-existent. ABARE (2000) collected information on the mean volume of water used by pasture (34,960 ML) (RSE = 36) in the Sydney–South Coast Region (③). However, the total water use for all broadarea and dairy farms in the Sydney–South Coast Region was estimated to be 34, 656 ML (RSE 31) (table 4, ③). The pasture figure is derived using fewer sample points than the total water use figure and the RSE is accordingly greater and therefore less reliable.

There is hardly any information on rates of water application. Until better estimates of the volume of water used by crops can be collected, estimates and theoretical requirements must be used.

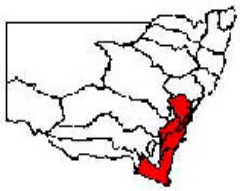


Table 5. Estimated irrigation requirements based on volumetric conversion rates for crops in the Sydney–South Coast Region

Crop class[a]	Zone 9b. Approximating Hawkesbury–Nepean catchment and Sydney subregion (ML/ha)	Zone 11. Approximating the South Coast subregion (ML/ha)
Turf	10	8.5
Perennial pasture: dairy	7	6.5
Orchards	6	5.5
Nuts	6	5.5
Vegetables	5.5	4.5
Perennial pasture: non dairy	5	4.5
Cut flowers	5	4.5
Lucerne	4.5	5
Citrus	3.5	3.5
Olives	3.5	3
Summer cereal	3	2.5
Pulses	3	2.5
Annual pasture	2	1.5
Vines	1.5	1.5
Summer oilseeds		3
Winter cereal		1

Source: DLWC 2000e, ③. [a] Crop class refers to a class of crops that have similar physiologies and therefore a similar requirement for water.

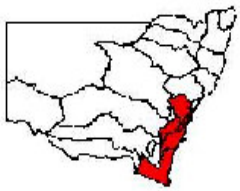
A range of crop irrigation requirements (IR) are reported in appendix 13.10. The IR (the water requirement of the crop after rainfall has been taken into account) has been calculated for the Hawkesbury–Nepean catchment and the Sydney subregion and the South Coast subregion. An efficiency of 70% was used in calculating the IR, and it represents the losses between the farm gate and the crop, and then losses within the crop. These data show that turf and perennial pasture for dairies have the highest IR in the region (table 5, DLWC 2000e).

4.5 Irrigation methods (all sources)

Data on irrigation methods are scant. According to ABARE 2000, 62% of the total area irrigated on broadarea and dairy farms was by travelling irrigators while 31% was irrigated using moveable sprays (③).

This information was collected from NSW Agriculture staff and has a reliability rating of ④:

- In the Hawkesbury–Nepean catchment, pasture is irrigated by travelling irrigators, hand shift or lateral move (B. Yiasoumi, pers. comm.).
- It is believed that 80% of dairy farms in the Bega catchment use bike shift. The remainder use travelling irrigators or centre pivots (H. Kemp, pers. comm.).
- Pasture grown along the Brogo River is irrigated by travelling irrigators (J. O'Connor, pers. comm.). As water reforms and deregulation take effect, some irrigators may shift to centre pivot or fixed sprinklers, as these systems require less labour (H. Kemp, pers. comm.).
- Dairy farmers in Kangaroo Valley use travelling irrigators (J. Gillett, pers. comm.).
- Citrus is irrigated by under-tree sprinklers (appendix 13.10).
- Wine grapes are irrigated by drip (appendix 13.10).
- Stonefruit in the Araluen Valley is irrigated by under-tree sprinklers (J. Gillett, pers. comm.).
- Pome and stonefruit are irrigated by under-tree sprinklers or drip (appendix 13.10).
- Vegetables are irrigated by either sprinkler or hydroponic media (appendix 13.10) and drip (J. Gillett, pers. comm.).
- In Robertson, potato farmers use travelling irrigators (J. Gillett, pers. comm.) and handshift spray lines (M. Robbins, pers. comm.).
- Ornamentals (nursery plants and cut flowers) are irrigated using bottom watering systems, fixed overhead, drip and micro-irrigation systems (J. Gillett, pers. comm.).



4.6 Irrigation yields (all sources)

Information on yields from irrigated crops is scant. In the recent ABARE Irrigation Survey, lucerne and hay and silage production were calculated to be 10.5 t/ha each (ABARE 2000) (③)[9].

There are many vegetable and turf growers operating in the Hawkesbury–Nepean catchment.

- Strawberry yields ranged between 20 and 40 t/ha with an average of 30 t/ha (L. Ullio, pers. comm.);
- Nectarines and peach yields ranged between 15 and 40 t/ha and had an average yield of 20 t/ha (L. Ullio, pers. comm.) (appendix 13.10) (④).

In the South Coast subregion:

- Potato yields at Robertson ranged between 15 and 50 t/ha and had an average of 20 t/ha (C. Beckingham, pers. comm.) (appendix 13.10) (④);
- Perennial pasture yields ranged between 12 and 18 t/ha around Berry with an average of 15 t/ha (J. Whitely, pers. comm.). In the South Coast subregion, average pasture yields were 20 t/ha in Bega and ranged between 15 and 50 t/ha (H. Kemp, pers. comm.) (appendix 13.10) (④).

4.7 Value of irrigated production (all sources)

The total value of production from dryland and irrigated production in the Sydney–South Coast Region was estimated by Donovan (2000, ③) to be $727 million in 1996–97. The value of irrigated agriculture in the Sydney–South Coast Region is estimated to be either $173 million (Donovan 2000) (appendix 13.11) (③) or $727 million (④) (see below for references).

The first figure was derived synthetically by Donovan (2000, ③) using ABS information. The individual irrigated commodity values for Australia were derived by estimating the percentage of the total commodity value that could be attributed to irrigation. The irrigated percentage was determined from numerous agency reports, and wide consultation with industry bodies (DWC 1990). These individual commodity percentages were then applied to the total New South Wales commodity value data from the ABS for each SLA over the period between 1991 and 1997 (Donovan 2000) (②). These estimated irrigated commodity values were then summed to provide synthetically generated estimates of the total value of irrigated agriculture for each catchment.

[9] Hay and silage production were determined using area and tonnage data with RSEs of less than 31%. Lucerne production was determined using area and tonnage data with RSEs of less than 78% and is less reliable than the hay and silage production estimates.

The reliability of the estimated percentage value for individual commodities may vary from crop to crop. For example, grape values are more likely to be reliable than wheat values. This is because grapes are usually irrigated with high security water that helps to ensure yields, and areas remain reasonably static. Cereal areas and yields can by comparison vary markedly with climate and water availability. The overall reliability rating for these data is ③.4114

The second figure ($727 million ④) was calculated by summing the value of irrigated agriculture in the South Coast subregion ($62 million) (Donovan 2000) with the estimated values of irrigated produce from the Hawkesbury–Nepean catchment. Where two values were available for the one commodity, the higher value was chosen. Consequently, $727 million represents the upper boundary in value for the region. The values used for the calculation from the Hawkesbury-Nepean catchment were:

- nurseries - $200 million (B. Yiasoumi, pers. comm., ④)*;
- vegetables - $100 million (B. Yiasoumi, pers. comm., ④)*;
- tree crops - $90 million (B. Yiasoumi, pers. comm., ④); and,
- turf - $45 million (B. Yiasoumi, pers. comm., ④).
- cut flowers $200 million (D. Ryan, pers. comm., ④),
- dairy $30 million (B. Gollnow, pers. comm., ④)*

* Where two figures were available, the higher figure was chosen.

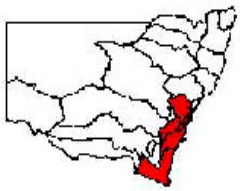
The value of $727 is clearly anomalous given it matches the total value of production from dryland and irrigated production in the Sydney–South Coast Region

4.7.1 Production in the Hawkesbury–Nepean

The value of dairy farms that rely on irrigated pasture in the Hawkesbury–Nepean catchment has been estimated to be $30 million (D. Ryan, pers. comm., ④) or $11.7 million (Donovan 2000) (③). The cut flowers industry has been estimated to be $200 million (B. Gollnow, pers. comm.). The equine industry relies heavily on feed sourced from areas outside the Hawkesbury–Nepean catchment (for example, the Hunter and Murrumbidgee catchments) and the value of the industry that is dependent on irrigated agriculture within the subregion is believed to be insignificant (H. Doughty, pers. comm., ④).

In the Hawkesbury–Nepean catchment, the category called 'other crops'[10] (Donovan 2000) had the highest irrigated value in the Hawkesbury–Nepean

[10] Other crops include cotton, sugar cane, field peas, chick peas, lupins, nursery production, canola, soybean, sunflowers, peanuts, tobacco and other. The dominant industry in this category is the nursery industry.



catchment and Sydney subregions[11]. This category has fallen in value over the last decade from $87 million in 1991–92 to $57.4 million in 1996–97 (Donovan 2000) (③). The most valuable crop in the 'other crops' category is likely to be the nursery industry. This industry has a strong presence in the Hawkesbury–Nepean catchment and Sydney subregions and was estimated to have a value of between $31.2 million (see below for references) (③) and $200 million (B. Yiasoumi, pers. comm.) (④).

The first figure ($31.2 million) was derived from the estimate that, of the 764 New South Wales production or wholesale businesses worth $125 million (Atkinson 1998) (②)[12], a quarter of these nurseries exist in the Sydney–South Coast Region (R. Stephens, pers. comm.) (④), giving an estimated value of $31.2 million.

Fruit ($21.6 million) and then vegetables ($19.5 million) were the next most valuable industries in the Hawkesbury–Nepean catchment (Donovan 2000) (③). Vegetables were also estimated to be $100 million (B. Yiasoumi, pers. comm., ④). All these industries had a reasonably constant ratio between the irrigated value and the total value (irrigated plus dryland) for the period between 1991–92 and 1996–97 . Irrigated cereals and vegetables were the exceptions (Donovan 2000, ③) (figure 9).

4.7.2 Production in the South Coast subregion

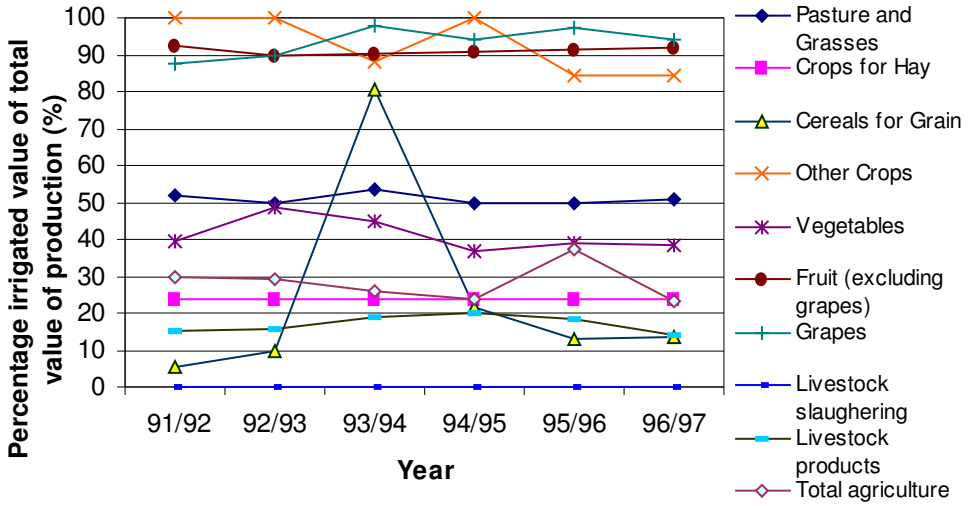
In the South Coast subregion, the dairy industry was the most valuable irrigated industry. The value of this industry has increased steadily between 1991–92 and 1996–97 from $27.8 million to $47.2 million (Donovan 2000) (③). The Bega catchment's milk production from dryland pasture and irrigated pasture accounted for over $50 million in revenue in 1996–97 , when the gross value of agricultural production (dryland and irrigated pasture) in the region was $60 million (Econsearch 2000) (②). The value of the dairy production reliant on irrigated pasture is believed to be approximately one-third of the total value of production (H. Kemp, pers. comm., ④), that is, $20 million.

The category 'other crops' (cotton, sugar cane, field peas, chick peas, lupins, nursery production, canola, soybean, sunflowers, peanuts, tobacco and other) ($9.4 million) and vegetables ($2.4 million) were the next most important industries and contributed only a small proportion of the total value when compared with livestock products. Most industries maintained around the same percentage of the total value of that industry except for cereals for grain and vegetables (figure 10).

[11] The Hawkesbury–Nepean area in Donovan's report includes the areas that drain into the Hawkesbury–Nepean River, the urban rivers in Sydney and the Shoalhaven River (Donovan 2000).

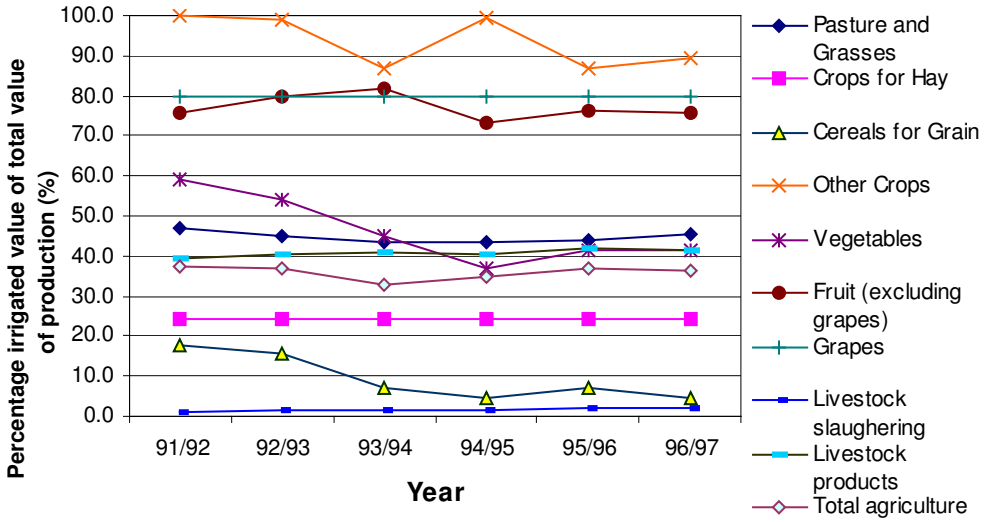
[12] Data are based on the 1993/94 survey of nurseries in Australia (②).

Figure 9. Total value of industry production attributable to irrigation in the Hawkesbury–Nepean catchment and Sydney subregions (%)



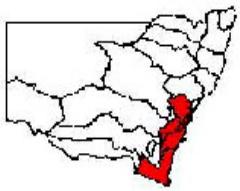
Note, milk production and eggs are the most valuable commodities in the livestock products category.

Figure 10. Total value (as a % of industry production) attributable to irrigation in the South Coast subregion



Source: Donovan 2000, ③

Note, milk production is the most valuable produce in the livestock products category.

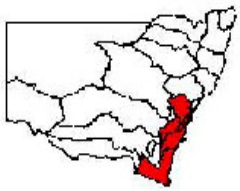


5. IRRIGATION FROM REGULATED RIVERS

5.1 Summary

The Bega and the Brogo rivers are regulated by Brogo Dam in the Bega catchment. These are the only regulated rivers in the Sydney–South Coast Region. Brogo Dam has a capacity of 9,800 ML (EPA 1997).

Irrigation from regulated supplies		References
Area irrigated (ha)	1,199 (1990–91)	DLWC 1998a, ②
Total water used (ML)	range: 5,692 – 9,684 (1997 – 2000)	Data obtained from DLWC 2000c, ①
Volumetric entitlement (ML)	14,310	DLWC 2000f, ①
No. of licences	79	DLWC 2000f, ①
No. of enterprises	79 (④)	All the licences using water from regulated streams for irrigation were assumed to be active; one licence was assumed to equal one irrigation enterprise.
Crop area irrigated (ha)	No recent information available. Between 1989 and 1991, the area of pasture irrigated accounted for 95%–97% of the total area irrigated. (②)	DLWC 1998a
Crop water use (ML)	No recent information available. Between 1989 and 1991, the water used by pasture was 92%–95% of the total water used. (①)	DLWC 1998a
Value ($ million)	no data	
Methods	Pasture (80% bike shift) (④).	H. Kemp, pers. comm.
Yield (t/ha)	Pasture (12 and 18 t/ha) (④)	H. Kemp, pers. comm.



5.2 Description of the regulated system

The Bega catchment contains the only regulated rivers in the Sydney–South Coast region. There are three major rivers: the Bega, the Brogo and the Bemboka. The Bega and the Bemboka rivers begin in the mountainous hills of the western reaches of the Bega catchment and move in an easterly direction towards the coast. The Bemboka joins the Bega before the Bega township. The third river, the Brogo, lies to the north of the Bega and Bemboka and is unregulated in its upper reaches. The river becomes regulated after Brogo Dam (capacity 9,800 ML) (EPA 1997, Healthy Rivers Commission 1999a, ①). The Brogo converges with the Bega River at Bega and flows to the sea. The Bega River becomes regulated after the confluence with the Brogo River.

5.3 Number of volumetric licences with the purpose of irrigation (regulated)

There are 79 licences using water from the regulated portions of the Bega and the Brogo (DLWC 2000f, ①) (figure 11). This number will increase by more than 2,000 once all area-based licences are converted to volume-based licences.

5.4 Number of enterprises using irrigation (regulated)

The number of enterprises in the Bega catchment using irrigation is estimated to be less than 79. This figure was determined from the total number of licences with the purpose of irrigating (79, (DLWC 2000f) (④)). It has been assumed that most licences are active and that one licence equals one enterprise (D. Barma, pers. comm.).

