

# Audit of the Sydney Drinking Water Catchment

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Report to the  
Minister for the Environment  
NSW State Government

December 2003



Department of  
**Environment and Conservation (NSW)**

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# Main Findings

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## Overall

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Based on available information the health of the Catchment has not changed extensively since the last audit. There are large parts of the Catchment in very good condition while there are significant parts of the Catchment that remain in poor condition. The ongoing drought during the audit period has contributed to good water quality in the storages but has also caused additional stress to ecosystems within the Catchment.

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## Minimising contamination of raw water supply

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Agriculture and sewage treatment plants (STPs) are major sources of nutrient pollution within the Catchment.

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Significant re-use of grey water in Goulburn appears to be responsible for a significant reduction in nutrient loads from the Goulburn STP.

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Raw drinking water generally meets the requirements of Sydney Water and NSW Health. There was however, an increase in the number of exceedences of the criteria in the Bulk Water Supply Agreement for some parameters.

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The incidence of toxic Cyanobacteria blooms increased slightly from the previous audit.

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There is continued high incidence and long duration of cyanobacteria blooms indicating high levels of nutrients in some parts of the storage system (i.e. upstream of the water filtration plants).

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The incidence of *Cryptosporidium* and *Giardia* have not changed significantly from the previous audit and remains generally low with some exceptions.

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There is continued high incidences of *Cryptosporidium* and *Giardia* at Gibbergunyah Creek.

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## Managing water resources

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Very little information is available on surface or groundwater extraction upstream of the dams and their effect on the health of the Catchment.

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Sydney Catchment Authority complied with environmental release requirements 99.7% of the time.

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Environmental flow requirements within the Catchment need to be further developed.

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The transfer of bulk water may be affecting the health of waterways within the Catchment.

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## Protecting and improving land condition

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The large areas of agriculture, increases in intensive agriculture and increased urbanisation and rural residential development will all continue to put pressure on water quality within the Catchment.

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Identification of potentially polluting sites has been undertaken. Risk assessment and management process for these sites needs to be progressed.

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11% of the Catchment has very high or high estimated rill or sheet soil erosion, while 82% has low or very low estimated rill or sheet erosion.

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Salinity is not a major problem in the Catchment. However, there are areas susceptible to salinity that require appropriate management.

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## Maintaining and enhancing ecosystem health

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Current water quality within the Catchment has the potential to affect ecosystem health.

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A 'low' AusRivAS health rating was found in 41% of locations sampled in the Catchment.

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The diversity of fish species is generally poorer above the dams and characterised by a higher proportion of exotic species.

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The extent of riparian vegetation within the Catchment ranges from large areas with almost intact native vegetation cover to areas such as the Upper Wollondilly River and Mulwaree River sub-catchments with little or no native vegetation in their riparian zones.

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Native vegetation covers approximately 63% of the Catchment and has a similar pattern of distribution to native riparian vegetation. While almost half of this cover is protected within National Parks over 37% is dispersed across the Catchment on privately owned land.

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Table 1 shows which sub-catchments are believed to be under pressure. A blue dot indicates a sub-catchment that was identified as being under pressure from a particular indicator or parameter. The table, however, does not take into account that some indicators may be more important than others. Therefore, no attempt has been made to indicate the relative importance of these pressures: their implications are discussed within the audit report. For these reasons the table should be used as a guide only.

The sub-catchments already determined by SCA as priority sub-catchments for action are highlighted in the table. The criteria used by SCA to determine priority sub-catchments included some that differed from audit indicators.

There are a number of sub-catchments which are under pressure from a large number of factors. They are the Kangaroo River, Mulwaree River, Wingecarribee River and Wollondilly River sub-catchments. There are also a number of sub-catchments which are under less pressure than the above sub-catchments, but where there is still potential that the health of the ecosystem could be affected. These sub-catchments are Lower and Upper Coxs River, Nattai River, Upper Wollondilly River and Werriberri Creek.

**Table 1: Issues arising in each sub-catchment from the audit of available data for each indicator and issue in this audit report**

Indicator Number	Indicator or Issue	Back & Round Mountain Creek	Blue Mountains	Boro Creek	Braidwood Creek	Bungonia Creek	Endrick Creek	Jerrabagulla Creek	Kangaroo River	Kowmung River	Lake Burrigorang	Little River	Lower Coffs River*	Mid Coffs River*	Mid Shoalhaven River	Mongarlowe River	Mulwaree River*	Natta Riveri	Nerrimunga River	O'Hares Creek	Reedy Creek	Upper Coffs River*	Upper Nepean River	Upper Shoalhaven River	Upper Wollondilly River*	Werriberri Creek*	Wingecarribee River*	Wollondilly River*	Woronora River
		2.1	Phosphorus								•								•					•					•
	Nitrogen																•					•			•		•	•	
	STP																					•					•	•	
	Unsewered								•			•										•					•	•	
2.2	Water Quality at WFPs												•	•															
2.3	Algal Blooms	~	~	~	~		~	~	•	~	•	~		~	~	~	~	~	~	~	~	~		~	~	~	•	~	
2.4	Pathogens	~	~	~	~	~	~	~		•		~	•		~	~	~	•	~	~	~	~		~	~			~	~
3.1	Extraction Licences								•				•	•	•								•		•				•
	Farm dams				•												•		•			•			•	•	•		
3.2	Bores																	•				•				•	•		
3.3	Weirs								•														•			•			
	Transfers																										•		
4.1	Increasing urbanisation								•																			•	•
	Other developments								•									•								•		•	•
4.2	Sites of pollution or potential contamination												•				•	•					•			•	•		
4.3	Soil erosion																						•						•
4.4	Salinity			•												•				•									
5.1	Ecosystem water quality	~	~	~	•		~	~	•								•	•	~	~	~	~		~	~	•	•	•	
5.2	Macroinvertebrates			•	•	•			•		•	•	•	•			•					•	•	•	•		•	•	
5.3	Fish								•															•					
5.4	Riparian vegetation				•												•					•				•			
5.5	Native vegetation																•									•			

**Notes:** ~ = no data available. Criteria for the presence of a blue dot are in Appendix A Table 1.

\* Highlighted sub-catchments are those determined by SCA as a priority sub-catchment.

# Recommendations

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- 1 That the review of the SWCM Act consider extending the frequency of the Catchment Audit to five years. Consideration should also be given as to the potential for rationalising catchment audit processes within the Catchment as natural resource management frameworks evolve.
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## Minimising contamination of raw water supply

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- 2 That SCA develops a catchment model for the purpose of estimating nutrient pollution loads (based on land use) for each sub-catchment.
  - 3 That SCA identifies the cause of exceedence of the Bulk Water Supply Agreement for pH and algae at Cascade and Greaves Creek water filtration plants.
  - 4 That SCA identifies the cause of the 'high' incidences and long duration of algal blooms in its storages.
  - 5 That SCA further investigates the reason for oocysts of *Cryptosporidium* detected at low-levels at the inlet to Prospect water filtration plant between October and December 2001.
  - 6 That SCA investigates the source of *Cryptosporidium* and *Giardia* oocysts and cysts measured at Gibbergunyah Creek.
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## Managing water resources

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- 7 That DIPNR expands research into the impact of different levels of extraction of water from rivers and the harvesting of water in farm dams on ecosystems and flow regimes within the Catchment in order to establish sustainable extraction levels and to guide resource allocation and management.
  - 8 That DIPNR develops and implements a monitoring plan and reporting requirements that provide reliable information on groundwater extraction within the Catchment.
  - 9 That DIPNR expands research to establish and refine estimates of sustainable yields from groundwater systems within the Catchment.
  - 10 That DIPNR and SCA expand research to better understand the interaction between surface and ground water systems within the Catchment.
  - 11 That DIPNR develops and implements appropriate mechanisms to enable the reliable reporting of environmental flows for relevant sub-catchments.
  - 12 That DIPNR initiates an investigation of the management of large flows during transfers under the SCA Water Management Licence to minimise impacts on the health of the ecosystem.
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## Protecting and improving land condition

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|----|--|
| 13 | That SCA prepares a detailed land use map for program planning purposes. The resolution and categorisation used for this map should be sufficient for robust nutrient export and erosion modelling.                                      |
| 14 | That relevant agencies commission the development of methods and tools to indicate the effectiveness of management practices applied to reduce water impacts from different land uses, for use in nutrient export and erosion modelling. |
| 15 | That SCA sets specific time frames for progressing and completing risk assessment and management processes for activities identified as 'sites of pollution and potential contamination'.  |
| 16 | That programs addressing soil erosion in the Catchment demonstrably target areas with high estimated erosion rates.  |
| 17 | That DIPNR in conjunction with SCA develops a land degradation map incorporating land use and land management for erosion risk management and future audit reporting.  |
| 18 | That DIPNR and SCA investigate the development of a methodology to identify and report on areas of land affected by salinity.  |
- 

## Maintaining and enhancing ecosystem health

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- |    |  |
|----|--|
| 19 | That SCA adopts 300 $\mu\text{S}/\text{cm}$ as a practical conductivity trigger value for compliance monitoring of lakes and reservoirs in its Water Quality Monitoring Program.   |
| 20 | That SCA reviews its water quality monitoring program to ensure that appropriate ecosystem water quality monitoring is undertaken in areas of the Catchment identified by other indicators as subject to environmental stress.   |
| 21 | That a monitoring and management strategy for fish stocks in the Catchment be developed.   |
| 22 | That Riparian Management programs undertaken by government agencies in the Catchment be funded and integrated to achieve Catchment-wide mapping and aid in increasing the amount of riparian vegetation in a good or near intact condition.  |
| 23 | That SCA creates an integrated database to allow monitoring and assessment of all works undertaken that affect the quality of riparian vegetation and streambank stability.  |
| 24 | That SCA undertakes vegetation mapping in conjunction with DIPNR and the Department of Environment and Conservation (NSW) for the remaining areas of the Catchment with the priority being given to areas of native vegetation. This mapping should be consistent with the mapping undertaken of the Special Areas and include information on disturbance and condition. |
| 25 | That SCA ensures that mapping of riparian and native vegetation is appropriately integrated to ensure full compatibility of data.  |
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# Chapter 1

## Introduction

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### 1.1 Terms of reference for the audit

The *Sydney Water Catchment Management (SWCM) Act 1998* requires that a catchment audit of the state of the Sydney Drinking Water Catchment area be undertaken every two years. The Catchment covers over 16,000 square kilometres. It extends from the north of Lithgow south to the source of the Shoalhaven River near Cooma, and from the Woronora River in the east to the source of the Wollondilly River west of Goulburn. To facilitate the selection of management options to improve water quality and the health of the catchment the Sydney Drinking Water Catchment has been divided into 28 sub-catchments (see Figure 1.1).

The Act also requires that a report of the audit be submitted to the Minister for the Environment (being the Minister administering the Act). The primary purpose of the audit is to provide guidance for the management of the Sydney Drinking Water Catchment by reporting catchment health indicators and identifying trends (where data is available).

The Minister commissioned the Environment Protection Authority (EPA)\* in July 2003 to undertake the 2003 audit and issued it with the following terms of reference with the requirement to submit the Audit Report by 30 November 2003:

1. Audit and report on the catchment consistent with current methods used for the purpose of New South Wales' state of the environment reporting, focusing on the priority sub-catchments.
2. As part of the audit, consult with stakeholders within and outside the catchment to seek information and data that may assist with the audit and to seek comments relating to the state of the catchment.

### 1.2 Application of pressure-state-response model to the audit

The Terms of Reference for the audit requires the use of a state of the environment 'pressure-state-response' (PSR) model for reporting its findings. The PSR model has been developed as an approach to understand the condition or health of large complex environmental systems where problems are either difficult to observe or ascribe to specific causes.

PSR is an appropriate model to use for a catchment audit especially for an area as large and diverse as the Sydney Drinking Water Catchment. Specifically it provides a framework for systematically reporting the state of the environment. This approach, which has been adopted by most State and Territory governments, not only attempts to describe the state or condition of the environment but also to identify the pressures that have caused, or are still causing problems, and the implications of these for the wider environment. This approach also broadly describes governmental and societal responses to deal with those problems and highlights significant gaps.

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\* The Department of Environment and Conservation (NSW) is a new State Government department which was created on 24 September 2003. It brings together the Environment Protection Authority (EPA), the National Parks and Wildlife Service (NPWS), Resource NSW and the Royal Botanic Gardens and Domain Trust, and also links with the work of the Sydney Catchment Authority (SCA).

## Indicators

The primary challenge in using the PSR model is to develop an agreed set of indicators that describe key features of the system under investigation and where possible describe how important attributes are behaving through trend analysis. As the problems that are identified by a catchment audit have generally emerged over long time frames (often over many decades) and will take considerable time to fully resolve, using indicators that can be efficiently collected over long periods to provide robust trend analyses are particularly important. This will enable trends to be documented and changes identified against the baselines (once established).

A key focus of this audit has therefore been the development of a set of core indicators that will provide effective headline information to guide the management of the Catchment. In considering indicators for the audit the following were taken into account:

- the objectives of the SWCM Act
- indicators used and/or proposed by previous catchment audits by the CSIRO (1999, 2002)
- Review of the Catchment Audit Framework - Sustainable Investment Research Institute (SIRIS) (2003)
- Catchment Indicators for the Sydney Catchment Audit – CRC for Freshwater Ecology (1999)
- monitoring currently undertaken by Sydney Catchment Authority (SCA) for various reporting requirements
- indicators used/proposed and monitoring being undertaken for related natural resource management frameworks including National Monitoring and Evaluation Working Group and Catchment Blueprints
- draft NSW *State of Environment Report 2003* indicators.

In selecting a suite of indicators there is often a temptation to broaden the number of indicators used to gain a comprehensive understanding of the environmental systems that are being reported on. However the experience of previous and current audits is that there are significant limits and gaps in the data sources available to generate indicators. In proposing a methodology for future audits, the CSIRO in its 2001 audit reviewed the applicability of the biophysical indicators it had recommended in its 1999 audit for relevance (see CSIRO 2002, pp. 168–171). This review suggested combining several indicators and dropping others that had a primarily operational focus. The effect of these suggestions was to reduce the number of proposed indicators to 26.

The *Review of the Catchment Audit Framework* (SIRIS, 2003) cautioned against further expansion of the indicators for the audit including recommending against the adoption of social and economic indicators. It also recommended that the audit task be clearly focused on the state of the land constituting the Catchment.

The auditors support this view and consequently have sought to identify a minimum set of indicators that would provide a coherent understanding of the condition of the Catchment across two key objectives:

- protection of water quality
- protection of ecosystem health.

The approach taken was to identify themes that address the key elements of these objectives (four themes were chosen) and then relevant pressure and state indicators were selected from the sources referred to above, to optimise the alignment between the audit's indicators and those used for other purposes. Similar to the approach taken by the CSIRO in its 2002 report, the audit team sought to minimise duplication and further consolidate indicators. Through this process 17 indicators were identified for potential use.





A draft outline of the report themes and proposed indicators was made available to stakeholders. Comments received were considered in the finalisation of the themes and the 16 indicators used for the audit. Table 1.1 outlines the themes and indicators used by the audit, and shows whether the indicator is used by the 2001 Audit Report, the SCA's Annual Report or the draft NSW State of the Environment Report 2003. Details regarding the themes and the indicators are provided in the relevant chapters of this report.

### **1.3 Audit methodology**

#### **Scope**

The audit has focused on developing and reporting on indicators related to the state of the Sydney Drinking Water Catchment to guide responses by all relevant stakeholders. The audit has not attempted to set response indicators nor to do an operational assessment or evaluation of programs referred to in the audit.

There are other processes more appropriately set-up for the assessment of programs. Similarly the audit has primarily focused on issues within the Catchment area and has not sought to address issues such as water demand management external to the Catchment (see section 1.6).

#### **Review of documentation**

The SCA provided the audit with a large range of background material to support its task, including the reports of the 1999 and 2001 Catchment Audits conducted by the CSIRO. This material was used extensively by the audit team and provided a strong foundation for developing the Audit Plan and preparing this Report. A full list of material provided to the Audit by the SCA is provided at Appendix B.

#### **Conduct of the audit**

A work plan was prepared outlining key steps for the audit process including:

- scoping the project
- selecting core indicators (see section 1.2)
- identifying information needs and gathering data to prepare indicators
- consultation with stakeholders including requesting specific information and data for the audit analysis (see section 1.4)
- inspection of the Catchment area
- collecting, processing and analysing the available data to prepare the indicators and actions and response sections
- reviewing quality assurance and quality control processes for main data provided to the audit (see Appendix C)
- identify data, knowledge and response gaps
- develop options for addressing these and draft findings and recommendations for the report.

#### **Assessment of data used in the audit**

The audit did not directly collect primary data for this report. Rather, it deliberately set out to use existing datasets so that wherever possible it could report on the condition of the Catchment over the audit period. This generally involved the audit requesting agencies (primarily SCA) to prepare specific

analyses of databases to provide input to the indicators. A number of different processes were used to test the reliability and integrity of such data and analysis. These include:

- reviewing datasets used for analyses and seeking explanations of anomalies or gaps
- comparing data/analysis to relevant independent sources
- reviewing internal audit reports for specific datasets.

Stakeholders that provided information and data to the audit were provided with a draft of the relevant part of the report to provide an opportunity to comment on the accuracy of use of that information. A list of these stakeholders is provided at Appendix D.

## **1.4 Consultation**

A key component of the audit was consultation with stakeholders. The audit used a variety of mechanisms to seek input from stakeholders ranging from a broad invitation to submit relevant information and comments, to direct contact and meetings with key stakeholders to help gather information and data to assist the conduct of the audit.

Submissions were invited from interested parties through a notice in the press (in *The Sydney Morning Herald* and 20 regional papers) and letters to key stakeholders including state and local government agencies, industry and non-government organisations and members of SCA's consultative forums. Twenty-three submissions were received: 12 from State Government agencies (including the Hawkesbury–Nepean Catchment Management Board), four from local government, three from non-government groups, two from industry and two individual responses. A full list of organisations who made submissions to the Audit is provided at Appendix E.

**Table 1.1 Themes and indicators for the audit report**

Minimising contamination of raw water supply		2001 CA	SCA AR	2003 SoE	Managing water resources		2001 CA	SCA AR	2003 SoE	Protecting and improving land condition		2001 CA	SCA AR	2003 SoE	Maintaining and enhancing ecosystem health		2001 CA	SCA AR	2003 SoE
<b>2.1 Nutrient loads</b> Loads from point and diffuse sources by land use	P	✓	✓	✓ 5.4	<b>3.1 Surface water extraction</b>	P	✓		✓ 5.2	<b>4.1 Changes in land use</b> Extent and type of land use in the catchment area and any changes	P	✓	✓	✓ 4.1	<b>5.1 Ecosystem water quality objectives</b> Exceedence of ANZECC guidelines	S		✓	✓ 5.5
<b>2.2 Raw water quality criteria</b> Operating requirements for water filtration plants	S		✓		<b>3.2 Ground water extraction</b>	P	✓		✓ 5.8	<b>4.2 Sites of potential contamination</b> Progress of risk assessment and management process	P				<b>5.2 Macro invertebrates</b> AusRivAS health rating	S	✓	✓	✓ 5.1
<b>2.3 Algal blooms</b> Incidence of toxic and non toxic algal blooms	S	✓	✓	✓ 5.7	<b>3.3 Environmental flow objectives</b>	S	✓	✓	✓ 5.3	<b>4.3 Soil erosion</b> Erosion hazard map	S	✓	✓	✓ 4.2	<b>5.3 Fish</b> Fish populations in streams and storages	S	✓		
<b>2.4 Pathogens</b> Occurrence of <i>Cryptosporidium</i> and <i>Giardia</i>	S	✓	✓							<b>4.4 Salinity</b> Salinity hazard map	S	✓	✓	✓ 4.3	<b>5.4 Riparian</b> Extent and condition of riparian vegetation	S	✓	✓	
															<b>5.5 Native vegetation</b> Extent and condition of native vegetation	S	✓	✓	✓ 6.1

P – Pressure Indicator      S – State Indicator

2001 CA – Catchment Audit 2001 (CSIRO)

SCA AR – SCA Annual Environment Report 2001–02

2003 SoE – draft *NSW State of the Environment Report 2003* – indicator numbers refer to draft NSW SoE 2003 Indicators (May 2003)

## 1.5 Report on recommendations of 2001 audit

The 2001 Audit made 31 recommendations covering a very broad range of issues. This audit has taken careful account of these recommendations and where appropriate has made reference to specific recommendations within relevant sections of the report. A summary of the recommendations, the key issues they raise and the level of response since the 2001 audit are outlined below. The recommendations from the 2001 audit have been divided into the following categories so that wherever possible they are grouped within the themes presented in this report. Therefore categories 2 to 5 correspond to the themes presented in Chapters 2 to 5 respectively. The 2001 audit recommendations, as numbered in the report, have been categorised as follows:

Category name	2001 Audit recommendation
1. Integrated catchment management – institutional arrangements	1, 6, 25
2. Minimising contamination of raw water supply	13, 14, 15, 16, 17, 22
3. Managing water resources	10, 11, 12, 24, 28
4. Protecting and improving land condition	4, 5,
5. Protecting and enhancing ecosystem health	8, 9, 18, 19, 20, 21, 23
6. Audit structure and synthesis of information	2, 3, 7, 31
7. Other issues	26, 27, 29, 30

### Progress against the 2001 recommendations

#### Integrated catchment management – institutional arrangements

Integrated Catchment Management was covered by three recommendations in the 2001 audit which made specific recommendations regarding institutional arrangements for managing the Catchment. Institutional arrangements clearly influence the ease in which appropriate responses to the catchment issues are developed and implemented. However there are a multiple of options of institutional arrangements to address the issues confronting the Catchment with a variety of strengths and weaknesses. Given that new institutional arrangements relating to catchment management have only recently been announced this Audit has not addressed the responses to these recommendations. It should also be recognised that good catchment outcomes will only be achieved by the cooperation of all stakeholders regardless of institutional arrangements.

#### Minimising contamination of raw water supply

Minimising contamination of raw water supply was featured by six recommendations in the 2001 audit. These recommendations covered two broad contamination issues. The first on microbial pathogens which required further research into detection, risk, behaviour and impact on water supplies, while the second highlighted the need for improved management of sewage treatment plants (STPs).

Progress on these recommendations have generally been positive with a number of research projects having been initiated in response to the audit recommendations. Disease surveillance studies undertaken during and after the 1998 outbreak of *Cryptosporidium* found no evidence of increases in gastroenteritis cases. Hence the recommendation for an epidemiological study into reported gastroenteritis cases in relation to wet weather

events was not actioned because it was unlikely to provide any conclusive results. Increased emphasis was placed on the priority and monitoring of STP compliance and the management of the consequences of compliance failure.

The actions and responses to minimising contamination of raw water supply from various diffuse and point sources including pathogens and STPs are also outlined in Chapter 2 – Actions and Responses.

### **Managing water resources**

Managing water resources was covered by five recommendations in the 2001 audit which covered improvements to water resource data collection, assessment of environmental impact and improving the efficient use of water resources.

There has been little action on improving the collection of data on water flows or extractions from surface water or groundwater. Although the 2001 audit attributed this task to the SCA, this is more appropriately a responsibility of the Department of Infrastructure, Planning and Natural Resources (DIPNR). This audit has made similar recommendations regarding the need to address these issues. There has been some progress on the issue of undertaking baseline surveys in waterways potentially affected by longwall coalmining. (See also a broader discussion of mining related issues in Chapter 4).

### **Protecting and improving land condition**

Protecting and improving land condition was referred to by two recommendations within the 2001 audit. The issue of progressing the risk assessment and management process for potentially polluted sites in a more systematic manner is also the subject of a recommendation from this audit (see Chapter 4).

### **Protecting and enhancing ecosystem health**

Protecting and enhancing ecosystem health was featured by seven recommendations in the 2001 audit. These recommendations covered improved monitoring and assessment of native vegetation, habitats and water quality across the entire Catchment and development of management plans to restore and protect the ecological value of Special Areas and riparian zones.

While there has been progress on the water quality monitoring, gaps still exist (see Chapter 5). Monitoring and assessment of native vegetation and habitats has undergone a scoping study assessment but as yet no decision has been made towards on-ground actions. There has also been development and implementation of management plans for Special Areas. A comprehensive riparian strategy has been developed by the SCA however it is still in its assessment stage.

### **Audit structure and synthesis of information**

Audit structure and synthesis of information was featured by four specific recommendations in the 2001 audit. These recommendations cover the frequency and structure of the audit, integration, analysis and interpretation of existing data and the inclusion of social and economic indicators into the terms of reference of future audits.

There is a strong argument that once core water quality and catchment health indicators have been committed to, and baseline data established for trend analysis, the frequency of the state of the catchment audit should be reduced because of the small changes in ecosystem conditions that could be expected to be shown in under a five-year period. There has however only been limited progress in developing core water quality and catchment health indicators, and related trend analyses. This audit has therefore particularly focused on developing a core set of indicators for measuring catchment health for use in the future audits.

It is important to consolidate the information collection that would result in the relevant information being available for indicator analysis. Responsibility for the collection of specific data most appropriately lies with the agency charged with managing that issue (e.g. surface water quality data should be collected by SCA

while surface and ground water extraction data should be collected by DIPNR). As discussed in section 1.2, the *Review of the Catchment Audit Framework* (SIRIS, 2003) recommended against the adoption of social and economic indicators.

As noted above under 'Integrated catchment management', the Government has recently announced new institutional arrangements for catchment management. At the time of the audit enabling legislation for these reforms (i.e. Native Vegetation Bill 2003, Catchment Management Authorities Bill 2003 and the Natural Resources Commission Bill 2003) were before Parliament. It is anticipated that among other functions these reforms will create catchment audit processes which could potentially duplicate the requirements under the SWCM Act.

**Recommendation 1:** That the review of the SWCM Act consider extending the frequency of the Catchment Audit to five years. Consideration should also be given as to the potential for rationalising catchment audit processes within the Catchment as natural resource management frameworks evolve.

### Other issues

The final group of recommendations primarily related to the management of cultural and heritage sites and the SCA's internal management practices. As outlined above the audit has not considered these issues.

## 1.6 Relationship of the audit to other government processes

In addition to the Sydney Drinking Water Catchment audit there are a number of audit and review processes that examine various aspects of the Catchment's management and health, and the supply of drinking water to Sydney and Illawarra areas. These include:

- **Audit of SCA's Operating Licence** – This process which is undertaken by the Independent Pricing and Regulatory Tribunal (IPART) includes an annual audit, a mid-term review (May 2003), and an end-term review (June 2005). These audits establish the SCA's operational compliance in regard to: memoranda of understanding with key agencies, customer supply, bulk water quality, catchment management and protection, management of catchment infrastructure and its environment plan.
- **Audit of SCA's Water Management Licence** – This process, undertaken by DIPNR, includes an annual audit of the SCA's Water Management Licence issued under Part 9 of the *Water Act 1912*. The major objective in licensing the SCA is to manage its access to water resources within its area of operations.
- **Statement of Intent (SOI) Audits undertaken by the Healthy Rivers Commission (HRC) for the Hawkesbury–Nepean, Georges River/Botany Bay, and Shoalhaven River catchments** – This process involves an audit two years after the release of the SOI to report on the progress of the general and specific principles and strategies endorsed by the government on river specific issues.
- **Hawkesbury–Nepean River Management Forum (HNRMF) and Independent Expert Panel** – As part of the Government's response to the Hawkesbury–Nepean River Inquiry by the HRC, the HNRMF was established. The purpose of the HNRMF is to examine and recommend environmental flow release strategies downstream of the Sydney Catchment Authority's dams to enhance the environmental quality of the river for their inclusion in the SCA's Water Management Licence. The HNRMF is supported by the Independent Expert Panel which was appointed by the Government. It's anticipated that the HNRMF's report will address the sustainability of Sydney's water supply, demand management, inter catchment transfers, water efficiency targets, effluent re-use and environmental flows.

The audit has sought not to duplicate the core work of these processes and has focused reporting on the health of the Sydney Drinking Water Catchment, consistent with its terms of reference.

## 1.7 Stakeholders roles and responsibilities for the health of the Catchment

The SWCM Act established the SCA with specific powers and responsibilities with respect to the management of the Catchment. However there are a diverse range of organisations and communities who also have significant roles and responsibilities that impact upon the state of the Catchment. A list of these and their roles and responsibilities is provided in Appendix F.

In addition to other State agencies including the recently announced Catchment Management Authorities, councils have an important role as environmental managers. Local businesses, landowners and residents generally can also have a significant impact through their day-to-day decisions.

It is important to acknowledge that in many instances the overall environmental outcomes for the Catchment are a culmination of smaller decisions by multiple stakeholders.

## 1.8 Independence of the audit

In July 2003, the Minister for the Environment asked the EPA to undertake an audit of the state of the land within the Sydney Drinking Water Catchment area. *The Sydney Water Catchment Management Act 1998* requires an audit to be conducted every two years by a person nominated by the Minister for the Environment. The two previous audits were undertaken by the CSIRO in 1999 and 2001. On 24 September 2003 the Minister and the Premier established the Department of Environment and Conservation (NSW), incorporating the staff of the EPA. While the SCA continues as a separate statutory authority, a new close linkage between the new department and SCA was established.

The EPA initially instituted the following structural arrangements to preserve the independence and transparency of the audit:

- Tony Wright, as Deputy Chairperson of the EPA Board and Chairman of the State of the Environment Advisory Council, was invited to review the Audit Report and to confirm the independence and integrity of the audit process. In particular, he was invited to confirm that the audit had appropriately reviewed the EPA's own roles and responsibilities as a regulator operating within the Catchment.
- A project manager was appointed to the then Policy, Economics and Environmental Reporting Branch to undertake the audit to ensure that the audit was independent of any regulatory role of the EPA for activities within the Catchment area. A project team was established drawing significantly from the Environmental Science Branch as well as on the expertise of other areas of the EPA as required. The project team operated at 'arms-length' from the relevant regulatory staff.
- An internal Steering Committee was established to oversight the preparation of the audit comprising senior staff from relevant areas of the Department to ensure all aspects of the audit were undertaken transparently.

Following the establishment of the Department of Environment and Conservation (NSW) the Steering Committee for the audit reconsidered the Audit Report review and approval process and confirmed that the previously established process of review by Tony Wright continued to provide appropriate review of the independence of the Audit Report. The Report was jointly endorsed by Mr Tony Wright and Mr Simon A Y Smith (Chair of the Steering Committee) and forwarded to the Minister for the Environment.

## **1.9 Audit Team**

Mr Michael Crowley, Senior Project Manager

Mr Greg Howarth, Environmental Project Officer

Dr John Chapman, Director Ecotoxicology and Water Science, Policy and Science Division

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Dr Peter Scanes, Manager Catchment Processes Unit, Water Science

Mr James Smith, Environmental Scientist, Water Science

Mr Graham Turner, Remote Sensing GIS Specialist, Remote Sensing GIS Service

## **1.10 Audit Steering Committee**

Mr Simon AY Smith, Acting Deputy Director General Environment Protection and Regulation

Dr Klaus Koop, Executive Director Environmental Science

Ms Barbara Richardson, Director Waters and Catchment Policy

# Chapter 2

## Minimising Contamination of Raw Water Supply

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### Key Points

Indicator	Status of Indicator
2.1 Nutrient load	<p>Agriculture and sewage treatment plants (STPs) are major sources of nutrients within the Catchment.</p> <p>Significant re-use of grey water in Goulburn appears to be responsible for a significant reduction in nutrient loads from the Goulburn STP.</p>
2.2 Raw water quality requirements for water filtration plants	<p>Raw drinking water generally meets the requirements of Sydney Water and NSW Health. There was however, an increase in the number of exceedences of the criteria in the Bulk Water Supply Agreement for some parameters.</p>
2.3 Algal blooms	<p>The incidence of toxic Cyanobacteria blooms increased slightly from the previous audit.</p> <p>There is continued high incidence and long duration of cyanobacteria blooms indicating high levels of nutrients in some parts of the storage system (i.e. upstream of the water filtration plants).</p>
2.4 Pathogens	<p>The incidence of <i>Cryptosporidium</i> and <i>Giardia</i> have not changed significantly from the previous audit and remains generally low with some exceptions.</p> <p>There is continued high incidences of <i>Cryptosporidium</i> and <i>Giardia</i> at Gibbergunyah Creek.</p>

### Pressures in the Catchment

The raw water in the Sydney Drinking Water Catchment is generally of good quality and meets most applicable guidelines. However, significant pressures to water quality exist from point and diffuse sources of pollution. Point sources include discharges from sewage treatment plants (STPs), and other licensed activities such as mining. Diffuse sources, which contribute to the majority of pollution loads in the Catchment, include urban stormwater and rural runoff. Pollution from these sources are driven by population growth and land utilisation.

Population growth in urban areas puts pressure on waste water management, often forcing the need for upgraded infrastructure, and increases the amount of urban stormwater. Population growth in rural areas can result in increased on-site sewage treatment which, if not well managed, can add to the diffuse pollution loads. Population growth can also drive the intensification of land use, which increases land clearing, runoff and ultimately more contamination of the water supply.

The performance of the STPs in the Catchment vary, and upgrades at some of these are necessary to deal with the increased loads. The successful management of STPs, such as pollution reduction programs and wastewater re-use, has great potential to reduce the amount of pollution and nutrients reaching the catchment's rivers and streams. Improved management of urban runoff, or stormwater, which is traditionally piped straight to waterways, is increasing with urbanisation and will also have a positive effect on water quality.

There are large areas of agriculturally productive land in the Catchment, which have had much of the native vegetation removed. When it rains, water readily moves directly from cleared or farmed land to a water body, and takes whatever particles it can dislodge with it. Rural runoff can carry large amounts of sediment and nutrients into rivers and creeks. If there are areas of bare soil or reduced riparian vegetation, the amount of material mobilised into the water body is increased. Other pollutants in rural runoff include pesticides and pathogenic material from areas with livestock. The condition and role of native vegetation in protecting the water supply is dealt with in Chapter 5.

Sites of pollution and contamination due to industrial and commercial activities in the catchment are another source of contamination of raw water, and these are dealt with in Chapter 4 as a land management issue.

## **2.1 Nutrient load**

### **Background**

Nutrients, in small amounts, are required for plant growth, however, in large amounts they can cause excessive algal growth in waterways. This can put natural ecosystems out of balance, thereby affecting the health of the waterways. The main sources of nutrients in rivers include runoff from urban areas, erosion and runoff from grazing and cultivated land, tail water from irrigation areas, river and stream bank erosion and point source discharges.

Point sources discharge a variety of pollutants to aquatic environments, including nutrients. Nutrients can also be used as an indicator of general pollution. The point sources include STP discharges, urban stormwater drains and other industrial outfalls. Point sources have potential to cause severe long-term impacts on water quality, the ecosystem and human health. Rivers that receive large volumes of STP effluent may be prone to increased eutrophication and algal blooms.

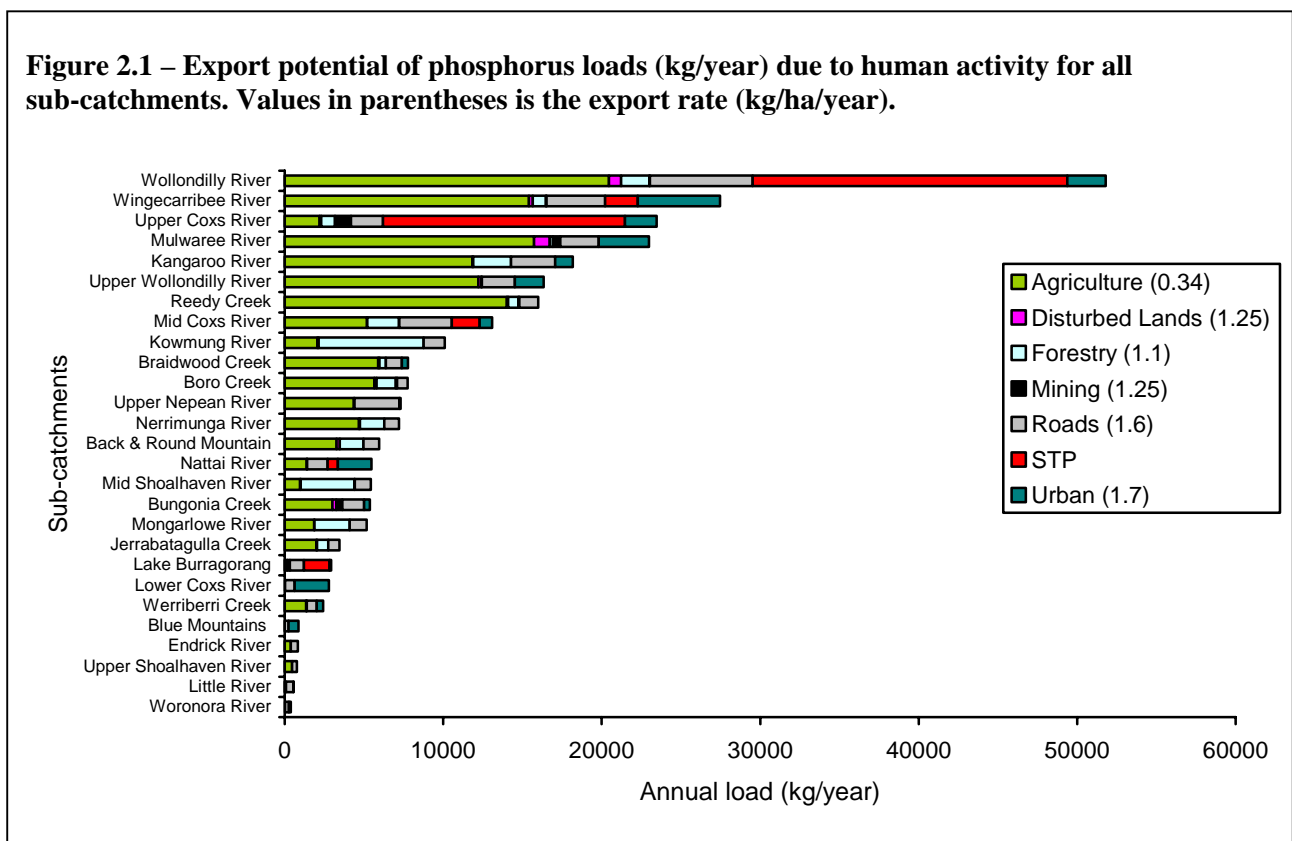
As the performance of large point sources improves understanding the relative contribution of different point and diffuse sources is important in guiding the next phases of nutrient reduction programs. Catchment modelling for nutrient loads can provide valuable information on potential hot spots and have been effectively used in the South Creek Catchment.

It was not possible to develop the detailed inputs required for such modelling within the time available for this audit. However, the audit team worked with SCA to develop specific approaches to estimating the annual nutrient loads for each sub-catchment based on extrapolating nutrient export rates for land use types from other studies. Land use classes were derived from land cover categories shown in Chapter 4, Figure 4.2.

## Findings

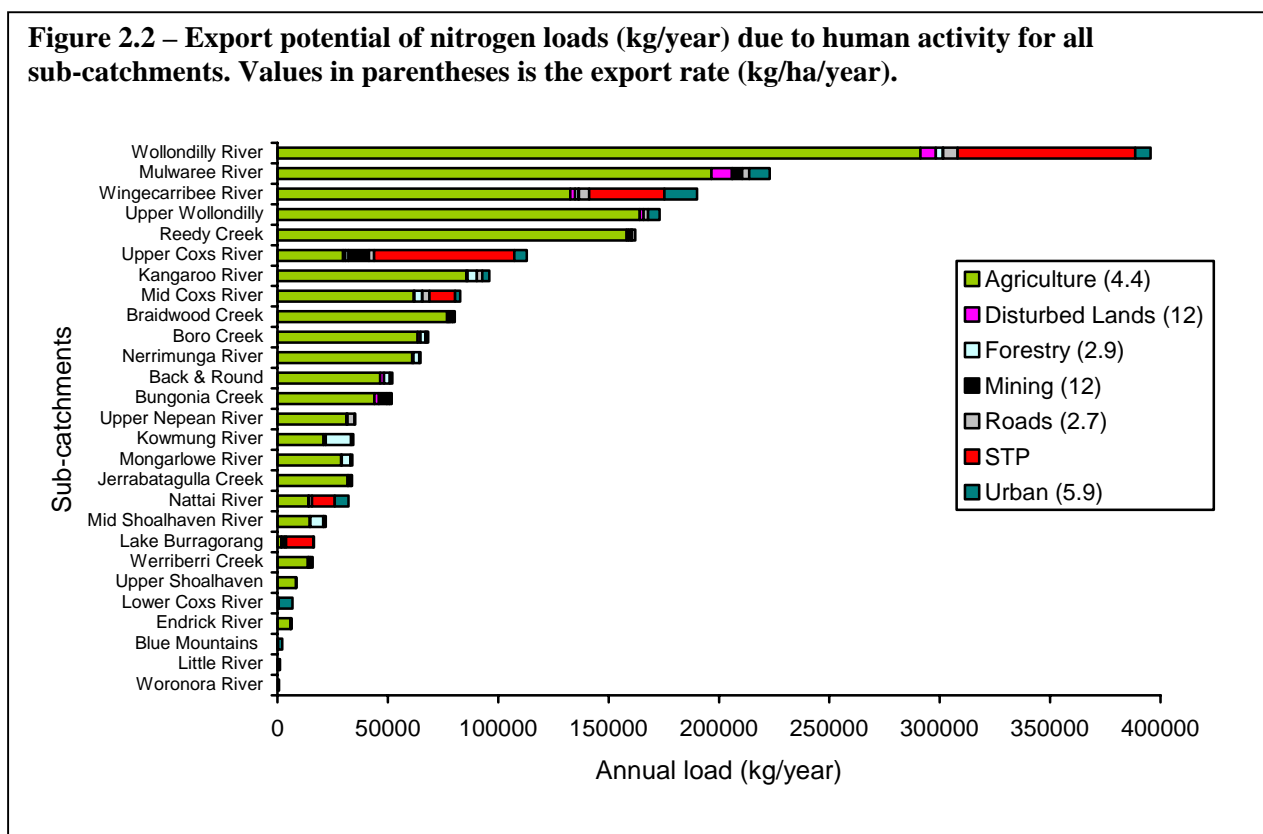
Figures 2.1 and 2.2 present estimates of annual phosphorus and nitrogen export potential due to human activity from each sub-catchment for 7 land use categories (i.e. in excess of exports from natural land cover). Agriculture is estimated to be the largest source of phosphorus and nitrogen within the Catchment. STPs were also a significant contributor of phosphorus and nitrogen in the Wollondilly River and Upper Coxs River sub-catchments. The top 5 sub-catchments with the greatest export potential of phosphorus loads were Wollondilly River, Wingecarribee River, Upper Coxs River, Mulwaree River and Kangaroo River sub-catchments (Figure 2.1). The top 5 sub-catchments with the greatest export potential of nitrogen loads were Wollondilly River, Mulwaree River, Wingecarribee River, Upper Wollondilly River and Reedy Creek sub-catchments (Figure 2.2).

The generation rates of phosphorus were greatest in agricultural areas particularly in the Reedy Creek and Mulwaree River sub-catchments (Figure 2.3). The generation rates of nitrogen had similar hot spots to phosphorus, however, there were also hot spots of nitrogen generation in urban areas (Figure 2.4). In addition to the Reedy Creek and Mulwaree River sub-catchments, the Upper Wollondilly River and Wingecarribee River sub-catchments are important for nitrogen generation.



**Note:** Data prepared by SCA to the specifications requested by the audit.

**Figure 2.2 – Export potential of nitrogen loads (kg/year) due to human activity for all sub-catchments. Values in parentheses is the export rate (kg/ha/year).**



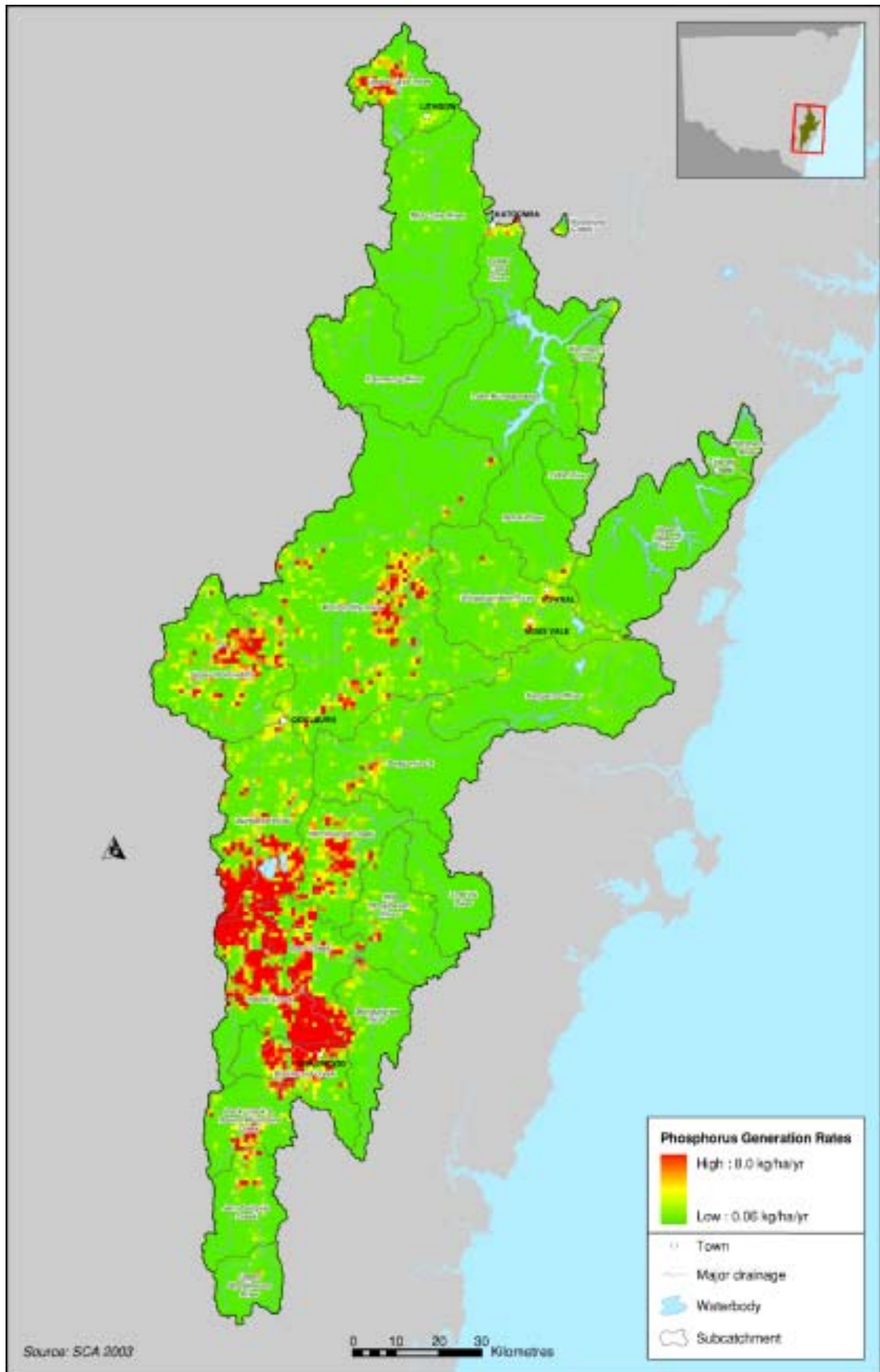
**Note:** Data prepared by SCA to the specifications requested by the audit.

### Sewage treatment plants (STPs)

As indicated in Figures 2.1 and 2.2 STPs are the major point source discharges of nutrients within the Catchment. There are currently 11 municipal STPs in the Catchment: Bowral, Lithgow, Moss Vale, Bundanoon, Goulburn, Warragamba (Marulan), Berrima, Braidwood, Braemar, Wallerawang and Mount Victoria. Warragamba (Marulan) discharges treated effluent outside of the Catchment, however bypasses and overflows can occur within the Catchment. The Mittagong STP was decommissioned in 2001 and replaced by the Braemar STP, and the discharge points remained unchanged. The STPs are operated by the relevant councils and regulated by the EPA<sup>1</sup>. The EPA licensing system contains data on the actual loads of nitrogen and phosphorus for the Bowral, Lithgow, Moss Vale, Bundanoon, Goulburn and Warragamba STPs that have been used to generate Figures 2.5 and 2.6.

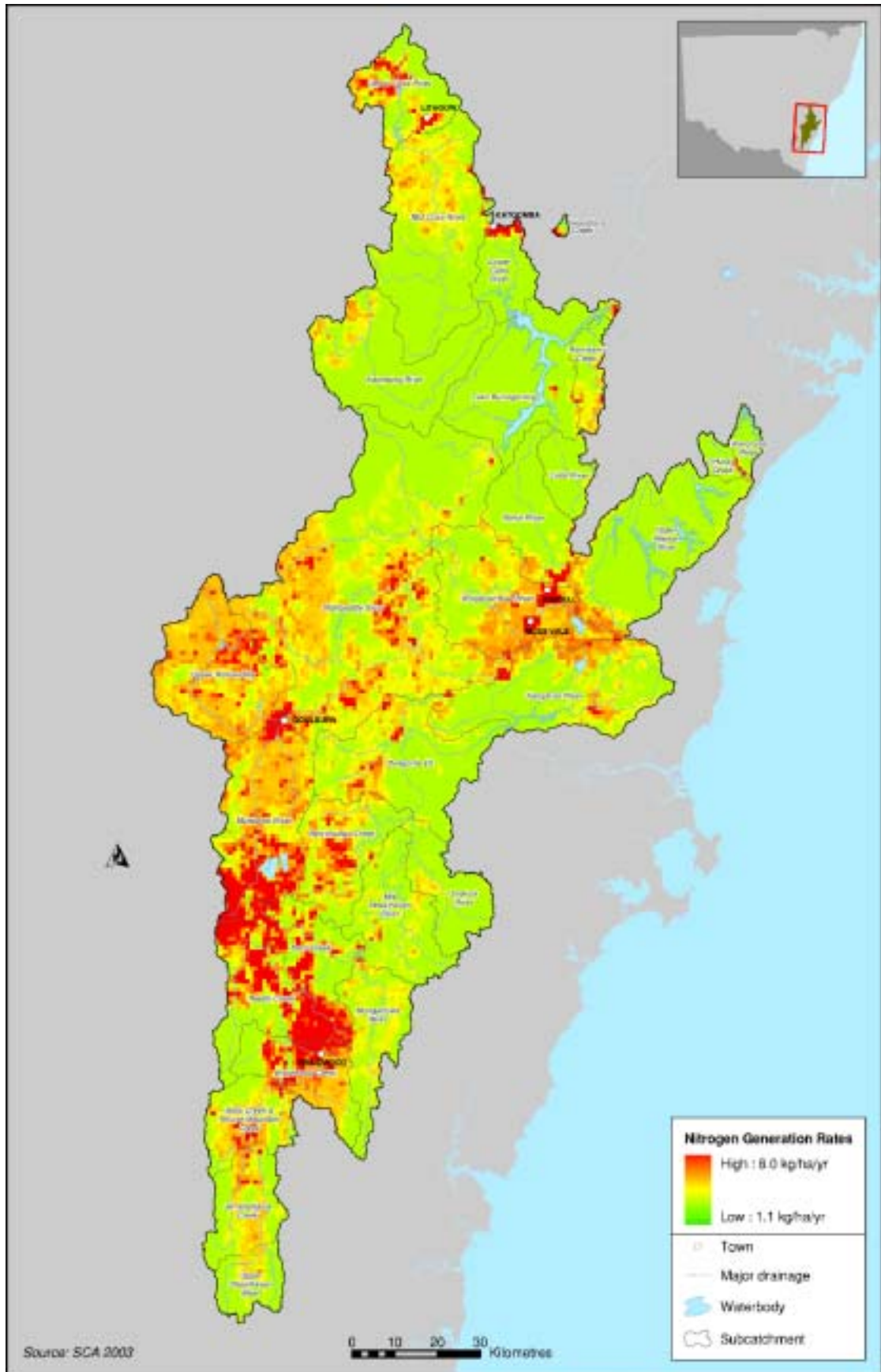
The loads of nitrogen discharged from the Lithgow, Moss Vale, Bundanoon, Goulburn and Warragamba STPs decreased from the previous year (Figure 2.5). The load of nitrogen at the Bowral STP increased from the previous 2 years (Figure 2.5). Similar to the load of nitrogen, the load of phosphorus at the Moss Vale, Goulburn and Warragamba STPs decreased over the past year (Figure 2.6). In contrast to nitrogen, the load of phosphorus decreased at the Bowral STP and increased at the Lithgow STP (Figure 2.6).

<sup>1</sup> Notwithstanding the establishment of the Department of Environment and Conservation (NSW), certain statutory functions and powers, including those of the *Protection of the Environment Operations Act 1997*, continue to be exercised in the name of the EPA, a statutory body created by the *Protection of the Environment Administration Act 1991*. Staff employed by the Department of Environment and Conservation (NSW) provide services to the EPA to exercise its statutory functions including authorised or enforcement officer powers.



**Figure 2.3 – Modelled generation rates of phosphorus (kg/ha/year) within the Sydney Drinking Water Catchment (excluding point source discharges)**

**Note:** Modelled export rates for land cover/land use were averaged within 1km<sup>2</sup> grid cells.



**Figure 2.4 – Modelled generation rates of nitrogen (kg/ha/year) within the Sydney Drinking Water Catchment (excluding point source discharges)**

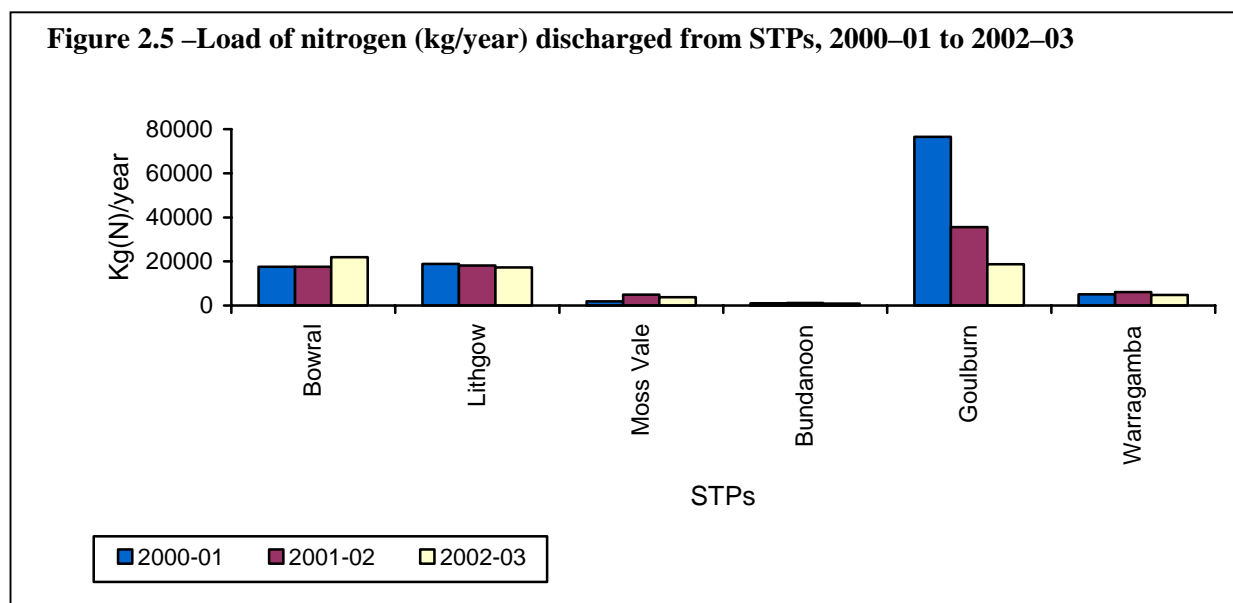
**Note:** Modelled export rates for land cover/land use were averaged within 1km<sup>2</sup> grid cells.

The large decrease in the loads of nitrogen and phosphorus from the Goulburn STP is primarily due to a significant drop in throughput at the STP. It is believed that in response to long-standing water restrictions, residents in Goulburn are re-using an increasing proportion of their grey water with a resulting drop in the volume of sewage being discharged.

All effluent is released directly into waterways, except at the Goulburn STP which uses the effluent for irrigation at a number of licensed discharge points. There are also 12 small package STPs within the Catchment which are not licensed by the EPA. There was no information available to indicate the effectiveness of the environmental management of these plants.

In the Sydney Drinking Water Catchment area there are 10 sites where biosolids are applied to land and 10 sites where effluent is irrigated. There was no data available to indicate the effectiveness of environmental management of these sites. The point source discharge sites within the Catchment are indicated in Figure 2.7.

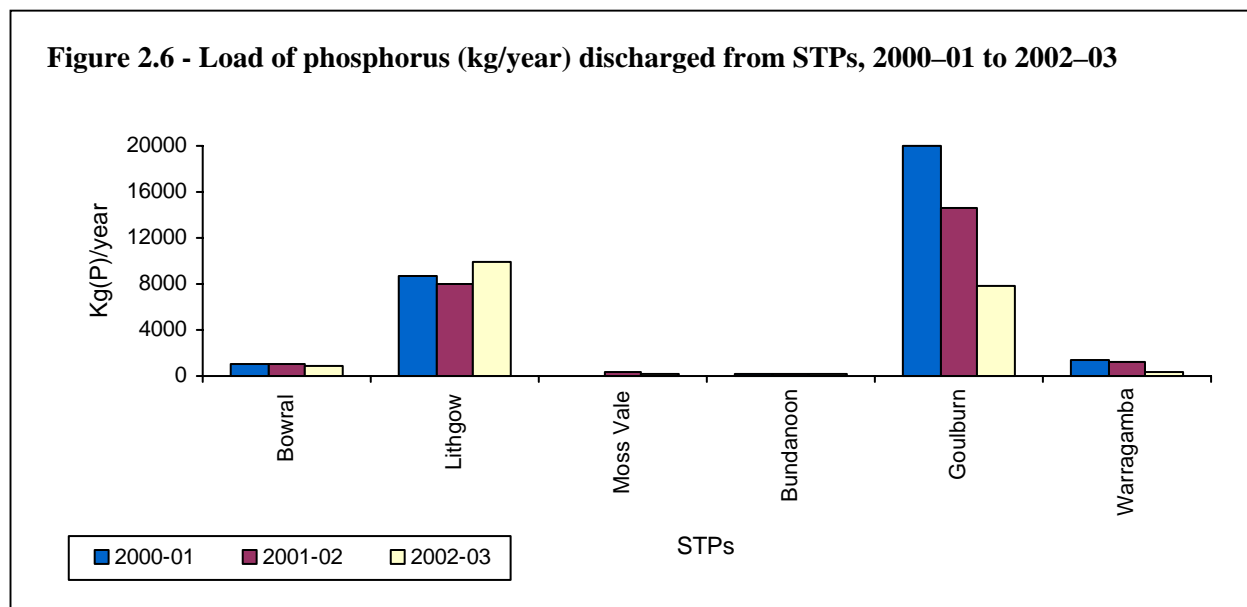
In May 2002, the Environmental Science Branch of the EPA conducted a series of toxicity tests on effluents collected from Lithgow and Moss Vale STPs. The tests comprised acute toxicity tests with the Australian cladoceran (waterflea) *Ceriodaphnia dubia*, an alga (*Pseudokirchneriella subcapitata*), and a bacterial test (Microtox®). The waterflea is sensitive to pesticides and other chemicals and the algae to some herbicides. Of the 15 samples tested over two weeks, only one sample showed any toxicity; a single sample from Moss Vale STP was toxic to the waterflea. No toxicity to the algae or bacterium was detected. It was not possible to determine the cause of toxicity in this single sample.



**Source:** EPA licensing database

**Note:** Goulburn STP effluent is irrigated and is not discharged to water.

**Figure 2.6 - Load of phosphorus (kg/year) discharged from STPs, 2000–01 to 2002–03**



**Source:** EPA licensing database

**Note:** Goulburn STP effluent is irrigated and is not discharged to water.

Sewerage systems have designed overflow points that stop sewage from backing up into homes and businesses when a sewer is overloaded. A number of sewage bypasses and overflows occurred at the following STPs during the current audit period. Between 2001–02 and 2002–03, the Bowral STP consistently had wet weather bypasses over the audit period, and within the Goulburn sewerage system there were 7 overflows (manhole discharges) (Table 2.1). There was an increase in the number of overflows within the sewerage system in the period between 2002–03 compared to the previous year. The Goulburn STP has a 600ML storage pond designed to receive overflows. Bowral STP’s licence includes a PRP to manage overflows (see case study on the Bowral STP).

**Table 2.1 – Number of discharges of untreated sewage from licensed STPs during the audit period**

Licensed STP	2000–01		2001–02		2002–03	
	Bypass	Overflow within sewerage system	Bypass	Overflow within sewerage system	Bypass	Overflow within sewerage system
Braemar		2 x transfer main				1 x manhole discharge 1 x break in sewer main
Bowral	1 x wet		2 x wet		2 x wet	1 x pumping station
Berrima						1 x pumping station
Braidwood						2 x manhole discharge
Goulburn						1 x pumping station 7 x manhole discharges 1 x effluent from irrigation area
Mittagong	1 x dry 1 x wet			1 x pumping station 2 x access point		
Moss Vale			1 x wet			1 x manhole discharge

**Source:** SCA data, as at 2003

## Unsewered villages

There are a number of villages (Figure 2.7) within the Sydney Drinking Water Catchment that have no sewerage service and are served by on-site effluent management systems such as septic tanks. Unsewered villages have been identified as key sources of pollution threats to drinking water quality. It is estimated that there are 8,951 unsewered properties in urban areas in the Warragamba catchment and 2,984 such properties in the Shoalhaven catchment (SCA 2003a).

Equivalent population (EP) estimates for 2001 show that these villages vary in population size up to 1,767 (Table 2.2). Goulburn, Marulan, Mt Victoria, Woodford and Blackheath have STPs, however there are significant numbers of residences that have on-site systems. There are also a number of houses owned by the SCA within the Upper Nepean River sub-catchment at the Cordeaux, Cataract, Avon and Nepean Dams which are unsewered.

**Table 2.2 – Equivalent population (EP) estimates for 2001**

Village	EP estimate	Village	EP estimate
Balmoral	165	Nattai	ND
Belimba Park	543	Nerriga	ND
Burrawang	235	Oakdale	1044
Buxton	1509	Penrose	169
Exeter	369	Robertson	1191
Fitzroy Falls	ND	Sutton Forest	218
Hartley	ND	Tarago	ND
Kangaloon	ND	Taralga	382
Kangaroo Valley*	1320	The Oaks	1767
Majors Creek	ND	Wingello	264
Medlow Bath*	750	Yerranderie and Quigtown	ND
Mongarlowe	ND	Yerrinbool	927

**Source:** CH2MHILL 2001

**Notes:** ND – Not Determined, but significantly below 200 EP.

\*Values quoted in table are peak summer loadings.

## Case Study – Bowral STP

Bowral STP is located in the Wingecarribee River sub-catchment, one of five STPs in Wingecarribee Shire, and services about 10,500 people. Bowral STP, along with two other STPs in the Shire, use outdated treatment technologies and are overloaded. The EPA and SCA have been working with Wingecarribee Shire Council for some years to achieve an upgrade of the Bowral STP.

The EPA negotiated a Pollution Reduction Program (PRP) requiring the council to either decommission or upgrade the plant by 1 July 2001. This PRP was not achieved and a new PRP was negotiated. The new PRP also required council to complete a risk assessment of overflows from its sewerage system and prepare a prioritised action plan to address identified risks to public health and the environment by 1 August 2006.

The current PRP for the Bowral STP specifies that the plant must be upgraded to increase treatment levels and capacity by 1 October 2004.

The most recent *Protection of the Environment Operations Act 1997* (POEO Act) licensing information available records two non-compliances for the 2001–2003 period. Bowral STP discharges exceeded the total phosphorus concentration limit (2 mg/L) twice during high storm flows and exceeded the BOD concentration limit (20 mg/L) twice due to algal growth in a tertiary pond. The EPA advises that no enforcement action was taken against these specific non-compliances, because of the planned upgrade specified in its PRP and the progress that has been made on the current program.

To date the council has met the milestones in the PRP. However, the council has indicated that due to delays in the approval of works that it will have difficulties completing the upgrade by the due date. The EPA has not agreed to extend the PRP at this stage but will review progress over the coming months.

## Implication

Large export loads of phosphorus and nitrogen were estimated from agricultural areas in the Wollondilly River, Wingecarribee River, Mulwaree River, Kangaroo River, Upper and Mid Coxs River sub-catchments. Two sewerage systems are of concern regarding overflows: Bowral and Goulburn in the Wingecarribee River and Wollondilly River sub-catchments respectively. The sewerage systems are being examined and management options progressed by the councils, the EPA and SCA. A large number of unsewered villages are found in the Kangaroo River and the Mid Coxs River sub-catchments.

These nutrient loadings due to human activity can contribute to algal problems and nuisance plant growth which affect raw water quality as well as ecosystem health. Impoundments such as dams, can exacerbate the problem because they slow the flow of water and create favourable conditions for algal growth. In the context of this audit, algal problems include failure to meet algal criteria in raw water delivered to some water treatment plants (see Section 2.2) and potentially toxic cyanobacteria blooms occur within the Catchment (see Section 2.3).

Findings highlight the need to insure good agricultural practices including preservation or establishment of riparian zones (see also Section 5.4), the potential for reducing nutrient loading from STPs by encouraging re-use, and the scope to reduce un-controlled releases of nutrients and other pollutants from sewerage systems.

A better understanding of the magnitude and pattern of delivery of nutrient loadings is required to further optimise management strategies to reduce nutrient loads and mitigate impacts.





## Future directions

As mentioned earlier (2.1 Background), more sophisticated catchment modelling of nutrient loads from the Sydney Drinking Water Catchment is necessary to guide an effective nutrient reduction program. Such a model would incorporate a better definition of land use, simulation of runoff in response to rainfall patterns across the Catchment and a thorough review of relevant nutrient export data.

**Recommendation 2:** That SCA develops a catchment model for the purpose of estimating nutrient pollution loads (based on land use) for each sub-catchment.

## Target

A reduction in the export of nutrients to waterways within the Catchment from human activities.



**Figure 2.8 – An example of increased beneficial reuse of effluent, Goulburn abattoir reuses its water to irrigate holding paddocks. Foreground shows irrigation area, August 2003.**

# State of the Catchment

## 2.2 Raw water quality requirements for water filtration plants

### Background

Water filtration plants (WFPs) are an important part of a multiple barrier approach to improve drinking water quality (SCA 2003). These barriers include catchment management, storage management, water filtration, distribution, and integrated water quality management. The level of contaminants in raw water supplied to the WFPs is monitored by SCA so as to optimise the quality of raw water supplied to minimise treatment costs. It should not be expected that raw water in storages will meet drinking water quality standards. However, the most cost effective provision of good drinking water will be a balance between ensuring good quality raw water and the application of water treatment technologies.

Site-specific raw water quality guidelines for each WFP (Prospect, Warragamba, Orchard Hills, Macarthur, Nepean, Illawarra, Woronora, Cascade and Greaves Creek) owned by Sydney Water are outlined in the operating licence and the Bulk Water Supply Agreement (BWSA) (Table 2.3). The parameters that were selected for the audit were turbidity, colour, manganese, pH and algae. These parameters were selected as they are important for the delivery of quality drinking water and effective operation of the WFPs.