The number of enterprises using irrigation was collected by water source by the ABS, but the DLWC definition of regulated rivers does not match the one the ABS used to collect data. ABS collected data on activities of irrigation extracting water from rivers or streams 'controlled by a Water Board or a Water Resource Commission dam or weir'. In other words, data were collected from rivers controlled by government-owned dams and private dams, and the division between regulated and unregulated cannot be provided.

5.5 Volumetric entitlement to irrigation (regulated)

The volumetric entitlement for licences using water from regulated rivers in the Sydney–South Coast Region was 14,310 ML (DLWC 1999c; DLWC 1999a; DLWC 2000f) (appendix 13.12) (①). The volumetric entitlement will increase significantly once all area-based licences are converted to volume-based licences.

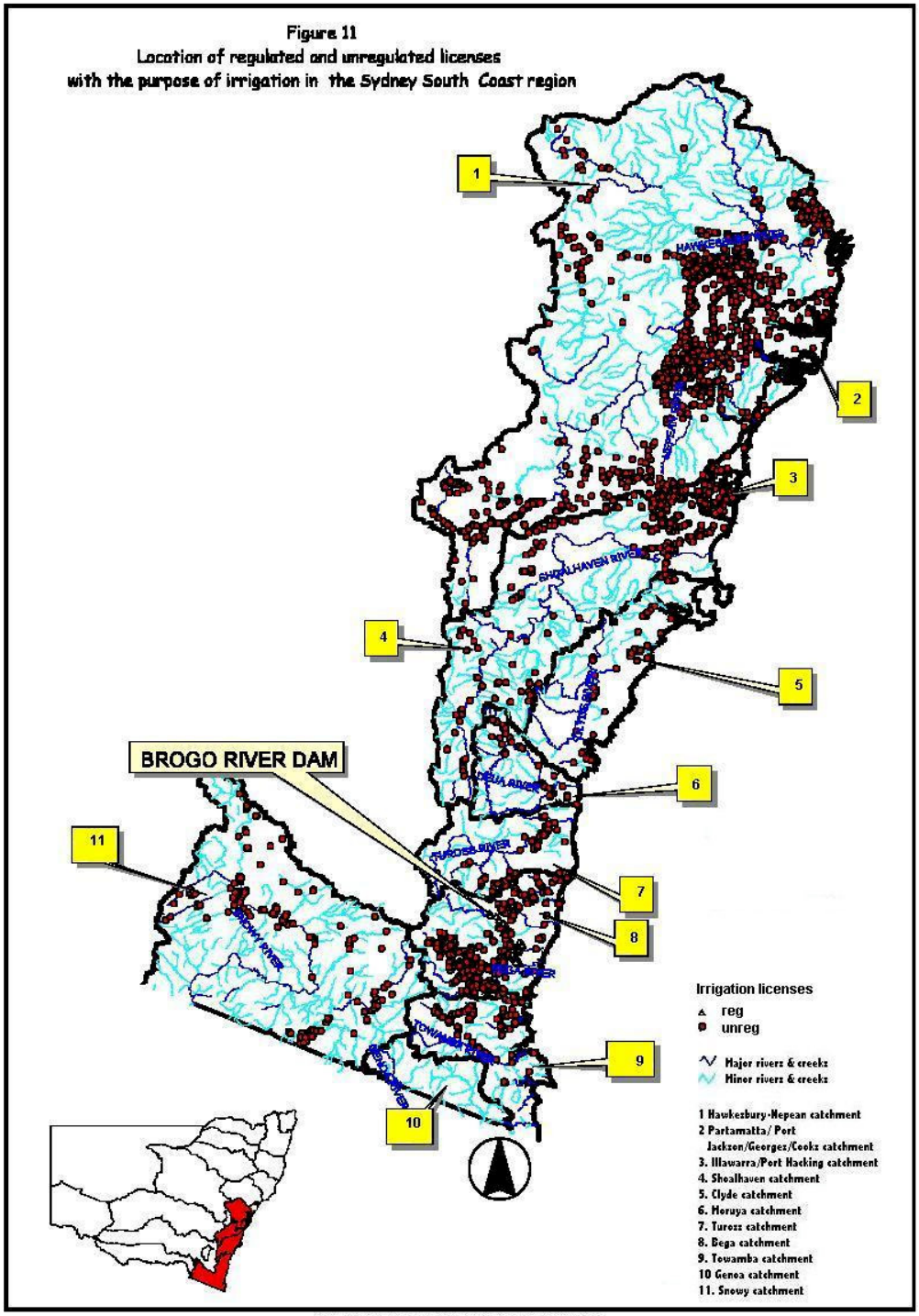
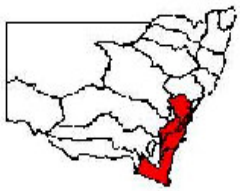


Figure 11
Location of regulated and unregulated licenses
with the purpose of irrigation in the Sydney South Coast region
1
2
3
4
5
6
7
8
9
10
11
BROGO RIVER DAM
Irrigation licenses
reg
unreg
Major rivers & creeks
Minor rivers & creeks
1 Hawkesbury-Nepean catchment
2 Parramatta/ Port Jackson/Georges/Cooks catchment
3. Illawarra/Port Hacking catchment
4. Shoalhaven catchment
5. Clyde catchment
6. Moruya catchment
7. Tuross catchment
8. Bega catchment
9. Towamba catchment
10 Genoa catchment
11. Snowy catchment
Prepared by the Resources Information Unit, NSW Agriculture.
Irrigation licenses locations and catchment boundaries from data provided by DLWC, topographic features from AUSLIG Topo 250K Geodata.
November 2000



5.6 Area irrigated and water used (regulated)

The area of land irrigated from regulated rivers was 861 ha in 1989–90 and increased to 1,199 ha in 1990–91 (appendix 13.13) (②). There is little recent information on the area of land irrigated from regulated rivers (see also section 6.4). The total volume of water used was 9,684 ML in 1997–98, 5,692 ML in 1998–99 and 6,663 ML in 1999–00 (①), representing approximately 41% of the entitlement. (These data were obtained by P. Clemson (pers. comm.) from metered records monitored for billing purposes (DLWC 2000c) and attract the highest reliability rating ①.) When data from the early 1990s are compared with these current data, the amount of water extracted by irrigated agriculture has increased (①) (appendix 13.14).

Pasture was the most significant crop in the Bega catchment. The area of pasture irrigated from regulated supplies was 95–97% of the total area irrigated in 1989–90 and 1990–91(②)[13] (appendix 13.13). Pasture used 92–95% of the total water from regulated streams in the Sydney–South Coast Region (appendix 13.14)(②).

5.7 Irrigation methods (regulated)

Most of the water used in the Bega catchment is used to irrigate pasture, usually using bike shift or centre pivot systems (section 4.5).

5.8 Irrigated yields (regulated)

There are no data on yield from crops grown specifically from regulated water supplies (see section 4.6 for yields from all sources of water.)

5.9 Value of irrigated production (regulated)

There are no data on the value of irrigated agriculture solely from regulated rivers in the Sydney–South Coast Region.

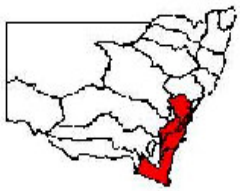
[13] The area of each individual crop irrigated was estimated by the Licence Officer and attracts the lower reliability rating ②.

6. IRRIGATION FROM UNREGULATED RIVERS

6.1 Summary

All rivers except the Brogo and parts of the Bega rivers are unregulated.

Irrigation from unregulated rivers		Reference
Area irrigated (ha)	23,987 (②)	Average of 6 years of data (DLWC 2000d)
	22,279 (②) (1993–94)	DLWC 2000d
	22,722 (③) (1993–94)	ABS 1998; DLWC 1998a. ABS figures usually attract a reliability rating of ②, but the assumptions that were made in calculating this particular figure mean the number attracts a lower reliability rating (see section 5.6.)
Area authorised (ha)	33,374 (①)	DLWC 2000f
	31, 890 (②)	DLWC 2000d
Total water used (ML)	no data	
No. of licences	2,304 (①)	DLWC 2000f
No. of enterprises	765 (③)	ABS 1998. Due to the assumptions that were made in calculating this figure, the number attracts a lower reliability rating (see section 5.4).



Irrigation from unregulated rivers		Reference
	1,382 (④)	This figure was estimated by assuming 60% of total number of licences (2304) ((DLWC 2000f, ①) were active and one active licence equals one enterprise. The value 60% approximates the number of licences that were active as a proportion of the total number of licences (DLWC 2000d). The figure drops to the lowest reliability rating due to the assumption that 60% of licences were active.
Crop area irrigated (ha)	Perennial pasture: 10,983 (②) (1998–99)	DLWC 2000d
Crop water use (ML)	no data	
Value ($ million)	no data	
Methods	Refer to methods in section 4.5.	
Yield (t/ha)	Refer to yields in section 4.6.	

6.2 About the unregulated water supply

All licences on unregulated rivers in NSW are being converted from area-basis to volume-basis by the DLWC. As of September 2001, around 9,500 licences of the total of 12,000 licences have been converted.

This profile has maintained a separation between irrigation that depends on unregulated rivers and irrigation from regulated rivers because:

- the volumetric conversion process is not yet complete, and
- there are large differences in the reliability and availability of data from area-based and volumetric-based licences.

All of the rivers in the Sydney–South Coast Region (with the exception of parts of the Brogo and the Bega rivers) are unregulated. The rivers with the largest and most variable flows in the region are the Hawkesbury–Nepean river system and the Shoalhaven (appendix 13.3). Flows are generally larger in winter and spring (EPA 1997). The irrigation industry is heavily dependent on unregulated supplies, especially in the Hawkesbury–Nepean catchment. The industry is facing increasing competition for water as rural, urban and industrial developments intensify in the region (DLWC 1999d).

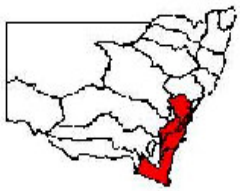
The DLWC undertook a desktop assessment of the environmental and hydrological stress of subcatchments in the Sydney–South Coast Region. An environmental stress rating for each of the freshwater subcatchments within each catchment was assessed using a series of environmental indicators. After each of these indicators was analysed, each subcatchment was rated for overall environmental stress. The environmental stress was determined using a decision-tree method. The indicators are as follows:

- extent of riparian vegetation;
- geomorphological health;
- presence of major dams;
- barriers to fish passage;
- gully erosion;
- dryland salinity;
- presence of acid sulfate soils; and,
- water quality (indicative purposes only – not used in decision tree).

This method was used for both the estuarine and freshwater indicators. Where two-thirds of the environmental indicators returned a high classification for a particular subcatchment, the overall environmental stress was assessed to be high. Where two-thirds of environmental indicators returned a low classification for a particular subcatchment, the overall environmental stress was determined to be low. The remaining subcatchments were classified as being of medium environmental stress.

The hydrological stress of a subcatchment was calculated as the estimated proportion of daily flow that has been made available for extraction under existing licences. This required estimation of streamflow and water use.

Streamflow estimation was made using information available through DLWC's flow gauging network and a range of hydrologic predictive techniques to extend estimates into rivers without local gauging sites. Estimates of the peak monthly water extractions have been made using the surface water returns lodged by licence-holders, but, since not all survey cards were returned to DLWC, volumes were adjusted for the proportion of licence-holders who chose not to lodge a return. A hydrologic index (indicating hydrologic stress) was derived for each subcatchment for current use and full water use development by proportioning estimated water extraction to the estimated streamflow. Each subcatchment was then classified as being of low (0–30% extraction of flow), medium (40–60% extraction) or high (70–100% extraction) hydrologic stress. For borderline subcatchments, that is, those with 30% to 40% or 60% to 70% extraction of flow, additional local information was used to place these subcatchments into the higher or lower category.



The data that were used to generate hydrological and environment stress ratings, and therefore management options, were not always reliable. For example, the hydrological stress rating was determined using crop return card information. This source may be incomplete because not all growers returned the information to the DLWC (DLWC 1999d). The raw data were adjusted up to account for these growers. Despite underlying difficulties and concerns with the data, the assessment provides the most comprehensive overview of the land and water resources of subcatchments in the Sydney–South Coast Region.

There are 228 subcatchments in the Sydney–South Coast Region, and of these, 25 subcatchments exhibited high environmental stress and high levels of extraction from rivers while 52 subcatchments exhibited low environmental stress and low extraction levels. There are 16 subcatchments that have a high environmental stress and low hydrological stress, while three subcatchments have a high hydrological stress and low environmental stress. Appendix 13.15 provides details of stress classification and management categories and a summary of the number of stressed subcatchments in the Sydney–South Coast Region. Appendix 13.16 provides information on present management classification, hydrological and environmental stress, conservation value for all sub-catchments by catchment in the region.

6.3 Number of licences (unregulated)

There are 2,304 irrigation licences with an authorised area for extraction of water from unregulated rivers in the Sydney–South Coast Region (DLWC 2000f) (①). Most of these licences are located along the Hawkesbury River (1,364), along the unregulated portions of the Bega River (185), and along the Shoalhaven River (181) (appendix 13.6) (figure 11). In time, the full 2,304 licences with a purpose of irrigation will be converted from area-basis to volume-basis.

6.4 Number of enterprises using irrigation (unregulated)

The number of enterprises in the Sydney–South Coast Region using irrigation ranged between 765 (ABS 1998) (③) and 1,382 (④) (see below for references). Neither of these figures is reliable.

The first figure pertains to data that were collected by ABS (1998) in 1993–94. This estimate was determined by subtracting the number of enterprises using water from regulated supplies in the Bega catchment (79, ④, see section 4.3) from the total number of enterprises extracting water from any river (both regulated or unregulated) in the Sydney–South Coast Region (ABS 1998, ②). This approach was necessary since the ABS survey questions did not differentiate clearly between regulated and unregulated streams (see appendix 13.17).

The second figure represents a maximum number of enterprises that are likely to be irrigating (④). The figure was determined by assuming that 60% the unregulated licences (2,304) (DLWC 2000f, ②) in the Sydney–South Coast Region were active (④) and by assuming that one active licence was equivalent to

one irrigated enterprise (④). The value 60% approximates the number of licences that were active as a proportion of the total number of licences (DLWC 2000d).

6.5 Area authorised for irrigation (unregulated)

There were 33,374 ha of land authorised for irrigation in the Sydney–South Coast Region (DLWC 2000f, ①). The Volumetric Conversion survey showed that 31,890 ha were authorised for irrigation (DLWC 2000d) (②: this figure attracts a lower reliability rating because it is based on survey return information).

Once all licences on unregulated streams are converted from area-basis to volume-basis, the area authorised for irrigation will be reported as a entitled volume.

6.6 Area irrigated and water used (unregulated)

In 1993–94, the area irrigated using water from unregulated rivers in the Sydney–South Coast Region was either 22,722 ha (ABS 1998, ③) [14] or 22,279 ha (DLWC 2000d) (②). The first figure was determined by summing the area irrigated from all surface water supplies (including farm dams) and then subtracting 1,000 ha, or the average area irrigated from regulated rivers as estimated by the DLWC (1998a, ②) between 1989–90 and 1990–91. This approach was necessary since the ABS survey questions did not differentiate clearly between regulated and unregulated streams (see appendix 13.17). The second figure was determined from the Volumetric Conversion survey of all irrigators using water from unregulated streams for the same year (1993–94).

Most of the area irrigated exists in the unregulated sections of the Bega Valley SLA and in the Hawkesbury SLA (appendix 13.18) and has been steadily increasing since 1993–94 (figure 12) (②).

[14] this figure has attracted a lower reliability rating due to the calculation and assumptions that were made.

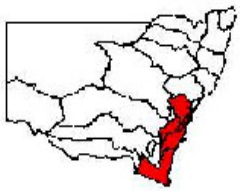
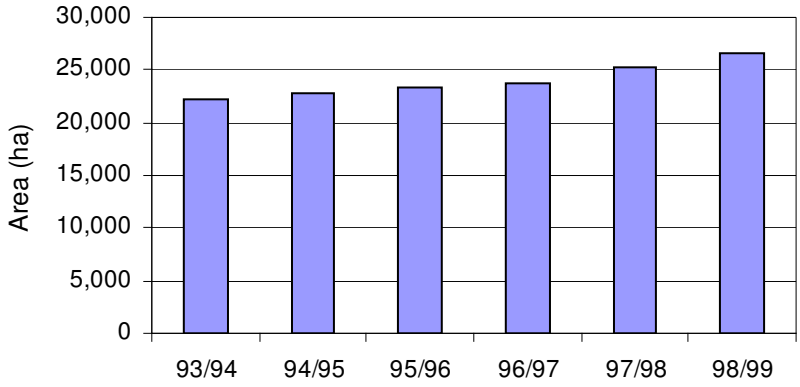


Figure 12. Area irrigated (ha) from unregulated streams in the Sydney–South Coast Region



Source: DLWC 2000d, ②

Of the total amount of land area irrigated, 41% was perennial pasture and 11% was annual pasture. Lucerne, vegetables and turf made up 10%, 11% and 11% of the total area respectively (appendix 13.19) (②).

There are no data on the volume of water extracted from unregulated streams in the Sydney–South Coast Region. ABARE (2000) estimated that broad area and dairy farms used 32,224 ML (table 4, ③): this figure does not include the area of irrigated vegetables and fruit crops. However, in the Hawkesbury–Nepean catchment alone, the extraction of water for irrigation is thought to be between 30,000 ML (Healthy Rivers Commission 1998) (③) and 80,000 ML (Webb, McKeown & Associates 1996) (③). The first figure, 30,000 ML, was based on return card information on extraction from unregulated systems during 1989-1991. (There are no detailed records of how much area was irrigated or how much water was used by different crops in the region.) This estimate does not include unlicensed water users and therefore grossly underestimates area irrigated and therefore water used. The second figure represents the maximum irrigation extraction and was determined using Landsat imagery and an assumed application rate of 6 ML/ha with no ground-truthing of irrigation areas (Webb, McKeown & Associates 1996, ③). Once area-based licences are converted to volume-based licences, water metering will be introduced. Over time, this will yield better data on water use in the region.