**Table 2.3 – BWSA water quality guidelines**

WFP	Turbidity (NTU)	Colour (CU)	Manganese (mg/L)	pH	Algae (ASU/mL)
Cascade	15	60	0.25	6.0 – 7.4	1000
Greaves Creek	40	60	1.00	4.4 – 9.2	1000
Illawarra	10	48	0.37	6.15 – 7.2	5000
Macarthur	60	40	0.35	5.72 – 7.65	500
Nepean	183	60	1.45	4.80 – 7.65	1000
Orchard Hills					
Prospect	40	60	1.40	6.27 – 7.87	1000
Warragamba					
Woronora	11	70	0.07	5.06 – 7.54	5000

**Source:** SCA 2002

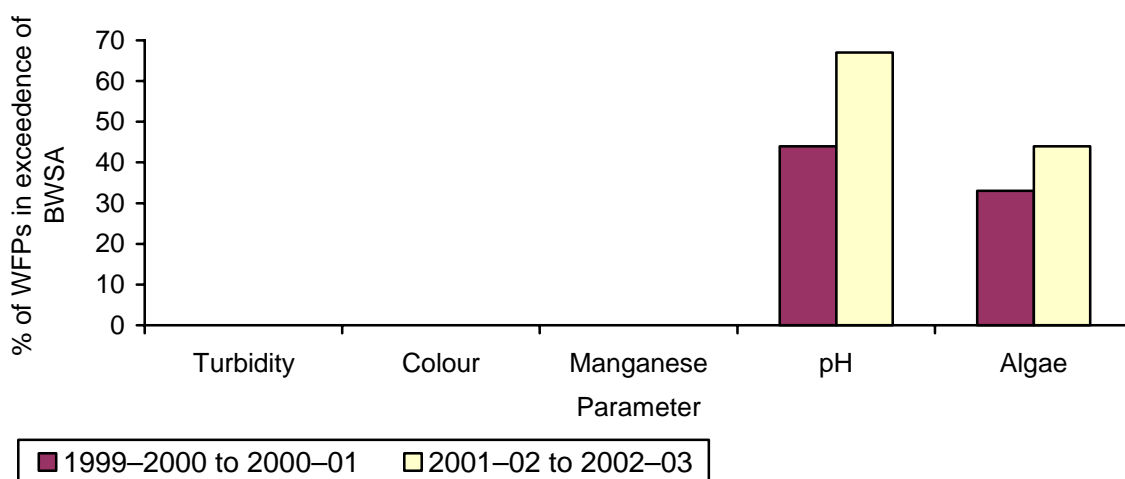
**Note:** All figures are maximum guideline limits, except for pH which is a range of guideline limits.

### Findings

The water supplied to a number of WFPs that exceeded the guidelines in the BWSA increased from the previous audit period for pH and algae (Figure 2.9). The guidelines for turbidity, colour and manganese were not exceeded by water supplied to any WFP. The percentage of samples of water supplied to each WFP that were outside the acceptable range of the BWSA for each parameter was in the 2–25% range (Table 2.4), except algae (54%) at the Greaves Creek WFP, and pH (31%) and algae (58%) at the Cascade WFP. At the Greaves Creek WFP and Cascade WFP the percentage exceedences were substantially increased from the previous audit period. Sydney Water advised that these exceedences did not cause difficulties with the quality of its supply to customers.

The audit also considered the results of monitoring at the WFPs under Schedule 4 of the SCA's Operating Licence. Schedule 4 covers impurities in the water (including heavy metals and pesticides) that may not be substantially removed or reduced through the water treatment process. IPART (2003) stated that SCA had full compliance with Schedule 4 from 2000–02 (Clause 6.2(a)).

**Figure 2.9 – Percentage of water filtration plants where raw water supplied exceeded BWSA guidelines for each parameter for the current audit period and the previous audit period**



Source: SCA 2003a

**Table 2.4 – Percentage of samples collected in exceedence of the BWSA for each parameter at WFPs**

WFP	Turbidity	Colour	Manganese	pH *	Algae
Cascade	0	0	0	31	58
Greaves Creek	0	0	0	0	54
Illawarra	0	0	0	6	0
Macarthur	0	0	0	11	3
Nepean	0	0	0	3	4
Orchard Hills	0	0	0	0	0
Prospect	0	0	0	19	0
Warragamba	0	0	0	0	0
Woronora	0	0	0	2	0

Source: SCA 2003a

Notes: Orange indicates exceedence of the BWSA by 50–75% and yellow 25–50%.

\* percentage of samples outside the guideline range

## Implication

Water quality during periods of low flow is known to be better than at times of high flow; in general, the likelihood of algal blooms increases as flow decreases. It is therefore important to identify the cause of the exceedences of the BWSA for pH and algae from water supplied to Cascade and Greaves Creek WFPs.

**Recommendation 3:** That SCA identifies the cause of exceedence of the Bulk Water Supply Agreement for pH and algae at Cascade and Greaves Creek water filtration plants.

## Target

Compliance with Bulk Water Supply Agreement for each parameter at all water filtration plants.

## 2.3 Algal blooms

### Background

Algal blooms are an indicator of high nutrient loads, or eutrophication. Algae can reproduce rapidly and form a bloom under favourable environmental conditions, such as high nutrient levels, reduced flow and high light penetration, for example, due to removal of riparian vegetation. Algal blooms give rise to a number of problems in waterways and water supply, including changes in dissolved oxygen concentrations resulting in the death of fish and other aquatic species, changes in pH, reduction of light penetration and the smothering of habitat. Algal blooms reduce the environmental values of water by limiting the potential uses of water resources and increasing the cost of treatment. They can also cause tainting of drinking water and disruption of filters and other operations. Blue–green algae, or cyanobacteria, are of particular concern as some species are potentially toxic and may cause skin irritations, gastrointestinal disorders and in extreme cases of prolonged exposure can result in permanent organ damage or death (SoE 2003). If the toxicity of the bloom is significant, the water becomes unusable for either drinking or other direct contact. Even at low concentrations some blue–green algae can impart strong tastes and odours to the treated water.

A bloom of total cyanobacteria was identified as a sample result with greater than 2000 cells/mL, as the NHMRC drinking water guideline identifies this level as requiring further action. The incidence of total cyanobacteria blooms is presented in Figure 2.10. A bloom of toxic cyanobacteria was identified as a sample result with greater than 500 cells/mL, as concentrations below 500 cells/mL are considered to be natural background levels. The incidence of toxic cyanobacteria is summarised in Figure 2.11. The frequency of SCA sampling varies from site to site. Sites are either sampled weekly, fortnightly or monthly. In summer some sites are sampled more regularly and *ad hoc* samples are also collected if a bloom is detected. Figure 2.12 presents an estimate of the duration of total and toxic blooms calculated. These estimates were based on data from 12 sites where weekly sampling was done. These locations were the sites labelled A, B, E, G, H, J, N, P, Q, X, AF and AG in Figure 2.10 (see Appendix G Table 1 for details of all locations).

### Findings

The incidence of all forms of cyanobacteria at sampling sites has not changed significantly from the previous audit period (Figure 2.10 and Appendix G Figure 1). Figure 2.10 shows three incidence categories high (>15000 cells/mL), medium (>2000<15000 cells/mL) and low (<2000 cells/mL). There were cyanobacteria counts above 2000 cells/mL in every sample taken from Lake Fitzroy Falls, Lake Cataract, Lake Burragorang 14 km upstream of the dam wall, 9 km upstream of Coxs River and at the Wollondilly arm 23 km upstream of dam wall and at the Wingecarribee Lake outlet (Figure 2.10 and Appendix G Figure 1). There were large increases in the incidence of total cyanobacteria at Lake Burragorang 14 km from the dam wall, Lake Yarrunga 100m from the dam wall, Upper Canal at the Prospect WFP, Broughtons Pass and Kenny Hill (Figure 2.10).

The number of incidences of toxic cyanobacteria increased from the previous audit period (Total Figure 2.11). The increase in total cyanobacteria did not correspond with increases in toxic cyanobacteria. Greater than 60 percent of total cyanobacteria incidences greater than 15000 cells/mL occurred at Bendeela-Pondage, Fitzroy Falls, Lake Burragorang, Wingecarribee Lake outlet and Lake Prospect (Yellow cells in Appendix G Table 1). Only two incidences of toxic cyanobacteria in the high range occurred in the current audit period, these occurred at Fitzroy Falls (Red cells in Appendix G Table 1).

Cyanobacteria blooms have also been recorded in the Algal Alert program at Farmers Creek in Lithgow, Pejar and Sooley Dams and Lake Lyell in the current audit period.

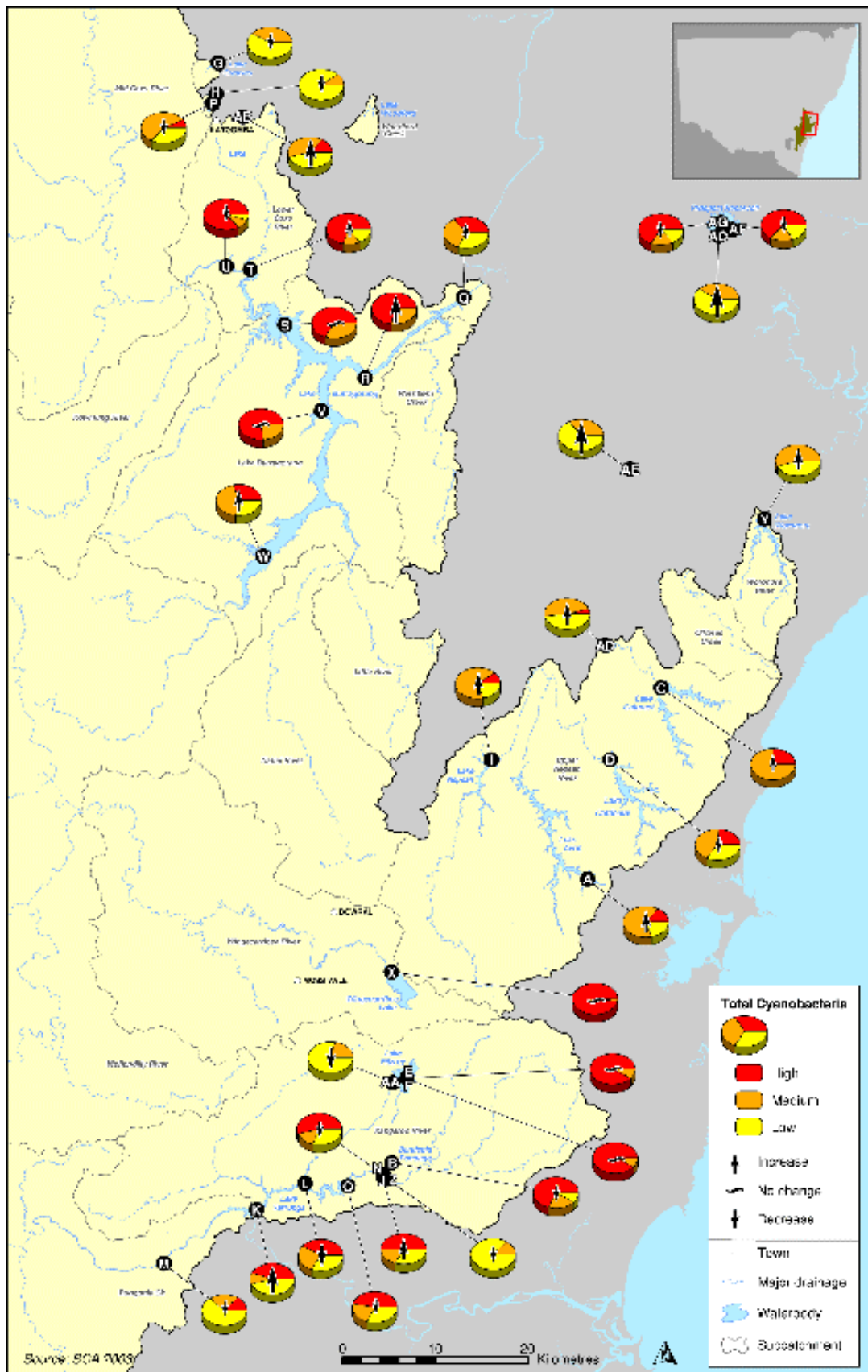
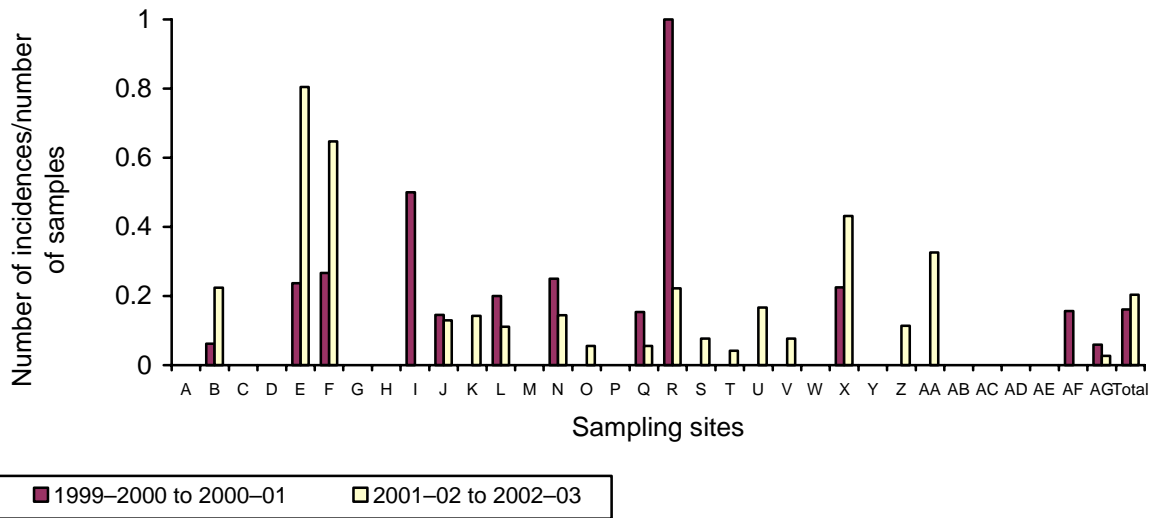


Figure 2.10 – Map of total cyanobacteria incidences in the high (>15000 cells/mL), medium (>2000<15000 cells/mL) and low (<2000 cells/mL) categories

**Note:** Change in the incidences from the previous audit period indicated by an arrow, the size of the arrow indicates the extent of change (see Appendix G Figure 1).



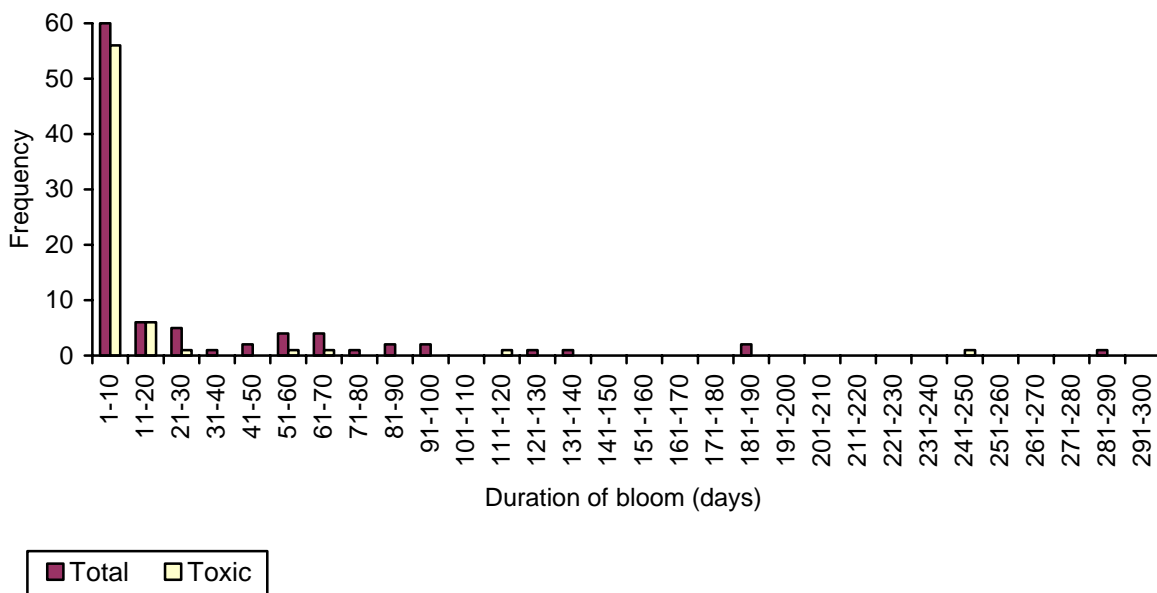
**Figure 2.11 – The number of incidences of toxic cyanobacteria per number of samples for the current audit period and the previous audit period**



Source: Generated from SCA algal sample dataset

The duration of most total and toxic cyanobacteria blooms was 1-10 days (Figure 2.12). There was a number of locations which had blooms that lasted greater than 100 days, and for total cyanobacteria these locations were Bendeela Pondage, Prospect reservoir and Lake Burragorang 500m upstream of the dam wall. For toxic cyanobacteria, Fitzroy Falls reservoir was the only location that exceeded 100 days in duration of the bloom.

**Figure 2.12 – The duration of total and toxic cyanobacteria blooms (days) in the current audit period, 2001-02 to 2002-03**



Source: Generated from SCA algal sample dataset

## Implication

The continued 'high' incidences and long duration of total and toxic cyanobacteria at Kangaroo River, Lake Burragarang and Wingecarribee River sub-catchments is of concern.

Algal blooms are triggered in various ways depending on the nature of the waterway and conditions in the Catchment. Nutrient inputs from catchment sources are clearly important, but other factors, such as turbidity of the water, internal nutrient cycling (i.e. nutrients regenerated from sediments) and stratification of the water are also important in triggering and maintaining algal blooms. Identifying the processes responsible for triggering and maintaining algal blooms in the "hot spots" will open up options for managing them and reducing their impact. A range of options is now available from disrupting stratification to reducing nutrient fluxes from sediments by clay capping, which can complement work on reducing inputs from the Catchment. In order to choose the best option the key processes driving blooms need to be identified.

The SCA will need to investigate the causes of the 'high' incidences and long duration of blooms in the sub-catchments identified in order to develop management strategies for these areas.

**Recommendation 4:** That SCA identifies the cause of the 'high' incidences and long duration of algal blooms in its storages.

## Target

Implement management plans which decrease the number of incidences of total and toxic cyanobacteria in the >15000 cells/mL category and decrease the duration of total and toxic cyanobacteria blooms.

## 2.4 Pathogens

### Background

There is potential for large amounts of pathogenic material to be mobilised during storm events and reach water storages. In order to assess the potential risk of pathogenic material, namely *Cryptosporidium* and *Giardia*, information is required on the presence of oocysts and cysts in the water supply.

*Cryptosporidium* and *Giardia* are pathogenic micro organisms which cause intestinal infections in humans. The micro organisms are transmitted among humans by means of cysts which are found in excreted faecal material. Consumption of water containing cysts is the principal method of contracting the disease (Braidech and Karlin 1985). Sources of these micro organisms include STPs, unsewered areas and native and domestic animals.

### Findings

There was little change in the number of incidences of *Cryptosporidium* and *Giardia* oocysts and cysts in the lakes, bulk supply and catchment streams between the two audit periods. There was one exception at the Prospect WFP where there was an increase in the incidence of *Cryptosporidium* oocysts in the low category from 0 to 2.7% of samples. The number of samples tested for *Cryptosporidium* and *Giardia* decreased by 20 – 40% in the current audit period compared to the previous audit period. This reduction followed agreement by NSW Health, Sydney Water and SCA through their Strategic Liaison Group and Joint Officer Group processes. The respective Ministers were subsequently advised. All incidences in the lake and bulk supply were in the low range of < 100 oocysts or cysts per 100L. A few locations had incidences of *Cryptosporidium* and *Giardia* in greater than 5% of samples collected, these were the upper canal at Prospect, Kowmung River at Cedar Ford, Kedumba River at Maxwells Crossing and Gibbergunyah Creek at the Mittagong STP (Red boxes in Table 2.5). There were a number of incidences of *Giardia* in the high and medium categories within catchment streams at Gibbergunyah Creek at the Mittagong STP and 1 incidence of *Cryptosporidium* in the medium category at Werriberri Creek at Werombi (Table 2.5). These incidences are similar to what was found in the previous audit period.

**Table 2.5: Percentage of incidences of oocysts of *Cryptosporidium* and cysts of *Giardia* in the high, medium and low categories, 2001–02 to 2002–03**

Code	Site	Number of samples	<i>Cryptosporidium</i>			<i>Giardia</i>		
			High	Medium	Low	High	Medium	Low
Q	Lake Burragarang at 500m upstream	631	0	0	0.5	0	0	0
X	Wingecarribee Lake at outlet	121	0	0	1.7	0	0	0.8
AC	Upper Canal at Prospect WFP	11	0	0	9.1	0	0	0
AD	Upper Canal at Broughtons Pass	100	0	0	0	0	0	0
AF	Lake Prospect at Midlake	208	0	0	0	0	0	0.5
AG	Lake Prospect near RWPS	202	0	0	2.0	0	0	0.5
AH	Prospect WFP	604	0	0	2.7	0	0	0.2
AI	Illawarra System	92	0	0	0	0	0	0
AJ	Blue Mountains System	96	0	0	2.1	0	0	0
CA	Coxs River at Kelpie Point	31	0	0	0	0	0	0
CB	Kowmung River at Cedar Ford	28	0	0	0	0	0	7.1
CC	Kedumba River at Maxwells Crossing	30	0	0	6.7	0	0	6.7
CD	Gibbergunyah Creek at Mittagong STP	27	0	0	14.8	18.5	37.0	18.5
CF	Nattai River at Smallwoods Crossing	22	0	0	0	0	0	0
CG	Little River at Fire Road	24	0	0	0	0	0	0
CL	Wollondilly River at Jooriland	31	0	0	0	0	0	3.2
CM	Werriberri Creek at Werombi	94	0	1.1	2.1	0	0	0
	All samples	2352	0	0.04	1.5	0.21	0.43	0.60

**Notes:** High – (>1000 oocysts or cysts per 100 L); Medium – (>100<1000 oocysts or cysts per 100 L); Low – (<100 oocysts or cysts per 100 L). See Appendix G Table 1 for details of all locations.

## Implication

There was an increase in oocysts of *Cryptosporidium* at the inlet to Prospect WFP. The reason for this increase has not been conclusively identified by SCA. Advice was sought from Associate Professor Nick Ashbolt from the University of NSW and scientists from Sydney Water. It was concluded that the levels detected did not present an on-going health risk. While this incident was not significant from a health perspective, its proper investigation is warranted to aid the development of appropriate responses. Based on the information available to the audit, it appears that the investigation has not yet fully considered all available information or documented its findings including any recommended response strategies.

**Recommendation 5:** That SCA further investigates the reason for oocysts of *Cryptosporidium* detected at the inlet to Prospect water filtration plant between October and December 2001.

There is also a continued high and medium incidence of *Cryptosporidium* and *Giardia* at Gibbergunyah Creek at the Mittagong STP outfall. Most of the high incidences were in waterways adjacent to urban areas. It is uncertain if the high incidences of *Cryptosporidium* and *Giardia* at Gibbergunyah Creek at the Mittagong STP outfall is due to the discharge from the STP. If due to the STP the levels detected could indicate an outbreak of infection in the area. The species of *Cryptosporidium* found in humans is

*Cryptosporidium parvum*. The species of *Cryptosporidium* detected at Gibbergunyah Creek needs to be identified to determine for certain if the discharge is from the STP.

**Recommendation 6:** That SCA investigates the source of *Cryptosporidium* and *Giardia* oocysts and cysts at Gibbergunyah Creek.

## Target

Implement management plans which reduce the percentage of incidences of oocysts and cysts of *Cryptosporidium* and *Giardia*.

## Actions and Response

### Response to issue

*The primary responses to reducing contamination of the raw water supply is to reduce the amount of the pollution entering waterways within the Catchment. Improving stream flow regimes, vegetation cover and riparian vegetation all contribute to reducing the impact of nutrients. These are dealt with in other sections. This section covers the major actions aimed at minimising pollution discharge into the rivers and streams of the Catchment. These include:*

- *programs to reduce pollution from major point sources*
- *programs to reduce pollution from diffuse sources.*

### Programs to reduce pollution from point sources

- The EPA regulates major point sources using licences with comprehensive requirements for pollution control, monitoring, reporting and audit. Pollution from small-scale activities is regulated by local government using powers such as notices and planning controls. Both the EPA and local government take enforcement action in cases of breaches of requirements or pollution incidents.
- The SCA aims to evaluate and manage the risks of those activities that are adversely impacting on water quality within the Catchment through the application of the Pollution Source Risk Management Plan (GHD 2000) and the Healthy Catchments Program (especially via the sewage strategy). Also under development is a framework for prioritising rectification action for existing impacting development and a Drinking Water Risk Management Plan which will guide management activities to minimise contamination of raw water supply. This in turn helps to prioritise necessary upgrades to sewage discharges, improvements to the quality of stormwater and other urban runoff issues within the Catchment.

### *Sewage effluent management*

There is a range of programs relating to the management of sewage effluent. These include:

- Septic Safe, a statewide partnership between the NSW Government and local councils to deliver improved management of on-site sewage management systems. Through Local Government regulation, Septic Safe provides education, support and supervision to landowners, to enable them to manage their systems so that they operate in accordance with health and environmental performance standards. Under the program, local government have developed sewage management strategies. The implementation of these strategies has included registration of the majority of on-site systems within the catchment, inspection of systems, and the issuing of approvals to operate.

- The SCA has provided assistance to Blue Mountains City Council in a pilot project to accelerate the roll-out of the council's implementation of Septic Safe. In addition, the SCA has provided assistance to Mulwaree Shire Council to educate residents in the most effective and efficient ways to manage their own on-site systems via a training package developed by the Institute for Sustainable Futures. The results of this program will facilitate councils in improved planning and impact assessment of decentralised sewage management in this sensitive catchment.
- Priority Sewerage Program identifies priority areas for sewerage system improvements from an environmental and human health perspective, within the Greater Metropolitan Region. Within the Catchment, Sydney Water is progressing the Werriberri Creek Priority Sewerage Program. This Program has been designed to capture effluent from the unsewered villages of The Oaks, Oakdale and Belimbla Park and transfer it through a carrier main to West Camden Tertiary Treatment STP which is outside the Sydney Drinking Water Catchment. Construction began in November 2001 with The Oaks and Oakdale already completed and Belimbla Park due for completion in 2004. This new infrastructure is designed to reduce nutrients and pathogens entering Werriberri Creek, reduce the incidence of overflows and illegal waste disposal at an estimated cost of \$39 million.
- Upgrade of municipal sewage treatment plants: as noted in the review of indicators (see 2.1), a number of STPs operated by councils within the Catchment are operating at well below best practice and require upgrades in capacity and technology. Through Pollution Reduction Programs (PRPs) issued by the EPA and funding support from the Department of Energy, Utilities and Sustainability's Country Towns Water Supply and Sewerage Program and the SCA's Accelerated Sewerage Scheme the NSW Government is working with relevant councils to implement the following upgrades:
  - Goulburn to purchase additional effluent irrigation lands, install irrigation equipment including installation of phosphorus removal facilities. The upgrade once completed will concentrate on sustainable agricultural re-use of effluent from the existing treatment facility and provide re-use opportunities within the City. Scheduled for completion by December 2005.
  - Lithgow to improve effluent quality through additional nutrient and ammonia removal, protect groundwater by sealing leaking storage lagoons and adding extra effluent storage capacity to reduce the incidence of storm water overflows. Scheduled for completion by September 2005.
  - Wallerawang to improve effluent quality through additional nutrient and ammonia removal. Scheduled for completion by September 2006
  - Bowral to improve effluent quality by reducing the level of nutrients discharged and to increase capacity of the plant to a population equivalent (PE) of 13,000. Scheduled for completion by June 2005.
  - Bundanoon to improve effluent quality through additional best practice nutrient and ammonia removal technology and expand capacity to a PE of 5,000. Scheduled for completion by June 2006.
  - Robertson to construct a new facility using best practice technology designed for PE of 2,000. Scheduled for completion by June 2006.
  - Kangaroo Valley to provide complete sewerage collection, treatment and disposal facility for PE of 2000. Scheduled for completion by December 2005.
  - Taralga to provide a new system in an unsewered town with PE of 600 that will then discharge to land. These works are on scheduled for completion by December 2004.

## Programs to reduce urban stormwater runoff pollution from diffuse sources

### *Stormwater runoff*

In 1998 NSW Councils were required to prepare and implement stormwater management plans for urban areas. This has contributed to significant improvements in the design and performance of stormwater controls in many of the new urban developments in the Catchment.

The upgrading of existing stormwater services, many with few or no controls, will be a long-term process. Funding to support the implementation of these plans in existing areas has been provided through the NSW stormwater Trust and SCA's Stormwater Improvement Program. For example SCA funding assisted in the installation of stormwater pollution control measures (sub-surface wetlands, sediment basin, pollution traps) and monitoring and community awareness campaign as part of the Wollondilly Council's multi-faceted stormwater management program to improve water quality in the Werriberri Creek near The Oaks.

### *Rural runoff*

State Government has allocated funds to help local government and other organisations manage rural runoff. Through this funding, rural runoff pollution is managed by:

- the Catchment Protection Scheme, a joint initiative between landholders, the SCA and DIPNR to provide financial assistance and professional advice to landholders trying to manage moderate to severe erosion, riparian zones and effluent runoff.
- the Best Practice Guidelines (BPGs) to maintain a strong, profitable agricultural sector at the same time as promoting environmentally sound practices that will assist in the protection of the long term provision of clean raw water collection from the Catchment e.g. *Best Practice Guidelines - Horticulture in the Sydney Drinking Water Catchment* (NSW Agriculture 2002).
- the Healthy Catchments Program (HCP), a framework for seven major strategies developed by the SCA to protect water quality and catchment health from both point and diffuse sources of pollution. This includes the rural lands strategy to identify, prioritise and manage impacts within the Catchment caused by priority industry groups, diffuse sources, rural waste disposal and water erosion.

### *Algae*

Monitoring – the SCA has a water quality monitoring program that includes specific assessments for the incidence and severity of cyanobacteria outbreaks. This program sets out the frequency and locations of compliance monitoring and the analytes to be measured at lakes within the SCA's area of operation. In addition to the routine monitoring regime the program specifies an increased monitoring frequency once trigger exceedence levels occur.

Contingency Plans – the Metropolitan/South Coast Regional Algal Coordinating Committee (RACC), which is chaired by DIPNR has the role of coordinating the response to algal blooms for recreational purposes in the Metropolitan/South Coast Region which includes the Sydney Drinking Water Catchment. The membership of RACC also includes representatives from NSW Health, Department of Environment and Conservation (NSW), NSW Agriculture, SCA, catchment management bodies, NSW Shellfish Quality Assurance Program, NSW Fisheries and local government.

The SCA and RACC have developed algal contingency plans. The primary aim of these plans is to assist in the effective management and control of algal blooms in order to minimise their impacts and provide adequate warning to the public. The plans outline various steps to be taken in the event of an algal bloom including determining the type of water body, the responsible agency, alert levels and the relevant actions.

### *Pathogens*

In response to the risk of contamination of raw water supplies with pathogens the SCA in collaboration with other research organisations has initiated research into the following:

- Movement of microbial pathogens – This has included the completion of the first phase of a research project into the movement of microbial pathogens using existing SCA data to develop a pathogen budget model for the Wingecarribee River sub-catchment pilot study area. The next phase due to be completed by mid 2004 will refine the model by using data specifically collected during wet weather events. This data will then be used to determine which variables drive the model through sensitivity analysis.
- Links between microbial and physico-chemical parameters – A research project entitled Fate and Transport of Surface Water Pathogens in Watersheds with an estimated budget of \$500,000 is due for completion in early 2004. One of its main aims is to characterise the physico-chemical interactions of key pathogen groups associated with sediment and organic matter in watersheds. In order to predict concentrations of *Cryptosporidium* and *Giardia* in water at various locations within and at the bottom of the sub-catchment. This project is being led by the Cooperative Research Centre for Water Quality and Treatment in collaboration with SCA, Melbourne Water, the Water Services Association of Australia and funded by the American Water Works Association Research Foundation.
- Impact of wet weather flows on movement of microbial pathogens – The SCA commissioned a separate study in 2002 to analyse and compare the contaminant loads during wet weather and dry weather using historic data from auto-samplers. There were indications during the pathogen modelling of Wingecarribee River sub-catchment that the presence of pathogens in water was moderately higher during wet weather compared to the dry weather period. This knowledge can be used to prioritise which sub-catchments, and which locations within those sub-catchments should be targeted for rectification actions.
- Development of innovative detection methods for pathogens in large volumes of water – The SCA completed a research project on the methodology to detect and quantify *Giardia* and *Cryptosporidium* in raw water with the University of NSW and Sydney Water. The project showed that the method currently being used by SCA is the best available method and that other large volume sample methods showed a poor level of detection and were not recommended.

## Effectiveness of response

A number of the initiatives to reduce pollution from STPs have failed to achieve earlier milestones despite being the subject of pollution reduction programs (PRPs) under Environment Protection Licences. These include:

- Bowral STP – Wingecarribee Council failed to meet the timeframe for the original PRP of 1 July 2001 for the upgrade of the STP. A new PRP has been negotiated requiring that the upgrade be operational by 1 October 2004. To date council has met the milestones in the new PRP however council has indicated that due to delays in the approval of the works that it will have difficulty completing the upgrade by the due date.
- Lithgow STP – Lithgow City Council has negotiated an extension of the PRP for the upgrade of this STP to 31 July 2004. It is anticipated that most of the new treatment processes required to achieve the PRP will be installed and operational by the due date.
- Wallerawang STP – Lithgow City Council has advised that it will not meet the due date of 31 December 2003 for the completion of the update of the PRP. The EPA is currently negotiating an extension of the timeframe for the PRP.

While Algae contingency plans have been developed at state, regional and local level, there is a need to adopt a more proactive strategy to reduce the incidence and severity of cyanobacteria outbreaks by identifying and mitigating activities within the Catchment that directly contribute to cyanobacteria in its waterways and storages. The SCA's *Cyanobacterial Risk Management Strategy* (May 2003) has identified the need to place more emphases on diffuse source to provide for long-term control of cyanobacterial risks. At present, the planning frameworks that integrate the long-term strategies, and the programs leading to their delivery, are still being developed.





# Chapter 3

## Managing Water Resources

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### Key Points

Indicator	Status of Indicator
3.1 Surface water extraction	Very little information is available on surface water extraction and its effect on the health of the Catchment.
3.2 Groundwater extraction	Very little information is available on groundwater extraction and its effect on the health of the Catchment.
3.3 Environmental flow objectives	SCA complied with environmental release requirements 99.7% of the time.  Environmental flow requirements within the Catchment need to be further developed.  The transfer of bulk water may be affecting the health of waterways within the Catchment.

### Pressures in the Catchment

Managing water resources in a sustainable way is essential for our long-term utilisation and for the health of ecosystems. Extraction of surface water and groundwater for human uses such as agriculture, drinking water and industry can place significant stress on the environment, and increasing demands for extraction increase the importance of sustainable management practices.