6.7 Irrigation methods (unregulated)

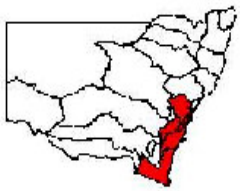
There is no information on the methods used to irrigate crops where water is taken from unregulated streams. Refer to section 4.5 for an overview of the methods that are used to irrigate crops in the Sydney–South Coast Region.

6.8 Irrigated yields (unregulated)

There is no account of irrigated yields obtained from crops that have been watered from unregulated streams. Refer to section 4.6 for details on irrigated yields obtained from all sources of water in the region.

6.9 Value of irrigated production (unregulated)

There are no data on the value of irrigated production from unregulated systems in the Sydney–South Coast Region, but other data suggests that the value of irrigated agriculture in the Hawkesbury–Nepean catchment could be as much as $485 million (④) (B. Yiasoumi, pers. comm.). The value of irrigated agriculture from unregulated streams in the whole of the Sydney–South Coast Region could therefore be greater than this figure and greater than the value of irrigated agriculture from all industries as estimated by Donovan (2000).



7. IRRIGATION FROM GROUNDWATER

7.1 Summary

Irrigation from groundwater supplies occurs mostly in the Hawkesbury–Nepean catchment. Extraction for irrigation in the South Coast subregion is limited (NSW State Water Plan Task Force 1984).

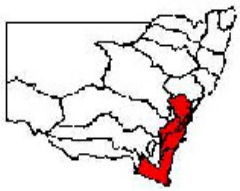
Irrigation from groundwater supplies		Reference
Area irrigated (ha)	1,904 (②)	ABS 1998
Total water used (ML)	no data	
No. of licences with the purpose of irrigating	452 (①)	Data obtained from DLWC 2000a by D. McKibbin.
No. of enterprises using irrigation	89 (②)	ABS 1998
Crop area irrigated (h)	no data	
Crop water use (ha)	no data	
Value ($ million)	no data	
Methods	Refer to methods in section 4.5.	
Yield (t/ha)	Refer to yield figures in section 4.6.	

7.2 About groundwater supplies

There has been limited extraction of groundwater for irrigated agriculture in the South Coast subregion. The drainage basins in the South Coast subregion tend to be narrow, which restricts the collection of water in underground reserves.

There is some extraction of groundwater in the Araluen Valley to irrigate stonefruit, and Bega Municipal Council uses significant groundwater stores to supply water for the towns of Bega and Tathra. Coastal sand beds contain important reserves of good quality groundwater, but the agricultural problems with growing and irrigating crops on sandy soils limit demand (NSW State Water Plan Task Force 1984).

Extraction of groundwater by irrigated agriculture in the Hawkesbury–Nepean catchment is more developed and occurs mostly around Mangrove Mountain in



the Gosford SLA (D. McKibbin, pers. comm.) and in the Southern Highlands of the Wollondilly SLA (SKM 1999).

7.3 Number of licences with the purpose of irrigation (groundwater)

There are 452 groundwater licences with the purpose of irrigation in the Sydney–South Coast Region. Data were obtained from DLWC (2000a, ①).

7.4 Number of enterprises using irrigation (groundwater)

The total number of enterprises that irrigated crops in the Sydney–South Coast Region using water from groundwater sources, according to ABS (1998, ②), was 89. An alternative figure of 271 (④) can be derived by assuming that 60% of the total irrigation licences using water from groundwater (452) were active (①). This figure attracts a lower reliability rating because of the uncertain assumption that 60% of licences are active (there are no data on groundwater licence activity). The value of 60% is an estimate based on the number of active area-based licences as a proportion of the total number of area-based licences (DLWC 2000d).

7.5 Area irrigated and water used (groundwater)

There were 1,904 ha irrigated from groundwater in 1993–94 (ABS 1998, ②). The total amount of water used from groundwater supplies in 1984 was 16,800 ML (NSW State Water Plan Task Force 1984) (④). More recent information is not available. ABARE (2000) showed in their most recent survey of broadarea and dairy farms that no groundwater was extracted (table 4, ③) in 1996–97. This result is most likely to be a function of the small sample population used.

7.6 Irrigation methods (groundwater)

There are no data on the methods used to irrigate crops with water from groundwater (see section 4.5 for the methods from all water sources).

7.7 Irrigated yields (groundwater)

There are no data on the yields that have been obtained from crops irrigated using groundwater (see section 4.6 for irrigated yields from all sources).

7.8 Value of irrigated production (groundwater)

There are no data on the value of agriculture irrigated using groundwater.

8. IRRIGATION FROM FARM DAMS

8.1 Summary

Extraction of water from farm dams occurs mostly in the Bega catchment, Eurobodalla, Camden, Gosford, Greater Lithgow, Mulwaree, Penrith, Hornsby, Baulkham Hills and Bankstown SLAs (ABS 1998).

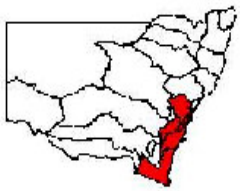
Irrigation from farm dams		Reference
Area irrigated (ha)	6,983 (②)	ABS 1998
Total water used (ML)	no data	
No. of licences	Licensing of farm dams is being undertaken by DLWC and numbers are as yet unavailable.	
No. of enterprises using irrigation	533 (②)	ABS 1998
Crop area irrigated (ha)	no data	
Crop water use (ML)	no data	
Value ($ million)	no data	
Methods	Refer to methods in section 4.5.	
Yield (t/ha)	Refer to yield figures in section 4.6.	

8.2 About farm dam water supplies

Farm dams are a small but important resource for irrigated agriculture in the region. Farm dams are concentrated mainly in the SLAs of Bega Valley, Eurobodalla, Camden, Gosford, Greater Lithgow, Mulwaree and Penrith, Hornsby, Baulkham Hills and Bankstown (appendix 13.18) (ABS 1998, ②).

In the past, a dam of up to 7 ML could be built without needing to be licensed providing the water was used for non-commercial purposes. This limit was considered to be inappropriate in many areas of New South Wales because there was no allowance for the size of the property or for climatic variation. In addition there was no restriction on the number of dams that could be built on a property.

The Farm Dams policy announced in September 1998 provided a harvestable right for all landholders regardless of the purpose for which the water is used.



This policy will allow the collection of 10% of the regional run-off figure from the landholding each year (DLWC 1999b). People who collect more than 10% of the regional run-off figure will require a licence.

8.3 Number of enterprises using irrigation (farm dams)

There were 533 irrigators using water from farm dams in 1993–94 in the Sydney–South Coast Region (ABS 1998) (②). Other sources suggest that there could be many more enterprises than is shown by the ABS. It is believed that the number of vegetable enterprises in the Hawkesbury–Nepean catchment that depend on farm dams was greater than 800 (A. Senn, pers. comm., ④).

8.4 Area irrigated and water used (farm dams)

There were 6,983 ha irrigated from farm dams in 1993–94 (ABS 1998) (②). There are no data on the total volume of water used, nor on the crop areas irrigated or the water used on crops from farm dams (table 4, ③).

8.5 Irrigation methods (farm dams)

There is no account of the methods used to irrigate crops with water from farm dams. The information provided in section 4.5 gives an overview of the methods used to irrigate crops in the Sydney–South Coast Region.

8.6 Irrigated yields (farm dams)

There is no account of the irrigated yields that have been obtained from crops watered from farm dams. Refer to section 4.6 for details on irrigated yields obtained from all sources of water in the Sydney–South Coast Region.

8.7 Value of irrigated production (farm dams)

There are no data detailing the value of production based on water extraction from farm dams.

9. IRRIGATION FROM TOWN WATER SUPPLIES

9.1 Summary

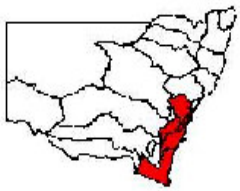
Irrigated enterprises (mostly high value cut flowers, nurseries and market gardens) use water from town water supplies. These enterprises are mostly located in the Shoalhaven, Eurobodalla, Baulkham Hills, Hornsby, Mulwaree and Penrith SLAs (ABS 1998).

Irrigation from town water supply		Reference
Total area irrigated (ha)	550 (②)	ABS 1998
Total water used (ML)	no data	
No. of licences	Irrigation from reticulated water supplies does not require a licence.	
No. of enterprises	192 (②)	ABS 1998
Crop area irrigated (ha)	no data	
Crop water use (ML)	no data	
Value ($ million)	no data	
Methods	Refer to methods in section 4.5.	
Yield (t/ha)	Refer to yield figures in section 4.6.	

9.2 About town water supplies

Irrigation from town water supplies is very limited because of the cost of the water. For example, Sydney Water charges $0.925/kL or $925/ML. Extraction is limited to the irrigation of high value crops such as nurseries and cut flowers (B. Yiasoumi, pers. comm., ④). (Nurseries that use drinking water supplies require a lower level of filtration.)

It is believed that the number of cut flowers and nursery enterprises relying on town water supplies could be as high as 80%. There are also 300 vegetable farms in the Hawkesbury–Nepean catchment that supplement farm dam water supplies with town water (A. Senn, pers. comm., ④). Irrigation enterprises in the SLAs of Shoalhaven, Eurobodalla, Baulkham Hills, Hornsby, Mulwaree and Penrith show some dependence on town water supplies for irrigation water (ABS 1998, ②).



9.3 Number of enterprises using irrigation (town water)

There were 192 irrigators using water from town water supplies and nearly half of these were located in the Shoalhaven catchment (ABS 1998) in 1993–94 (②). There are no data showing what combinations of water sources are used by enterprises. More recent data are unavailable. For many of the reasons outlined in section 4.3, the number of enterprises may be an underestimate.

9.4 Area irrigated and water used (town water)

There were 552 ha irrigated from town water supplies in 1993–94 (②) and roughly 50% of this was located in the SLAs of Shoalhaven and Eurobodalla (ABS 1998) (appendix 13.18). There are no data on the total volume of water used from town water supplies and the crop areas irrigated and water used.

9.5 Irrigation methods (town water)

There is no account of the methods used to irrigate crops using water from town water supplies. Refer to section 4.5 for an overview of the methods that are used to irrigate crops from all sources of water in the Sydney–South Coast Region.

9.6 Irrigated yields (town water)

There is no account of irrigated yields that have been obtained from crops watered from town water supplies. Refer to section 4.6 for details on irrigated yields obtained from all water supplies in the Sydney–South Coast Region.

9.7 Value of irrigated production (town water)

There are no data on the value of irrigated agriculture extracting water from town water supplies in the Sydney South Coast.

10. OPPORTUNITIES AND ISSUES

10.1 Opportunities for irrigated agriculture

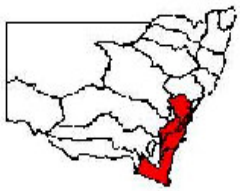
Deregulation may free water in the dairying regions of the Bega catchment by forcing some operators into dryland farming (Econsearch 2000) or even into other crop enterprises. The same could apply to the dairy industry in the Shoalhaven, Moruya, Clyde, Tuross and Snowy-Genoa catchments. The opportunity exists to grow high value, small area crops such as olives, wine grapes, cut flowers and vegetables and trees (Healthy Rivers Commission 1998; Lim-Applegate and McClintock 1999).

Coastal sand beds contain good quality groundwater, but the sandy soils along coastal areas limit irrigation. The opportunity exists to develop a hydroponic greenhouse industry in these areas. Agriculture provides opportunities for better catchment management, stormwater management and visual amenity in the peri-urban areas. Land use planning controls and urban development plans need to recognise and accommodate the values of agriculture in the landscape of this region.

10.2 Issues for irrigated agriculture

There are relatively poor data on the irrigation industry in the Sydney–South Coast Region, that is, on the number of enterprises, yields, value and water used. This will make it harder to effectively deploy resources to improve water management. Current extension efforts that aim to improve WUE are likely to be less effective, especially in the Hawkesbury-Nepean catchment.

- For example, with inadequate data on the value of irrigated agriculture ($173 million or $727 million), how can the impact of water management planning be estimated? How can extension programs be implemented?
- With inadequate data on the number and type of enterprises irrigating, resources may be skewed towards the better known industries (dairy farmers) and away from vegetable or cutflower enterprises.
- Secondly, there are many people from NESB. Specifically designed extension programs about irrigation may need to be developed to suit the range of cultural groups and literary levels in the region.
- Thirdly, pressures such as urban encroachment into rural areas may reduce the effectiveness of extension messages that aim to improve irrigation efficiency. Land has become the ideal cash crop and can sometimes be viewed as superannuation (Healthy Rivers Commission 1999b) rather than as a



valuable resource for irrigated agriculture. The Hawkesbury–Nepean catchment (B. Yiasoumi, pers. comm.) and Kangaroo Valley (Healthy Rivers Commission 1999b) are affected by this pressure.

Options to expand and develop irrigation operations may be limited in some regions of the South Coast, especially in subcatchments that extract large volumes of water during low flow periods. This may force growers to construct farm dams for extracting water during high flow periods.

11. SUMMARY

Irrigation has a significant role in the Sydney–South Coast region, particularly in the local economies of the Bega catchment and the Hawkesbury–Nepean catchment. The implementation of water reform has increased the need for accurate and reliable data on the activities of the industry.

This Profile has shown that the reliability and availability of irrigation data are generally poor. This paucity of accurate information affects the ability of agencies and communities to:

- strategically focus extension and research to address areas of inefficient water use
- undertake subcatchment and catchment water management planning
- measure change as a result of extension activities and water management planning.

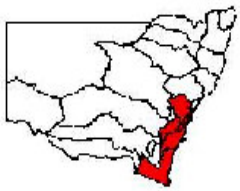
One of the most serious issues for the region is the lack of information on the irrigation industry, especially in the Hawkesbury–Nepean catchment. The Healthy Rivers Commission raised this as a problem that hampered community decision making about the management of water in the Basin (Healthy Rivers Commission 1998). For example, there are believed to be up to 1,000 additional enterprises in the Hawkesbury–Nepean catchment that are not licensed but which continue to irrigate. It has been difficult to provide a reliable estimate of the volumes of water being extracted for irrigation. As populations continue to rise and as competition for limited water resources increases, obtaining better data on the irrigation industry is critical. The DLWC has developed a communication strategy which aims to licence irrigators from NESBs who do not have a licence (DLWC 1998b).

This report has highlighted difficulties in obtaining basic information on irrigation in the Sydney–South Coast Region: on the number of enterprises using irrigation, total area irrigated and water used, crop areas irrigated and water used, methods of irrigation, production and value. In part these difficulties arise because in the past data have been collected for various reasons which may not fulfil present data needs.

The reliability of data varied:

- from subregion to subregion. See in section 4.3, for example, the difficulties encountered in estimating the number of enterprises using irrigation in the Hawkesbury–Nepean catchment.
- with source of water. Information on the volume of water used and the area irrigated from regulated streams was better than the information collected from unregulated streams. There was hardly any information on irrigation from farm dams and town water.

SUMMARY



A more comprehensive and consistent approach to the collection of irrigation statistics is needed. Such an approach would help to ensure that data are comparable across different water sources and industries. Protocols for the collection, management and distribution of irrigation data are required to ensure that data are accurate and reliable. This comprehensive approach can only be developed with the full involvement of the many agencies and irrigator groups that require these data.

12. REFERENCES

Alexander, P. & Foley B. 1998, *Rural Water Industry Terminology and Units*, report prepared by Hydro Environmental Pty Ltd and Sinclair Knight Merz for the Australian National Committee on Irrigation and Drainage.

Allen, R. G., Pereira, L. S., Raes, D. & Smith, M. 1998, *Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements*, Irrigation and Drainage Paper 56, Food and Agriculture Organization, Rome.

Atkinson, I. 1998, 'The Australian Nursery Industry - Improving Water Management', *Irrigation,* 13, no. 2: 22-23.

Australian Bureau of Agricultural Resource Economics [2000], *NSW Irrigation Survey 1996-97*, ABARE [ASPIRE database], web page, accessed 13 July 2000, available at http://www.abareconomics.com/Irrigation/default.htm

Australian Bureau of Statistics 1991, *ABS Census*, ABS, Canberra.

—— 1994, Agricultural Commodity Survey, NSW, ABS, Canberra.

—— 1998, *AgStats*, Ver. Cat. no. 1353.0, ABS, Canberra.

—— 1999, *Australian Standard Geographical Classification (ASGC) 1999*, Chapter 2. Main Structure. The spatial units, Statistical Local Area (SLA), web page, accessed 14 February 2001, available at http://www.abs.gov.au/ausstats/abs%40.nsf/66f306f503e529a5ca25697e0017661f/b61577a4a9a88d8bca25697e00184c76!OpenDocument

—— 2000, *Population Statistics*, ABS, Canberra.

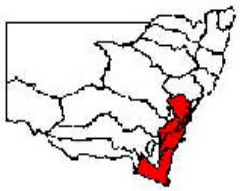
Bureau of Meteorology 2000, 'Climate Averages by Name', web page, accessed 20 June 2000, available at http://www.bom.gov.au/climate/averages/tables/cw_066037.shtml

Clewett, J. F., Smith, P. G., Partridge, I. J, George, D. A., & Peacock, A. 1999, *Australian Rainman® Version 3: An integrated Software Package of Rainfall Information for Better Management*, ver. QI98071, Queensland Department of Primary Industries, Qld.

Crabb, P. 1997a, Irrigation Data for the Murray-Darling Basin: Group Irrigation Schemes 1996-97, unpubl.

——— 1997b, *Murray-Darling Basin Resources,* Murray-Darling Basin Commission, Canberra, ACT.

Deborah Wilson Consulting 1990, *Database for Selected Rural Products and Industries including Separate Figures for Irrigation*, report prepared by Deborah Wilson Consulting (DWC) for National Irrigation Research Fund, Suite 65, 7th Floor, STC House, 545 Queen Street, Brisbane.