The major outcome from surface water extraction, and the associated weirs and dams, is the reduction and modification of a river's natural flows. Impacts of flow modification include:

- reduced volumes of water for the downstream environment
- reduced ability of the environment to cope with natural drought periods
- reduced variability of flow regimes, e.g. the flooding of riparian zones
- changes in the duration and timing of flow events
- creation of large, standing water bodies which are ideal for algal blooms
- degraded water quality (Chapters 2 and 5)
- loss of habitat connectivity, including physically blocking fish passage (Chapter 5)
- change in water temperatures (Chapter 5).

Groundwater extraction further modifies the catchment's hydrology, which impacts on groundwater dependent ecosystems, such as wetlands, and adds stress to many creeks and streams, which can be reliant on groundwater during dry periods. Groundwater is extracted for irrigation, industry and commercial purposes, but the majority of extraction is for stock and domestic purposes. The Southern Highlands is an area of increasing groundwater use due to generally good water quality in aquifers and current restrictions on surface water extraction.

Climatic variability, including rainfall and drought periods, should be reflected in the management of flow regimes and water extraction to provide sufficient environmental flows. Groundwater use can increase in drought periods in response to availability of surface waters, which may impact on groundwater dependent ecosystems.

Raw water is also often transferred in large amounts between areas and storages in the Catchment as part of SCA's management of raw water. These bulk water transfers can place significant stress on streams and creeks. The physical process of erosion and the rapid and extreme change in flow volume can adversely affect the riparian ecosystem.

### **3.1 Surface water extraction**

#### **Background**

The allocation of water is very important in Australia as rainfall is highly variable. The harvesting of surface water through farm dams or from direct extraction from waterways must be sustainable so that enough water is available to supply residences and to maintain healthy ecosystems. So that the water resource can be used in a sustainable manner, it is important to know both the amount of surface water that is extracted and the ecological impacts of different levels of extraction within the Catchment.

While the quantities of water extracted within the Catchment are modest compared to the 630 gigalitres extracted from the storages per annum for urban water supply, their importance lies in their location and timing. Water retained and extracted from the storages primarily impacts on the natural flows of the river systems below the dams. This is a major focus of the Hawkesbury–Nepean River Management Forum (HNRMF). Similarly, retention and extraction of water within the Catchment can impact on the flows required for local ecosystem health and therefore need to be appropriately assessed and monitored.

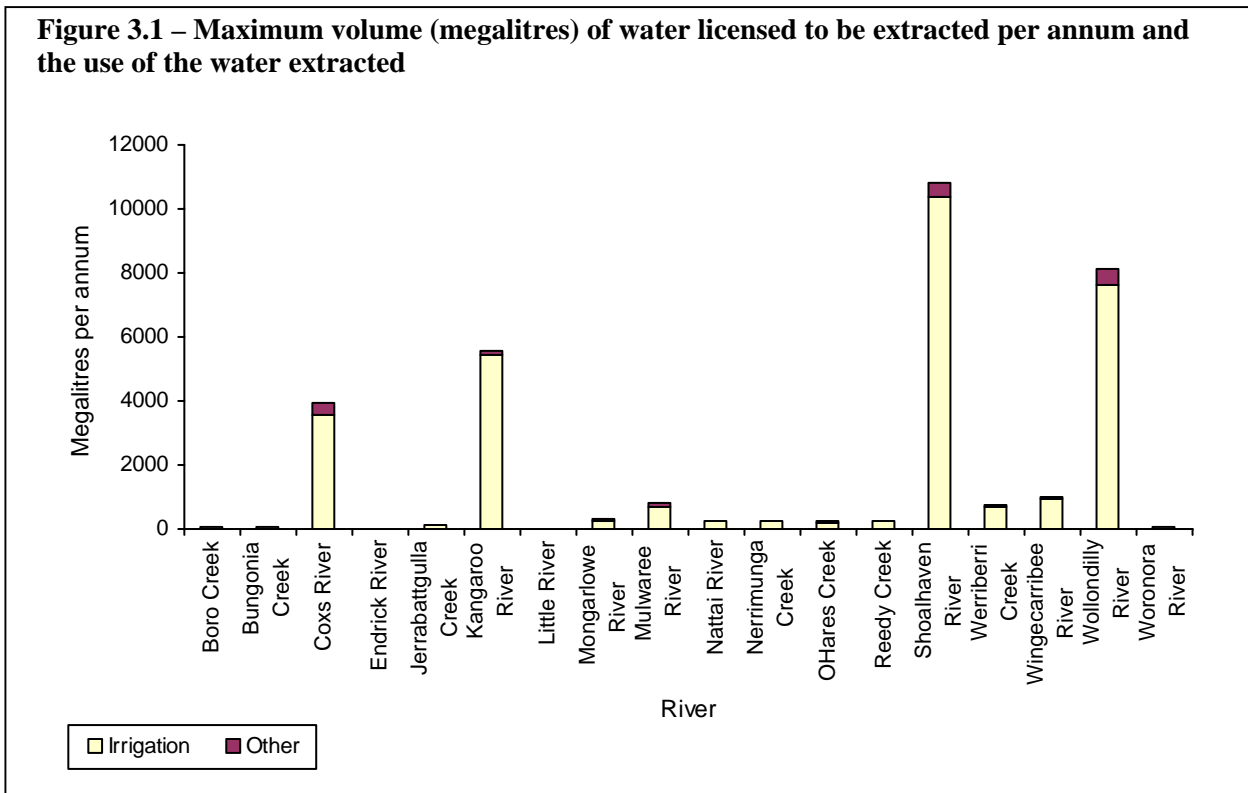
To extract water from rivers and streams beyond 'basic' land holder rights, an access licence must be obtained from DIPNR. These licences detail what the water is extracted for and the maximum volume that is to be extracted per annum. This information is summarised in Figure 3.1 below. However, the allocation of water in the licence may differ greatly from actual use as the volume of water extracted, in most cases, is not measured. Accurate measurements of volumes of water extracted will be available in the near future. DIPNR has issued notices to all water users requiring monitoring of all extractions. This will include time event monitoring of annual volumes exceeding 200 ML per annum, use of electricity consumption and pump calibration to estimate annual volumes between 20 ML and 199 ML per annum and the use of pump diaries for annual volumes 20 ML per annum.

From 1998 landholders right to harvest the runoff from their property without needing a licence, registration, fees or metering was limited to 10%. This is referred to as the 'harvestable right'. The harvestable right means that the water must be captured from the land and not extracted from rivers, streams or groundwater. There are also licence exemptions which include dams constructed for the control or prevention of soil erosion, dams constructed for runoff detention or flood mitigation, dams that capture contaminated waters and dams on very small properties. Figure 3.2 maps the location of all farm dams greater than 50 m in diameter using data from Landsat imagery. The green dots mark dams that were in place in 1990 and the red dots mark the dams that were built between 1990 and 2000.

## Findings

The greatest volume of water that is licensed for extraction within the Catchment is from the Shoalhaven, Wollondilly, Kangaroo and Coxs Rivers, with the majority of the water extracted used for irrigation (Figure 3.1). Less than 10% of water licensed for extraction from each river was for purposes other than irrigation, except at Mongarlowe River where 20% was for other purposes. These uses were town water, stock, railway, pisciculture, domestic, industry, mining, farming, high and low security recreation. Additional information see Appendix E Table 2.

The other major user of water within the Catchment is Delta Electricity which on average extracts almost 15,000ML per annum from the Upper Coxs River for the operation of Mt Piper and Wallerawang power stations.



Source: DIPNR data, as at 2003

Farm dams may indicate pressure on water quantity for ecosystem health within the Catchment as they intercept a significant proportion of surface flow from low and medium intensity rainfall events. In high rainfall events, which are the most important for filling the main reservoir, Lake Burrangorang, it is assumed that farm dams will overflow and do not retain the greater proportion of that flow.

There is a very large number of farm dams in the Upper Wollondilly River, Mulwaree River, Wingecarribee River and Werriberri Creek sub-catchments (Figure 3.2). The Nerrimunga Creek, Reedy Creek and Braidwood Creek sub-catchments also have a large number of farm dams. The sub-catchments that feed into Warragamba Dam have the higher concentration of farm dams than the other sub-catchments feeding storages. There was a 17% increase in the number of farm dams from 1990 to 2000 (Figure 3.2).

## Implication

There is growing demand for water within the Catchment primarily for agricultural purposes. The extent of this demand, its sustainability and impacts on local ecosystems is not well quantified.

There is a clear, well-established link between the volumes of water in the river and the health of aquatic ecosystems. Current data do not allow a solid assessment to be made whether water extraction from the river system, or water harvesting in farm dams have a detrimental effect on river health. However research undertaken by DLWC on the impact of farm dams on streamflow concluded that an increase in the volume of farm dams has the potential to significantly impact on streamflow particularly under low flow conditions (Sinclair Knight Merz, 1999).

Widespread sub-division of agricultural land for rural residential subdivision could potentially lead to the take-up of currently unused 'harvestable rights' continuing the rapid increase in the numbers of farm dams seen in the 1990s. It is consequently imperative that data on extractions and farm dams be collected to inform the discussion about magnitudes and timing of environmental flows required to maintain healthy rivers in the Catchment. In that context it is also important to collect data on magnitudes and patterns of background flow that allow assessments of the relative impacts of water extractions.

Availability of such data will allow informed management decisions to be made about sustainable levels of extraction and water harvesting in the Catchment.

## Future directions

Quantification and reporting of actual extractions as proposed by DIPNR is essential for monitoring the issue and establishing trends. This needs to be supported by research into the impacts of increasing farm dams and water extraction on flows, and their impact on ecosystems at different levels.

**Recommendation 7:** That DIPNR expands research into the impact of different levels of extraction of water from rivers and the harvesting of water in farm dams on ecosystems and flow regimes within the Catchment in order to establish sustainable extraction levels and to guide resource allocation and management.

## Target

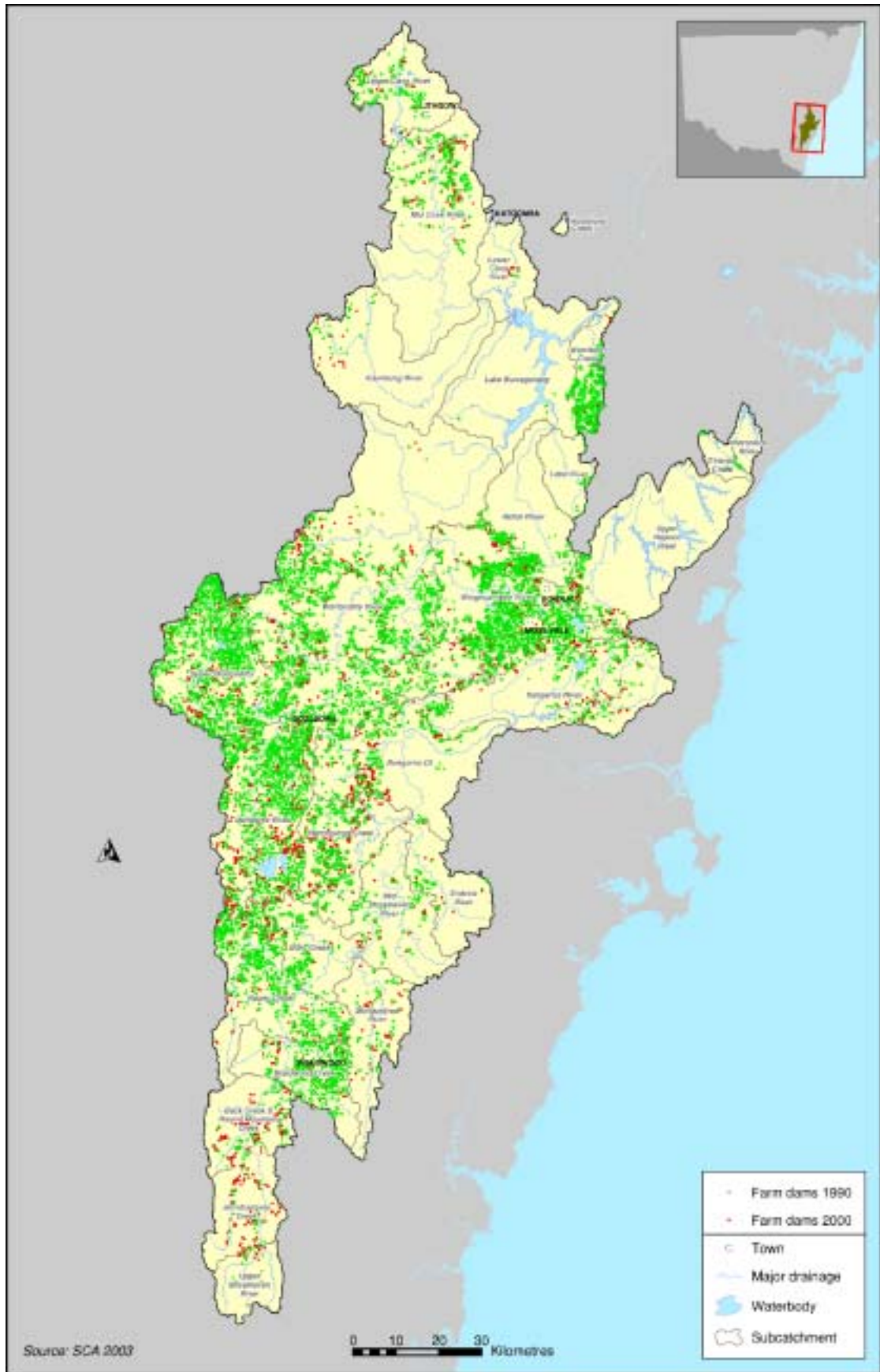
That the harvesting of surface water and the extraction from waterways minimise impacts on ecosystem health. In the longer-term surface water harvesting should be within levels specified in relevant water management/sharing plans.

## 3.2 Groundwater extraction

### Background

In periods of low flow and drought, groundwater can assume greater importance to maintaining base flows in streams and wetlands and for the water supply. Groundwater can be the main source of flows in many rivers and streams in summer months. The extraction of groundwater must also be managed, as extraction of groundwater can introduce more saline water into an aquifer and reduce base flows to waterways.

Groundwater is derived from rain which percolates down through the soil or fractures in rock, filling up the pores between sand grains or the fissures in rocks. Up to half of the rainfall in a given area may reach the water table and thus recharge the groundwater. Geological formations such as those composed of sand, sandstone and limestone which contain usable quantities of groundwater are called aquifers. The aquifer closest to the ground surface is called the shallow, or unconfined, aquifer (its upper surface is the water table) but there are also deeper confined (sometimes called artesian) aquifers where the water is confined under pressure between relatively impervious layers (Water and Rivers Commission 2003).



**Figure 3.2 – Map of farm dam locations in the Sydney Drinking Water Catchment**

**Note:** The green dots mark dams that were in place in 1990 and the red dots mark dams that were built between 1990 and 2000.



The extraction of groundwater requires a licence under the *Water Act 1912* which is administered by DIPNR. Extraction for irrigation, industry, recreation (e.g. golf courses) and commercial purposes is managed through renewable licences. Extraction for stock and domestic supply as a 'basic landholder right' is administered through a non-renewable (perpetual) licence. Applications for extractions of significant quantities of groundwater are required to be supported by an impact assessment. There are however, no requirements to meter or report actual groundwater usage.

Management of groundwater resources in the Catchment is mainly limited to monitoring of groundwater levels in the Southern Highlands. There has also been a number of studies on the sustainability of groundwater extraction in the Wollondilly–Nepean aquifers and in portions of the Coxs River sub-catchment (DIPNR).

## Findings

As noted above there is currently no information available on the quantity of groundwater extracted within the Catchment. The results of groundwater monitoring in the Southern Highlands indicates that levels have declined since 1999, however, there was a partial recovery during 2003 (DIPNR). It is anticipated that groundwater pumping will increase in response to reduced volumes of stored water in farm dams.

There are 2229 groundwater works (mostly bores) within the Catchment, these are concentrated in the Kangaroo River, Werriberri Creek and Wingecarribee River sub-catchments and around the town of Goulburn (Figure 3.3).

## Implication

As was found for surface water extraction, the extent of demand for groundwater and its sustainability is not well quantified. High demand areas such as the Southern Highlands, Kangaroo River, Werriberri Creek and Wingecarribee River sub-catchments need to be a priority for management. Measures should be put into place to determine and protect the quality and quantity of groundwater.

## Future directions

Quantification of groundwater usage is important for monitoring this issue and establishing trends. The development of a catchment-wide groundwater monitoring 'key sites' network would also assist assessment and management of resource capacity and help identify any deterioration trends. The information should be supported by research into the extent and capacity of systems experiencing high levels of demand to enable the assessment of sustainable yields for these resources.

**Recommendation 8:** That DIPNR develops and implements a monitoring plan and reporting requirements that provide reliable information on groundwater extraction within the Catchment.

**Recommendation 9:** That DIPNR expands research to establish and refine estimates of sustainable yields from groundwater systems within the Catchment.

## Target

Management of groundwater resources to ensure sustainable use by:

- maintaining water level and pressure
- maintenance of water quality.

## Surface and groundwater interaction

Surface and groundwater systems are interconnected with water moving between the two systems at different locations. The specific dynamics of this interaction within the Catchment is not well documented although DIPNR has undertaken some assessments of groundwater in the Southern Highlands and the Coxs River sub-catchment. The Water Sharing and Water Management Plans managed by DIPNR also consider groundwater issues.

The importance of this issue for the overall sustainable management of the water resources is reflected in the work being undertaken by the Drought Expert Panel. This panel is examining the potential of groundwater to be used to supplement water supplies from storages. The report from this work is expected to be available in 2004.

**Recommendation 10:** That DIPNR and SCA expand research to better understand the interaction between surface and groundwater systems within the Catchment.

## State of the Catchment

### 3.3 Environmental flow objectives

#### Background

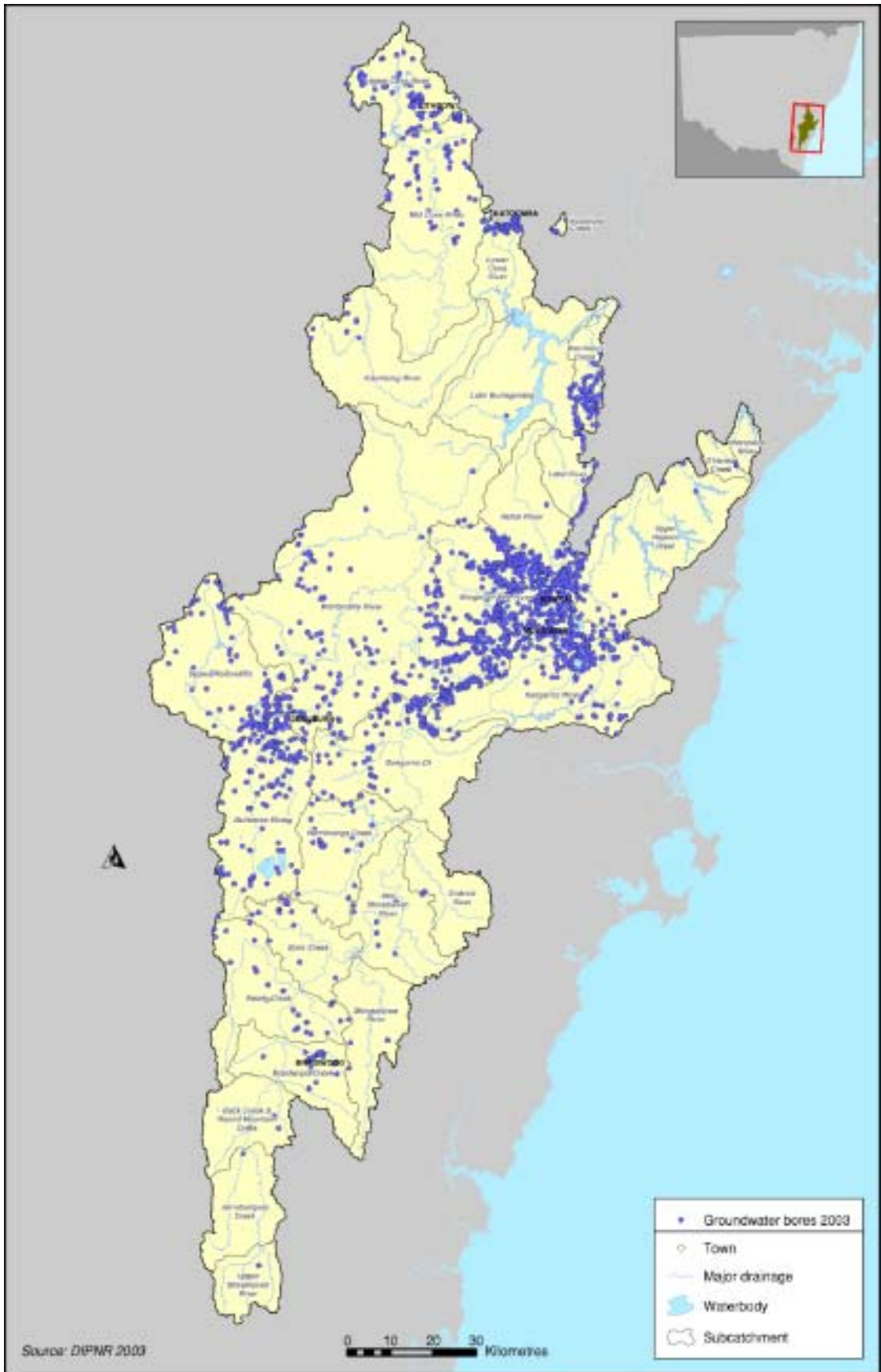
Flow regime is a key driver of river condition. Changes in the flow regime can cause changes to river geomorphology, habitat, water quality and greatly influence the riverine biota. 'Environmental flows' is the term used to describe the mimicking of elements of natural variability between high and low flows, which are intended to supply the needs of the environment to maintain ecosystem function (Nature Conservation Council of NSW 2003).

The magnitude and timing of flows in many NSW rivers has been modified as a result of the demand for both urban and agricultural development. The harvesting of water through farm dams and river extractions (see 3.1 Surface Water Extraction) and the construction of dams and weirs in NSW rivers has reduced and changed the frequency of natural flow. This has resulted in an increase in periods of no flow or extremely low flow, degraded water quality, reduced riverine habitat, reduced flooding of riparian zones, floodplains and wetlands, increased algal blooms and erosion of river channels.

To ensure sufficient volumes of flow for the riverine environment, the amount of water extracted and the amount of water captured by dams must be managed. The SCA is obligated to ensure they release certain volumes, specified in their licence, from its storages for the downstream environment. However, the pressure that extractions and other barriers within the Catchment place on the volumes left for the environment is less well documented.

The current environmental flow requirements are recommendations of the HRC Inquiry into the Hawkesbury–Nepean River system. The HRC also recommended the HNRMF develop detailed recommendations for environmental flows which if approved by Government will be included into the SCA's water management licence to improve the current requirements.

The most appropriate process for addressing the issue of environmental flows is the development of water management plans for sub-catchments subject to significant demand for water extraction. This issue is being examined in detail by the HNRMF and is a critical link in maintaining healthy ecosystems throughout the Catchment.



**Figure 3.3 – Map of groundwater bore locations in the Sydney Drinking Water Catchment**



The bulk transfer of water through natural water courses can also significantly affect ecosystems through prolonged flooding impacting bank stability and riparian vegetation.

## Findings

Dams, weirs and barriers permanently alter the flow of rivers and streams, create a barrier to fish passage and effect water quality, particularly temperature and the occurrence of algal blooms. Within the Catchment the majority of weirs and barriers are in the Upper Wollondilly River, Kangaroo River, Wingecarribee River, Werriberri Creek, Upper Coxs River sub-catchments and the upper section of the Bungonia Creek sub-catchment around Barbers Creek (Figure 3.4).

There are 36 SCA gauging stations present in the Catchment, most of these are located around water storages (Figure 3.4). There are also 11 SCA gauging stations located outside the Catchment, in the lower Hawkesbury–Nepean Catchment area. Most of this gauging is for the purpose of managing the main water storages and the bulk water transfers between storages and to water filtration plants. There is very little gauging within most sub-catchments.

### *Environmental flows*

The *Stressed Rivers Assessment Report NSW* (1998) rated Lake Burragorang, Upper Coxs River, Wingecarribee River and Upper Wollondilly River with a high combined stress rating for proportion of water extracted and environmental stress. However, no action has been taken to date to prepare water management or water sharing plans for any of these sub-catchments.

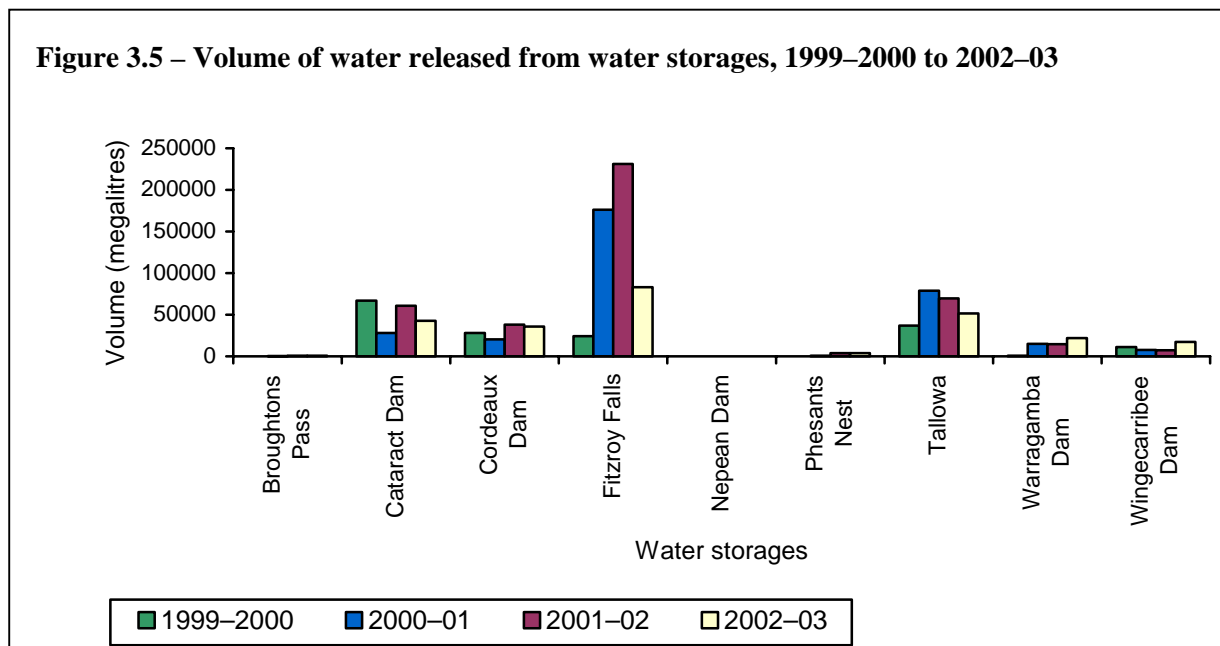
A water sharing plan has been prepared for the Kangaroo River and a water management plan is currently being prepared for the Coxs River. The commencement of these plans has been delayed to July 2004 while the Council of Australian Governments national water initiative is developed. It is anticipated that the National Plan for Water will be announced in April 2004. It is then intended that the *NSW Water Management Act 2000* will be amended to reflect the new agreed principles and outcomes outlined in the National Plan. As noted above the preparation and implementation of water management plans to address environmental flows within the Catchment is anticipated to be addressed by the HNRMF.

### *Releases from SCA storages*

The SCA is required to release specified volumes for environmental flow purposes from Avon Dam, Broughtons Pass Weir, Cataract Dam, Cordeaux Dam, Nepean Dam, Pheasants Nest Weir, Warragamba Dam and Wingecarribee Dam according to its Water Management Licence (DLWC 2001). The SCA met its environmental release requirements 99.7–99.8% of the time since the introduction of the Water Management Licence in April 2001, except for Avon Dam. The outlet works at Avon Dam do not allow the required flow to be released at present (DLWC 2001). In 2002–03 the SCA released a total of 279 597 ML of bulk water from its major storages to rivers, 80,956 ML of which was released specifically for environmental flow. Corresponding volumes for 2002–02 were total flows of 232,960 ML including environmental flow releases of 91,585 ML.

The volume of water released from water storages and weirs for a combination of environmental flow and bulk transfer targets over the past four year is summarised in Figure 3.5. The release of water from water storages decreased at Cataract Dam, Cordeaux Dam Fitzroy Falls reservoir, Tallowa Dam and Broughtons Pass weir from the previous year and an increase in water released from Warragamba and Wingecarribee Dams (Figure 3.5). There was also large increases in the volume of water released from Cataract Dam, Cordeaux Dam and Fitzroy Falls reservoir from 2000–01 to 2001–02. The release of water from Tallowa Dam has gradually decreased over the past three years.

**Figure 3.5 – Volume of water released from water storages, 1999–2000 to 2002–03**



Source: SCA data, as at 2003

### *Bulk water transfer*

The volume of water transferred from the Shoalhaven system to the Wingecarribee reservoir and from the Fish River to Cascades Dam remained unchanged from the previous audit period. The volume of water transferred from the Wingecarribee Reservoir to Warragamba Dam increased by 24% and to the Nepean Dam via the Glen Quarry Cut increased by 85% from the previous audit period (SCA 2003).

In accordance with the SCA’s Water Management Licence an independent assessment was completed in May 2003 of the environmental impacts of bulk water releases from its Upper Nepean storages. This assessment covered the river stretches between the Cataract, Cordeaux, Nepean and Avon Dams, and the downstream off-take weirs at Pheasants Nest and Broughtons Pass.

The conclusions from the assessment on the impact of bulk water transfers were that:

- the loss of variation in stream flow and loss of habitat due to long periods of reliance on environmental flows may impact on stream biota
- it is likely that the geomorphological and chemical similarities between streams above and below the storages outweighed the combined impacts of the storage and the release regimes.

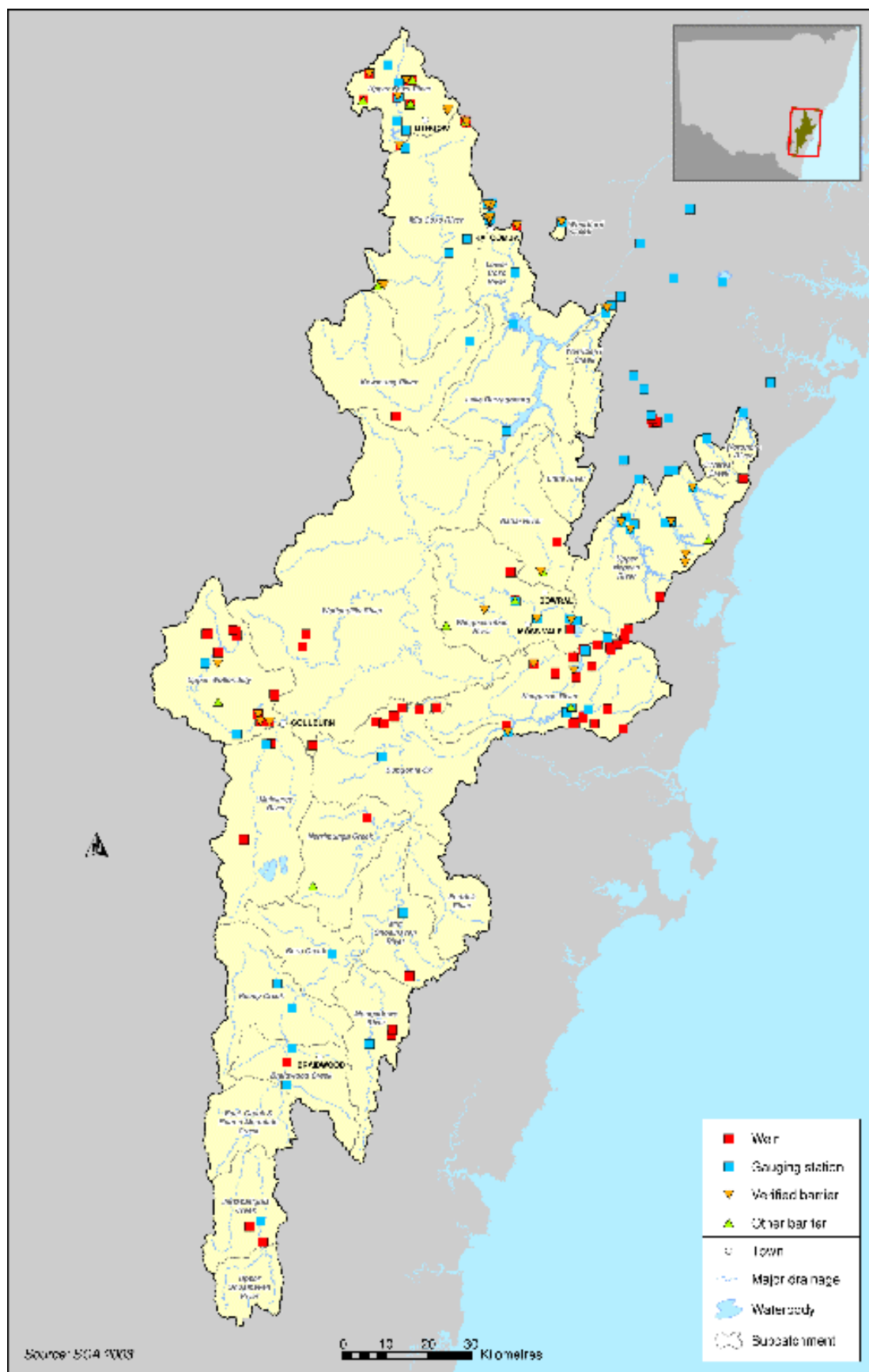
As a result, the report recommended that releases from dams should reflect increasing flow variation (where possible, without compromising security of water quality and quantity) to mimic actual inflows. That the releases should incorporate a mix of flows rather than from a single dam for long periods.

## **Implication**

### *Environmental flows*

The lack of specific provision of environmental flows to ecosystems throughout the Catchment is a significant source of stress for many sub-catchments and almost certainly contributes to poor outcomes noted across other indicators. It is important that a program for implementing water management plans be quickly established once the recommendations of the HNRMF have been adopted.