DLWC, see NSW Department of Land and Water Conservation.

Donovan, G. 2000, NSW Irrigators' Council, North Revesby NSW 2212.

Doorenbos, J. & Pruitt, W. O. 1977, *Crop Water Requirements*, FAO Irrigation and Drainage Paper no. 24, Food and Agriculture Organization of the United Nations, Rome.

EBC 1999, *The Social Impacts of Dairy Industry Deregulation and Water Reform on Dairy Farmers and Communities in the Bega Valley,* report prepared by Environment & Behaviour Consultants for the Bega Valley Water Management Committee, 62 Hooper Street, Belgian Gardens, Townsville, 4810.

Econsearch 2000, *The Impact of Water Reform and Dairy Industry Deregulation on the Economy of Bega Valley Shire*, report prepared by EconSearch Pty Ltd for the Bega Valley Water Management Committee, Stirling, PO Box 1148, SA 5152, 2 June.

EPA 1997, Interim Environmental Objectives for NSW Waters: Coastal Rivers, discussion paper, Environmental Protection Authority, Chatswood.

Healthy Rivers Commission 1998, *Independent Inquiry into the Hawkesbury Nepean River System, Final Report, August*, Healthy Rivers Commission, Sydney, NSW 2000.

——— 1999a, *Independent Inquiry into the Bega River System - Draft Report, October*, Healthy Rivers Commission of New South Wales, Sydney.

——— 1999b, *Independent Inquiry into the Shoalhaven River System, Final Report, July 1999,* Healthy Rivers Commission of New South Wales, Sydney.

Hope, M. A. & Elliott, S. 2000, 'Irrigation in NSW: A summary of data availability and reliability', *Water is Gold,* conference proceedings, Irrigation Association of Australia, Melbourne, 23-25 May, Melbourne Convention Centre, pp. 227-239.

Lim-Applegate, H. & McClintock, A. 1999, *Bega River Catchment, River Flow Access and Irrigated Dairy Farms - ABARE Report to the Healthy Rivers Commission,* ABARE, Canberra.

Mason, D. n.d., Notes on Agriculture in Western Sydney, unpubl. report prepared by David Mason, NSW Agriculture , Windsor.

McGowan International 1986, *Water Use Efficiency in Irrigation and Measures for Improvements*, Water Resources Commission, Sydney.

National Land and Water Resources Audit 1999, *Description of Audit Themes*, National Land and Water Resources Audit, Canberra.

NSW Agriculture 1998, *Strategic Plan for Sustainable Agriculture, Sydney Region*, NSW Agriculture, Orange.

NSW Department of Land and Water Conservation 1998a, Crop and licence database, confidential information developed by Licence Administration Systems, NSW DLWC, for the NSW Agriculture Water Reform Structural Adjustment Program, electronic format.

—— 1998b, Hawkesbury Nepean Water Amnesty Steering Group Tour, 29 October, NSW DLWC, Penrith.

—— 1999a, Information to assist the preparation of Community Water Profiles, Lower South Coast Catchment, Socio-Economic Services Unit, NSW DLWC, Sydney.

—— 1999b, *Sharing the Water Resources on Unregulated Rivers, Volumetric Conversion and Access Conditions for Water Licenses*, NSW DLWC, Sydney, September.

—— 1999c, *Stressed Rivers Assessment Report, Clyde, Deua, Tuross, Bega and Towamba Catchments*, NSW DLWC, Sydney, August.

—— 1999d, *Stressed Rivers Assessment Report, Hawkesbury–Nepean Catchment*, NSW DLWC, Sydney, August.

—— 1999e, *Stressed Rivers Assessment Report, Shoalhaven and Illawarra-Hacking Catchments*, NSW DLWC, Sydney, August.

—— 1999f, *Stressed Rivers Assessment Report, Snowy–Genoa Catchment*, NSW DLWC, Sydney, August.

—— 2000a, Groundwater licence database, NSW DLWC, Parramatta, July.

—— 2000b, *Information to Assist the Preparation of Community Water Profiles, Shoalhaven Catchment, First Draft*, DLWC, Sydney, unpubl.

—— 2000c, Licence Administration System, NSW DLWC, July.

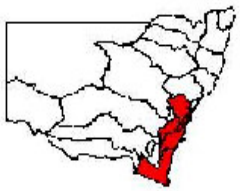
—— 2000d, Volumetric Conversion Crop and License Database, NSW DLWC, Parramatta, November.

—— 2000e, *Volumetric Conversion - the next stage - A booklet for landholders with licences on unregulated rivers in NSW*, NSW DLWC, Sydney.

—— 2000f, *Volumetric, area based and groundwater licence information for the Sydney – South Coast and Hunter region,* Water Analysis and Audit Branch, NSW DLWC, Sydney, unpubl.

NSW Government 1998, *The Premier's Task Force on Market Gardening by People of Non-English Speaking Background,* ed. D. Dixon, NSW Agriculture, Orange.

NSW State Water Plan Task Force 1984, *Groundwater in New South Wales*, Water Resources Commission, NSW.



SKM 1999, *Blue Mountains Sandstone Aquifer Status Report,* report prepared by Sinclair Knight Merz and National Centre for Groundwater Management, University of Technology, Sydney for NSW DLWC, Sinclair Knight Merz, St Leonards, NSW and University of Technology, Sydney.

Sloane, P. H. 1993, *Skills Audit of the Irrigation Industry,* Sloane Cook and King Pty Ltd, np.

Swann, B. 2000, 'Establishment of a mobile irrigation evaluation unit, Macquarie Valley NSW: Measure water to manage water', *Water - Essential for Life,* conference proceedings, Irrigation Association of Australia, Melbourne Exhibition and Convention Centre, Melbourne, Australia, pp. 619-26.

Webb, McKeown & Associates 1996, *A Preliminary Study of the Availability and Usage in the Nepean Hawkesbury Catchment,* Webb, McKeown & Associates, Level 2, 160 Clarence Street, Sydney.

WRC 1980, *Water Resources Inventory,* Water Resources Commission.

Personal communications

D. Barma, Water Management Systems, Natural Resource Products Division, DLWC, Sydney 2001.

C. Beckingham, District Horticulturalist, Bathurst, NSW Agriculture, 1999.

P. Clemson, OIC, Brogo Dam, DLWC, 31 July 2000.

D. Dekel, License Administration, DLWC Hawkesbury Nepean Office, July 2000.

H. Doughty, Lecturer in Equine Science, Charles Sturt University, Wagga Wagga, February 13, 2001.

J. Gillett, Irrigation Officer, NSW Agriculture, Windsor, July 2000.

B. Gollnow, District Horticulturalist, EMAI, NSW Agriculture, 1999.

H. Kemp, District Agronomist, NSW Agriculture, Bega, July 2000.

P. Malcolm, District Horticulturalist, Fruit, NSW Agriculture, Windsor, February 2001.

D. McKibbin, Resource Officer, Hydrology, DLWC, Sydney South Coast Region Office, Parramatta, July 2000, February.

J. O'Connor, Resource Management Officer, NSW Agriculture, 2000.

M. Raine, Director of the Agricultural Statistics Centre, Hobart, ABS, July 2000.

M. Robbins, Irrigation Officer, NSW Agriculture, Orange Agricultural Institute, January 2000.

C. Rolfe, Irrigation Officer, NSW Agriculture, Wollongbar, November 2000.

D. Ryan, VRO, NSW Agriculture, February 2000.

A. Senn, Soil Advisory Officer (Horticulture), NSW Agriculture, Windsor, 19 January 2001.

A. Senn and A. Jones, Soils Advisory Officer (Horticulture) and Technical Officer, NSW Agriculture, 19 January 2001.

R. Stephens, Nursery Industry Development Officer, NIAN, Sydney, November 2000.

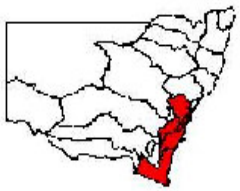
D. Trewin, Hawkesbury–Nepean Catchment Management Trust, December 2000.

L. Ullio, District Horticulturalist, EMAI, NSW Agriculture, 1999.

B. Watt, Resource Access Coordinator, Water Licensing, DLWC, Sydney South Coast Region Office, Parramatta, July 2000.

J. Whitely, District Agronomist, Berry, NSW Agriculture, 1999.

B. Yiasoumi, Irrigation Officer, NSW Agriculture, Windsor, July 2000



13. APPENDICES

13.1 Definitions of statistical units used by the ABS

Extract from ABS web page (ABS 1999)

An SLA is a general purpose spatial unit. It is the base spatial unit used to collect and disseminate statistics other than those collected from the Population Censuses. SLAs are based on the boundaries of incorporated bodies of local government where these exist. These bodies are the Local Government Councils and the geographical areas which they administer are known as Local Government Areas (LGAs). In the Northern Territory, an incorporated administrative body gazetted under the Northern Territory Local Government Act can take the form of a Community Government Council (CGC). Where there is no incorporated body of local government, SLAs are defined to cover the unincorporated areas.

An LGA is an SLA if:

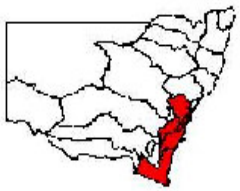
- the LGA fits entirely within an Statistical Subdivision (SSD); and
- the LGA is broadly similar in size, economic significance and user needs for statistics to other LGAs in Australia.

An LGA forms two or more SLAs when the two conditions above are not met. This can occur when:

- an LGA is divided by the boundary of one or more SSDs. The LGA is split into two or more SLAs each of which falls within the relevant SSD; or
- an LGA is substantially different in size, economic significance and user needs for statistics to other LGAs. The LGA is split into two or more SLAs which generally correspond to one or more suburbs (as occurs in the predominantly urban LGA of the City of Brisbane) or other areas of interest.

For those parts of Australia which are not administered by incorporated local government bodies, an SLA is an unincorporated area. Unincorporated SLAs cover the following areas:

- unincorporated on-shore area(s) and/or off-shore island(s) in an SSD;
- that part of an unincorporated area which is considered of sufficient economic significance as to warrant the formation of a separate SLA;
- Off-Shore Areas & Migratory SLAs, formed for census purposes for all S/Ts [states and territories] except the Australian Capital Territory and Other Territories to encompass off-shore, shipping and migratory CDs [collection districts] (off-shore, shipping and migratory CDs are explained in chapter 2);
- the entire area of the Australian Capital Territory. Each SLA is either a suburb, a locality or the non-urban area of an SSD; and



- the unincorporated part of the Northern Territory. In some SSDs (e.g. Daly, Bathurst-Melville) the entire area is covered by one unincorporated SLA. In other SSDs (e.g. East Arnhem), the unincorporated area is split into several SLAs to distinguish an economically significant town (e.g. Nhulunbuy), island (e.g. Groote Eylandt) or administrative region.

13.2 Number of irrigators and area irrigated in each SLA in the Sydney–South Coast Region

Catchment/subregion	SLA	1994 Area (ha)	1996 Area (ha)	1997 Area (ha)	1994 Respondents	1996 Respondents	1997 Respondents
Hawkesbury-Nepean Catchment	Baulkham Hills	641	323	435	130	64	99
	Blacktown	266	19	145	27	8	20
	Blue Mountains	88	17	22	12	7	6
	Camden	1735	1950	1748	37	24	33
	Campbelltown	289	251	235	13	9	8
	Fairfield	39	24	40	14	6	14
	Gosford	988	685	849	128	78	103
	Goulburn	248	28	8	2	1	1
	Greater Lithgow	1225	15	39	14	2	6
	Hawkesbury	2193	959	2277	165	75	130
	Hornsby	394	279	420	95	57	79
	Ku-ring-gai	0	6	4	0	3	1
	Liverpool	146	99	277	25	11	25
	Mulwaree	3447	445	398	30	16	15
	Penrith	852	421	513	39	20	30
	Pittwater	0	1	4	0	1	3
	Warringah	30	17	14	22	10	13
	Wingecarribee	1477	780	923	77	58	60
	Wollondilly	1589	628	806	94	50	68
	Subtotal	***15647***	***6946***	***9156***	***924***	***500***	***714***
South Coast	Bega catchment	4350	4471	4401	145	106	113
	Eurobodalla	983	322	263	24	18	14
	Kiama	86	32	110	12	8	7
	Shellharbour	86	44	55	8	3	6
	Wollongong	72	123	66	9	9	5
	Shoalhaven	1983	1157	856	60	34	51
	Bombala	33	58	73	5	5	5
	Snowy River	721	80	82	10	3	5
	Tallaganda	367	83	111	16	12	14
	Subtotal	***8680***	***6369***	***6016***	***289***	***198***	***220***
Sydney	Bankstown (C)	5	2	0	6	1	0
	Botany (M)	11	11	11	2	1	1
	Holroyd (C)	6	15	0	3	1	0
	Parramatta (C)	0	0	0	2	1	0
	Ryde (C)	1	1	0	5	1	0
	Sutherland (S)	1	5	4.5	10	3	2
	Subtotal	***25***	***34***	***16***	***28***	***8***	***3***
	TOTAL	**24351**	**13348**	**15188**	**1241**	**706**	**937**

Source: ABS 1998, ②

13.3 Flow characteristics of the major rivers in the Sydney–South Coast Region

Catchment	Ann. discharge (× 1000) (ML)	Max. ann. discharge/mean ann. discharge	Min. ann. discharge/mean ann. discharge	Ann. evap. (mm)	Ann. rainfall (mm)	Av. run-off (mm)	Rainfall pattern
Hawkesbury –Nepean	3,010	5.2	0.02	900–1,250	640–1,300	139	Summer dominant, lowest falls in spring
Georges	357	3.92	0.02	900–1,000	850–1,300	189	Uniform, highest falls in summer months and lowest in spring.
Wollongong[a]	176	3.2	0.17	800–900	1000 –1600	234	Uniform, high falls in early winter
Shoalhaven	1,788	4.3	0.08	800–1,020	700–1640	245	Summer dominant with low falls midwinter.
Clyde	932	3.55	0.03	900	950–1450	286	High falls in summer and early autumn with dry months in early spring.
Moruya	370	3.3	0.05	900	730–1150	239	Summer dominant. Dry periods in August to November.
Tuross	495	2.6	0.06	900	700–1000	227	Summer dominant. Dry periods in August to November.
Bega	570	3.6	0.09	850	635–1270	200	Uniform distribution with summer months wettest and winter months the driest.
Towamba	484	4.6	0.03	800	780–1100	220	December to April receive slightly higher rainfall than May to November.

Source: WRC 1980 [a] Wollongong catchment are equivalent to the Illawarra/ Port Hacking catchment in figure 2.

13.4 Climate in the Sydney–South Coast Region

	Sydney	Wollongong	Moss Vale	Nowra	Moruya	Narooma	Bega
Mean daily max temp. (°C) [1]	22	22	19	21	20	20	22
Mean daily min temp. (°C) [1]	13	13	7	11	11	11	8
Highest max. temp. (°C) [1]	43	42	38	44	43	40	45
Lowest min. temp. (°C) [1]	-1	1	-6	-1	0	1	-8
Mean relative humidity (%)[1]	62	62	64	63	70	74	67
Mean ann. rainfall (mm) [1]	1,106	1,406	987	1,142	968	912	879
Annual reference evapotranspiration[2] (mm)	1,341	1,328	1,203	1,286	1,147	1,077	1,292

Source: [1] Bureau of Meteorology 2000

[2]calculated using FAO 56 methodology for determining crop water requirements (Allen et al. 1998).

13.5 Characteristics of dairy farms in the Bega catchment

Physical characteristics	Unit	Av. per farm	Summer
Cows	no.	200	
Heifers	no.	50	
Calves	no.	50	
Area sown	ha	280	
Area irrigated (a)	ha	72	
Ryegrass/white clover	ha	68	41
Kikuyu	ha	-	27
Sorghum	ha	4	
Dryland area	ha	209	
Ryegrass/white clover	ha	95	
Paspalum	ha	107	
Oats	ha	7	

Source: Lim-Applegate and McClintock 1999, ④

(a) During summer, 40% of area sown to irrigated ryegrass and white clover is taken over by kikuyu.

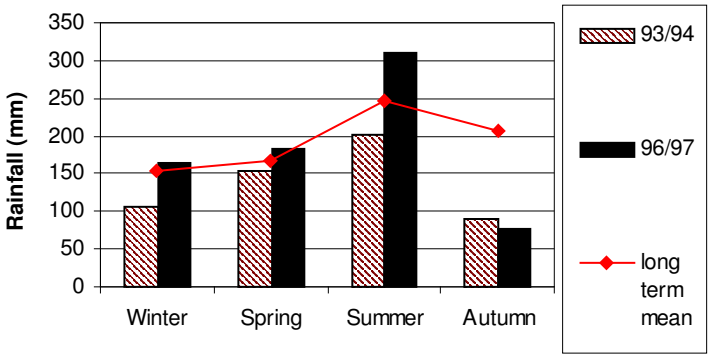
13.6 Area authorised and number of licences in catchments in the Sydney–South Coast Region

Catchment	Total no. of licences	Authorised area (ha)	Total irrigating
Gosford-Wyong catchment	222	1,764	186
Hawkesbury River	1,626	18,905	1,364
Bunnerong Creek	1	0	0
Cooks River	3	28	2
Georges River	47	277	26
Manly Lagoon	2	39	2
Middle Harbour	2	0	0
Narrabeen Lagoon	7	73	7
Parramatta River	16	205	10
Pitt Water	8	49	6

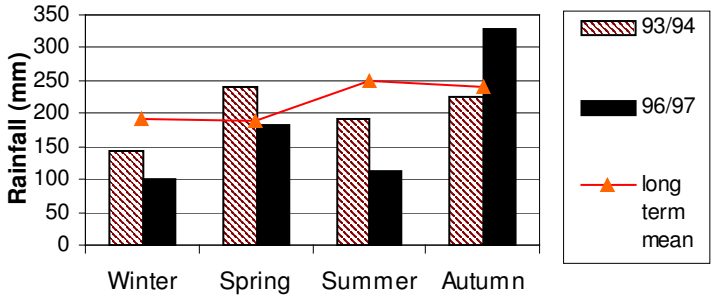
Catchment	Total no. of licences	Authorised area (ha)	Total irrigating
Port Hacking Catchment	5	10	1
Lake Illawarra	64	361	43
Minnamurra River	29	228	19
Port Kembla catchment	1	0	0
Stanwell Creek	1	0	0
Towradgi Creek	1	0	0
Burrill Lake	2	19	2
Shoalhaven River	229	2,682	181
Clyde River	12	117	8
Conjola Lake	4	10	1
Croobyar Creek	13	100	9
Currambine Creek	3	28	2
Millards Creek	1	0	0
Sussex Inlet Catchment	7	44	6
Tomaga River	2	4	2
Moruya River	36	287	31
Tilba Tilba Lake	9	50	4
Tuross River	56	953	48
Wagonga River	1	0	0
Bega River	226	5,083	185
Murrah River	25	351	18
Wallaga Lake	30	234	23
Wapengo Lagoon catchment	3	31	3
Merimbula Lake	7	35	5
Pambula River	27	207	21
Snowy River	79	729	40
Coastal streams	68	472	49
Grand total	**2875**	**33,374**	**2,304**

Source: DLWC 2000f, ①.

13.7 Annual rainfall at the Windsor and Bega weather stations, 1993–94 and 1996–97, and long-term average rainfall



Comparison of rainfall at the Windsor weather station in 1993-94 and 1996-97 against the long-term average(Clewett et al. 1999). (①).



Comparison of rainfall at Bega Composite weather station in 1993-94 and 1996-97 against the long-term average (Clewett et al. 1999) (①).

13.8 Announced allocation for the Bega catchment

Year	Date announced	Allocation announced
1982–83 [a]	13/09/1982	100%
	17/11/1982	120%
1983–84 [a]	22/07/1983	80%
	29/09/1983	100%
1984–85 [a]	13/07/1984	100%
1985–86 [a]	23/09/1985	100%
1986–87 [a]	12/09/1986	100%
1987–88 [a]	23/10/1987	100%
1988–89 [a]	15/09/1988	100%
1989–90 [a]	1/08/1989	80%
	15/01/1990	100%
1990–91 [a]	26/08/1990	80%
	13/02/1991	100%
1991–92 [b]	5/09/1991	80%
	1/01/1992	100%
1992–93 [b]	14/09/1992	80%
	9/02/1993	100%
1993–94 [b]	17/11/1993	80%
	9/02/1994	100%
1994–95 [b]	1/09/1994	80%
	8/02/1995	100%
1995–96 [b]	14/09/1995	80%
	26/03/1996	100%
1996–97 [b]	1/12/1996	80%
1997–98 [b, c]	16/01/1998	100%
1998–99 [b]		80%

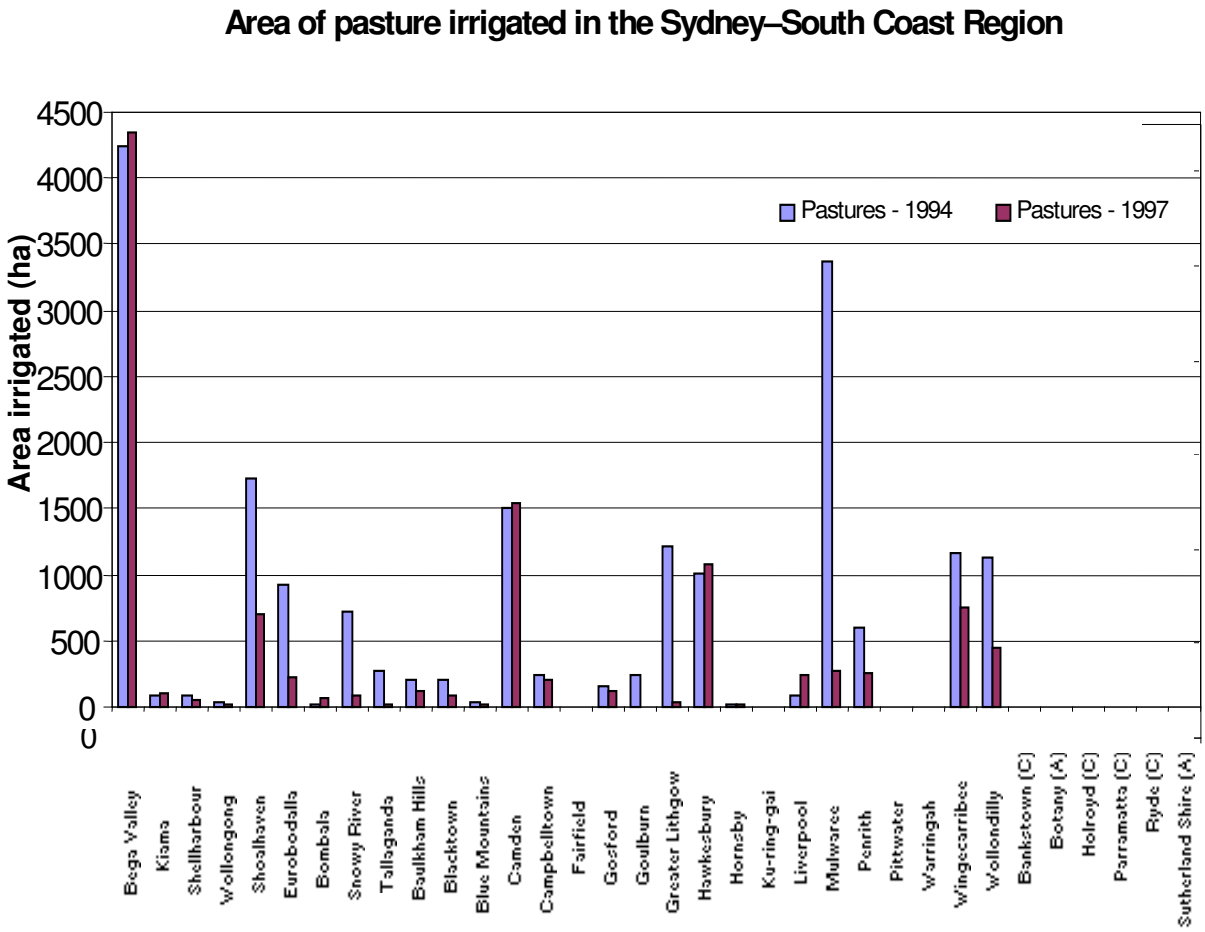
Source: (DLWC 2000f), (①)

[a] Minister announced allocation

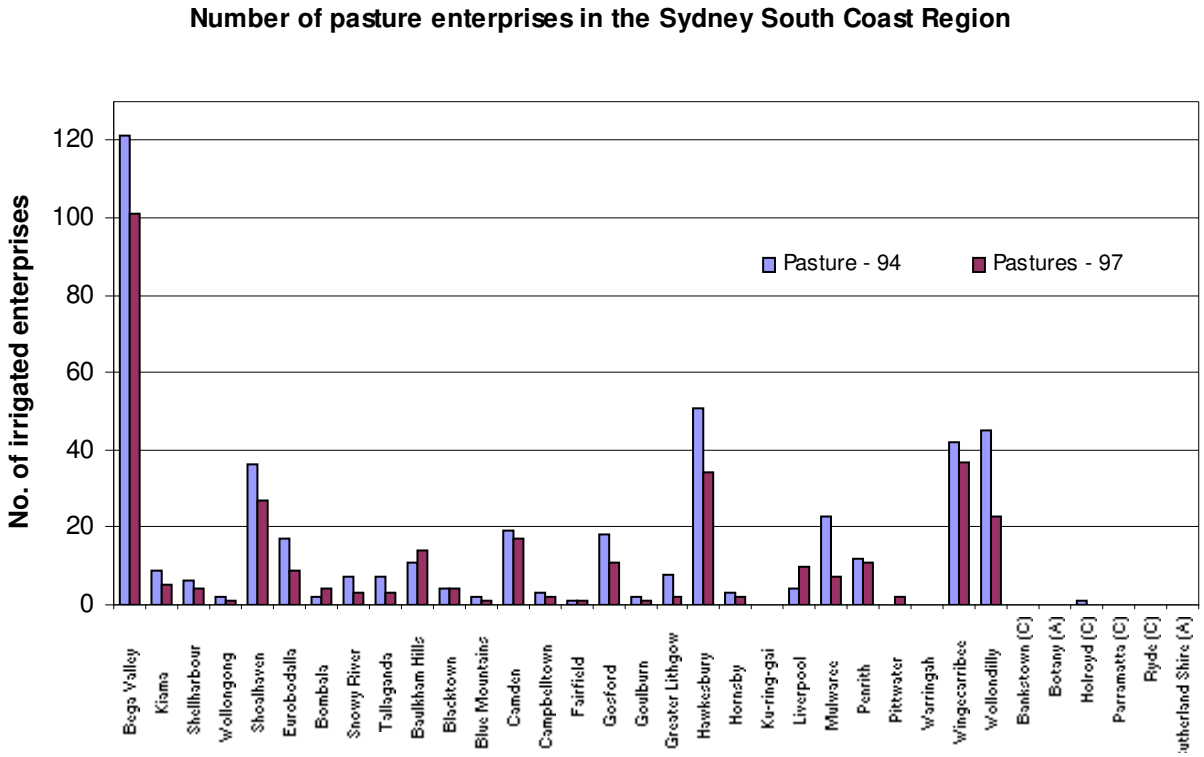
[b] Manager announced allocation. Area of crops irrigated and number of enterprises using irrigation in 1993–94 and 1996–97.

[c] late allocation announcement due to off-allocation until 23/11/97 and confusion over protocols following Department restructure.

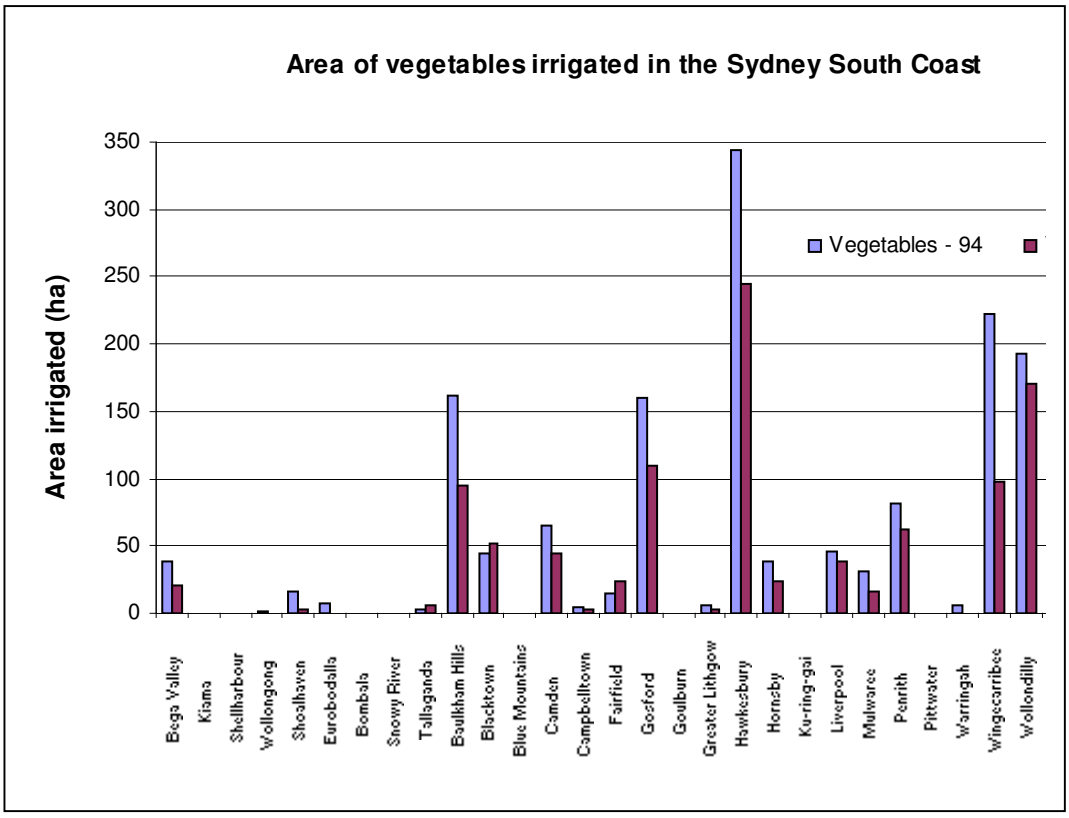
13.9 Area of crops irrigated, and number of enterprises using irrigation in 1993–94 and 1996–97



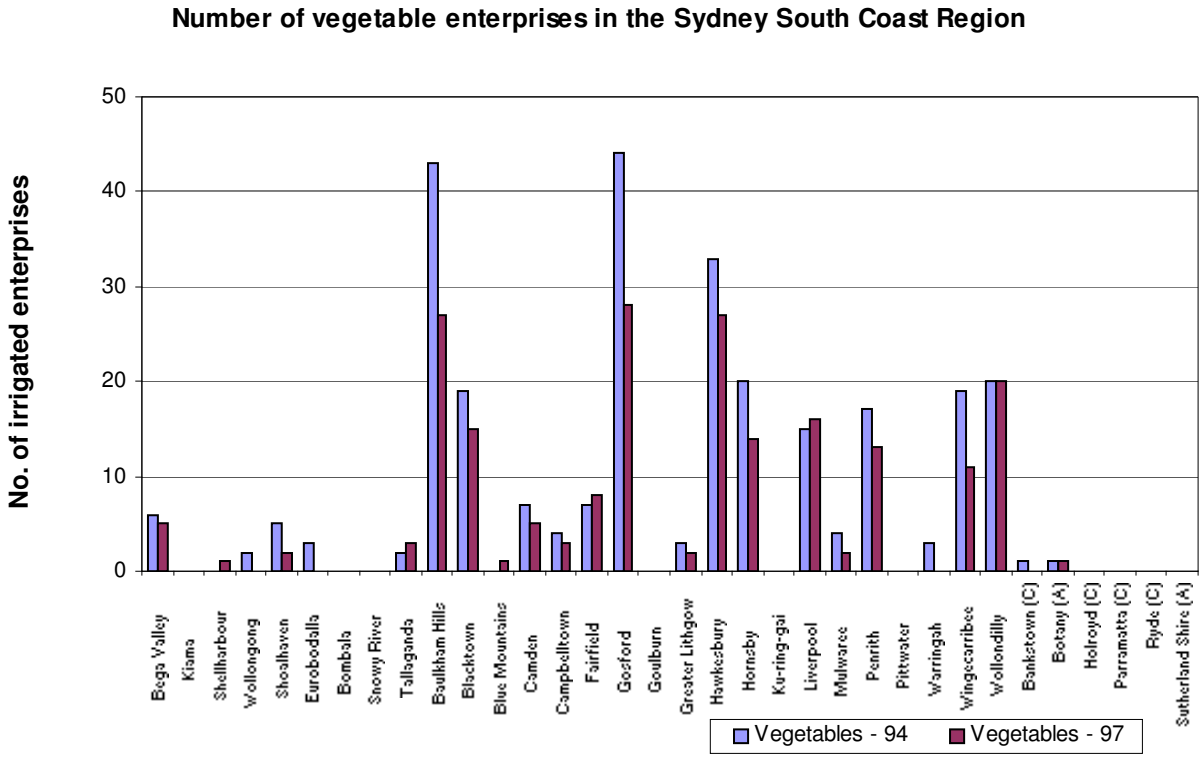
Area of pasture irrigated in the Sydney–South Coast Region, (ABS 1998), (②).



Number of pasture enterprises in the Sydney–South Coast Region, (ABS 1998), (②).



Area of vegetables irrigated in the Sydney–South Coast Region, (ABS 1998), (②)



Number of vegetable enterprises in the Sydney–South Coast Region, (ABS 1998), (②).