Volumes of water released from storages is measured by SCA. However, the volumes flowing in upstream sites and inflows to storages are not measured adequately to provide sufficient information for provision of



**Figure 3.4 – Map of weirs, gauging stations and barriers in the Sydney Drinking Water Catchment**



environmental flows. The HNRMF recommendations will address this issue. Due to the large number of weirs and other barriers reducing flows and flow variability (Figure 3.4), plus many water extractions throughout the Catchment, representative gauging sites or other effective mechanism for the monitoring of flows would be valuable. At present, there appears to be a limited spread of gauging stations across the Catchment (Figure 3.4). An accurate knowledge of extractions and flow volumes would assist the management of environmental flows across the entire Catchment. Again a quick response to the recommendations of the HNRMF on this issue is important to ensure that appropriate mechanisms are in place to manage water allocations and environmental flows.

#### *Management of impacts of bulk water transfers*

The increase in the volume of water transferred from the Wingecarribee Reservoir will put increased pressure on the receiving waterways with large flows causing localised flooding (e.g. Wingecarribee River Figure 3.6) and bank erosion. The release of water from the Glen Quarry Cut (Figure 3.7) increases the flow into Glen Quarry Creek, which increases bank erosion (Figure 3.8). There needs to be an investigation into whether the large flows during transfers can be managed in a way that does not affect the health of the ecosystem. Ramping of transfer water (i.e. the gradual increasing or decreasing of the volume of water) is designed to assist the stability of banks and also enable fauna to adjust to changing flows. The ramping volumes are based on findings of a 1994 study, however, a recent study during the releases in August 2003 has identified erosion and bank retreat due to releases.

**Recommendation 11:** That DIPNR develops and implements appropriate mechanisms to enable the reliable reporting of environmental flows for relevant sub-catchments.

**Recommendation 12:** That DIPNR initiates an investigation of the management of large flows during transfers under the SCA Water Management Licence to minimise impacts on the health of the ecosystem.

#### **Target**

Initially, the development and implementation of water management plans for all relevant sub-catchments. In the longer term, environmental flows consistent with requirements of the water management plans.



**Figure 3.6 – Localised flooding in the Wingecarribee River from water transfer to Warragamba Dam, August 2003**



**Figure 3.7 – Water released from Glen Quarry Cut into the Glen Quarry Creek, August 2003**



**Figure 3.8 – Increased flow in Glen Quarry Creek 100m downstream of Glen Quarry Cut – bank erosion on the right bank of the creek, August 2003.**

# Actions and Response

## Response to issue

*It is widely recognised that water is a finite resource and we are extracting too much. Both the scale of human population and economic activity are placing excessive water demands on the environment through landuse change, discharges and overflows from sewerage reticulation and urban runoff. All of these factors which contribute to reducing the sustainability of water resources are dealt with in other sections. This section covers the major actions aimed at managing water resources within the Catchment. The management of external demands for water from the Catchment (e.g. water supply to Sydney) is being addressed through other processes such as the Hawkesbury–Nepean River Management Forum. The three major responses to the unsustainable use of water have been to:*

- *quantify available water resources and develop mechanisms to allocate water for the environment and other uses*
- *undertake bulk water transfers between storages within the Catchment to balance the supply and demand of water customers*
- *increase the efficiency of water use to achieve more with the available water.*

## Water management

A key element of the water reform process was a legislative basis for water management plans to provide a clear direction on how water is to be shared between users and the environment. One of the primary objectives of this process is to improve the health of the State's waters by requiring that protection of water sources and their dependent ecosystems has first priority in water sharing plans.

The Hawkesbury–Nepean River Management Forum (HNRMF) and the Independent Expert Panel on Environmental Flows were established to determine appropriate environmental flow regimes for the Hawkesbury–Nepean River System.

The water sharing plans are statutory plans that will be in effect for 10 years and reviewed after five. They will provide a period of security to meet environmental needs as well as for water users. Within the Sydney Drinking Water Catchment, the Kangaroo River water sharing plan was gazetted on the 26 February 2003. The water sharing plan covers an unregulated water source. The interim environmental flow objectives established in 1998 were used to guide river management committees and form the basis for the environmental water provisions in the water sharing plan.

The Water Administration Ministerial Corporation (WAMC), administered by DIPNR regulates surface and groundwater extractions. The WAMC licences the SCA to access water resources in its area of operations and requires environmental flows to be released from storages to help maintain the ecological health of downstream rivers.

## Water use efficiency

The SCA initiated an independent study of water loss from its assets as part of a maintenance strategy. A program of works is being developed in response to the study's recommendations.

Many assistance schemes are in place to promote efficient water use by irrigators across the state of NSW. Of those that apply to lands within the Catchment, the Water Reform Structural Adjustment Program provides extension, education services and financial assistance to the NSW irrigated agricultural sector. There are two specific initiatives under the program relating to water use efficiency:

- the WaterWise on the Farm initiative which aims to improve the capacity of irrigated farm managers to adjust to water reforms primarily through the adoption of best irrigation management practices and technologies
- the NSW Agriculture Water Use Efficiency Unit has also been established to provide information and advice to irrigators and government on water use efficiency, water access and licensing.

As well as water use efficiency, another key role in the effective re-use of water resources is:

- the NSW Water Conservation Strategy which promotes integrated water-cycle management in NSW, including improving water efficiency in the industrial, commercial and agricultural sectors.

### **Effectiveness of response**

Previous audits have identified the need to collect data on stream flow for both managing water extraction and monitoring environmental flows. This audit confirms the importance of this issue (see Recommendation 11).

Previous audits also recommend that data should be collected to enable assessment of groundwater extraction against sustainable yield. While there has been some work on this issue, this audit considers that there would be benefit in undertaking further work on this issue (see Recommendation 8 and 9).

# Chapter 4

## Protecting and Improving Land Condition

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### Key Points

Indicator	Status of Indicator
<b>4.1</b> Changes in land use	The large areas of agriculture, increases in intensive agriculture and increased urbanisation and rural residential development will all continue to put pressure on water quality within the Catchment.
<b>4.2</b> Sites of pollution and potential contamination	Identification of potentially polluting sites has been undertaken. Risk assessment and management process for these sites needs to be progressed.
<b>4.3</b> Soil erosion	11% of the Catchment has very high or high estimated rill or sheet soil erosion, while 82% has low or very low estimated rill or sheet erosion.
<b>4.4</b> Salinity	Salinity is not a major problem in the Catchment. However, there are areas susceptible to salinity that require appropriate management.

### Pressures in the Catchment

Land condition is closely linked with water quality and the biotic environment, and the key pressure affecting land condition is land use. There are urban centres and rural residential areas in the Catchment, plus large agriculture and livestock farming. These broad types of land use are altered from the natural landscape in varying severities by their intensity. The more intense and invasive the land use, the more altered the landscape and generally poorer the land condition, however all land uses have the potential to degrade land condition if improperly managed.

More specific pressures occur from land uses such as land clearing, livestock grazing, and the agricultural practices of irrigation and chemical application. If poorly managed, these can result in the erosion, degradation and contamination of soil, salinisation, and the loss of riparian zones and habitat, which in turn can impact upon other parts of the catchment ecosystem. Poor land use practices can greatly increase the impacts on land condition, for example, unchecked irrigation can cause the salinisation of agricultural land, and the unrestricted access of stock can cause soil erosion and degrade riparian zones.

Urbanisation and rural residential development are also potential sources of pressure on land condition, especially during the site preparation and construction phase when vegetation is cleared and soil exposed.

Industry is necessary and economically important in the Catchment. However, industry includes some very intensive land uses, which if inappropriately managed can have significant impacts on land condition. Activities including mining, electricity generation, and intensive livestock industries can cause land pollution

or contamination, which may spread to other areas including water bodies. Other types of sites, including waste disposal, operate in the Catchment and are also a potential threat.

There is sometimes subsidence due to underground mining, particularly longwall coal mining. Subsidence occurs when the overlying rock mass moves toward a mining void. This can have serious impacts on the environment, including soil erosion, diversion of water flow, reduction in water quality, and physical disturbance of the geological and built environments.

The 2001 census indicated that approximately 111,000 people were living in the Catchment. This was an increase of 5.9% over the 1996 population. This growth was primarily focused in the urban areas of the Catchment and reinforces the importance of managing the impact of urban development. Figure 4.1 provides a map of the population density within the Catchment and confirms that population in the Catchment is concentrated in urban areas.

These figures may understate the growth of rural residential development within the Catchment, especially where these premises are used as rural retreats and therefore not reflected in census population counts.

## **4.1 Changes in land use**

### **Background**

Different land uses and how they are managed are a major reason for differences in environmental condition. A clear understanding of land use within the Catchment is critical in identifying likely impacts on water quality in drinking water storages. Extensive clearing of vegetation has altered the physical, chemical, biotic and hydrologic balances in the landscape, accelerating the degradation of soils, water and vegetation. Changes in land use can include transferring from one type of land use to another or changing the intensity of land use. Examples include moving from native pasture to improved pasture, pasture to cropping or intensive agriculture and agriculture to urban or rural residential. The changes in land use have both the potential for greater impact and an opportunity to improve performance where best management practices are applied.

The Sydney Drinking Water Catchment is generally composed of native bushland areas or land that has been cleared for agricultural purposes. To identify the extent of change in land use over the audit period the number and type of SEPP 58 development applications submitted to SCA was used for trend assessment.

### **Findings**

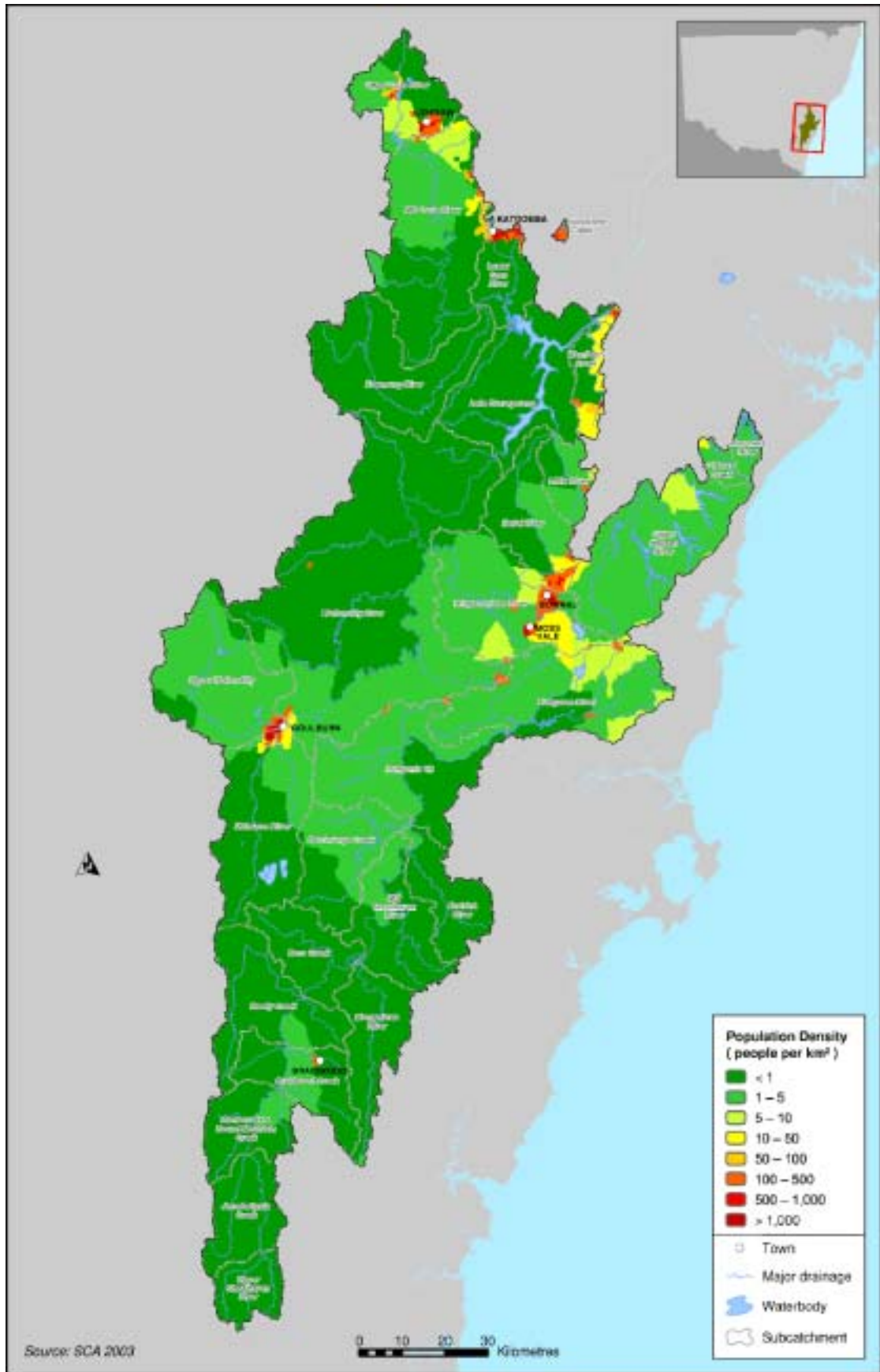
The Upper Wollondilly, Mulwaree River, Wingecarribee River, Reedy Creek and Braidwood Creek sub-catchments have large areas of pasture (Figure 4.2). Large urban areas are Goulburn, Bowral, Moss Vale, Lithgow and Katoomba (Figure 4.2). The urban areas in the Kangaroo River, Wingecarribee River and Wollondilly River sub-catchments are continuing to expand with the greatest number of SEPP 58 development applications\* received for dwellings during the audit period (Figure 4.3). The Bungonia Creek, Kangaroo River, Nattai River, Upper Wollondilly River, Wingecarribee River and Wollondilly River sub-catchments had the greatest number of SEPP 58 developments that did not include dwellings or subdivisions (Figure 4.4). These developments include agriculture, effluent/biosolid disposal, forestry, mining, poultry farm, tourism and vineyards.

### **Implication**

Increases in urbanisation, rural residential and commercial developments occurred in the Nattai River, Upper Wollondilly River, Wingecarribee River, Wollondilly River and Kangaroo River sub-catchments from the previous audit period. This will continue to put pressure on water quality in these sub-catchments. Other

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\* SEPP 58 applications are for specified development types of a potentially polluting nature which must be sent to SCA for approval



**Figure 4.1 – Map of population density in the Sydney Drinking Water Catchment, 2001**

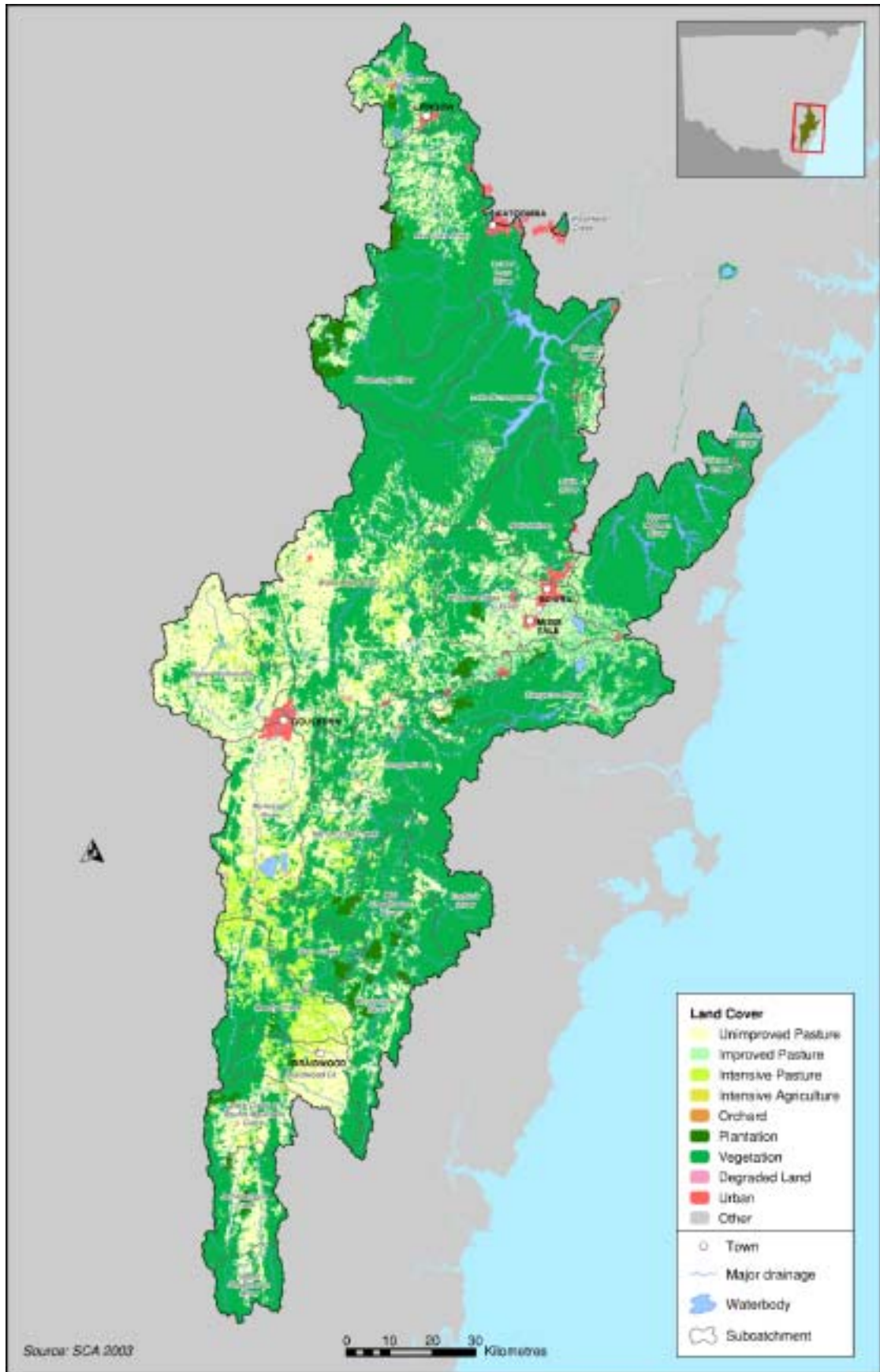
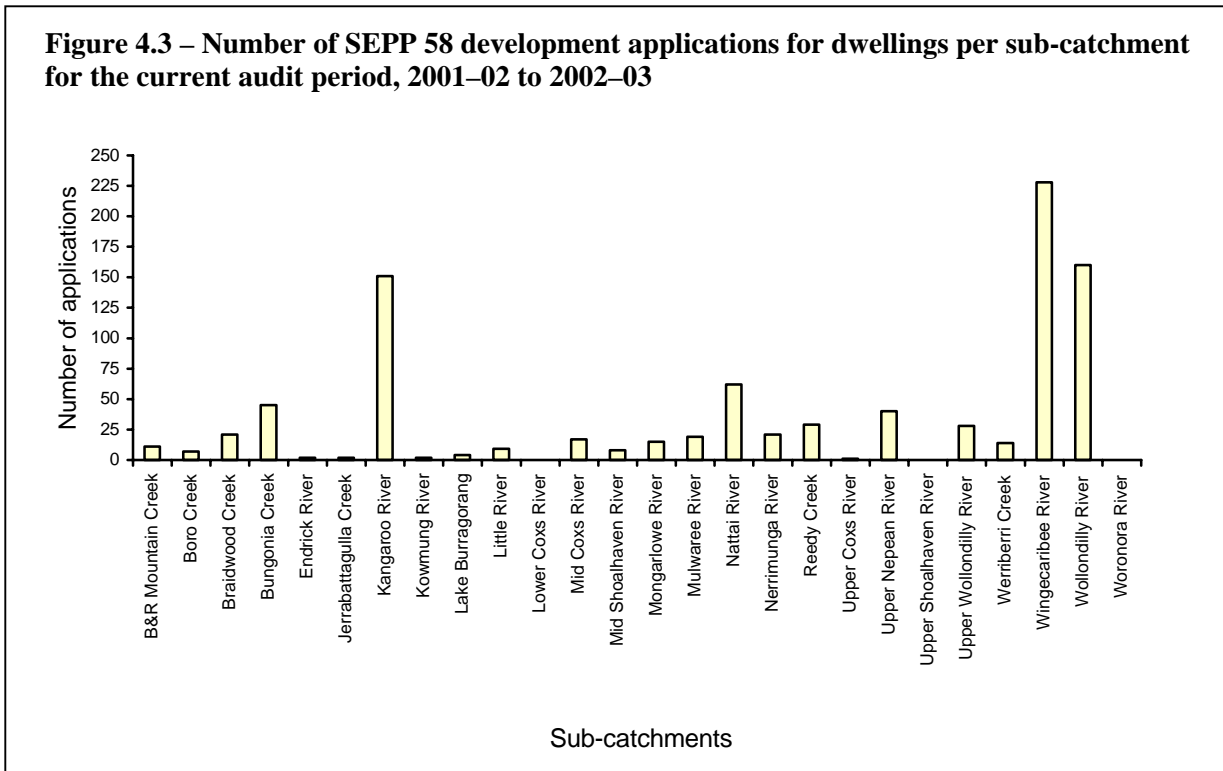


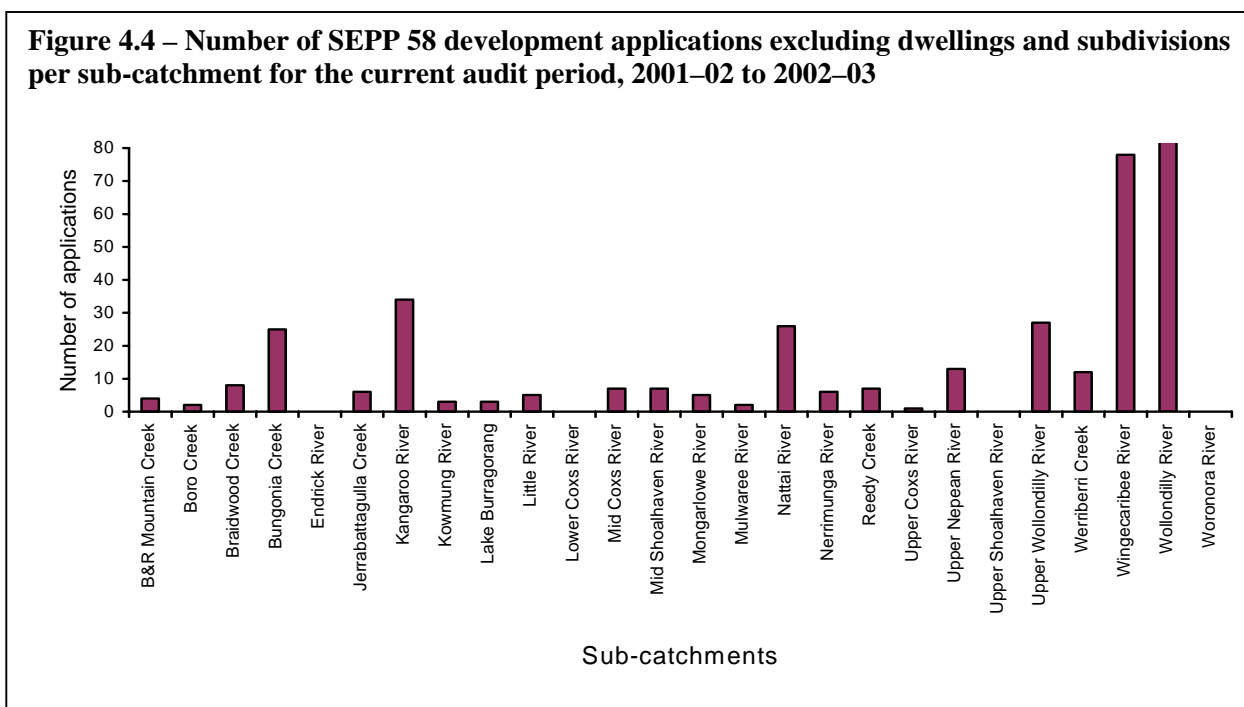
Figure 4.2 – Map of land cover in the Sydney Drinking Water Catchment

changes in land use such as improvement to pasture through cultivation and application of fertiliser are more difficult to quantify as they are not subject to planning approval processes. Similarly, changes in management practices can significantly change the impact of activities for better or worse but these are difficult to quantify.

Developing processes to track such changes through remote sensing or sampling would greatly assist in better understanding and managing the pressures arising from these changes.



Source: SCA data, as at 2003



Source: SCA data, as at 2003

## Future directions

A detailed land use map that characterises use at a fine scale (i.e. 25m grid squares) using land use categories relevant for nutrient and erosion modelling would provide both a sound benchmark for determining trends in land use change and provide a valuable input for nutrient load and erosion indicators and related management processes. Given the anticipated rate of land use change across the Catchment it is envisaged that this map would be updated at 5–10 year intervals depending on advances in remote sensing technology and analysis.

During intervening periods supplementary indicators such as development applications could be used to indicate type and amount of land use change occurring in the Catchment.

**Recommendation 13:** That SCA prepares a detailed land use map for program planning purposes. The resolution and categorisation used for this map should be sufficient for robust nutrient export and erosion modelling.

Changes in land use, particularly those changes leading to the removal of native vegetation and disruption of soil almost inevitably lead to increased impact. However, with appropriate design and management such impacts can be minimised and potentially can lead to overall improved outcomes especially where degraded landscapes are rehabilitated and best practice water sensitive design principles implemented. Therefore, it may be appropriate to develop an indicator of level of management as a supplementary pressure indicator to inform the land use indicator. Given the complexity of this task, development could be targeted to the most relevant land use(s) as a pilot for the next audit.

**Recommendation 14:** That relevant agencies commission the development of methods and tools to indicate the effectiveness of management practice applied to reduce water impacts from different land uses, for use in nutrient export and erosion modelling.

## Targets

Existing and new developments and activities moving towards sustainability by:

- all new developments incorporating ecologically sustainable development principles (e.g. water sensitive urban design)
- all land use incorporating sustainable best practice
- no increase in the cumulative impact of developments and activities.

## 4.2 Sites of pollution and potential contamination

### Background

The pollution and contamination of the land is a common side effect of human activity. Many industrial or agricultural processes are capable of polluting the land during operation and/or by leaving contaminated materials behind. Any resulting contamination of the land can potentially be mobilised from a localised problem to a widespread problem by entering surrounding water bodies. Therefore, it is important to identify active and historical sites within the Catchment that have a potential to pollute the Catchment.

The proposed indicator for this issue is the progress of the risk assessment and management process for each site. The process began with the preparation of the Pollution Source Risk Management Plan in December 2000. This plan identified and ranked activities that were expected to occur in the Catchment and that have the potential to pollute land. SCA has commissioned nine Environmental Assessment of Sites and Infrastructure (EASI) reports, which were aimed at identifying all specific instances of activities occurring in

the Catchment. The output of this process is reported here to show the extent of these activities within the Catchment (Figure 4.5 and 4.6).

## Findings

The EASI reports identified 1025 locations of potential polluting activities or contamination, excluding mines and quarries (Table 4.1 and Figure 4.5). There are a large number of commercial and manufacturing facilities and intensive horticulture sites in the Catchment (Table 4.1). The majority of these sites of potential contamination are located in the Wingecarribee River, Kangaroo River, Werriberri Creek, Upper Coxs River sub-catchments and the area around Goulburn (Figure 4.5). Primarily the waste facilities and manufacturing sites are in the towns of Bowral, Moss Vale, Goulburn, Katoomba, Lithgow and Braidwood. There is a large concentration of horticultural sites in the Werriberri Creek, Wingecarribee River and Kangaroo River sub-catchments (Figure 4.5).

The EASI report on Telecommunications and Energy production is generally comprehensive and is able to suggest with confidence that these activities are generally of low risk to the Catchment. Most other information for the above sites and industry is generic, and conclusions cannot yet be made.

The Mining EASI report (Environmental and Earth Sciences 2002) identified operating sites with existing licences, leases, titles and claims and old mines in highly sensitive areas. The study found 33 sites were relevant to the SCA for further investigation (see Wallerawang Colliery Case Study). The EASI report (R.W. Corkey and Co. 2003) on quarries identified 433 quarries and of the 95 operational quarries, 11 have environment protection licences but 29 had no formal approval (if not otherwise regulated, councils are the regulators under the *Protection of the Environment Operations Act 1997* (POEO Act)). The licensed quarries were generally the larger quarries, and only one of the 11 has reported licence non-compliances (see Penrose Quarry Case Study). No risk assessment was done on the quarries identified in this EASI report.

The Survey of Derelict Mines Report (Coffey 2001) identified 891 potential sites of interest. Following desktop assessment and ranking, 21 sites were selected for field assessment. The field assessment was used to allocate remediation resources. Seven sites were selected as in need of remediation works to prevent contamination of waterways. These sites and the 33 mines identified in the EASI report are shown in Figure 4.6.

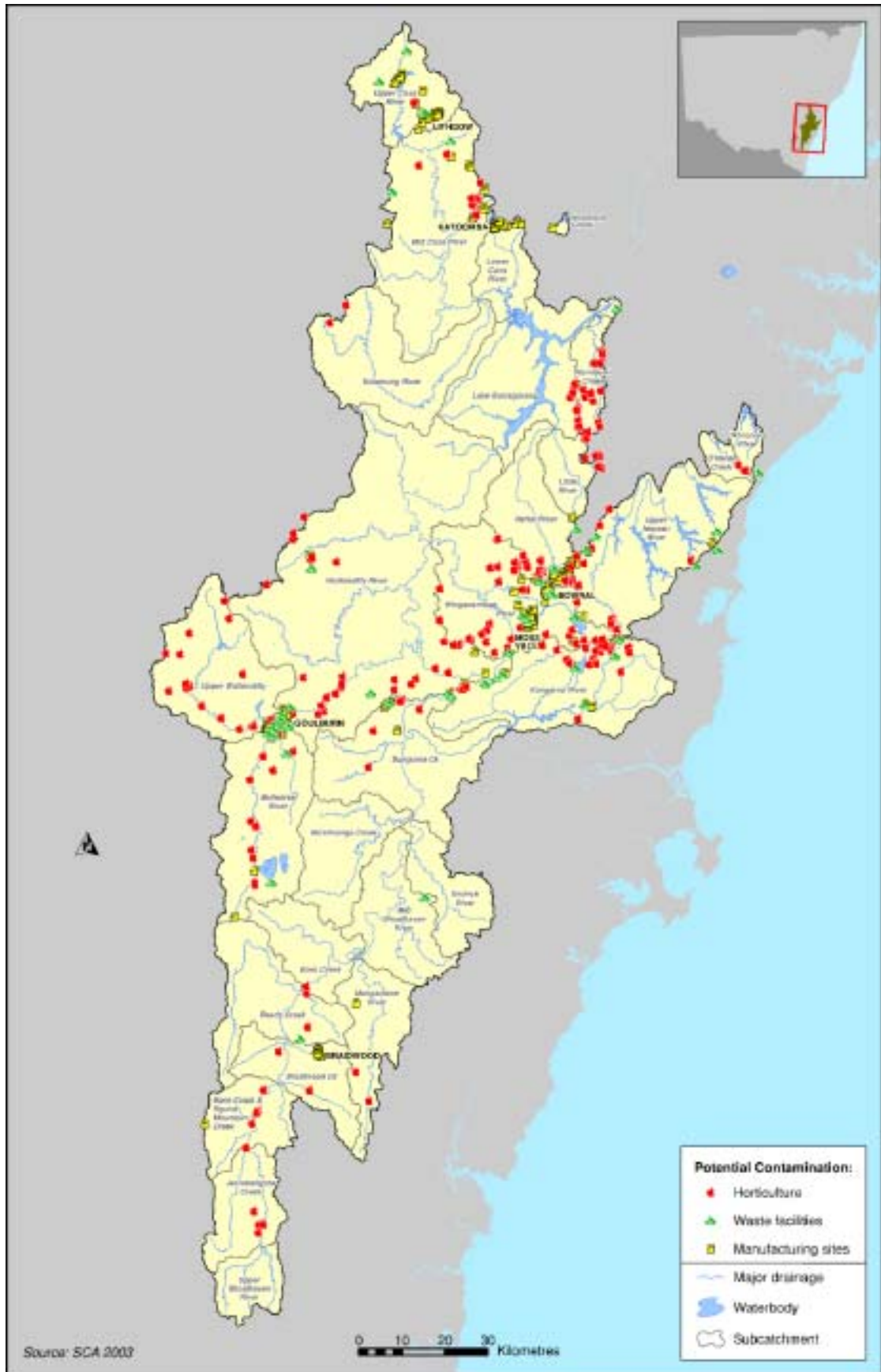
The Yerranderie Silver Field is made up of a number of separate leases and is number one on the top 50 derelict mine sites list of NSW published by the Department of Mineral Resources (DMR). This area was not included in the Survey of Derelict Mines Report because a taskforce responsible for remediation of the site has already been established. The Yerranderie Silver Field is also represented on Figure 4.6.

**Table 4.1 – Type and number of potentially polluting sites in the Sydney Drinking Water Catchment**

Type of site	Number of sites	Type of site	Number of sites
<b>Commercial and Manufacturing Facilities</b>	<b>463</b>	<b>Intensive Livestock Industries</b>	<b>96</b>
Automotive sites	330	Aquaculture	2
Farm, grain, building and garden supply	8	Dairy	37
Fertiliser manufacture and distribution	6	Feedlots	1
Food manufacture	13	Saleyard	5
General manufacture	34	Horses	30
Metal industry	35	Livestock processing	3
Timber Industry	6	Piggery	3
Construction Industry	31	Poultry	10
		Domestic animals	5
<b>Intensive Horticulture/Forestry</b>	<b>226</b>	<b>Sewage and Water Treatment</b>	<b>196</b>
Vegetable growing	36	Sewage Treatment plant	11
Floodplain cropping	37	Water pumping station	11
Grapes	46	Sewage pumping station	103
Flowers	5	Water filtration plant	15
Forestry	6	Effluent irrigation	18
Fruit	52	Biosolids disposal	14
Nursery	10	Swimming pool	12
Olives	24	Small STP	12
Nuts	2		
Berries	8		
<b>Waste Disposal</b>	<b>44</b>		
Operating Landfill	9		
Former landfill	13		
Recycling drop off	10		
Transfer station	4		
Waste storage	2		
Illegal Dumping site	6		

**Source:** Meinhart, 2003; URS, 2003a, b, and c; Woodlots and Wetlands, 2003

There were 3 mining-related development SEPP 58 applications made between July 2001 and June 2003. These were two ancillary applications in the Upper Nepean River sub-catchment and one Part-4 application in the Upper Coxs River sub-catchment.