13.10 Water requirements, yield, sowing dates, irrigation method and efficiency by crop class and crop

CROP CLASS[a]	Crop	Location	Name	Position	CWR avg. (ML/ha)[b]	CWR min. (ML/ha)[b]	CWR max. (ML/ha)[b]	IR avg. (ML/ha)[c]	IR min. (ML/ha)[c]	IR max. (ML/ha)[c]	Y avg. (t/ha)[d]	Y min. (t/ha)	Y max. (t/ha)	Sowing date[e]	Time of growth Total (d)[f]	System[g]	Effic (%)[h]
BERRY FRUITS	Strawberries	Camden	Lawrence Ullio	District Horticulturalist				14.0	8.0	30.0	30.0	20.0	40.0		200	drip	
CEREALS	Maize	Windsor	John Gillett	Irrigation Officer	6.0	4.0	8.0	7.0	3.0	4.0				15-Oct	120	sprinkler	
CITRUS	Grapefruits	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	210	undertree sprinkler	85
CITRUS	Lemons	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	210	undertree sprinkler	85
CITRUS	Oranges	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	210	undertree sprinkler	85
GRAPES	Wine grapes	Windsor	John Gillett	Irrigation Officer	2.0	1.0	3.0	3.0	2.0	4.0						drip	90
MISCELL	CUT FLOWERS	Sydney Basin	Bettina Gollnow	District Horticulturalist				3.5									
MISCELL	Kiwi fruit	Windsor	John Gillett	Irrigation Officer	3.0	2.0	4.0	4.0	3.0	5.0				15-Oct	210	undertree sprinkler	
MISCELL	Mushrooms	Windsor	John Gillett	Irrigation Officer													
PASTURE	Annual	Windsor	John Gillett	Irrigation Officer	6.0	4.0	8.0	7.0	3.0	4.0				15-Oct	210	sprinkler	70
PASTURE	PASTURE	Bega	Harry Kemp	District Agronomist	4.0	1.0	8.0	6.0		8.0	20.0			15-Apr	365	bike shift	60
PASTURE	Pasture (Kikuyu)	Berry	John Whiteley	Extension Agronomist													
PASTURE	Pasture (Kikuyu)	Windsor	John Gillett	Irrigation Officer	6.0	4.0	8.0	7.0	3.0	4.0				15-Oct	210	sprinkler	70
PASTURE	Perennial	Berry	John Whiteley	Extension Agronomist	4.0	2.0	5.0	3.0	2.0	4.0	15.0	12.0	18.0	1-Apr	365	bike shift linear move only a few centre pivots	70
PASTURE	Perennial	Windsor	John Gillett	Irrigation Officer	6.0	4.0	8.0	7.0	3.0	4.0				15-Oct	210	sprinkler	70
POME FRUIT	Apples	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	8.0				15-Oct	210	undertree sprinkler	80
POME FRUIT	Nashies	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	8.0				15-Oct	210	undertree sprinkler	80
POME FRUIT	Pears	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	8.0				15-Oct	210	undertree sprinkler	80
POME FRUIT	Persimmons	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	8.0				15-Oct	210	undertree sprinkler	80
STONE FRUIT	Canning peaches	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	210	undertree sprinkler	80

CROP CLASS[a]	Crop	Location	Name	Position	CWR avg. (ML/ha)[b]	CWR min. (ML/ha)[b]	CWR max. (ML/ha)[b]	IR avg. (ML/ha)[c]	IR min. (ML/ha)[c]	IR max. (ML/ha)[c]	Y avg. (t/ha)[d]	Y min. (t/ha)	Y max. (t/ha)	Sowing date[e]	Time of growth Total (d)[f]	System[g]	Effic (%)[h]
STONE FRUIT	Low chill stonefruit	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	210	undertree sprinkler	80
STONE FRUIT	Orchards (Low Chill)		John Slack	District Horticulturalist										1-Jul	300		
STONE FRUIT	Nectarine	Camden	Lawrence Ullio	District Horticulturalist							20.0	15.0	40.0		250	drip, mini-sprinkler	
STONE FRUIT	Nectarine	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	210	undertree sprinkler	80
STONE FRUIT	Peaches	Camden	Lawrence Ullio	District Horticulturalist							20.0	15.0	40.0		250		
STONE FRUIT	Peaches	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	210	undertree sprinkler	80
VEGIES	Broccoli	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	90	sprinkler	
VEGIES	Cabbage	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Apr	120	sprinkler	
VEGIES	Capsicum	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	210	sprinkler	
VEGIES	Carrots	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	210	sprinkler	
VEGIES	Cauliflower	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	165	sprinkler	
VEGIES	Chinese cabbage	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Apr	120	sprinkler	
VEGIES	Cucumbers - field	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	90	sprinkler	
VEGIES	Cucumbers-protected	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0						sprinkler	
VEGIES	Garlic	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0						sprinkler	
VEGIES	Gherkins	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0						sprinkler	
VEGIES	Leeks	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	68	sprinkler	
VEGIES	Onions	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Apr	240	sprinkler	
VEGIES	Parsnips	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	165	sprinkler	
VEGIES	Potatoes	Robertson	Stephen Wade	District Horticulturalist										15-Jun	169		
VEGIES	Potatoes	Roberson	Stephen Wade	District Horticulturalist										1-Feb	89		
VEGIES	Potatoes	Robertson	Clarrie Beckingham	District Horticulturalist				3.5	1.0	4.5	20.0	15.0	50.0	15-Aug	110	travelling gun	

CROP CLASS[a]	Crop	Location	Name	Position	CWR avg. (ML/ha)[b]	CWR min. (ML/ha)[b]	CWR max. (ML/ha)[b]	IR avg. (ML/ha)[c]	IR min. (ML/ha)[c]	IR max. (ML/ha)[c]	Y avg. (t/ha)[d]	Y min. (t/ha)	Y max. (t/ha)	Sowing date[e]	Time of growth Total (d)[f]	System[g]	Effic (%)[h]
VEGIES	Potatoes	Windsor	John Gillett	Irrigation Officer	4.0	3.0	5.0	5.0	4.0	6.0				15-Oct	165	sprinkler	
VEGIES	Salad crops	Windsor	John Gillett	Irrigation Officer	2.0	1.0	3.0	3.0	2.0	4.0						hydroponic sprinkler	
VEGIES	Sweet corn	Windsor	John Gillett	Irrigation Officer	2.0	1.0	3.0	3.0	2.0	4.0				15-Oct	105	sprinkler	
VEGIES	Tomatoes - field	Windsor	John Gillett	Irrigation Officer	2.0	1.0	3.0	3.0	2.0	4.0				15-Oct	99	hydroponic sprinkler	
VEGIES	Tomatoes - protected	Windsor	John Gillett	Irrigation Officer	2.0	1.0	3.0	3.0	2.0	4.0						hydroponic sprinkler	

(④)

a Crop class refers to a category under which similar crops can be grouped.

b CWR – Crop Water Requirement, the depth of water needed to meet the water loss through evapotranspiration of a disease-free crop, growing in a large field under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment. Note, this figure excludes leaching fractions and does not allow for system inefficiencies. Average, minimum, and maximum figures correspond to water requirements in normal, wet and dry seasons respectively. b

c The depth of water required to satisfy crop water requirement, leaching requirement and system inefficiencies (conveyance, distribution, and application). Essentially the depth of water that must be delivered to the farm to ultimately satisfy actual crop water use. Average, minimum, and maximum figures correspond to irrigation requirements in normal, wet and dry seasons respectively.

dY Ave, Min and Max – Average, Minimum and Maximum Yield or the total seasonal production derived from the irrigated crop. The unit being considered should be specified (e.g. dry matter, grain, fibre etc).

e Date on which annual crops are typically sown.

f For field and vegetable crops, the total number of days between sowing and harvesting. For perennial crops usually 365 days.

g System refers to irrigation system used.

h Effic – Irrigation efficiency - the term irrigation efficiency is taken to mean the ratio between crop water requirement and the irrigation water delivered to the farm. It therefore describes losses due to leaching requirement and conveyance (deep percolation and evaporation), distribution, and application inefficiencies.

13.11 Value of agriculture in the Sydney–South Coast Region in 1996–97

	South Coast subregion			Hawkesbury–Nepean catchment			Total Sydney & South Coast region	
	Irrigated ($)	Total ($)	%	Irrigated ($)	Total ($)	%	Irrigated ($)	Total ($)
Pastures and grasses	742,919	1,641,294	45.3	295,728	581,818	51	1,038,647	2,223,112
Crops for hay	36,483.60	152,015	24	46,589	194,123	24	83,073	346,138
Cereals for grain	34,285	764,526	4.5	76,031	561,976	14	110,316	1,326,502
Other crops [a]	9,372,216	10,508,521	89.2	57,353,341	68,012,274	84	66,725,557	78,520,795
Vegetables	2,408,098	5,782,650	41.6	19,525,374	50,714,983	39	21,933,472	56,497,633
Fruit (excl. grapes)	570,518	755,086	75.6	21,586,565	23,538,278	92	22,157,083	24,293,364
Grapes	53,350	66,688	80	280,706	299,399	94	334,056	366,087
Livestock products	774,419	34,459,776	2.2	152,184	246,307,436	0.1	926,603	280,767,212
Livestock products	48,238,723	117,116,495	41.2	11,878,737	83,773,628	14	60,117,460	200,890,123
TOTAL	**62,231,014**	**171,247,051**	**36.3**	**111,195,255**	**473,983,915**	**24**	**173,426,269**	**645,230,966**

Source: (Donovan 2000), (③) [a] other crops: cotton, sugar cane, field peas, chick peas, lupins, nursery production, canola, soybean, sunflowers, peanuts, tobacco and other

13.12 Entitled volume by licence purpose in the Lower South Coast microregion

Licence purpose	Entitlement volume (ML)
Irrigation	14,310
Town water supply	700
Recreation – high security	70
Industrial - sand & gravel	50
Stock	30
Domestic	30
Industrial	28
Farming	21
Recreation - low security	10
Horticulture	8
Augmentation	-
Total	15,257

Source: DLWC 1999a (①)

13.13 Crop areas (ha) irrigated using water from regulated rivers

Crops	1989-90	1990-91	
Summer grains	20	0	②
Summer pasture	836	1,149	②
Vegetables	5	50	②
Total	**861**	**1,199**	②

Source: DLWC 1998a

13.14 Water used (ML) from regulated rivers to irrigate crops

Crops	1989–90	1990–91	1991–92	rr
Farming	43	43	nd	②
Summer grains	93	0	nd	②
Summer pasture	1,620	4,196	nd	②
Vegetables	3	166	nd	②
Total	**1,759**	**4,405**	**5,456**	①

Source: DLWC 1998a nd = no data

13.15 Matrix of stress classifications and management categories

	Low environmental stress	Medium environmental stress	High environmental stress
High proportion of water extracted	CATEGORY U1. Despite high levels of water extraction, the river seems reasonably healthy. However, more detailed evaluation should be undertaken to confirm. It is also likely that conflict between users may be occurring during critical periods.	CATEGORY S3. Water extraction is likely to be contributing to environmental stress.	CATEGORY S1. Water extraction is likely to be contributing to environmental stress.
Medium proportion of water extracted	CATEGORY U2. There is no indication of a problem and, therefore, such rivers would be a low priority for management action.	CATEGORY S4. Water extraction may be contributing to environmental stress.	CATEGORY S2. Water extraction may be contributing to environmental stress.
Low proportion of water extracted	CATEGORY U4. There is no indication of a problem and, therefore, such rivers would be a low priority for management action.	CATEGORY U3. Environmental stress is likely to be due to factors other than water extraction and, as stress is not high, these rivers would be a low priority for management action.	CATEGORY S5. While environmental stress is likely to be due to factors other than water extraction, the high level of environmental stress means it is important to ensure extraction is not exacerbating the problem.

Source: DLWC 1999d

- In the Hawkesbury-Nepean catchment, there were 30 subcatchments and 29 of these have been classified (the Hawkesbury River subcatchment remains unclassified). Half of the subcatchments were considered to be highly stressed (DLWC 1999d).
- The Shoalhaven catchment has 25 subcatchments and of these, 20 have been classified. Of the number classified, 20% of these were considered to be highly stressed and to have high levels of extraction. There are a number of subcatchments that were exhibiting high environmental stress but low extraction levels (DLWC 1999e).
- There are 51 subcatchments in the Illawarra/Hacking catchment. All of these have been classified and none was highly stressed or had high levels of extraction. Most subcatchments exhibited low environmental stress and low extraction levels (DLWC 1999e).

- The Clyde catchment has 35 subcatchments and 23 of these have been classified. Of this total, only 1 exhibited high environmental stress and high levels of extraction. Most subcatchments were classified as being of low environmental stress and low extraction (DLWC 1999c).
- In the Deua, there were 8 subcatchments and 7 of these have been classified. Of this total, none was considered to have high environmental stress and high levels of extraction (DLWC 1999c).
- In the Tuross catchment, there are 22 subcatchments. Of these, 9 have been classified and none of these were considered to have high environmental stress and high levels of extraction (DLWC 1999c).
- In the Bega catchment, there are 26 subcatchments. Fourteen of these have been classified and seven of these subcatchments had high environmental stress and high levels of extraction (DLWC 1999c).
- In the Towamba catchment there are 18 subcatchments and of those that have been classified (8) none of these had high environmental stress and high levels of extraction (DLWC 1999c).
- In the Snowy–Genoa, there are 13 subcatchments and 9 of these have been classified. One subcatchment was considered to be exhibiting high levels of environmental stress and high levels of extraction (DLWC 1999f).

13.16 Subcatchment statistics

13.16.1 Summary of Stressed River Classification in the Hawkesbury–Nepean catchment

Catchment	NAME	Environmental stress	Hydrological stress	Management Classes	Full development management classes	High Conservation value
Hawkesbury–Nepean	Cowan/Pittwater	medium	low	U3	U3	no
Hawkesbury–Nepean	Mooney Mooney Creek	low	high	U1	U1	no
Hawkesbury–Nepean	Berowra Creek	low	low	U4	U4	no
Hawkesbury–Nepean	Mangrove Creek	high	high	S1	S1	no
Hawkesbury–Nepean	Macdonald River	medium	high	S3	S3	no
Hawkesbury–Nepean	Webbs Creek	low	low	U4	U4	no
Hawkesbury–Nepean	Colo River	low	low	U4	U4	yes
Hawkesbury–Nepean	Hawkesbury River	medium	unres	unres	unres	no
Hawkesbury–Nepean	Cattai Creek	high	medium	S2	S1	no
Hawkesbury–Nepean	South Creek	high	high	S1	S1	no
Hawkesbury–Nepean	Grose River	low	medium	U2	U2	no
Hawkesbury–Nepean	Erskine Ck/Sassafras River	low	low	U4	U2	yes
Hawkesbury–Nepean	Nepean River	high	high	S1	S1	no
Hawkesbury–Nepean	Bargo River	medium	low	U3	S4	no
Hawkesbury–Nepean	Upper Nepean River	high	high	S1	S1	yes
Hawkesbury–Nepean	Lake Burragorang	high	high	S1	S1	no
Hawkesbury–Nepean	Monkey Creek	high	high	S1	S1	no
Hawkesbury–Nepean	Little River	low	low	U4	U4	no
Hawkesbury–Nepean	Nattai River	medium	low	U3	U3	no
Hawkesbury–Nepean	Lower Coxs River	high	high	S1	S1	no
Hawkesbury–Nepean	Wollondilly River	low	high	U1	U1	no
Hawkesbury–Nepean	Capertee River	high	high	S1	S1	no
Hawkesbury–Nepean	Wollemi Creek	low	low	U4	U2	no
Hawkesbury–Nepean	Wolgan River	low	low	U4	U4	no
Hawkesbury–Nepean	Kowmung River	low	low	U4	U4	no
Hawkesbury–Nepean	Mid Coxs River	high	high	S1	S1	yes

Catchment	NAME	Environmental stress	Hydrological stress	Management Classes	Full development management classes	High Conservation value
Hawkesbury–Nepean	Upper Coxs River	high	high	S1	S1	no
Hawkesbury–Nepean	Wingecarribee River	high	high	S1	S1	yes
Hawkesbury–Nepean	Mulwaree River	medium	high	S3	S3	no
Hawkesbury–Nepean	Upper Wollondilly	high	high	S1	S1	no
Illawarra–Hacking	Munna Munnora Creek	low	low	U4	unres	no
Illawarra–Hacking	Spring Creek	low	low	U4	unres	no
Illawarra–Hacking	Minnamurra River	medium	low	U3	S4	no
Illawarra–Hacking	Dunmore	medium	low	U3	unres	no
Illawarra–Hacking	Little Lake	medium	low	U3	unres	no
Illawarra–Hacking	Macquarie Rivulet	low	low	U4	U2	no
Illawarra–Hacking	Koona Bay East	high	low	S5	unres	no
Illawarra–Hacking	Duck Creek	medium	low	U3	U3	no
Illawarra–Hacking	Windang	high	low	S5	unres	no
Illawarra–Hacking	Brooks Creek	medium	low	U3	unres	no
Illawarra–Hacking	Mullett Creek	medium	low	U3	unres	no
Illawarra–Hacking	Allans Creek	medium	low	U3	unres	no
Illawarra–Hacking	Fairy Creek	medium	low	U3	unres	no
Illawarra–Hacking	Towradgi Creek	medium	low	U3	unres	no
Illawarra–Hacking	Bellambi Gully	medium	low	U3	unres	no
Illawarra–Hacking	Bulli	medium	low	U3	unres	no
Illawarra–Hacking	Thirroul	medium	low	U3	unres	no
Illawarra–Hacking	Austinmer	medium	low	U3	unres	no
Illawarra–Hacking	Coledale	medium	low	U3	unres	no
Illawarra–Hacking	Wombarra	medium	low	U3	unres	no
Illawarra–Hacking	Clifton	low	low	U4	unres	no
Illawarra–Hacking	Stoney Creek	low	low	U4	unres	no
Illawarra–Hacking	Stanwell Creek	low	low	U4	unres	no
Illawarra–Hacking	Bundeena Gully	medium	low	U3	unres	no
Illawarra–Hacking	Cabbage Tree Creek (Hacking)	low	low	U4	unres	no
Illawarra–Hacking	South West Arm Creek	low	low	U4	unres	no

Catchment	NAME	Environmental stress	Hydrological stress	Management Classes	Full development management classes	High Conservation value
Illawarra–Hacking	Muddy Creek	low	low	U4	unres	no
Illawarra–Hacking	Lower Hacking River	low	low	U4	unres	no
Illawarra–Hacking	Engadine Creek	low	low	U4	unres	no
Illawarra–Hacking	Kangaroo Creek	low	low	U4	unres	no
Illawarra–Hacking	Waterfall Creek	low	low	U4	unres	no
Illawarra–Hacking	Frews Gully	low	low	U4	unres	no
Illawarra–Hacking	Cawleys Creek	low	low	U4	unres	no
Illawarra–Hacking	Wilsons Creek	low	low	U4	unres	no
Illawarra–Hacking	Mid Hacking River	low	low	U4	unres	no
Illawarra–Hacking	Camp Gully	low	low	U4	unres	no
Illawarra–Hacking	Cedar Gully	low	low	U4	unres	no
Illawarra–Hacking	Herbert Gully	low	low	U4	unres	no
Illawarra–Hacking	Upper Hacking	low	low	U4	unres	no
Illawarra–Hacking	Gills Gully	medium	low	U3	unres	no
Illawarra–Hacking	Dents Creek	low	low	U4	unres	no
Illawarra–Hacking	North Hacking Urban Area	high	low	S5	unres	no
Illawarra–Hacking	Royal National Park (coastal)	low	low	U4	unres	no
Shoalhaven	Broughton Ck	high	low	S5	S2	no
Shoalhaven	Broughton Mill Ck	high	medium	S2	S1	yes
Shoalhaven	Jaspers Brush Ck	high	low	S5	S2	no
Shoalhaven	Bomaderry Ck	high	low	S5	S2	no
Shoalhaven	Flat Rock Ck	high	high	S1	S1	no
Shoalhaven	Calymea Ck	low	unres	unres	unres	no
Shoalhaven	Bugong Ck	low	low	U4	U4	no
Shoalhaven	Yalwal Ck	high	high	S1	S1	yes
Shoalhaven	Lower Shoalhaven R	high	high	S1	S1	yes
Shoalhaven	Kangaroo River	high	high	S1	S1	yes
Shoalhaven	Bungonia Ck	high	high	S1	S1	no
Shoalhaven	Nerrimunga Creek	high	medium	S2	S1	no
Shoalhaven	Endrick River	low	low	U4	U4	no

Catchment	NAME	Environmental stress	Hydrological stress	Management Classes	Full development management classes	High Conservation value
Shoalhaven	Mid Shoalhaven River	medium	low	U3	U3	no
Shoalhaven	Mongarlowe River	medium	low	U3	U3	yes
Shoalhaven	Boro Creek	high	low	S5	S5	no
Shoalhaven	Reedy Creek	high	low	S5	S5	no
Shoalhaven	Braidwood	high	low	S5	S5	no
Shoalhaven	Back Ck - Round Mountain Ck	medium	low	U3	U3	no
Shoalhaven	Jerrabattgula Creek	medium	low	U3	S3	no
Shoalhaven	Upper Shoalhaven River	medium	low	U3	U3	no
Shoalhaven	Lake Wollumboola	low	unres	unres	unres	no
Shoalhaven	Shoalhaven Estuary	medium	unres	unres	unres	no
Shoalhaven	Crooked River	high	unres	unres	unres	no
Shoalhaven	Ooaree Creek	high	unres	unres	unres	no
Clyde	Nelligen Creek	medium	unres	unres	unres	yes
Clyde	Cyne Mallows Creek	low	low	U4	unres	no
Clyde	Currowan Creek	low	low	U4	unres	no
Clyde	Cockwhy Creek	low	low	U4	U4	no
Clyde	Mid Clyde River	low	low	U4	U4	yes
Clyde	Bimberamala River	low	low	U4	unres	no
Clyde	Boyne Creek	low	low	U4	unres	no
Clyde	Upper Clyde River	low	low	U4	U4	yes
Clyde	Yadboro River	low	low	U4	unres	no
Clyde	Pigeon House Creek	low	high	U1	U1	no
Clyde	Holland Creek	low	low	U4	unres	no
Clyde	North Moruya	medium	unres	unres	unres	no
Clyde	Tomaga River	medium	unres	unres	unres	no
Clyde	Buckenbowra River	low	low	U4	U4	yes
Clyde	Batemans Bay/Clyde	medium	unres	unres	unres	yes
Clyde	Durras Lake	low	low	U4	unres	no
Clyde	Kioloa	low	low	U4	unres	no
Clyde	Willinga Lake	low	low	U4	unres	no

Catchment	NAME	Environmental stress	Hydrological stress	Management Classes	Full development management classes	High Conservation value
Clyde	Meroo Lake	low	unres	unres	unres	no
Clyde	Termeil Lake	low	low	U4	unres	no
Clyde	Lake Tabourie	medium	low	U3	unres	no
Clyde	Burrill Lake	medium	unres	unres	unres	no
Clyde	Narrawallee Inlet	high	unres	unres	unres	yes
Clyde	Lake Conjola	medium	unres	unres	unres	no
Clyde	Conjola Creek	medium	low	U3	U3	no
Clyde	Nerrindillah Creek	low	unres	unres	unres	no
Clyde	Berrara Creek	low	low	U4	unres	no
Clyde	Swan Lake	low	low	U4	unres	no
Clyde	St Georges Basin/Sussex Inlet	low	unres	unres	unres	no
Clyde	Wandandian Creek	medium	low	U3	S4	yes
Clyde	South Jervis Bay	unres	low	unres	unres	no
Clyde	Moona Moona Creek	medium	low	U3	unres	no
Clyde	Currumbene Creek	high	high	S1	S1	no
Clyde	Callala Creek	low	low	U4	unres	no
Clyde	North Jervis Bay	unres	low	unres	unres	no
Deua	Deua River	medium	medium	S4	S4	yes
Deua	Mogendoura Creek	medium	low	U3	U3	no
Deua	Wamban River	medium	low	U3	S3	no
Deua	Burra Creek	medium	low	U3	S3	no
Deua	Araluen Creek	high	medium	S2	S1	no
Deua	Bettowynd & Moodong Ck	medium	low	U3	U3	no
Deua	Upper Deua River	low	low	U4	U4	no
Deua	Moruya River	medium	unres	unres	unres	yes
Tuross	Tuross River	medium	low	U3	S4	yes
Tuross	Bumbo Creek	medium	low	U3	U3	no
Tuross	Swamp Creek	medium	low	U3	S4	no
Tuross	Reedy Creek	medium	low	U3	S4	no
Tuross	Gulph creek	medium	low	U3	U3	no

Catchment	NAME	Environmental stress	Hydrological stress	Management Classes	Full development management classes	High Conservation value
Tuross	Wandella Creek	medium	high	S3	S3	no
Tuross	Little & Big Belimba Creek	medium	unres	unres	unres	no
Tuross	Belimba Creek	high	unres	unres	unres	no
Tuross	Wadbilliga River	low	unres	unres	unres	yes
Tuross	Yowrie Creek	high	low	S5	S5	no
Tuross	Mellion Creek	high	low	S5	S5	no
Tuross	Mid Tuross River	low	unres	unres	unres	yes
Tuross	Woila Creek	low	unres	unres	unres	no
Tuross	Bumberry Creek	low	unres	unres	unres	no
Tuross	Upper Tuross River	medium	low	U3	U3	no
Tuross	Tilba Tilba Lake	medium	unres	unres	unres	no
Tuross	Corunna Lake	medium	unres	unres	unres	no
Tuross	Wagonga Inlet	medium	unres	unres	unres	no
Tuross	Lake Mummuga	low	unres	unres	unres	no
Tuross	Brou Lake	low	unres	unres	unres	no
Tuross	Tuross Estuary	medium	unres	unres	unres	yes
Tuross	Coila Lake	low	unres	unres	unres	no
Bega	Bega River	high	unres	unres	unres	no
Bega	Brogo River	high	low	S5	S1	yes
Bega	Wolumla Creek	high	high	S1	S1	no
Bega	Candelo Creek	high	high	S1	S1	no
Bega	Tantawangalo Creek	medium	medium	S4	S3	no
Bega	Sandy Creek	medium	high	S3	S3	no
Bega	Bemboka River	high	high	S1	S1	no
Bega	Upper Brogo River	low	unres	unres	unres	no
Bega	Murrah River	medium	low	U3	S3	yes
Bega	Upper Murrah River	high	high	S1	S1	no
Bega	Tura Beach	medium	unres	unres	unres	no
Bega	Sandy Beach Creek	low	unres	unres	unres	yes
Bega	Bondi Lake	low	unres	unres	unres	no

Catchment	NAME	Environmental stress	Hydrological stress	Management Classes	Full development management classes	High Conservation value
Bega	Wallagoot Lake	low	unres	unres	unres	no
Bega	Bega Estuary	medium	unres	unres	unres	yes
Bega	Nelson Lagoon	medium	unres	unres	unres	no
Bega	Middle Lagoon	medium	unres	unres	unres	no
Bega	Wapengo Lagoon	medium	unres	unres	unres	no
Bega	Murrah Estuary	medium	unres	unres	unres	no
Bega	Cuttagee Lake	medium	low	U3	S3	no
Bega	Barragoot Lake	low	unres	unres	unres	no
Bega	Bermagui River	medium	high	S3	S3	yes
Bega	Wallaga Lake	medium	unres	unres	unres	no
Bega	Narira Creek	high	high	S1	S1	no
Bega	Dignams Creek	high	high	S1	S1	no
Bega	Bobundra Creek	low	unres	unres	unres	no
Towamba	Towamba River	high	low	S5	S5	yes
Towamba	Jingo Creek	high	unres	unres	unres	no
Towamba	Pericoe Creek	medium	unres	unres	unres	no
Towamba	Wog Wog River	low	unres	unres	unres	no
Towamba	Mid Towamba River	medium	low	U3	U3	no
Towamba	Myrtle Creek	low	low	U4	U2	no
Towamba	Mataganah Creek	medium	low	U3	S4	no
Towamba	Stockyard Creek	low	unres	unres	unres	no
Towamba	Far South Coast	low	unres	unres	unres	no
Towamba	Wonboyn River	medium	low	U3	U3	yes
Towamba	Green Cape	medium	unres	unres	unres	no
Towamba	Towamba Estuary	low	unres	unres	unres	no
Towamba	Nullica Creek	low	unres	unres	unres	no
Towamba	Eden	low	unres	unres	unres	no
Towamba	Curalo Lake	medium	unres	unres	unres	no
Towamba	Pambula River	medium	high	S3	S3	no
Towamba	Merimbula Lake	medium	low	U3	S3	no

Catchment	NAME	Environmental stress	Hydrological stress	Management Classes	Full development management classes	High Conservation value
Towamba	Merimbula Creek	medium	high	S3	S3	no
Snowy	Genoa River	medium	low	U3	U3	yes
Snowy	Mowamba River	high	unres	unres	unres	no
Snowy	Kara Creek	medium	unres	unres	unres	no
Snowy	Wullwye Creek	medium	low	U3	S3	no
Snowy	Bobundra Creek	high	low	S5	S1	no
Snowy	Maclaughlin River	medium	high	S3	S3	no
Snowy	Delegate River	medium	low	U3	S4	no
Snowy	Bombala River	high	high	S1	S1	yes
Snowy	Coolumbooka River	medium	medium	S4	U3	no
Snowy	Tombong Creek to Little River	high	low	S5	S5	no
Snowy	Matong Creek To Stoney Creek	high	low	S5	S5	no
Snowy	Reedy Creek	medium	unres	unres	unres	no
Snowy	Jacobs River to Pinch Creek	low	unres	unres	unres	no

Source: DLWC 1999c; DLWC 1999d; DLWC 1999e; DLWC 1999f

Summary of future risks in subcatchments in the Sydney–South Coast Region

Catchment	Subcatchment	Future risks[a]
Hawkesbury–Nepean	Bargo River	Increased rural-residential development, mining, agricultural and industry
Hawkesbury–Nepean	Berowra Creek	Water quality, stormwater run off
Hawkesbury–Nepean	Capertee River	Increased agriculture
Hawkesbury–Nepean	Cattai Creek	Increased urban areas, rural-residential development, agriculture, industry and discharge from Sewerage Treatment Plants and Biocycle systems
Hawkesbury–Nepean	Colo River	Increased agriculture
Hawkesbury–Nepean	Cowan/Pittwater	Stormwater pollution, boat discharge of grey water and sewage
Hawkesbury–Nepean	Erskine Ck/Sassafras River	No threats
Hawkesbury–Nepean	Grose River	Increased urban development and agriculture
Hawkesbury–Nepean	Hawkesbury River	Increased urban development, poor water quality
Hawkesbury–Nepean	Kowmung River	No threats
Hawkesbury–Nepean	Lake Burragorang	nd
Hawkesbury–Nepean	Little River	nd
Hawkesbury–Nepean	Lower Coxs River	nd
Hawkesbury–Nepean	Macdonald River	Increased agriculture and gravel extraction from rivers
Hawkesbury–Nepean	Mangrove Creek	Poor water quality and increased agriculture
Hawkesbury–Nepean	Mid Coxs River	Increased agriculture
Hawkesbury–Nepean	Monkey Creek	Increased urban and rural-residential development, agriculture and discharges from Sewage Treatment Plants and Biocycle systems
Hawkesbury–Nepean	Mooney Mooney Creek	On-going high levels of water extraction
Hawkesbury–Nepean	Mulwaree River	Agriculture
Hawkesbury–Nepean	Nattai River	Increased rural residential development, agriculture and highways
Hawkesbury–Nepean	Nepean River	Increased urban and rural-residential development, mining and agriculture, highways, river/floodplain gravel extraction and Sewage Treatment Plans and Biocycle discharges
Hawkesbury–Nepean	South Creek	Increased urban and rural-residential development, agriculture, new highways, industry, and increased Sewage Treatment Plan and biocycle discharges
Hawkesbury–Nepean	Upper Coxs River	Increased urban and rural-residential development, agriculture, new highways, industry, and increased Sewage Treatment Plan and biocycle discharges
Hawkesbury–Nepean	Upper Nepean River	Increased rural-residential development, mining and agriculture
Hawkesbury–Nepean	Upper Wollondilly	Increased rural-residential development, mining and agriculture
Hawkesbury–Nepean	Webbs Creek	Increased agriculture
Hawkesbury–Nepean	Wingecarribee River	Increased urban and rural -residential development and agriculture

Catchment	Subcatchment	Future risks[a]
Hawkesbury–Nepean	Wolgan River	nd
Hawkesbury–Nepean	Wollemi Creek	nd
Hawkesbury–Nepean	Wollondilly River	Increased rural-residential development, mining and agriculture
Shoalhaven	Bungonia Creek	Weeds along river banks, rural-residential development, potential for gold mining under prospecting lease, increased cropping (winter wheat production), gully erosion, dryland salinity
Shoalhaven	Flat Rock Creek	Degradation of river environment, sedimentation, acid sulphate soils, urban development, highway and gas pipeline construction and light industry
Shoalhaven	Kangaroo River	Willow infestation, gold mining under prospecting lease
Shoalhaven	Lower Shoalhaven River	Reduced frequency and quantity of flow if transfers to the Hawkesbury–Nepean system are increased. Proposed Welcome Reef Dam would affect river flows. Increased urban and rural residential development. Intensive animal enterprises, high and gas pipeline construction, gravel extraction.
Shoalhaven	Yalwal Creek	Highway and gas pipeline construction
Shoalhaven	Back Ck-Round Mountain Ck	Degradation of riverine environment, erosion, sedimentation, gold mining under prospecting lease
Shoalhaven	Bomaderry Ck	Degradation of riverine environment, acid sulphate soils, urban development, rural-residential, highway and gasline construction.
Shoalhaven	Boro Ck	Degradation of the riverine environment, dryland salinity, rural residential development, increased cropping (winter wheat), potential for gold mining under prospecting lease
Shoalhaven	Braidwood	Degradation of riverine environment, gully erosion. Development: urban, rural residential, gold mining under prospecting lease. Increased cropping (winter wheat)
Shoalhaven	Broughton Ck	Degradation of riverine environment, water quality, acid sulphate soils, dairying and effluent management. Development: urban, rural-residential.
Shoalhaven	Broughton Mill Ck	Degradation of riverine environment. Rural residential development, effluent management
Shoalhaven	Bugong Ck	Acid sulphate soils, highways and gas pipeline construction
Shoalhaven	Calymea Ck	Acid sulphate soils
Shoalhaven	Crooked Rv	Unknown
Shoalhaven	Endrick River	Potential for gold mining under prospecting lease, gas pipeline construction
Shoalhaven	Jaspers Brush Ck	Degradation of river environment, rural residential development, effluent management
Shoalhaven	Jerrabattgula Ck	Degradation of river environment, erosion, sedimentation, gold mining under prospecting lease
Shoalhaven	Lake Wollumbolla	Urban development
Shoalhaven	Mid Shoalhaven River	Sedimentation, gully erosion, dryland salinity, gold mining under prospecting lease, highway and gas pipeline construction, gravel extraction
Shoalhaven	Mongarlowe Rv	Erosion, sedimentation, dryland salinity, rural residential development, gold mining under prospecting lease
Shoalhaven	Nerrimunga Ck	Degradation of riverine environment, sedimentation, erosion, rural residential development, gold mining under prospecting lease, increased cropping (winter wheat), dryland salinity

Catchment	Subcatchment	Future risks[a]
Shoalhaven	Ooaree Creek	Extraction of surface water
Shoalhaven	Reedy Creek	Degradation of river, water quality, gully erosion and sedimentation, dryland salinty, rural-residential, increased cropping (winter wheat) and gold mining under prospecting lease
Shoalhaven	Shoalhaven Estuary	Extraction of surface water
Shoalhaven	Upper Shoalhaven Rv	Decline of riverine environment, streambank erosion, sedimentation, gold mining under prospecting lease
Illawarra/Hacking	Allans Creek	Flood mitigation works, urban redevelopment and industrial pollution
Illawarra/Hacking	Allans Creek Estuary	Surface water extraction
Illawarra/Hacking	Austinmere	Redevelopment of existing developed areas, higher density housing, flood mitigation words, channelisation and stream excavations
Illawarra/Hacking	Bellambi Estuary	
Illawarra/Hacking	Bellambi Gully	Redevelopment of existing developed areas, higher density housing, flood mitigation words, channelisation and stream excavations
Illawarra/Hacking	Brooks Creek	Encroachment by redeveloping urban areas on stream
Illawarra/Hacking	Bulli	Redevelopment of existing developed areas for high density housing, flood mitigation works (stream channelisation and excavations)
Illawarra/Hacking	Bundeena Gully	Further development and redevelopment of urban areas
Illawarra/Hacking	Cabbage Tree Creek (Hacking)	Further development and redevelopment of urban areas
Illawarra/Hacking	Camp Gullly	Urban development in Helensburgh
Illawarra/Hacking	Cawleys Creek	Unknown
Illawarra/Hacking	Cedar Gully	Unknown
Illawarra/Hacking	Clifton	Industrial pollution from mining
Illawarra/Hacking	Coledale	Redevelopment of developed areas for higher density housing and flood mitigation works
Illawarra/Hacking	Dents Creek	Redevelopment of existing urban areas
Illawarra/Hacking	Duck Creek	Flood mitigation works, urban development
Illawarra/Hacking	Dunmore	Subdivision of rural land for residential development
Illawarra/Hacking	Engadine Creek	Further development and redevelopment of urban areas
Illawarra/Hacking	Fairy Creek and Cabbage Tree Creek	Flood mitigation works, urban development, commercial developments
Illawarra/Hacking	Fairy Creek Estuary	No threats
Illawarra/Hacking	Frews Gully	Unknown
Illawarra/Hacking	Gills Gully	Urban development and redevelopment
Illawarra/Hacking	Herbert Gully	Urban development and redevelopment
Illawarra/Hacking	Kangaroo Creek	Urban development and redevelopment