**Figure 4.5 – Map of commercial and manufacturing facilities, intensive horticulture/forestry and waste disposal sites in the Sydney Drinking Water Catchment**

**Note:** Information was not provided by SCA on the location of the intensive livestock industries.



## Implications

There are a large number of activities within the Catchment with the potential for impacting water quality if they are not appropriately managed. These are concentrated in the Kangaroo River, Upper Coxs River, Werriberri Creek and Wingecarribee River sub-catchments. While there has been good progress in identifying these sites for most activities there does not appear to have been a specific on-site assessment of risk. Such an assessment is necessary in order to develop action plans to address issues that might be identified. Consequently there is little data available to indicate the effectiveness of environment management at these sites or what the actual risks that they may pose to the environment and water quality.

### Case Study – Wallerawang Colliery

Wallerawang Colliery is an underground coal mine 15 km north of Lithgow in the Upper Coxs River sub-catchment. The mine has, for all accounts, ceased operation, and has been undergoing rehabilitation since 1991. The rehabilitation process has been slow and unorganised and there remains a large area still in need of final rehabilitation (Figure 4.7). Areas of the site are acid generating which also creates a threat to water quality. The site is licensed to discharge water to Neubecks Creek, which is a tributary of the Coxs River. The site has numerous environmental controls, including sediment traps, neutralising ponds (Figure 4.8) and retention basins, but there have still been some exceedences of environment protection licence conditions.



Figure 4.7 – Wallerawang Colliery, August 2003



Figure 4.8 – Wallerawang Colliery neutralising ponds, August 2003

Between 2000–01, there were two non-compliances reported. One was the exceedence of water quality licence guidelines by mine water discharge. The second was the late reporting of the non-compliance. In 2001–02, there was one non-compliance reported, where the pH of discharged water exceeded the 6.5–8.5 licence limits for the entire 12-month period.

Rehabilitation is underway, and it is expected that progress in rehabilitation will reduce these licence non-compliances. To address acid being generated by the site's waste material, a project has been underway since 1999 which involves creating briquettes from coal fines excavated from a former pond for sale to Mount Piper Power Station. A rehabilitation plan for the site is currently being finalised by DMR. The plan is being closely reviewed by SCA and has been viewed by the Department of Environment and Conservation (NSW).

## Case Study – Penrose Quarry

Penrose sand quarry is in Paddys River in the Wingecarribee River sub-catchment. The quarry has council development approval with water management conditions and is licensed under the POEO Act. The quarry has some sediment control measures in the form of ponds and silt fences. It is located close to Hanging Rock Swamp, which is a heritage-listed peat swamp.

The most recent available information of licence compliance under the POEO Act is for 2001–02, when the quarry reported two non-compliances. One was the discharge of sediment to Hanging Rock Swamp, described below. The other was a stormwater erosion control failure, but the discharged water was mostly captured by secondary measures and the discharge off the premises was thought to be minimal.

The quarry was responsible for an incident in 2001 where 500 tonnes of sand slurry entered the swamp. The Clean-up Notices were issued and the quarry operators were forced to clean up the site. Prosecution for the event occurred in March 2003 and a fine was issued. The quarry operators were also required to undertake a year-long flora study of the swamp (completed August 2003) to assess swamp recovery. The pollution of Hanging Rock Swamp was directly due to machinery adjustments by the quarry operators, but inadequate control measures were also blamed for the severity of the incident.

Following a recent inspection (2/09/03) by the EPA the reported environmental management of the quarry is active and significantly improved. The flora study on Hanging Rock Swamp shows recovery to a good condition and no further work from the quarry operators in the swamp is considered necessary. The SCA was encouraged by the progress and, if the environmental management remains proactive, it will no longer consider Penrose Quarry as a potential ‘hot spot’.

### Future directions

The next step is to assess actual risk at each site and to take necessary action as required until it can be classified as a low risk site. Active sites will need to be flagged for reassessment at relevant intervals depending on the inherent risk of the activity. More information needs to be collected for each site on type of activity or operation, potential pollutants, exact pollution source, how the pollutant is discharged and the identification of processes, equipment, and materials that can impact on water quality. Cooperation with relevant regulatory bodies at all levels of government, involved in the approval or ongoing regulation of each activity, is also vital to managing this risk. Unlicensed sites, such as most quarries or illegal waste dumps, are especially in need of review.

**Recommendation 15:** That SCA sets specific time frames for progressing and completing risk assessment and management processes for activities identified as ‘sites of pollution and potential contamination’.

### Targets

Risk assessment and rehabilitation at all sites with potential polluting activities in the Catchment is completed. The final outcome would be no contamination of waterways from sites of potential pollution or contamination.



**Figure 4.6 – Map of mines, identified in the EASI and derelict mine reports, that need further investigation in the Sydney Drinking Water Catchment**



# State of the Catchment

## 4.3 Soil erosion

### Background

Soil erosion leads not only to a loss of organic matter and soil nutrients from the surface, but also the deposition of sediments and nutrients in streams. Soil erosion involves the dislodgement of soil particles, their removal and eventual deposition away from the original position. This natural process is fundamental in landscape and soil development. Susceptibility to erosion and the rate at which it occurs depends on land use, geology, geomorphology, climate, soil texture, soil structure and the nature and density of vegetation in the area. Erosion is a natural process that is accelerated by human activities. The clearing of native vegetation and agricultural land use activities have been major contributors to accelerated rates of erosion. The potential for soil erosion increases wherever vegetation cover is removed, soil is disturbed or exposed, and where high intensity rainfall or wind occurs. The main categories of soil erosion are sheet, rill, gully, tunnel, stream bank and wind erosion.

The estimated sheet and rill erosion was calculated by the National Land and Water Resources Audit (NLWRA) using the Revised Universal Soil Loss Equation (RUSLE). The following attributes were used in the RUSLE: soil erodibility (data derived from NSW Soil and Land Information System and the Australian Soil Resource Information System); rainfall erosivity (data from National Rainfall erosivity surface); slope gradient and length (derived from the National Digital Elevation model); and ground cover (Satellite imagery from Normalised Difference Vegetation Index – NDVI).

### Findings

The area within the Catchment with very high estimated sheet and rill erosion is 4.9%, this area includes parts of the Upper Coxs River and Wollondilly River sub-catchments. The Upper Wollondilly River, Mulwaree River, Reedy Creek and Braidwood Creek sub-catchments also contained areas of high estimated erosion, which covered 5.6% of the Catchment (Figure 4.9).

Multi-attribute mapping which also addressed gully and stream bank erosion as well as sheet and rill erosion was undertaken by the Soil Conservation Service in 1985 using air photo interpretation and ground truthing. This process identified that 8.9% of the Catchment was affected by severe sheet and rill erosion.

Observing actual erosion is a labour-intensive and time-consuming process and has only been completed in the Braidwood lands. The total area affected by erosion is 185 ha (1% of total Braidwood area).

### Implications

Areas within the Upper Coxs River, Upper Wollondilly River, Wollondilly River, Mulwaree River, Reedy Creek and Braidwood Creek sub-catchments are the most susceptible to soil erosion. Therefore, programs addressing soil erosion need to specifically target these areas to ensure that appropriate strategies and management controls are in place to prevent and remediate soil erosion.

The audit only had limited access to information on the multi-attribute mapping and so was unable to determine the reason for the apparent different assessment of the extent of severe rill and sheet erosion to the NLWRA process. However developing a reliable assessment of degradation will help guide an appropriate level and targeting of response.

**Recommendation 16:** That programs addressing soil erosion in the Catchment demonstrably target areas with high estimated erosion rates.

## Future directions

Using the NLWRA approach, a precise estimation of sheet and rill erosion can be calculated for future audits using the more detailed soil landscapes data of the Sydney Drinking Water Catchment that is now available. More detailed slope gradient and length data is also available from the State Digital Elevation model.

However consideration should also be given to alternate approaches to gathering and presenting information on land condition. In addition to the NLWRA and multi-attribute approach there is also the land degradation survey undertaken by the Soil Conservation Service In 1987-88. While relatively broad scale the survey methodology provides a comprehensive assessment of land condition with ten forms of land degradation being recorded. Prior to the next audit relevant agencies should investigate the most appropriate methodology for both monitoring trends in land condition and providing an information base for appropriate land management programs.

Land use practices are a major factor that contributes to soil erosion, as poor land use practices can cause erosion in even low risk areas and are able to change in the short-term. Inclusion of land use and management practices in the erosion risk models would increase their accuracy and better enable changes over short-time periods (years) to be observed. This, together with new information collected on soil landscapes, slope gradient and length and ground cover, could provide a more powerful management tool (see also discussion at 4.1).

**Recommendation 17:** That DIPNR in conjunction with SCA develops a land degradation map incorporating land use and land management for erosion risk management and future audit reporting.

## Target

To reduce potential soil erosion to very low levels.

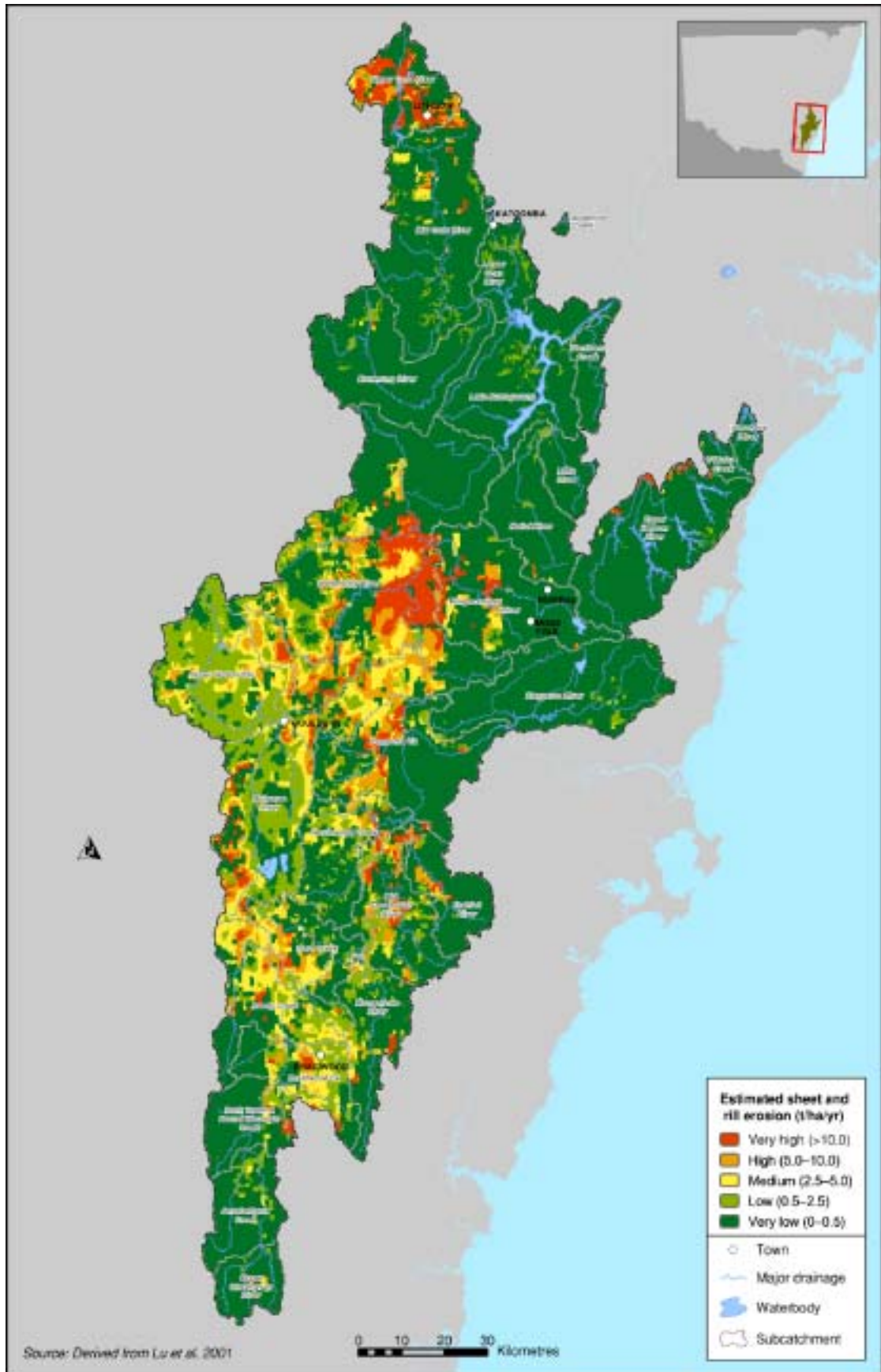
There is a link between the above target and the Warragamba Catchment Blueprint target SLMT3: By 2012 there is a 20% reduction in the area of historic moderately to severely degraded land and 10% of priority streambank is stabilised.

## 4.4 Salinity

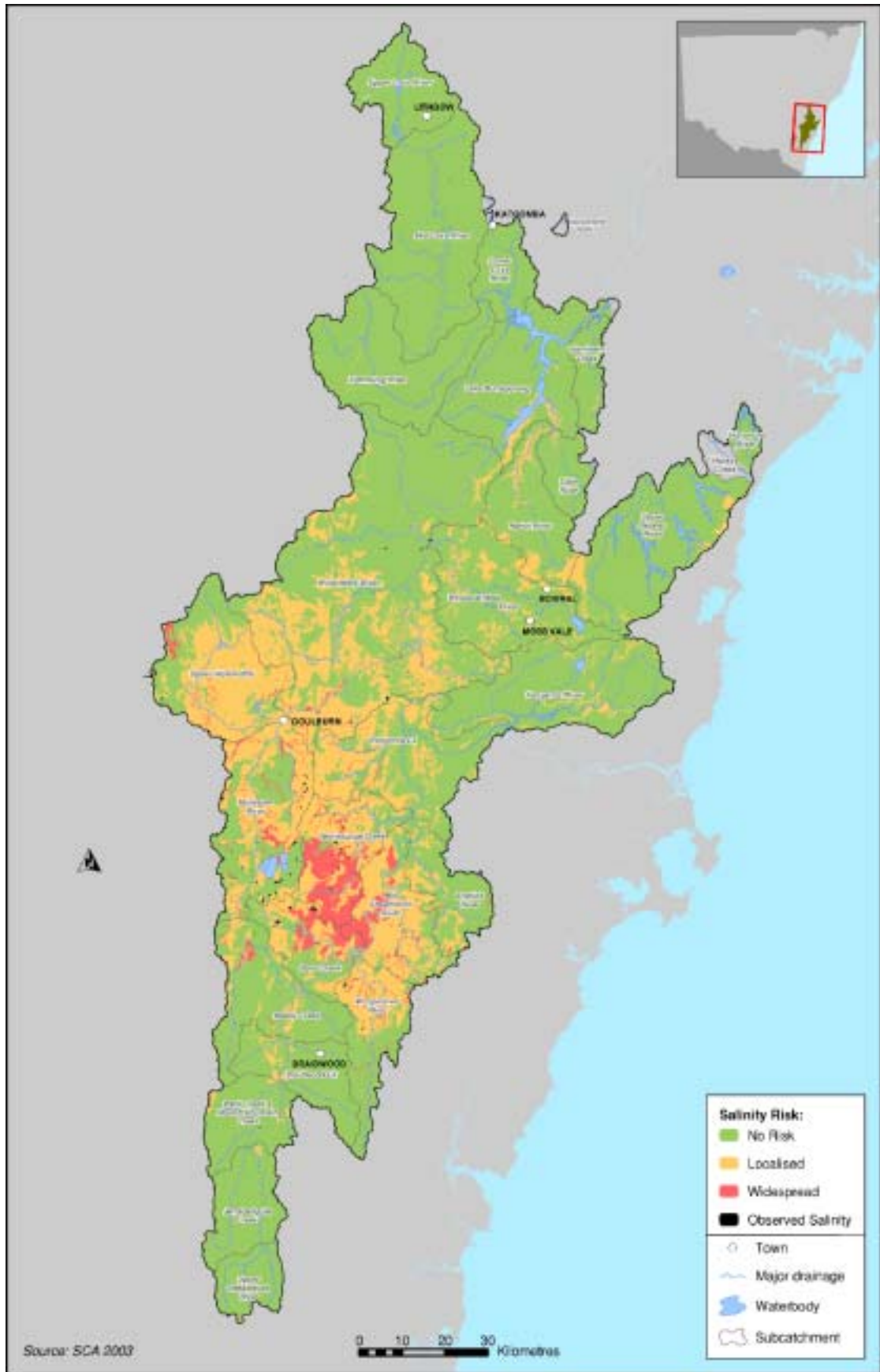
### Background

Salinity can be a threat to the health and productivity of a catchment, as plants and soil organisms are killed, or their productivity is severely limited, on affected lands. There are two kinds of soil salinity: inherent and induced. Salinity occurs when the natural balance and distribution of salt in the landscape is disturbed. The removal of native vegetation through land clearing and the adoption of unsuitable land uses and practices have resulted in ground water tables rising. This allows salts to move close to the soil surface where they are concentrated by evaporation or discharged into surface waters. Discharges of saline waste water from mines, power stations and STPs are other sources of salts reaching waterways.

The risk of salinity was determined by DIPNR using the Soil Landscapes data for the Catchment. The risk was placed into three categories: **widespread** – areas where saline soils occur or where scalding, salt efflorescence, vegetation dieback, salt tolerant vegetation and water logging can be found; **localised** – scattered areas of scalding and indicator vegetation have been noted; **no risk** – small likely hood of salinity occurring. The areas identified as widespread risk areas of salinity may not necessarily be affected by salinity at present, but, if land use practices change, these areas have a high potential to be affected by salinity. The observed salinity distribution is of areas which are currently affected by salinity and do not necessarily occur in high risk areas. The observed salinity within the Catchment was associated with soil erosion.



**Figure 4.9 – Map of estimated sheet and rill erosion in the Sydney Drinking Water Catchment**



**Figure 4.10 – Map of salinity risk and observed salinity in the Sydney Drinking Water Catchment**

## Findings

Salinity is not a major problem within the Catchment. There are however, areas that are susceptible to salinity. The area of the Catchment that has a widespread risk of salinity is 2.8%; this area is located in the Boro Creek, Mid Shoalhaven River and Nerrimunga Creek sub-catchments (Figure 4.10). The Boro Creek, Nerrimunga Creek, Mulwaree River Mid Shoalhaven River, Mongarlowe River and Wollondilly River sub-catchments have a number of areas with identified salinity (Figure 4.10).

## Implication

Areas within the Boro Creek, Mid Shoalhaven River and Nerrimunga Creek sub-catchments are most susceptible to salinity. Salinity issues may be emerging at several sites not within these sub-catchments where there has been extensive effluent re-use. These together with areas where irrigated land salinity is occurring should be identified, prioritised and appropriately managed.

## Future directions

Given the salinity risk profile within the Catchment there is a need to monitor the incidence of salinity and be able to reliably report trends.

**Recommendation 18:** That DIPNR and SCA investigate the development of a methodology to identify and report on areas of land affected by salinity.

## Target

No increase in the area of the Sydney Drinking Water Catchment affected by salinity. Ultimately to reduce the area of land affected by salinity.

There is a link between the above target and the Warragamba Catchment Blueprint target SLMT4: By 2012 there is a 20% reduction in the area of severely to moderately degraded saline discharge sites.

# Actions and Response

## Response to issue

*The two primary responses to protecting and improving land condition are to prevent or at least mitigate against the potential impacts from future activities, and where scientifically and economically feasible, to repair lands already degraded. Reducing pollution from both point and diffuse sources all contribute to reducing the impact on land condition. These are dealt with in section 2. This section covers the major actions aimed at protecting and improving land condition in the Catchment. These include:*

- *programs to reduce land degradation from urbanisation*
- *programs to reduce land degradation from changes in land use*
- *programs to reduce land degradation from identified high risk industries*
- *programs to reduce land degradation from agriculture*
- *programs to reduce land degradation from mines*
- *programs to reduce land degradation within Special Areas*
- *programs to protect high quality catchment land outside the Special Areas*
- *programs to reduce land degradation from bushfires.*

## Urbanisation

There is a range of programs relating to the management of urbanisation, these include:

- sewage management programs that exist between the NSW Government and local councils to deliver improved outcomes from STPs, unlicensed sewage treatment systems (excluding single dwelling on-site systems), on-site sewage treatment systems and sewerage infrastructure. All of these programs are discussed in Chapter 2.
- stormwater programs have been allocated funds from the NSW and federal governments to help local government manage stormwater generation, conveyance and discharge. Work in collaboration with other agencies to identify and implement best stormwater management practices for reducing runoff from urban areas are discussed in Chapter 2.

## Changes in land use

The management and control of land uses within the Sydney Drinking Water Catchment is primarily guided by the *Environmental Planning and Assessment Act 1979*. Local councils also have a range of powers under the *Local Government Act 1993* and the *POEO Act* that can be used to manage specific land use issues. Planning documents that cover the uses of land as well as the way it is managed include:

- **State Environmental Planning Policy 58 (SEPP 58)** – SEPP 58 establishes controls over development that may have an impact on water quality within the Sydney Drinking Water Catchment. Consent authorities, primarily local councils, are required to refer particular applications to the SCA, so the effect of the development on water quality can be assessed. Depending on the type and the location of the development the SCA will either have a concurrence or an advisory role. SEPP 58 was introduced as an interim measure and is to be replaced by a Regional Environmental Plan (REP) that has yet to be finalised.

During the year SCA reviewed 231 concurrence applications and 418 notification applications (compared to 202 and 532 respectively in 2001–02). Most applications were for unsewered residential developments with more than 90 percent of the applications being processed within the statutory period.

- **Local Environmental Plans (LEP)** – All councils within the Catchment have LEPs that cover specific land use controls within their area. They list the land use zones and specific controls on land. LEPs must be consistent with relevant REPs or SEPPs.
- **Regional Environmental Plan (REP)** – The SWCM Act requires an REP to be prepared as part of a broader regional plan. The regional plan will make provision for the control and management of all land uses within the Catchment. It will also make provision for the preparation of a series of strategies and action plans aimed at improving the land management and ultimately water quality within the Catchment. A draft REP was first exhibited in October 2000. The SCA has been working with DIPNR towards re-exhibiting the REP. In light of changes to institutional arrangements including the creation of DIPNR and Catchment Management Authorities, no announcement on when the REP will be exhibited has yet been made.
- **Rectification Action Plans (RAPs)** – The SWMC Act also requires the development of action plans to rectify existing land uses that do not have a neutral or beneficial effect on the quality of water, within certain time limits after the gazettal of the REP. RAPs must be prepared for each sub-catchment or a combination of sub-catchments in consultation with relevant councils, State agencies, natural resource management groups, interest groups and communities. RAPs are to be used by both the SCA and other government agencies to inform budgetary decisions and programs. Development of RAPs has been postponed due to the delay in re-exhibiting the REP.
- **The Sydney Drinking Water Catchment Management (Environment Protection) Regulation 2001** – Enables the SCA to exercise certain regulatory functions under the POEO Act with regard to non-scheduled premises and activities. During 2002–03, 5 Clean-up Notices, 1 Prevention Notice, 2 notices requiring information and ten Penalty Infringement Notices were issued in the water supply catchment area.

### Identified high risk industries

In 2001 the SCA undertook a preliminary Pollution Source Risk Management Plan (PSRMP) as part of the SCA's 2000–2005 Operating Licence. The plan identified and assessed sources of pollution, set out actions that must be undertaken to improve the quality of bulk water, and identified agreements with other agencies. However, this plan only identified risks at an industry type level and therefore an inventory of specific sites was necessary to fill gaps and understand the scale of the risk.

The SCA has carried out a process of EASI projects within the Catchment during the past 2 years, which has continued to reduce identified gaps in knowledge. There are nine EASI reports which cover intensive livestock industries, commercial and manufacturing facilities, sewerage systems, water treatment plants and bio-solids application sites, intensive horticulture and forestry industries, Commonwealth facilities, telecommunications and energy supply, waste disposal sites, quarries and extractive industries and mining. The EASI projects are a useful part of the process in identifying and quantifying risks to water quality as part of a risk management program, but further actions will be necessary to produce on-the-ground improvements to manage risk within the Catchment through the use of rectification and rehabilitation programs.

### Agriculture/rural lands

The SCA has developed a range of strategies, programs and actions to protect water quality and catchment health in Sydney's hydrological catchments. The management of rural lands is a major component of these initiatives.

- **Strategic Land and Water Capability Assessments (SLWCAs)** – The SCA has developed a tool to allow identification of land uses that are either currently impacting on water quality or have the potential to affect water quality in the future. To date SLWCAs have been completed for the Wollondilly River,

Upper Wollondilly River, Mulwaree River, Wingecarribee River and Nattai River sub-catchments. These assessments are intended as an input to the REP and LEPs.

- **Ecosystem Services Scheme** – An ecosystem services approach provides a potentially effective tool for rectifying the negative impact of existing agricultural activities on water quality. In the Sydney Drinking Water Catchment, a process of service payments is being developed to provide a means of implementing priority actions under the Riparian and Rural Lands Strategy of the Healthy Catchments Program. In addition it is intended that work undertaken as part of the ecosystem services project will link with the RAP process under the REP.
- **Healthy Catchments Program (HCP)** – has been implemented by the SCA to integrate strategies (including the Rural Lands Strategy and Riparian Strategy) in response to continuing urban, rural and industrial development to improve catchment health. Each strategy is comprised of programs and projects that focus action on identifying, understanding and rectifying impacts to water quality and catchment health, and form a basis for working with other agencies, councils and community groups.
- **Catchment Protection Scheme** – This joint initiative between landholders, SCA and DIPNR across the Sydney Drinking Water Catchment provides financial assistance and professional advice to landholders trying to manage moderate to severe erosion on their properties.

## **Mining industries**

Government agencies including DMR, SCA, the Department of Environment and Conservation (NSW) and DIPNR are working closely with mine operators to initiate programs to ensure that the Sydney Drinking Water Catchment is not impacted by mining. These actions which relate to active and derelict mines as well as subsidence and water re-use issues are as follows:

### *Derelict mines*

The Derelict Mine Committee sets priorities for the Derelict Mine Program which is aimed at reducing the safety and environmental risks posed by derelict mines. It is administered by DMR, but involves the Department of Environment and Conservation (NSW), Department of Lands, and the NSW Minerals Council.

A Derelict Mines Report (Coffey 2001) identified all known derelict mines in the Catchment. Site inspections of 21 sites believed to exhibit the highest potential environmental impact revealed that seven of these sites require remediation. In addition to this the Yerranderie site has a taskforce chaired by DMR and involving other agencies including SCA, the Department of Environment and Conservation (NSW) and DIPNR who are working to rehabilitate the Yerranderie Silver Mine Field (identified as a real threat to water quality). So far initial actions to improve safety and assess rehabilitation options funded by an Environmental Trust grant has cost \$631,320.

### *Active mines and mines on existing leases*

The SCA and the Department of Environment and Conservation (NSW) are currently developing a strategy to address mining and extractive industry in the Catchment. The strategy proposes close cooperation with the DMR in its implementation. The SCA commissioned a report to identify all mines that were active or on active leases in the Catchment, and examined the 33 resulting mines. The information was added to their Pollution Source Database for later use. The EPA includes PRPs in licences to encourage reductions in contaminants, for example, Clarence Colliery must resolve high metal concentrations in mine water discharge.

### *Subsidence Management Plans (SMP)*

To address the issue of river-bed cracking due to mine subsidence any mining activity that may cause subsidence must prepare an SMP in line with a new approval process under the *Mining Act 1992*. These plans must account for all possible impacts of potential subsidence to provide adequate protection for the

natural and built environments. SMP approval is essential and will involve primarily DMR but will also involve other state agencies and the community.

### *Re-use of mine water*

The Cocks River Water Management Committee comprising of community, government and industry representatives was established to develop a water management plan for the area. The Committee is considering the use of mine water during the development of the water management plan.

## **Special Areas**

The Special Areas Strategic Plan of Management and the Wingecarribee Swamp and Special Area Management Plan are comprehensive plans for managing Special Areas. The plans were prepared jointly by the SCA and the NPWS and developed in conjunction with stakeholder groups and technical experts.

Compliance in the implementation of both these plans is assessed annually as part of the Sydney Catchment Authority Operational Audit (IPART 2003).

## **High quality land outside the Special Areas**

The main government response to terrestrial ecosystem decline outside protected areas has been to:

- encourage conservation on private land under joint agreements between the landholder and government agencies to provide permanent protection for areas of high conservation value on private property, protect the native plants and animals on a property as well as sites that are significant for the conservation of natural heritage
- implement legislative and planning controls on clearing of native vegetation and protection of threatened species
- improve knowledge and collect data on biodiversity and ecosystem condition.

## **Bushfires**

Hazard reduction burns and grass slashing have been used by the NPWS and SCA to reduce fire fuel on land owned and managed by the SCA. During the cooler months, controlled hazard reduction burns take place in dry sclerophyll habitat to reduce the potential for summer bushfires. These hazard reduction burns (HRB) are conducted according to fire management plans, which are based on district plans approved by the Rural Fire Service. HRB are approved by a multi-agency bushfire committee for the local fire district prior to the commencement of burning operations. The HRB are controlled to minimise the impacts on water quality from increased runoff with high sediment and nutrient loads due to reduced vegetation cover.

NPWS under the joint management arrangement with the SCA undertook a number of HRB in 2002–03 in parts of the Warragamba Catchment that remained unaffected by recent bushfires across other parts of the Catchment. However during 2002–03 only one HRB was undertaken by SCA at Kangaloon in August 2002, as bushfires during the year made other planned HRB unnecessary. In 2001–02 the SCA undertook four HRB at Nepean (August 2001), Blackheath (May 2002) and two at Katoomba (May 2002).

## **Effectiveness of response**

Sustaining the Catchments REP has not been gazetted. During 2002–03 the REP remained in draft form, undergoing major revisions by DIPNR. Delays in the finalisation of the plan have adversely impacted upon the commencement of important sub-components of the plan.

The external consultation of RAPs has been postponed indefinitely while waiting for the REP to be exhibited. While the REP would provide a useful framework for RAPs it is not essential for it to be in place prior to commencing RAPs. Given the delay in progressing the REP there would be value in progressing the RAPs independently.

The development of ecosystem services schemes such as the green offsets which have already been established downstream of the Sydney Drinking Water Catchment should be given a high priority.

EASI projects are an important part of a risk management program, but their usefulness is limited without a structured plan to prioritise and carry out rectification and rehabilitation works.

Local Councils play a significant role in the monitoring of erosion and sediment control for construction activities. Further gains may be achieved through councils in the catchment adopting a cooperative role with government agencies similar to the 'Sitewise' best practice model as developed in Western Sydney.

# Chapter 5

## Maintaining and Enhancing Ecosystem Health

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### Key Points

Indicator	Status of Indicator
<b>5.1</b> Ecosystem water quality	Current water quality within the Catchment has the potential to affect ecosystem health.
<b>5.2</b> Macroinvertebrates	A 'low' AusRivAS health rating was found in 41% of locations sampled in the Catchment.
<b>5.3</b> Fish	The diversity of fish species is generally poorer above the dams and characterised by a higher proportion of exotic species.
<b>5.4</b> Riparian vegetation	The extent of riparian vegetation within the Catchment ranges from large areas with almost intact native vegetation cover to areas such as the Upper Wollondilly River and Mulwaree River sub-catchments with little or no native vegetation in their riparian zones.
<b>5.5</b> Native vegetation	Native vegetation covers approximately 63% of the Catchment and has a similar pattern of distribution to native riparian vegetation. While almost half of this cover is protected within National Parks over 37% is dispersed across the Catchment on privately owned land.

### Pressures in the Catchment

Healthy and intact natural systems play a crucial role in maintaining water quality. Largely taken for granted, these ecosystem processes provide both the conditions and processes that purify water and mitigate the effects of drought and flood. These ecosystem services are free, but, should they fail, the cost of replacing them is extremely high.

Many water supply authorities have secured these services by closing off, or in some way protecting, the hydrological catchments of their storages. The managers of the Sydney Drinking Water Catchment have historically taken a similar approach by creating the Special Areas around the major water storages. However, while the Special Areas do enclose the entire Catchments of some storages, they make up only approximately one quarter of the whole Catchment.

The previous audits have clearly challenged the view that the Special Areas can provide enough ecosystem services to play a sufficient role as the first barrier in a multi-barrier\* approach to protecting water quality. These barriers appear effective under low and moderate flow conditions when water can take several years to travel between the outer catchment and the dam wall. However, under periods of high flow, the barrier effect of the storage breaks down and the capacity of the broader ecosystem of the Catchment becomes critically important. This capacity is strongly dependent on the integrity and health of the ecosystems.

The main driving forces threatening ecosystem health are population growth, water demand, and current and intensifying land use. Each is responsible for placing pressure on parts of the ecosystem, including raw water quality and quantity, biodiversity, and riparian and native vegetation.

Land use often involves the clearing of native vegetation. This affects water quality, land condition, and biodiversity and is a key threatening process in the *Threatened Species Conservation Act 1995*. In the context of a catchment, riparian vegetation is particularly crucial for water quality and as habitat for fauna. Managing the clearing of native, and particularly riparian vegetation, and the rehabilitation of degraded areas is vital to maintaining ecosystem health. Exotic fauna are another pressure on ecosystem health, and can cause physical damage to soil and vegetation or prey on natives. Pest species can out-compete native species for resources.

Bushfires, like drought or flood, is part of the landscape context within which the Catchment needs to be managed. A regime of regular bushfires is a natural and often vital component of the Australian environment. Modified regimes of either very frequent or occasional but extremely intensive fires, however, can have detrimental effects on ecosystem health, especially in the short-term. Hazard reduction burns are a common management practice to reduce fuel on the land and decrease the likelihood of bushfires of devastating intensity. Management actions can also mitigate the post-fire impacts, for example by preventing sediment and particulates from entering the waterways. Treating the protection of riparian zones as a priority for fire management is advantageous in protecting water quality. In this audit, the result of bushfires is not treated as an indicator of catchment health, although it can influence it. Rather it is seen as a contextual pressure with limited management options.