Catchment	Subcatchment	Future risks[a]
Illawarra/Hacking	Koona Bay East	Redevelopment and impact on channel system
Illawarra/Hacking	Koona Bay East Estuary	Water quality from stormwater runoff
Illawarra/Hacking	Little Lake	Redevelopment of urban areas and potential impacts of flood mitigation works on streams
Illawarra/Hacking	Little Lake Estuary	Suface water extraction
Illawarra/Hacking	Lower Hacking River	Unknown
Illawarra/Hacking	Macquarie Rivulet	Rural subdivision into residential developments. Flood mitigation, increased water extraction
Illawarra/Hacking	Mid Hacking River	Unknown
Illawarra/Hacking	Minnamurra River	Activation of surface water licences. The catchment would be highly stressed with flows being over-allocation at the 80th percentile
Illawarra/Hacking	Minnamurra River Estuary	Unknown
Clyde	Batemans Bay.Clyde	Bank erosion, increases in development and increased water extraction
Clyde	Berrara Creek	Unknown
Clyde	Bimberamala River	Forestry activities
Clyde	Boyne Creek	Forestry activities
Clyde	Buckenbowra River	Forestry activities, increased extraction for water supply
Clyde	Burrill Lake	Urban development associated water quality, increased water extraction
Clyde	Callala Creek	Future urban development
Clyde	Cockwhy Creek	Roadwork, forestry practices
Clyde	Conjola Creek	Water quality, rural and forestry activities, rural-residential development
Clyde	Currowan Creek	Water quality
Clyde	Currumbene Creek	Future rural and residential development.
Clyde	Cyne Mallows Creek	Forestry activities may impact on water quality and flows
Clyde	Durras lake	Unknown
Clyde	Holland Creek	No threats
Clyde	Kioloa	Unknown
Clyde	Lake Conjola	Foreshore development, water quality, conversion of rural land to rural-residential development
Clyde	Lake Tabourie	Urban stormwater
Clyde	Meroo Lake	Unknown
Clyde	Mid Clyde River	Tourism, changes in landuse activities to intensive high value crops (eg Echinacea)
Clyde	Moona Moona Creek	Expansion of rural and residential developments, water quality
Clyde	Narrawallee Inlet	Increased water extraction

Catchment	Subcatchment	Future risks[a]
Clyde	Nelligen Creek	Rural residential development, water quality and flows
Clyde	Nerrindillah Creek	Unknown
Clyde	North Jervis Bay	Unknown
Clyde	North Moruya	Increased urban development
Clyde	Pigeon House Creek	No threats
Clyde	South Jervis Bay	Unknown
Clyde	St Georges Basin.Sussex Inlet	Development and storm water
Clyde	Swan Lake	Unknown
Clyde	Termeil Lake	Unknown
Clyde	Tomaga River	Increased urban development
Clyde	Upper Clyde River	Tourism, forestry activities
Clyde	Wandandian Creek	Degradation of wetlands
Clyde	Willinga Lake	Unknown
Clyde	Yadboro River	Tourism
Deua	Araluen Creek	Development of rural-residential areas, and the increased extraction of water for the irrigation of horticultural crops
Deua	Deua	Expansion of rural residential development along the river
Deua	Burra Creek	No threats
Deua	Wamban River	Increased water extraction or more intensive use of land
Deua	Bettowynd and Moodong Creek	Higher water extraction, more intensive use of land on river flats
Deua	Mogendoura Creek	High water extraction by agriculture
Deua	Upper Deua River	Increased water extraction
Deua	Moruya River	Increased water extraction
Tuross	Belimba Creek	Intensive landuse and water extraction
Tuross	Brou Lake	Not known
Tuross	Bumberry Creek	No threats
Tuross	Bumbo Creek	Clearing for forests
Tuross	Coila Lake	Water quality problems
Tuross	Corunna Lake	Water quality problems
Tuross	Gulph Creek	Clearing of forests. Intensive use of water
Tuross	Lake Mummaga	Not known

Catchment	Subcatchment	Future risks[a]
Tuross	Little&Big Belimba Creek	Forestry practices
Tuross	Mellion Creek	Intensive land, water and forestry uses. Land is extensive used for grazing and cropping
Tuross	Mid Tuross River	No threats
Tuross	Reedy Creek	Forestry practices
Tuross	Swamp Creek	Forestry practices
Tuross	Tilba Tilba Lake	Surface water extraction
Tuross	Tuross Estuary	Bank erosion
Tuross	Tuross River	Intensive land use and water use
Tuross	Upper Tuross River	Intensive land use and water use
Tuross	Wadbilliga River	No threats
Tuross	Wagonga Inlet	Erosion and urban development
Tuross	Wandella Creek	Intensive land use, water use and forest clearing
Tuross	Woila Creek	No threats
Tuross	Yowrie Creek	Intensive land, water and forest uses
Bega	Barragoot Lake	Not Known
Bega	Bega Estuary	Sedimentation
Bega	Bega River	Movement of the sand sheet
Bega	Bemboka River	Water extraction and regulated flow
Bega	Bermagui River	Continuing high levels of extraction
Bega	Bobundra Creek	Surface water licences
Bega	Bondi lake	Not known
Bega	Brogo River	Management of regulated flows
Bega	Candelo Creek	Vegetation loss
Bega	Cuttagee Lake	Not Known
Bega	Dignams Creek	Logging, increased water use.
Bega	Middle Lagoon	Not Known
Bega	Murrah Estuary	nd
Bega	Murrah River	Increased landuse and intensive logging
Bega	Narira Creek	Urbanisation, riparian rights, Increased demand for water, degradation of the water course, degraded water quality.
Bega	Nelson Lagoon	Not Known
Bega	Sandy Beach Creek	Suface water extraction

Catchment	Subcatchment	Future risks[a]
Bega	Sandy Creek	Channel instability
Bega	Tantawangalo Creek	Intensive landuse and increasing demand for water
Bega	Tura Beach	Development
Bega	Upper Brogo River	No threat
Bega	Upper Murrah River	Increasing demand for water between farming and rural enterprises especially during low flow periods
Bega	Wallaga Lake	Urban development, water quality issues, and surface water extraction
Bega	Wallagoot lake	nd
Bega	Wapengo Lagoon	Surface water extraction
Bega	Wolumla Creek	
Towamba	Curalo Lake	Water quality and urban development
Towamba	Eden	Not known
Towamba	Far South Coast	Not known
Towamba	Green Cape.Bittangabee Creek	Not known
Towamba	Jingo Creek	Forestry and degradation of riparian vegetation
Towamba	Mataganah Creek	Weeds, downsizing of rural allotments, sewerage
Towamba	Merimbula Creek	Continued high levels of extraction, urban development, water quality
Towamba	Merimbula Lake	High levels of extraction, urban development, water quality.
Towamba	Mid Towamba River	Forestry
Towamba	Murtle Creek	Forestry, declining riparian vegetation.
Towamba	Nullica Creek	Unknown
Towamba	Pambula River	High level of water extraction, water quality
Towamba	Pericoe Creek	Exotic species, forestry
Towamba	Stockyard Creek	Forestry
Towamba	Towamba Estuary	Unknown
Towamba	Towamba River	Exotic species, development of agricultural land on the flats into rural residential land, forestry, degradation of riparian vegetation by grazing.
Towamba	Wog Wog River	Forestry, sedimentation.
Towamba	Wonboyn River	Unknown
Snowy-Genoa	Bobundra Creek	Water quality
Snowy-Genoa	Bombala River	Stream bank erosion, water quality, increased extraction for town water supply.
Snowy-Genoa	Coolumbooka River	Increased extraction

Catchment	Subcatchment	Future risks[a]
Snowy-Genoa	Delegate River	Bank erosion, riparian weeds
Snowy-Genoa	Genoa River	Sedimentation, river bank erosion, weeds
Snowy-Genoa	Jacobs R. to Pinch Ck	Sedimentation and structural decline of river banks
Snowy-Genoa	Kara Creek	degradation of river banks
Snowy-Genoa	Maclaughlin River	Increased extraction
Snowy-Genoa	Matong Ck to Stony Ck	Sedimentation and structural decline
Snowy-Genoa	Mowamba River	Possible changes due to Snowy Mountain Scheme.
Snowy-Genoa	Reedy Creek	Sedimentation and structural decline
Snowy-Genoa	Tombong Ck to Little River	Sedimentation and structural decline
Snowy-Genoa	Wullwye Ck	Channel degradation, water quality, degradation of water quality.

Source: (DLWC 1999c; DLWC 1999d; DLWC 1999e; DLWC 1999f). [a] The future risks analysis identified future risks from new land-based activities that may threaten the riverine environmental values or change the stress rating of a subcatchment.

13.17 ABS question profile

Part 8. Do you irrigate or use any artificial fertilisers or soil conditioners No Go to part 9

Yes *show details below*

a. Pastures and Crops Irrigated – Season 1993-94

Where any area of pasture or crop was irrigated more than once during the season, show this area once only Hectares

- Pasture (native or sown) .....
- Cereals .....
- Vegetables for human consumption .....
- Fruit (including nuts) .....
- Grapevines .....
- All other crops .....

b. Source of water – season 1993-94

Where more than one source of water is used on a particular area of pasture or crop, show the area only once according to the main source.

Area (hectares) irrigated using:

- Channel or pipe supply in an irrigation area or district

  .....

- Other surface water (*Include* • private group schemes)

  .....

- A river or stream controlled by water board or a water resources commission dam or weir

  .....

- An uncontrolled river or scheme .....

- A farm dam with its own catchment and not filled by pumping from a river or stream .....

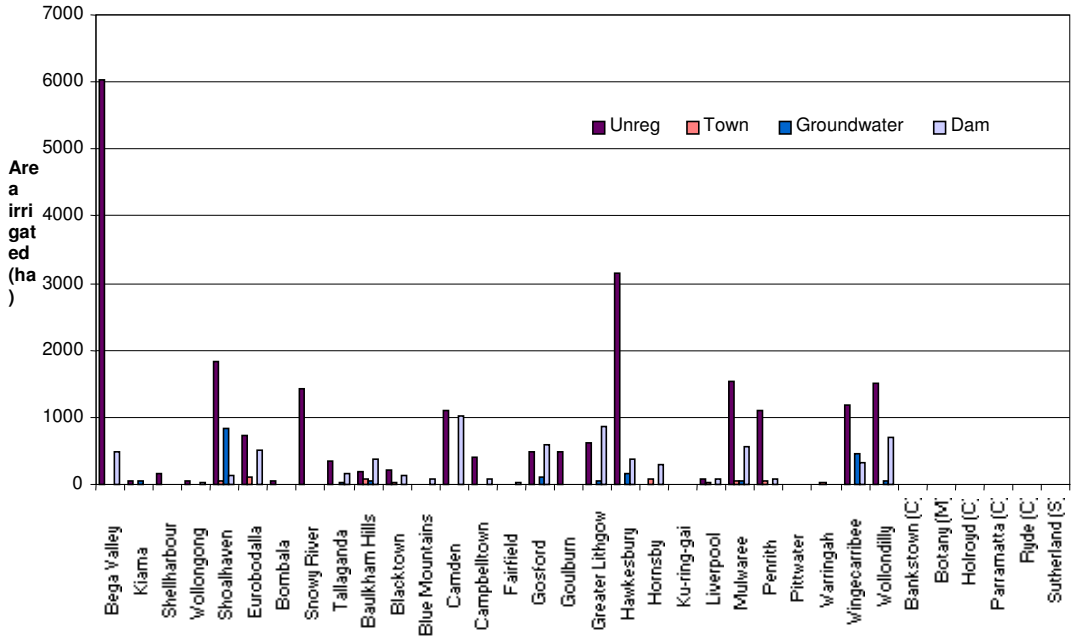
- Underground water supply (for example, bore, spear, well)

  - Within State schemes .....

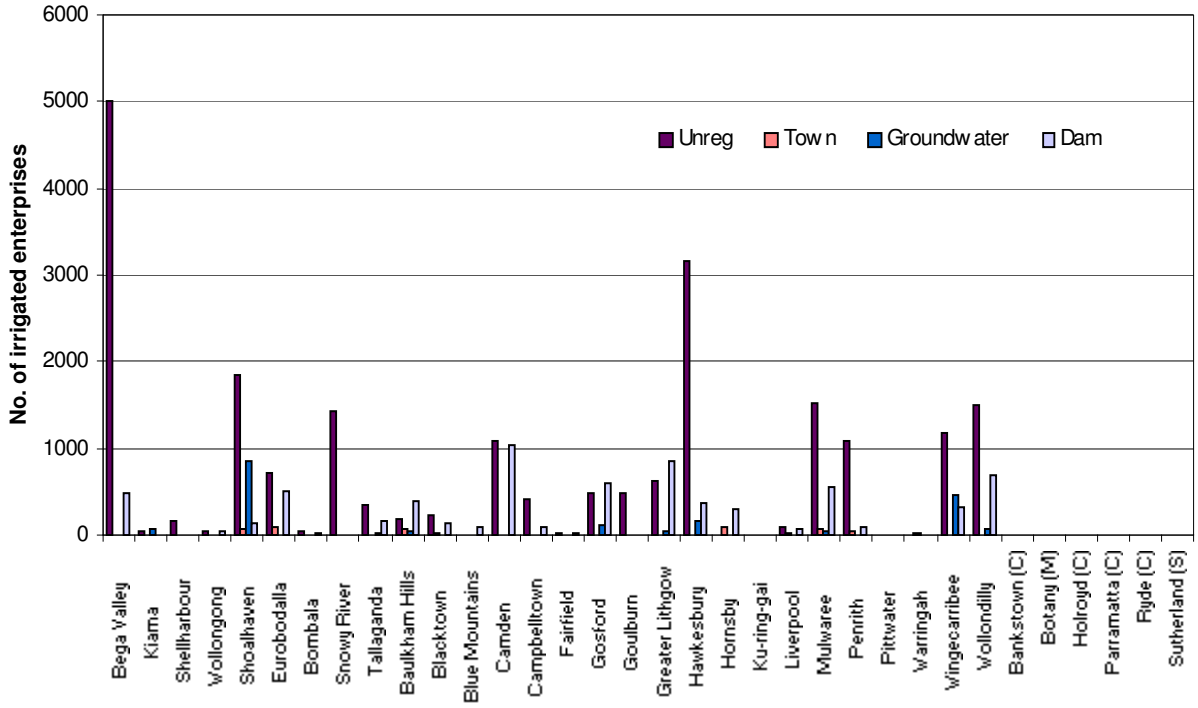
  - Other .....

Source: ABS 1994

13.18 Area irrigated and number of enterprises by source of water



Source: ABS 1998. The area irrigated by water source in the Sydney–South Coast Region (②). Note: The area irrigated from regulated streams in the Bega catchment was estimated to be 1,000 ha (②). This figure has been subtracted from the ABS estimates of the area irrigated from surface supplies (regulated and unregulated) in the Bega catchment (②) to give a reliability rating of ③. As noted in section 6.4, ABS did not collect information from regulated rivers as defined by DLWC in section 2.2.



Source: (ABS 1998). The number of irrigated enterprises by source of water (②). Note: The number of enterprises irrigating from unregulated supplies attracts a rr of ③. It has been estimated in this report that there area 79 irrigation enterprises using water from regulated supplies in the Bega catchment (④. This figure has been subtracted from the ABS estimate of the number of enterprises using water from surface supplies (regulated and unregulated) in the Bega catchment (②) to give a rr of ③. As noted in section 6.4, ABS did not collect information from regulated rivers as defined by DLWC in section 2.2.

13.19 Area irrigated using water from unregulated rivers

Data	Sum of 1993-94	Sum of 1994-95	Sum of 1995-96	Sum of 1996-97	Sum of 1997-98	Sum of 1998-99
Annual pasture	1,971	2,026	2,084	2,152	2,722	2,803
Citrus	825	834	798	750	745	751
Cut flowers	14	14	12	12	12	12
Fodder	421	456	468	580	628	635
Lucerne	2,618	2,685	2,758	2,440	2,412	2,448
Nurseries	183	188	186	192	197	198
Nuts	18	19	19	27	24	25
Olives	18	18	18	20	25	42
Other	896	905	942	1,017	1,042	1,071
Perennial pasture	8,572	8,764	9,044	9,434	9,892	10,983
Pulses	0	0	0	0	0	1
Summer cereal	395	461	335	397	538	486
Trees - orchards	667	668	654	604	619	630
Trees - other	137	147	147	247	255	378
Turf	2,362	2,401	2,418	2,447	2,525	2,657
Vegetables	2,772	2,778	2,814	2,832	2,853	2,830
Vines - tablegrapes	1	9	8	1	6	1
Vines - wine grapes	53	47	47	49	52	61
Winter cereal	357	456	537	525	615	583
Total	22,280	22,875	23,290	23,728	25,160	26,592

Source: DLWC 2000d, ②