## State of the Catchment

### 5.1 Ecosystem water quality

#### Background

Healthy ecosystems generate and maintain good water quality. This indicator is a composite indicator that draws together 12 parameters (Figure 5.1) that signal whether water quality may be impacting on ecosystem health. These parameters were assessed against the guidelines for ecosystem health in the ANZECC and ARMCANZ 2000 guidelines. The only exception was conductivity. The ANZECC and ARMCANZ 2000 guideline for conductivity (30  $\mu\text{S}/\text{cm}$ ) is based on typical values for Tasmanian lakes and reservoirs, which is not relevant for NSW given its different geology. Therefore, the conductivity criteria used for the audit was 300  $\mu\text{S}/\text{cm}$  which is based on values typically found in NSW lakes and reservoirs.

**Recommendation 19:** That SCA adopts 300  $\mu\text{S}/\text{cm}$  as a practical conductivity trigger value for compliance monitoring of lakes and reservoirs in its Water Quality Monitoring Program.

In order to provide a visual presentation of ecosystem water quality across the Catchment, the 12 parameters were combined into 4 groups (Physical – turbidity, pH and conductivity; Toxicants – total Al and total Fe; Nutrients – total nitrogen, total phosphorus, oxidised nitrogen, ammonia and filtered phosphorus; Chlorophyll-a and Dissolved Oxygen). The parameter with the highest level of exceedence within a group

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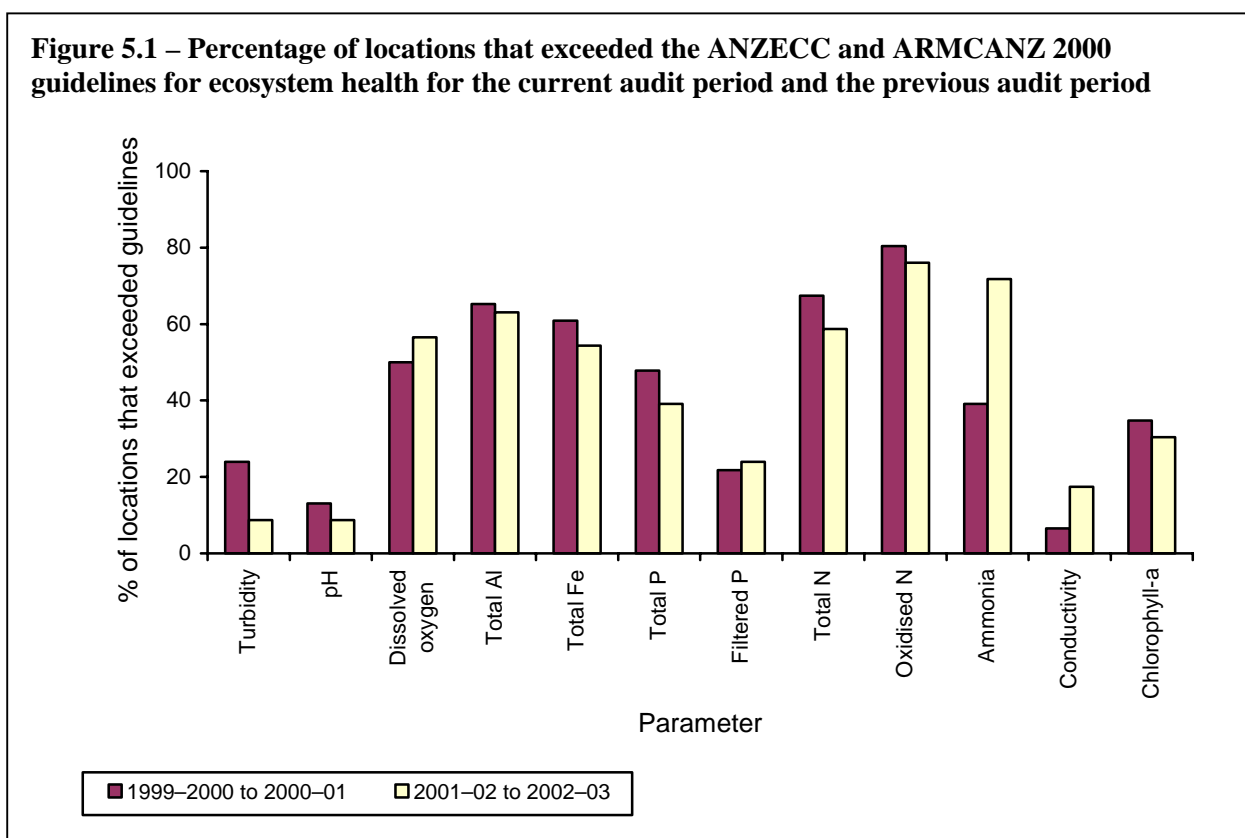
\* The other barriers are the storages themselves, water treatment processes and the delivery system to the tap.

was then used to rate that group. If one or more parameters exceeded the ANZECC and ARMCANZ 2000 guideline more than 75% of the time, then the group was rated very poor. If one or more parameters exceeded the ANZECC and ARMCANZ 2000 guideline between 50–75% of the time, then the group was rated poor, between 25–50% fair and less than 25% good.

The change in percentage exceedence of the guidelines from the previous audit period was shown as a negative or positive symbol in Appendix G Table 3 and 4. A negative symbol indicated an increase in the percentage exceedence and therefore a decrease in the health of the location.

## Findings

The percentage of locations that exceeded the guidelines was lower in the current audit period for 8 out of the 12 parameters tested than in the previous audit period (Figure 5.1). The parameters that had a greater percentage of locations in exceedence of the guidelines in the current audit period were dissolved oxygen, filtered phosphorus, ammonia and conductivity (Figure 5.1).



Source: SCA data, as at 2003

As described above, Figure 5.2, identifies water quality rating for four groups of water quality parameters at locations across the Catchment. Two locations were rated very poor for all 4 groups. They were Gibbergunyah Creek (CD) and Mulwaree River (CK). A number of other locations had three groups rated very poor. They were Gillamatong Creek (CV), Wollondilly River (CI), Lake Yarunga (L), Wingecarribee River (CH) and Werriberri Creek (CM).

The majority of the high exceedences were in the toxicant and nutrient groups (Figure 5.2). There were 33% of locations that exceeded the guideline for physical attributes in both the catchment and lakes and reservoir locations (Figure 5.2). Seventy to ninety percent of locations exceeded the guideline for toxicants and nutrients (see Appendix G Table 3 and 4 for details). The percentage exceedence of the guideline for ammonia increased at 54% of locations from the previous audit period (Indicated by a negative symbol in Appendix G Table 3 and 4).

Pesticides are monitored at certain locations within the Catchment, and specific projects have been undertaken to identify and maximise the detection of pesticides in the Catchment (see Case Study –Pesticides in the Sydney Drinking Water Catchment).

## Implication

Water quality indicators have long been used as surrogates for assessing aquatic ecosystem health. In recent years monitoring has increasingly shifted to measuring ecosystem health indicators directly (see 5.2 below). Water quality, however, continues to be used while additional ecological indicators are being developed and trialled.

Water quality monitoring in the Catchment is largely restricted to the northeastern region. There are no unambiguous patterns in the data. Clearly water quality is influenced largely by local inputs and processes with poor readings recorded mainly around towns and areas with pollutant inputs. Broadly, the groups ‘toxicants’ and ‘nutrients’ show greater exceedences than the other two categories. This stresses the need for reductions in the parameters of those two groups to improve water quality as a whole.

Water quality monitoring programs are often designed to monitor particular areas of impact and so data tend to reflect this with most sites sampled showing some form of impact. The current SCA monitoring program, thus, probably does not give a comprehensive picture of water quality throughout the Catchment, because many areas of the Catchment do not have monitoring sites. There are several sub-catchments with few or no monitoring sites where water quality could be expected to be under stress (see Future Directions below).

## Future directions

Routine ecosystem water quality monitoring is currently undertaken at 18 out of 28 sub-catchments. Some of the sub-catchments with few or no routine water quality monitoring have been identified as areas under environmental stress by other indicators. These include the Upper and Mid Coxs River, Upper Wollondilly and Wollondilly Rivers, Reedy Creek and Mulwaree River sub-catchments. These sub-catchments have been identified with other indicators as being under threat and have few or no water quality sampling sites.

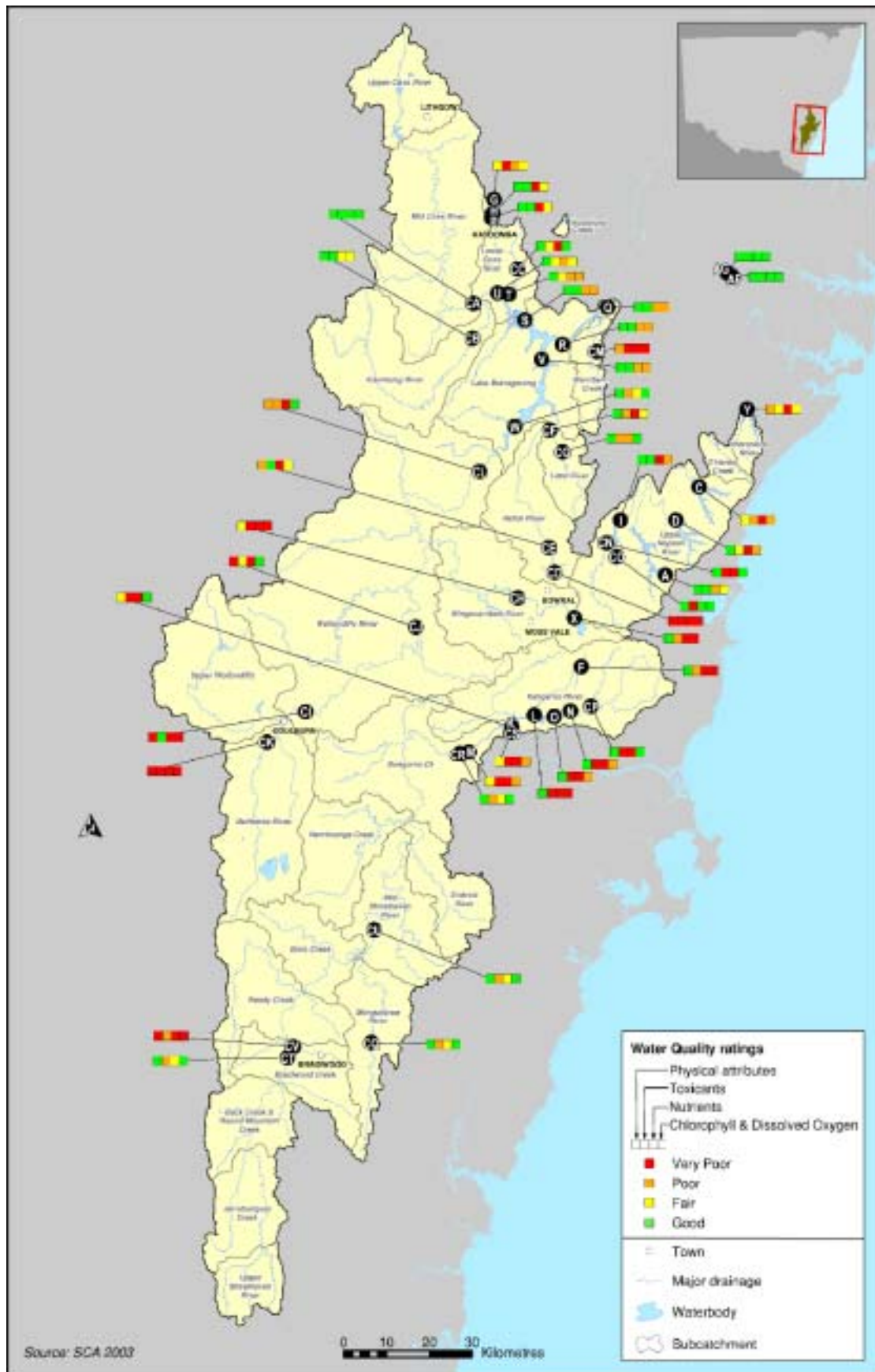
Further it would appear that the frequency of actual water quality monitoring as reflected in available datasets is less than what was committed to by SCA in its *Water Quality Monitoring Program July 2002 to December 2004*. While explanations were provided regarding the gaps in the dataset, the information available to the audit did not fully explain all the gaps. It is important that the monitoring program is reviewed to ensure that it is delivering relevant water quality information under reasonably anticipated conditions including drought.

Additional water quality monitoring (both frequency and location) would contribute to a better understanding of other indicator trends.

**Recommendation 20:** That SCA reviews its water quality monitoring program to ensure that appropriate ecosystem water quality monitoring is undertaken in areas of the Catchment identified by other indicators as subject to environmental stress.

## Target

Progressive reduction in number of exceedences for each parameter of the ANZECC and ARMCANZ 2000 guidelines. Ultimately, water quality that meets the guidelines for the protection of ecosystems.



**Figure 5.2 – Map of water quality monitoring sites showing the 4 parameter groups and the colour code in the Sydney Drinking Water Catchment**

**Note:** Location codes are provided in Appendix G Table 1



## Case Study – Pesticides in the Sydney Drinking Water Catchment

A 2001 review and risk assessment of pesticides (Bales 2001) in the Catchment discovered that while pesticide use in the Catchment was mostly of very low to moderate intensity, there could be areas of more concentrated use. SCA has undertaken sampling in the Catchment for the practical quantification of pesticides in the raw water supply. In 2000, the SCA commissioned a project aimed at detecting pesticides in the water supply using special lipid samplers that accumulate pesticides over time to enable detection of pesticides in normally undetectable concentrations. Since 2000, SCA also monitors inflows to water filtration plants (WFPs) for the presence of pesticides. In 2002, sampling for pesticides was done for a wet weather event, and pesticides were also sampled in the treated effluent from eight major STPs.

From the pesticides that are being detected, the vast majority of samples reveal concentrations below practical quantitation limits or below the National Health and Medical Research Council (NHMRC) drinking water guidelines. Three pesticides detected, Chlopyrifos, Diazinon and Malathion were above ANZECC and ARMCANZ (2000) guidelines. The trigger values (Table 5.3) equate to the percentage of species protected if not exceeded. It has been suggested that the very low amount (below NHMRC drinking water guidelines) of pesticides reaching WFPs is due to the biological and physical cleansing properties of the catchments, storages and Special Areas.

**Table 5.3: Pesticides detected by SCA sampling, and if any samples exceeded the ANZECC guidelines or NHRMC drinking water guidelines.**

Sampling location/type	Sampling date	Pesticides detected	Exceeded ANZECC trigger values (TVs)	Exceeded NHMRC drinking water guidelines
Lipid samplers – Inflows to Lake Burragorang and Nepean	July–Dec. 2000	Many types, including unregistered organochlorines (may be remnant of historical use)	N/A	N/A
Water samples – Inflows to WFPs	2000 onwards	Chlopyrifos (in 0.74% of samples)	Yes, exceeds 99, 95 and 90% TVs	No
Water samples – Discharged effluent from 8 STPs	May 2002	Diazinon (nine samples)	Yes, maximum concentration sampled exceeds all TVs	Yes
		2,4,5-T (one sample)	No	Yes
		4 Others	Insufficient data or no TVs specified	No
Water samples – Wet weather event	21 Feb. 2002	Malathion (one sample)	Yes, exceeds 99 and 95% TVs	No

## 5.2 Macroinvertebrates

### Background

Macroinvertebrates are the invertebrates that are typically visible with the naked eye, and exist in a variety of habitats in streams, lakes and wetlands. Freshwater macroinvertebrate assemblages are good biological indicators, because they are sensitive to various pollutants, react quickly, are ubiquitous, abundant and relatively easy to collect. The Australian River Assessment System (AusRivAS) generates river health assessments by predicting the macroinvertebrates that would be present (expected) and compares this with the macroinvertebrates collected (observed) to create an index of health. The lower the observed/expected value, the more impaired the macroinvertebrate assemblage.

An AusRivAS assessment of the Catchment is carried out each year in Spring, however, the first year's sampling was undertaken in Autumn 2001. A catchment map of the current macroinvertebrate health rating and an indication as to whether a positive or negative change from Spring 2001 to Spring 2002 is shown in Figure 5.3, locations without a change symbol were not sampled in 2001. Due to the relocating of some monitoring sites to new locations in 2002, the present limitation to measuring meaningful trends across all sites should be resolved when these new 2002 sites are sampled in the future. See Appendix G Table 6 for all location codes and description used in Figure 5.3.

### Findings

Four locations were given an AusRivAS health rating of severely impaired: Farmers Creek (NQ), Yosemite Creek upstream of Minnehaha Falls (NS), Kedumba River at Scenic Railway (NT) and Mulwaree River at the Towers (MI).

The AusRivAS health rating decreased from Spring 2001 to Spring 2002 at seven sites: Coxs River at the McKanes Bridge (NP), Woodford Creek at the Woodford Dam (NR), Yosemite Creek upstream of Minnehaha Falls (NS), Little River at the Six Foot Track (OC), Mulwaree River at The Towers (MI), Tarlo River at Tarlo (MB) and Boro Creek at the Marlowe River (MR).

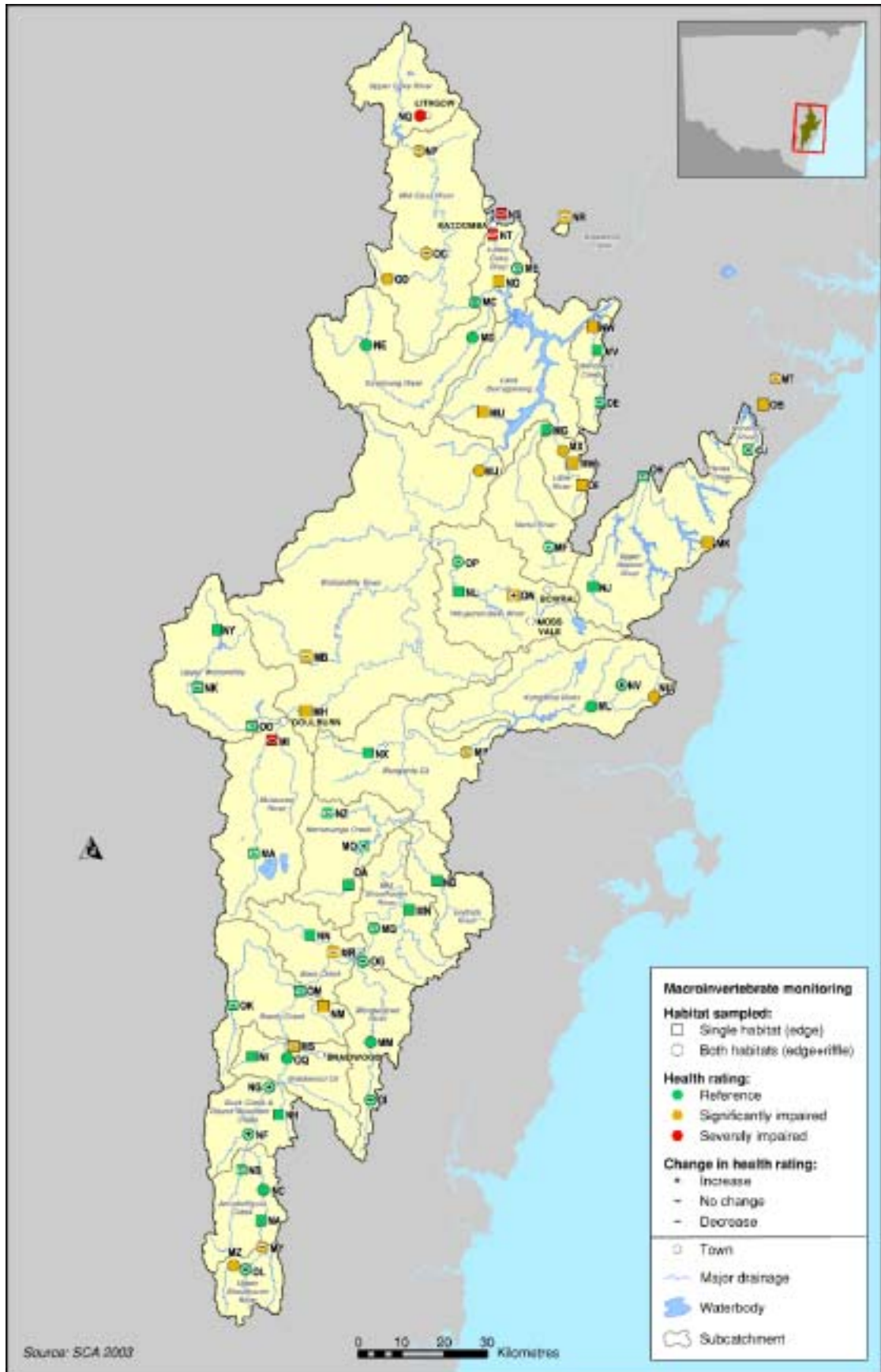
There was also a decreased from a AusRivAS health rating of 'richer than reference' to 'reference' at three sites: Coxs River at Kelpie Point (MC), Wollondilly River at Goonagulla (NK) and Mongarlowe River at Monga (OI).

The AusRivAS health rating increased from Spring 2001 to Spring 2002 at seven sites: Waratah Rivulet at Flat Rock crossing (OJ), Wingecarribee River at Berrima (ON), Kangaroo River at Upper Kangaroo (NV), Nerrimunga Creek at Minshall Trig (MO), Shoalhaven River at Farrington Crossing (NG), Witts Creek at the Krawaree Rd crossing (NF) and Currembene Creek at the Krawaree Rd crossing (OL),

The AusRivAS health rating remained unchanged at the other 19 sites since the 2001-02 survey. A number of locations with a health rating of significantly and severely impaired macroinvertebrate assemblages also exceeded ANZECC and ARMCANZ 2000 guidelines in 3 or 4 groups of physico-chemical water quality (Figure 5.2 and Figure 5.3). These locations include Gillamatong Creek (CV), Mulwaree River (CK), Wollondilly River (CI) and Wingecarribee River (CH).

### Implication

Overall, coverage of the Catchment by macroinvertebrate monitoring is better than that using water quality indicators. Fewer large gaps in coverage exist. There were sites with an AusRivAS health rating of 'severely impaired' at the Upper and Lower Coxs River and Mulwaree River sub-catchments that suggests these sub-catchments are very disturbed and the aquatic ecosystems are already degraded. Apart from those sites, stream health throughout the Catchment is generally reasonable although about a third of the remaining sites show quality significantly less than reference.



**Figure 5.3 – Map of macroinvertebrate AusRivAS health rating for Spring 2002 and change from Spring 2001**

**Notes:** Sites without a 'change' symbol in health rating were sampled only in 2002. Location codes are provided in Appendix G Table 6. Location codes are provided in Appendix G Table 6.



To be able to use a combination of water quality and macroinvertebrates in assessments of stream health in the Catchment it is essential that the two monitoring programs be better integrated. The value of this is seen in the few sites where both water quality and macroinvertebrate monitoring takes place and where, as a consequence, a more comprehensive assessment is possible.

### **Future directions**

The monitoring program for Spring 2002 (68 locations spread across all 28 sub-catchments) is supported as appropriate. For the full benefit of this monitoring effort to be realised and for trend data to be established it is essential that a significant majority of these sites becomes fixed sites for future years.

### **Targets**

Improvements in the health ratings of sites currently rated as severely and significantly impaired, and the preservation of ratings at the other sites. An ultimate target should be that all sampled sites in the Catchment have an AusRivAS health rating of those similar to reference locations.

## **5.3 Fish indicator**

### **Background**

Fish are an important component of most aquatic ecosystems. Fish are also seen as useful indicators of riverine health. Fish can reflect disturbances at a range of scales, because fish interact at many trophic levels and because they are sensitive to many kinds of human disturbance (Harris 1995). They are also considered useful for environmental assessments due to their mobility and long life. It has been demonstrated that the abundance of fish and fish species can decrease in areas with degraded riparian vegetation and poor water quality (Growth *et al.* 1998).

Of particular relevance to the fish populations in the Sydney Drinking Water Catchment are the possible negative effects from the modification of river flows by dams, the temperature of water released from dams, barriers to fish passage such as dams and weirs and exotic fish species.

Dams and weirs collect variable flows from rivers and streams and often release water downstream that is of constant or regulated flow. It can also be the case that less water is released. This modification of flows can have negative effects on a wide range of aquatic organisms, including fish, and can reduce the diversity of fish species and increase the success of introduced species (Gehrke & Harris 2001).

Water which is released from dams can often be colder than what should be flowing downstream, especially if the dam has a bottom valve off-take. Cold water pollution can negatively affect fish growth and survival plus potentially limit the distribution of fish within rivers to warmer areas (Astles *et al.* 2003).

Dams, weirs, and many types of in-stream works act as significant barriers to fish passage, reducing the abundance and diversity of fish throughout a river system (Thorncraft & Harris 2000). They prevent the upstream and downstream passage of migratory fish, plus the access of fish to other areas of rivers over shorter distances. Fishways are structures that allow the passage of fish past barriers, but, at this stage, there are very few effective fishways in NSW rivers.

Single parameters, or combinations thereof, of fish populations are used to indicate fish health. The Index of Biotic Integrity (IBI), which uses numerous metrics to assign a health rating to fish communities in an area and indicate the health of that same riverine area, was not used in the audit due to insufficient time. A number of other measures of fish populations used by NSW Fisheries can be used to ascertain the status of fish communities and determine riverine health. There are four measures that were derived in this audit (see Table 5.4).

**Table 5.4 –Fish indicators of riverine health used in the audit**

<b>Fish indicators of riverine health</b>
<p><b>Native species richness</b></p> <p>The total number of native species is often used and is a measure of the general health of aquatic ecosystems because it has been shown that the number of native species declines with increasing environmental stress.</p>
<p><b>Proportion of exotic species</b></p> <p>The presence and relative abundance of exotic (introduced) species also reflects the general condition of the aquatic ecosystem and may represent both a symptom and a cause of declines in stream health and disturbance (Harris 1995). The relative abundance of exotic species is expected to increase with increasing environmental stress due to their purported superior competitive abilities and tolerance for degraded water quality and habitat conditions.</p>
<p><b>Fish assemblage ratio</b></p> <p>The ratio of observed species (O) to expected fish species (E) in an area (O:E) can reflect the health of the fish community. A low O:E ratio (close to zero) suggests that a site had fewer species than was once there and has been disturbed.</p>
<p><b>Proportion of individuals</b></p> <p>The proportion of exotic to native fish adds detail to the ‘proportion of species’ measure, and reveals how many fish are introduced, and how successful exotic or native species are.</p>

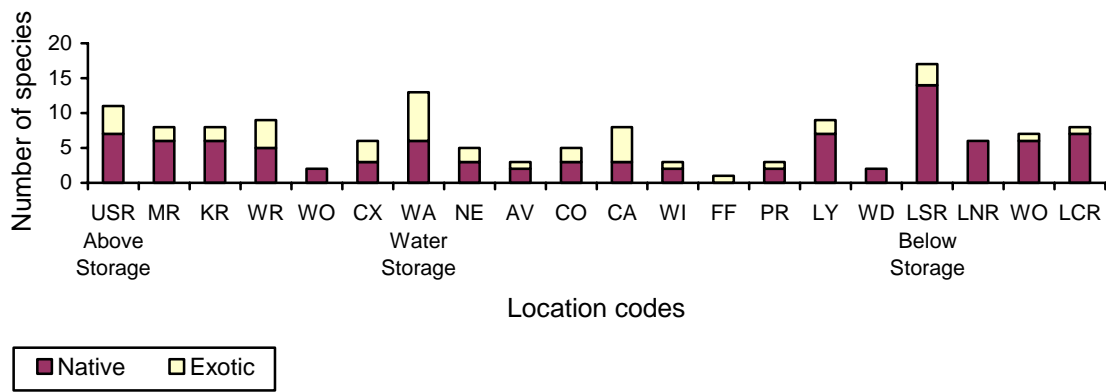
## **Findings**

SCA provided data on fish recorded within the Sydney Drinking Water Catchment. This data suggests that the lower Shoalhaven River had the greatest native species richness; double the amount of native fish species were found at this location than at the other locations (Appendix G Table 5). The Macquarie Perch (*Macquaria australasica*) is listed as a vulnerable species under the Fisheries Management Act and was found in the Mongarlowe River, Warragamba, Nepean, Avon, Cordeaux and Cataract Dams and in the Lower Nepean and Cataract Rivers below the storages. The Silver Perch (*Bidyanus bidyanus*) is also listed as vulnerable and was only found in the Avon and Cataract Dams. The Trout Cod (*Maccullochella macquariensis*) is listed as endangered and was only found in the Cataract Dam within the Catchment.

Warragamba Dam had the greatest percentage of exotic species, more than the other locations (Appendix G Table 5 and Figure 5.4). Water storage locations and locations above the water storages had greater ratios of exotic to native species than locations below the dams (Appendix G Table 5). A list of fish species that were expected in the Sydney Drinking Water Catchment was determined from NSW Fisheries and the Australian Museum records pre 1930s (Table 5.5). Using this list and the SCA supplied data, a ratio of fish species observed to those expected was calculated for each location (Figure 5.5 and Appendix G Table 5). The data used for upstream were a combination of upstream and storages where available. Locations downstream of the water storages had a higher ratio (i.e. fish communities closer to what would occur naturally) than water storages and locations above water storages.

Raw data were supplied by NSW Fisheries including the abundance of fish sampled between 1994–95 (or 1998–99 for the Shoalhaven) in 27 water bodies throughout the Catchment. In a catchment snapshot (Figure 5.6), the proportion of native species and native individuals are similar (59% and 55% respectively). Exotic fish species, however, make up a much larger proportion of the individuals (44%) than proportion of species (22%). This would suggest that, in the Sydney Drinking Water Catchment, the average exotic species is more successful than the average native species. The data also suggest that native species introduced out of their native range (19% of species) are generally not very successful in the Catchment (1% of individuals).

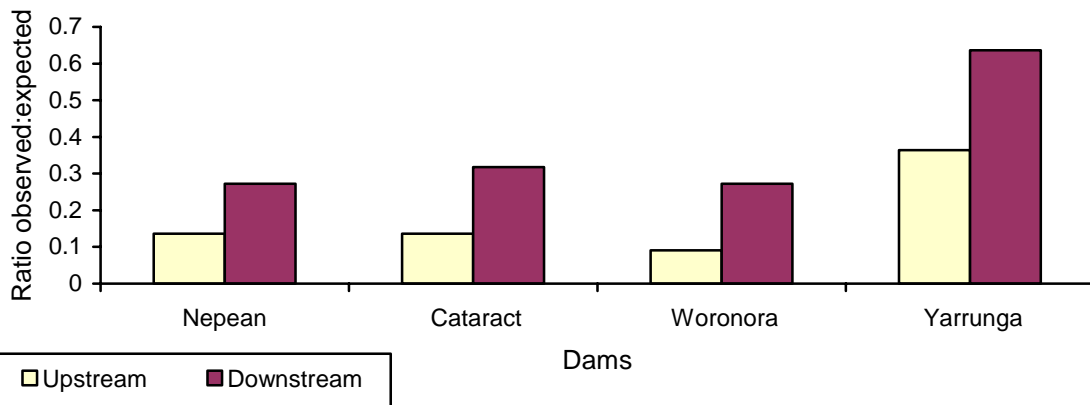
**Figure 5.4 – Number of native and exotic fish species recorded from the Sydney Drinking Water Catchment**



Source: SCA data, as at 2003

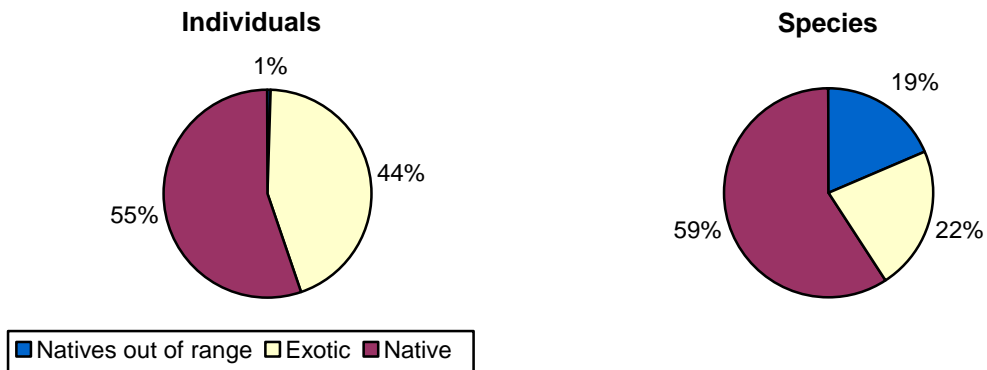
Note: See Appendix G Table 5 for location codes

**Figure 5.5 – Ratio of observed to expected native fish species upstream and downstream dams**



Source: SCA data, as at 2003

**Figure 5.6 – Proportion of native, natives out of range and exotic fish individuals and species collected between 1993 and 1995**



Source: SCA and NSW Fisheries data, as at 2003

**Table 5.5 – Fish species expected in the Sydney Drinking Water Catchment**

Common Name	Latin Name
Australian bass	<i>Macquaria novemaculeata</i>
Australian grayling	<i>Prototroctes maraena</i>
Australian smelt	<i>Retropinna semoni</i>
Bullrout	<i>Notesthes robusta</i>
Climbing galaxias	<i>Galaxias brevipinnis</i>
Common jollytail	<i>Galaxias maculatus</i>
Coxs gudgeon	<i>Gobiomorphus coxii</i>
Dwarf flathead gudgeon	<i>Philypnodon sp1</i>
Empire gudgeon	<i>Hypseleotris compressa</i>
Estuary perch	<i>Macquaria colonorum</i>
Firetailed gudgeon	<i>Hypseleotris galii</i>
Flathead gudgeon	<i>Philypnodon grandiceps</i>
Freshwater herring	<i>Potamalosa richmondia</i>
Freshwater mullet	<i>Myxus petardi</i>
Long finned eel	<i>Anguilla reinhardtii</i>
Macquarie perch	<i>Macquaria australasica</i>
Mountain galaxias	<i>Galaxias olidus</i>
Short finned eel	<i>Anguilla australis</i>
Shortheaded lamprey	<i>Mordacia mordax</i>
Southern blue eye	<i>Pseudomugil signifer</i>
Striped gudgeon	<i>Gobiomorphus australis</i>
Striped mullet	<i>Mugil cephalus</i>

**Source:** NSW Fisheries and Australian Museum records

## Implication

The areas above the water storages have been affected by the presence of the dam and have a reduced observed to expected ratio. This is confirmed by the detailed studies of Lake Yarrunga/Tallowa Dam which record not only changes in fish species, but in size structures of fish populations (Gehrke *et al.* 2000). These results highlight the need for fishways, which is a recognised issue in the Catchment and is receiving attention.

The number of exotic species in the Catchment probably highlights a moderate level of disturbance to riparian structure, flows and vegetation. The large proportion of exotic species highlights the importance of management and the monitoring of trends. Management should act primarily on achieving healthy riparian

areas and on managing pressures. Secondly, management should act on the exotic species directly. For this, consideration should be given to the involvement by SCA with the Murray–Darling Basin Commission and their ‘daughterless carp’ program to reduce this species in the Catchment. This genetics-based program, could considerably reduce carp numbers over the long-term, is currently being undertaken by CSIRO, with ancillary data being collected by NSW Fisheries in Collaboration with the CRC for Pest Animal Control. The same technology may also be used to combat *Gambusia* populations. Manual removal is also an option for exotic species control, but very resource intensive. Management initiatives should be prioritised to infested areas, particularly in storages (Warragamba and Cataract Dams would be a high priority) and inflows into storages (particularly the Cocks River).

### *Cold water pollution*

The Sydney Catchment Authority monitors the temperature of releases downstream from dams at a number of sites, and for 2002–03 the SCA has data for the Nepean, Warragamba and Tallowa Dams. There were differences, usually in the summer months, between outlet temperatures and inflow temperatures for all three lakes. For Warragamba and Tallowa Dams, there is at times a difference of 10–15 degrees between outlet and inflow temperatures. It is possible that this is having an effect on fish and other organisms, as temperatures 10 degrees below ambient have shown to have negative effects on some fish species (Astles *et al.* 2003).

For the Nepean and Warragamba Dams, the downstream temperature monitoring sites are approximately 20 and 40 km downstream. The temperatures are generally similar to the inflows of the lakes at these points, but it is uncertain how far downstream the differences in temperature last. A monitoring site for Tallowa Dam is 400 metres downstream, and measures temperature differences of 4–7 degrees between released water and inflows. This released water is reportedly a combination of water from off-takes and warmer water spilling over the dam.

### *Barriers to migration*

SCA has confirmed the presence of 68 weirs, excluding dam walls in the Catchment. Weirs are a major barrier to fish migration, and none of these has effective fishways.

Tallowa Dam, which separates the Upper Shoalhaven River and Lake Yarrunga from the Lower Shoalhaven River, has been well studied in recent years to assess the effect of the dam on fish passage (Marsden & Harris 1996; Marsden *et al.* 1997). Gehrke *et al.* (2000) have shown most recently that the dam is a major barrier to fish movement through the river, and that species richness is greatest downstream of the dam. It was found that 10 fish species accumulated directly below the dam in significantly larger numbers than anywhere elsewhere upstream or downstream, demonstrating the dam’s inhibition of fish migration and passage. It was also shown that, for the fish species found on both sides of the dam, their size distributions were significantly diverged between upstream and downstream populations, with the exception of the common carp. There is considerable evidence that also suggests the extinction of 10 migratory species upstream of the dam wall.

### **Future directions**

Monitoring and management of fish in the Catchment is needed. Sampling of fish at designated sites should be carried out approximately every 3 years to determine the status of, and changes in, the composition of fish communities and to measure the success of any pest-control initiatives. This time frame is consistent with that used in the Sustainable Rivers Audit of the Murray Darling Basin.

**Recommendation 21:** That a monitoring and management strategy for fish stocks in the Catchment be developed.

## Targets

The flow regime and connectivity of streams should be improved using fishways and flow design to allow free passage of fish within the Catchment.

Further declines of any native fish species should be avoided.

## 5.4 Riparian vegetation

### Background

Riparian zones typically consist of vegetated corridors adjacent to stream channels where the vegetation is influenced by the water. Riparian vegetation is very important in determining the health of stream ecosystems. These areas can be effective natural barriers, which prevent agricultural pollution from being exported and contaminating the larger ecosystem. The riparian zone plays a crucial role in the protection of water quality by also providing shade, stabilising banks and minimising erosion, limiting downstream flooding, supporting fisheries, storing and uptake of nutrients and contaminants and providing important habitat for a range of species. Riparian zones are often the most fertile part of the landscape and are subject to many pressures from land use change and human activities.

Willows and stock access have been identified as potential risks to native riparian vegetation. To date there has been no estimation of how many hectares are covered by willows or other exotic species. The number of applications to clear exotic weeds along rivers and streams was used to assess change in the condition of the riparian zone.

### Findings

SCA estimated that the predominant land cover in the riparian areas is native vegetation (SCA 2003a). The Mid and Lower Coxs River, Kowmung River, Lake Burragorang, Werriberri Creek, Little River, Nattai River, southern area of Endrick River and the Upper Shoalhaven River sub-catchments have 80–100% native vegetation cover in the riparian zone (Figure 5.7). The lowest percentage of riparian area covered with native vegetation occurs in the Upper Wollondilly River and Mulwaree River (0–20%) and Reedy and Braidwood Creek (20–40%) sub-catchments.



**Figure 5.7 – Native vegetation in the riparian zone of Glen Quarry Creek, August 2003**

A number of clearing applications were approved within the audit period to remove 16.8 hectares of exotic species including willows, from the riparian zone of the Wollondilly River, Mulwaree Ponds, Wingecarribee River, Paddys River and Gillamatong Creek. The SCA also removed 202 hectares of willows within the audit period which was a decrease of 77 hectares from the previous audit period (Figure 5.8).



**Figure 5.8 – Willow removal carried out by SCA along the Coxs River at Duddawarra Bridge, August 2003**

It was estimated in SCA's Annual Environment Report (2001) that 29% of the riparian zone of the Catchment is subjected to agricultural activity and that 21,000km (38%) of watercourse within the Catchment is presently being, or has the potential to be, accessed by stock (Figure 5.9). As data was not available, it was not possible to assess the extent of any change during the current audit period.



**Figure 5.9 – Stock access to Wallaby Creek causing the removal of vegetation, bank erosion and water contamination, August 2003**

## Implication

Healthy riparian zones assist in maintaining the health of streams and rivers in the Catchment, thereby enhancing the first of the multiple barriers in protecting drinking water quality (Section 2.2). These are particularly important in areas where the adjacent sub-catchments are subject to agricultural activity or where stock has ready access to stream banks. Overall, much of the riparian zone in the Catchment is in good condition but there is less than 40% cover of native vegetation along riparian zones in the Braidwood Creek, Mulwaree River, Reedy Creek and Upper Wollondilly River sub-catchments. Water quality and ecosystem health is at risk in these sub-catchments.

The absence of accurate, quantitative information on area or length of fencing and relatively intact riparian zone in non-protected areas and its condition is preventing any informed analysis of trends from one audit to the next.

Removal of willows is in itself a disturbance and it is important to follow such removal with further remedial action such as planting of appropriate native vegetation. This is a stated intention in the SCA Healthy Catchments program, and in other government programs, but data were not available for this audit.

## Future directions

The SCA Riparian Strategy outlined a program for the mapping of the condition and extent of the riparian zones within the Catchment by June 2006. This database would provide a benchmark for determining trends on riparian zone health in the longer-term. Given that the Catchment contains 55,000 km of riparian areas, a broad scale indicator of riparian zone health should be supplemented by activity indicators and areas of riparian zone protected or rehabilitated (e.g. area of fencing or area of weed removal/revegetation).

**Recommendation 22:** That Riparian Management programs undertaken by government agencies in the Catchment be funded and integrated to achieve Catchment-wide mapping and aid in increasing the amount of riparian vegetation in a good or near intact condition.

**Recommendation 23:** That SCA creates an integrated database to allow monitoring and assessment of all works undertaken that affect the quality of riparian vegetation and streambank stability.

## Target

Protect and repair the riparian zone native vegetation communities:

- complete the mapping of the extent and condition of riparian zone within the Catchment by June 2006
- reduce the extent of weed infestation
- increase the length fenced where appropriate and practical
- progressive revegetation and regeneration of disturbed riparian zones (Figures 5.10 and 5.11).



**Figure 5.10 – Degraded section of the Upper Cocks River, August 2003**

There is a link between the above target and the Warragamba Catchment Blueprint target RHMT10: Maintain existing native riparian vegetation along riparian zones within the Catchment and by 2012, improve the ranking of the condition of 10% of streambank from ‘good’ to ‘near intact’ as mapped in *Geomorphic Categorisation of Streams* (DLWC 2001).



**Figure 5.11 – Section of the Upper Cocks River (immediately downstream of Figure 5.10) undergoing revegetation, August 2003**

## 5.5 Native vegetation

### Background

Native vegetation within the Catchment is important for maintaining ecosystem, species and genetic diversity and health. The extent of native vegetation cover is used as a general indicator of the state of ecosystem health. The condition of the native vegetation is also important; diversity will be different between areas which are in good condition compared to areas which have been degraded by human activities. Degradation of native vegetation can impact on critical ecosystem services such as clean air and water, recycling nutrients and resources such as food and fibre. The decline of native vegetation can also induce soil salinity or acidity, soil erosion and loss of nutrients, changes to flow regimes and climate change.

The rate of biodiversity loss accelerates dramatically when a vegetation community declines below approximately 30% of its original area. In the Wollondilly River, Mulwaree River and Wingecarribee River sub-catchments, clearing has been extensive. These areas where native vegetation communities have been heavily modified and/or cleared are likely to have extinctions of species.

The Eastern Bushlands Database (EBD) was finalised by the National Parks and Wildlife Service (NPWS) in 1998. The database consists of broadscale mapping (1:100,000) of structural vegetation in three GIS datasets, Northern EBD, Central EBD and Southern EBD. The digital vegetation maps were created by visual interpretation of 1989, 1990 and 1991 satellite imagery using vegetation description outlined by Roberts (1992) (NPWS 1998). The three regions were mapped to a different level of detail; this creates problems when trying to match the three datasets. Unfortunately, the Catchment is covered by the Central and Southern EBD and where these two datasets join there is some discontinuity in vegetation communities which can be seen in Figure 5.12. The NPWS concluded that the benefits of edge matching the datasets were far outweighed by the effort required to do so, particularly given the general limitations of the mapping (i.e. scale and detail of analysis) and the fact that it does not provide any information about disturbances or condition of vegetation. Eight categories of native vegetation were extrapolated from the database, *Allocasuarina nana* Heath, dry forest, forest, moist eucalypt forest, plateau complex, rainforest, severely disturbed forest and woodland.

The areas of National Parks, Special Area and State Forests were overlaid onto the native vegetation cover from the EBD to estimate the percentage of native vegetation that was protected and managed in the Catchment (Figure 5.13).

Figure 5.13 also highlights a number of anomalies in the current boundary of the Special Areas, particularly where Special Areas border the National Parks Estate. It may be appropriate to review the boundaries of the Special Areas as part of an overall review of the role and effectiveness of Special Areas.

The NPWS and SCA completed more detailed vegetation mapping (1:25,000) of the Warragamba and Woronora Special Areas which describe and map all the native vegetation communities across the Special Areas including comprehensive information on disturbance and condition. This process has provided valuable information for both benchmarking the condition of vegetation and providing a sound basis for program development and planning for a number of agencies. An example of the output from this work is provided in Appendix G Figure 2.

The Special Areas primarily contain native vegetation and cover 23% of the Sydney Drinking Water Catchment. Almost 13% of the land within the Special Area which consists of privately owned lands which are not subject to the high level of control as the publicly owned areas (e.g. restrictions regarding access).

### Findings

Sixty-three percent of the Sydney Drinking Water Catchment is covered by native vegetation and of that 57% is in National Parks and Special Areas and 5% is managed in State Forests (Figure 5.13). Thirty-eight per cent of native vegetation is outside the above designated areas and is dispersed across the Catchment

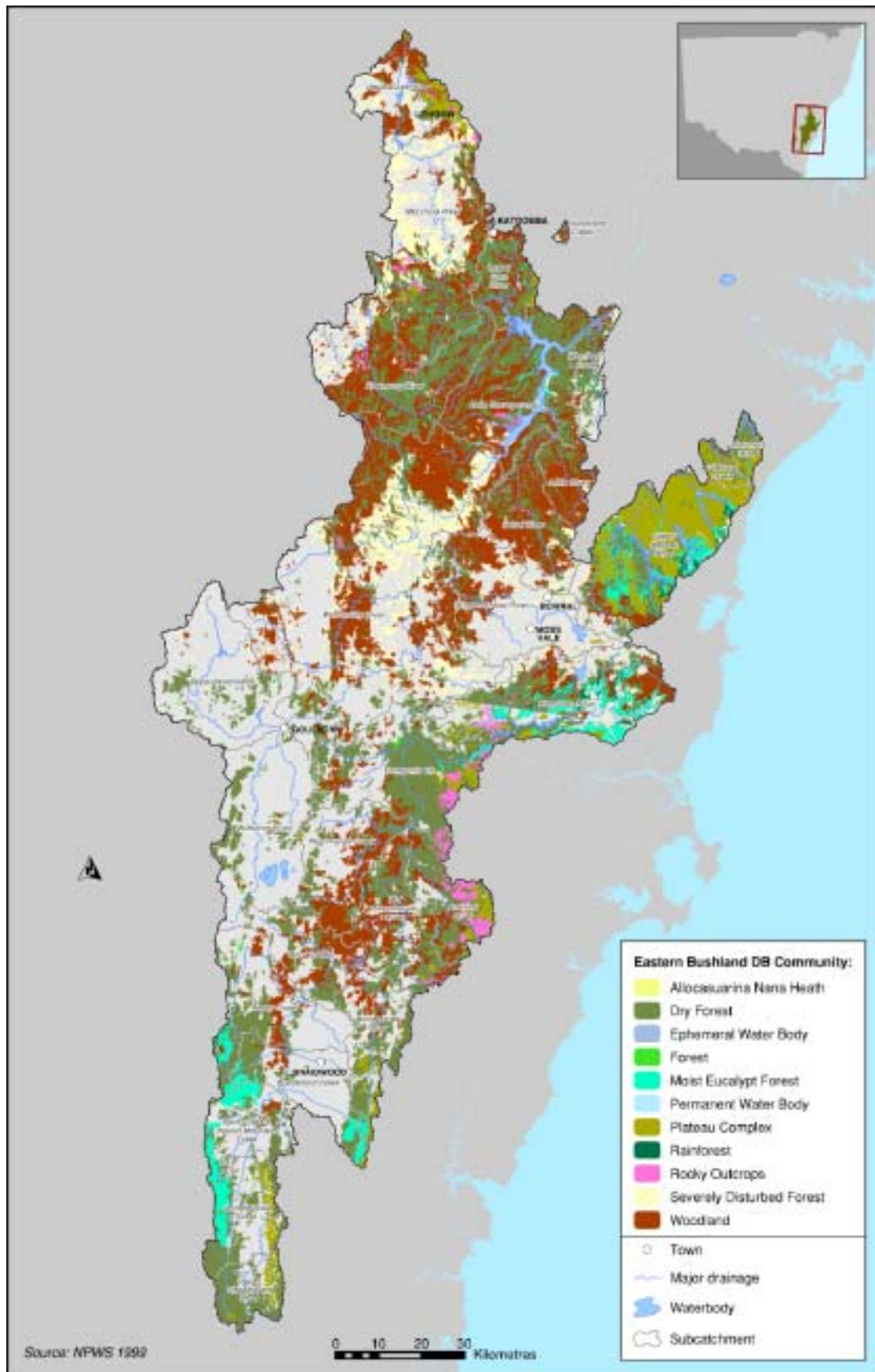
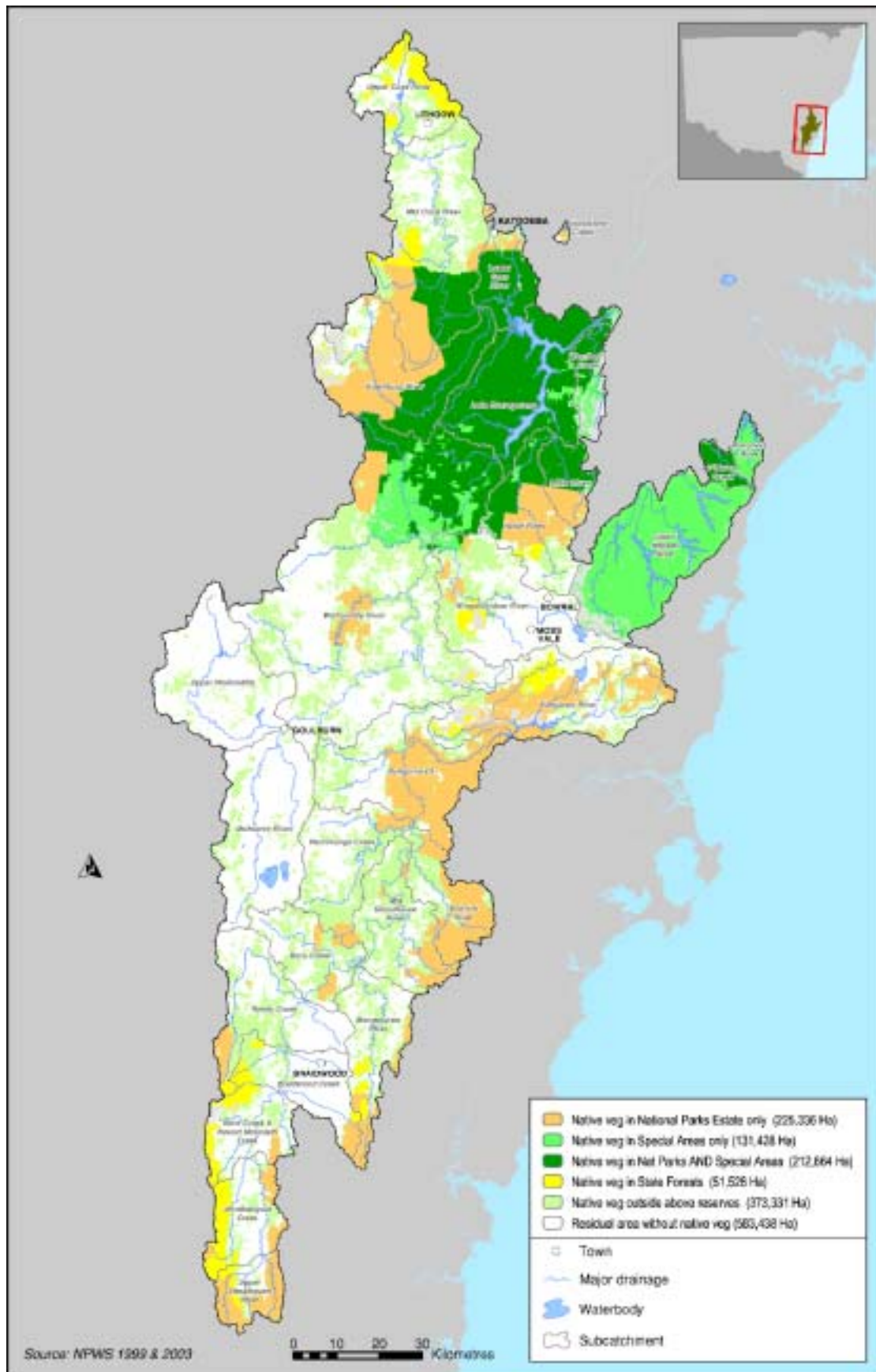


Figure 5.12 – Map of native vegetation derived from the Eastern Bushland Database for the Sydney Drinking Water Catchment



**Figure 5.13 – Map of native vegetation in National Parks, Special Areas and State Forests for the Sydney Drinking Water Catchment**

(Figure 5.13). The majority of this native vegetation is privately owned and the condition and importance of this vegetation is not well understood.

The Kowmung River, Lower Coxs River, Lake Burragorang, Little River, Nattai River, Woronora River, O'Hares Creek, Upper Nepean River and Upper Shoalhaven River sub-catchments have a large percentage of native vegetation cover (>80%). The sub-catchments with the lowest percentage of native vegetation cover (<20%) are the Upper Wollondilly River and Mulwaree River. A number of clearing applications were approved within the audit period to log native vegetation. The total area actually cleared was 728.76 hectares, all within the Braidwood district.

The detailed mapping of the Warragamba Special Area identified that privately owned land was likely to be disturbed (e.g. cleared, bare soil/erosion, used for urban or industrial activities). Areas which were undergoing revegetation were also included. The information gained from the mapping can be used to prioritise remediation works within the Special Areas.

### **Implication**

Data about the extent and condition of vegetation cover across the Catchment presents a generalised picture of the likely overall health of the Catchment and its capacity to yield high quality water. Certain areas of the Catchment, however, play a particularly important role in preventing pollutants entering the water supply and proper management and ongoing monitoring of vegetation within these areas is clearly important to maintaining water quality and quantity. These areas include those in immediate proximity to the water storages, riverine corridors (over 18 degrees) and flood liable lands.

Vegetation in other areas may play a less direct role in maintaining water quality but clearly has a significant role in maintaining ecological processes within these priority areas (for example – there are difficulties in maintaining the ecological integrity of a wetland without also managing vegetation within the immediate sub-catchment).

The lowest percentage of native vegetation cover was in the Upper Wollondilly River and Mulwaree River sub-catchments. The low percentage cover of native vegetation in these sub-catchments may put water quality and ecosystem health at risk.

### **Future directions**

Undertake new mapping of native vegetation communities in the Catchment at a comparable scale and resolution. The condition, relative significance and disturbance categories similar to the Special Areas mapping of vegetation needs to be determined; incorporated in this should be the identification of threatened vegetation communities and the amount of fragmentation. The condition and relative significance of the native vegetation that is not in protected or managed areas should be the basis of prioritisation and management. To determine change over time in the cover of native vegetation, the amount of native vegetation area cleared and revegetated should be collected.

**Recommendation 24:** That SCA undertakes vegetation mapping in conjunction with DIPNR and the Department of Environment and Conservation (NSW) for the remaining areas of the Catchment with priority being given to areas of native vegetation. This mapping should be consistent with the mapping undertaken of the Special Areas and include information on disturbance and condition.

**Recommendation 25:** That SCA ensures that mapping of riparian and native vegetation is appropriately integrated to ensure full compatibility of data.

## Target

Improve condition and decrease the degree of degradation of native vegetation through rehabilitation, restoration and revegetation. Appropriate management of native vegetation outside protected and managed areas.

There is a link between the above target and the Warragamba Catchment Blueprint targets.

BMT11: Increase to 60% by 2007 the proportion of all lands in the Catchment covered by an actively implemented integrated property management plan that addresses threats to biodiversity.

BMT12: By 2012, maintain the condition of all significant remnants of native vegetation and improve the condition of 20% of the area covered by priority native vegetation communities.

BMT13: By 2012, improve the value of the links (as indicated by number, width and native vegetation quality of links) between significant remnants of native vegetation by 10%.

## Actions and Response

### Response to issue

*There are many responses to the degradation of ecosystem health including programs to reduce the impacts of pollution (Chapter 2), new water management rules under statutory water sharing plans (Chapter 3) and programs to improve land management (Chapter 4). In addition to these issues previously discussed are a number of other government responses to the degradation of ecosystem health that are discussed below. These include:*

- *programs to maintain and enhance fisheries*
- *programs to maintain and enhance riparian zones*
- *programs to maintain and enhance native vegetation.*

### Programs to maintain and enhance fisheries

The impact of instream structures, such as weirs and other mechanisms that alter natural flow regimes has been recognised as a key ecosystem health issue. The Threatened Species Conservation Act and the Fisheries Management Act have established Scientific Committees who have both listed the alteration of natural flow regimes of rivers and streams and their floodplains and wetlands as a Key Threatening Process under each respective Act.

#### *Weir Review Program*

The Weir Review Program is responding to fish ecosystem health measures include improving fish passage at identified weirs within the Catchment where currently no effective fishways exist.

In 2001, NSW Fisheries, in collaboration with the then Department of Land and Water Conservation (DLWC), conducted an initial weir review of all licensed weirs in NSW, including those in the Sydney Drinking Water Catchment. The assessment identified those barriers which were a high priority for potential removal, modification or required a fishway to be installed. Also in 2001 the Statement of Intent (SOI) for the Hawkesbury–Nepean River System specifically identified the need for a review of the nine weirs on the upper Nepean with the primary goal of removing the maximum number of weirs, consistent with providing alternate, secure water supply to existing users, and to ensure that any remaining weirs provide for fish passage. Following the initial weir assessment, the DLWC (now DIPNR) commissioned further independent expert assessment of the upper Nepean weirs. The report recommended Thurns and Bergins weirs be removed, low level fishways be installed on Wallacia and Brownlow Hill and the remaining weirs of Mount

Huner, Cobbity, Sharpes, Camden and Menangle to be modified. SCA has indicated a willingness to assist in the remediation of the impacts of the upper Nepean weirs. However on-ground action at any of these sites has been delayed while an overall effluent management strategy is being finalised. This is because if highly treated effluent is used to provide an alternate water supply, flow regimes needs to be taken into consideration when determining where weir removal will create the greatest benefits to river health. NSW Fisheries has gained funding from the Environmental Trusts to complete detailed weir reviews of two priority structures in each catchment in NSW as well as undertaking works at four of these sites in NSW.

### *Fish pass at Tallowa Dam*

Currently a number of migratory fish species are prevented from gaining access to the Shoalhaven River habitat upstream of the 42-metre high dam wall at Tallowa. The SCA and NSW Fisheries have undertaken investigations into development of a detailed design of a combined fishway and multi-level off-take at Tallowa Dam. The SCA has advised that the detailed design phase of the Tallowa Dam Fishway has commenced. The SCA will further assess the project based on information gathered during this phase and the development of final designs and costing. NSW Fisheries will continue to assist the SCA with the design and follow-up of fish monitoring to test the effectiveness of the fishway on construction.

## **Programs to maintain and enhance riparian zones**

The SCA's Healthy Catchment Program being rolled out over a five-year period to 2007 has initiated a program of riparian improvement through the implementation of the Riparian strategy which requires the application of: grants and assistance schemes; community and industry assistance programs; education programs and regulatory processes in consultation with appropriate authorities to determine the condition of riparian zones within the Catchment and in consultation with landowners and other responsible agencies to develop and undertake riparian protection and rehabilitation programs in priority areas.

## **Programs to maintain and enhance native vegetation**

Of the two main responses to addressing native vegetation decline, the first is to slow down or stop the clearing of native vegetation and the second is to focus on revegetating cleared areas to restore biodiversity values.

### *Protection of native vegetation*

The major tools for addressing clearing of native vegetation are:

- legislation to control clearing
- protection of native vegetation from clearing by establishing conservation reserves
- conservation covenants and financial incentives for native vegetation protection on private land e.g. Native Vegetation Incentive Scheme in the Warragamba catchment with funding from the Natural Heritage Trust matched by state funds to enable landholders to identify and protect high conservation value communities in perpetuity.
- policies for the sustainable management of public native forests.

Within the Catchment 10-year targets are reinforced by the relevant Catchment Management Blueprints that use native vegetation as a surrogate for terrestrial biodiversity. The blueprints also have close links with the implementation of regional vegetation management plans. Actions identified under the blueprints include:

- mapping and analysing native vegetation, high conservation areas and cultural heritage values to identify priority areas for conservation.
- developing a regional vegetation management plan prioritising areas for conservation management
- negotiating voluntary conservation agreements with landowners for the protection of priority native vegetation communities and areas

- promoting the adoption and implementation of best management practices for managing native vegetation through education and incentive programs and in government planning instruments (eg. Environmental Services Scheme)
- implement a monitoring program on native vegetation status to determine that there is no net loss and that conservation targets are being achieved.

### *Revegetation of native vegetation*

Invasions of exotic plant species can make catchment areas vulnerable to erosion, reduce water quality, restrict the regeneration of native plants, and limit biodiversity. The SCA is providing \$110,000 in a two-year funding agreement with the Jenolan Caves Reserve Trust to begin a management program to control an infestation of sycamore trees at Jenolan Caves. Sycamore removal is a priority identified in a comprehensive weed management plan for the Jenolan region, commissioned by the NPWS.

### **Effectiveness of response**

A number of actions are required to effectively manage fish stocks in the Catchment. Partnerships between a number of stakeholders is needed to ensure major projects, i.e. removal or modification of barriers to fish passage, control of pest fish species and restoring aquatic habitats, can be achieved. The issue of river connectivity within the Catchment has progressed slower than expected during the audit period. Even for the priority streams of the upper Nepean, the program has been delayed while funding of capital works is resolved and consistency with an effluent strategy and wider State weir removal strategy is determined.

The issue of riparian zone protection and enhancement is progressing slowly. A riparian strategy under the Healthy Catchment Program is a positive response, however the capacity to undertake more works is limited by the absence of a prioritised work program. Once priorities are identified better use needs to be made of the capacity to influence and undertake on-ground riparian work by developing environmental services schemes, joint partnerships and grant funding.

The *Native Vegetation Conservation Act 1997* (NVC Act) established a system of community-based Regional Vegetation Committees to prepare Regional Vegetation Management Plans to identify and protect areas of high conservation value, but at present there are no NVMPs covering the Sydney Drinking Water Catchment.

The ability to assess the effectiveness of programs designed to maintain and enhance native vegetation remains impaired by the lack of knowledge as to the amount of vegetation cleared and the amount revegetated. The scoping study of mapping conducted by NPWS to provide a basis for mapping disturbance as well as the native vegetation communities, health and fragmentation in catchments under extensive private ownership is a positive step forward (see Recommendation 24). This work will match that which has already been undertaken for the sub-catchments within Special Areas. If approved, this will take approximately 6 years to be completed.

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# Acronyms

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ANZECC – Australian and New Zealand Environment and Conservation Council  
ARMCANZ – Agriculture and Resource Management Council of Australia and New Zealand  
AusRivAS – Australian River Assessment System  
BOD – Biological Oxygen Demand  
BPG – Best Practice Guidelines  
BWSA – Bulk Water Supply Agreement  
CAP – Compliance Activity Plan  
CEPP – Catchment Enhancement and Protection Program  
CMA – Catchment Management Authority  
CPIG – Catchment Protection and Improvement Grants  
CPS – Catchment Protection Scheme  
CSIRO – Commonwealth Scientific and Industrial Research Organisation  
DIPNR – Department of Infrastructure, Planning and Natural Resources  
DLWC – Department of Land and Water Conservation  
DMR – Department of Mineral Resources  
EASI – Environmental Assessment of Sites and Infrastructure  
EBD – Eastern Bushlands Database  
EP – Equivalent Population  
EP & A Act – Environmental Planning and Assessment Act 1979  
EPA – Environment Protection Authority  
ESD – Ecological Sustainable Development  
HCP – Healthy Catchments Program  
HNRMF – Hawkesbury Nepean River Management Forum  
HRB – Hazard Reduction Burn  
HRC – Healthy Rivers Commission  
IBI – Index of Biotic Integrity  
IMEF – Integrated Monitoring of Environmental Flows  
IPART – Independent Pricing and Regulatory Tribunal of NSW  
LEP – Local Environmental Plan  
NDVI – Normalised Difference Vegetation Index  
NHMRC – National Health and Medical Research Council  
NLWRA – National Land and Water Resources Audit  
NPWS – National Parks and Wildlife Service  
NVC Act – Native Vegetation Conservation Act 1997

NVMP – Native Vegetation Management Plan  
PE – Population Equivalent  
PIN – Penalty Infringement Notice  
POEO Act – Protection of the Environment Operations Act 1997  
PRP – Pollution Reduction Program  
PSR – pressure-state-response  
PSRMP – Pollution Source Risk Management Plan  
RACC – Regional Algal Coordinating Committee  
RAP – Rectification Action Plan  
REP – Regional Environmental Plan  
RUSLE – Revised Universal Soil Loss Equation  
SCA – Sydney Catchment Authority  
SEPP 58 – State Environmental Planning Policy 58  
SIRIS – Sustainable Investment Research Institute  
SLWCA – Strategic Land and Water Capability Assessment  
SMP – Subsidence Management Plan  
SoE – State of the Environment  
SOI – Statement of Intent  
STP – Sewage Treatment Plant  
SWCM Act – Sydney Water Catchment Management Act 1998  
WAMC – Water Administration Ministerial Corporation  
WFP – Water Filtration Plant

**Table 1: Criteria for identifying a sub-catchment as being under pressure in Table 1 Main Findings**

Indicator Number	Indicator or issue	Criteria	
2.1	Phosphorus	Top 5 sub-catchments with estimated annual load of phosphorus	Figure 2.1
	Nitrogen	Top 5 sub-catchments with estimated annual load of nitrogen	Figure 2.2
	STP	Bowral – consistent wet weather bypasses, Goulburn – 9 overflows 2002-2003. Upper Coxs River sub-catchment > 50% of estimated nutrient load from STPs.	Table 2.1 Figure 2.1 & 2.2
	Unsewered	Sub-catchments with unsewered population of > 1000	Table 2.2
2.2	Water Quality at WFPs	Exceedence of the BWSA at Cascade and Greaves Ck	Table 2.4
2.3	Algae Blooms	Sub-catchments with high incidence (>15 000 cells/ml) and long duration (> 100 days) of cyanobacteria blooms	Figure 2.10 & 2.12
2.4	Pathogens	Sub-catchments with > 5% of samples with incidences of <i>Cryptosporidium</i> or <i>Giardia</i>	Table 2.5
3.1	Extraction Licences	Sub-catchments with > 2000 megalitres licence for extraction per annum	Figure 3.1
	Farm dams	Sub-catchments with density > 1 farm dam / 1km <sup>2</sup>	Figure 3.2
3.2	Bores	Sub-catchments with density > 3 groundwater bores / 10km <sup>2</sup>	Figure 3.3
3.3	Weirs	Sub-catchments with > 10 weirs or barriers	Figure 3.4
	Transfers	Increase in volume of water transferred by 50%	Page 36
4.1	Increasing urbanisation	Sub-catchments with > 100 SEPP 58 dwelling applications	Figure 4.3
	Other developments	Sub-catchments with > 25 SEPP 58 other development applications	Figure 4.4
4.2	Sites of pollution or potential contamination	Sub-catchments with density > 1 site of pollution or potential contamination / 10km <sup>2</sup>	Figure 4.5
4.3	Soil erosion	Sub-catchments with very high or high estimated erosion	Figure 4.9
4.4	Salinity	Sub-catchments with widespread risk of salinity	Figure 4.10
5.1	Ecosystem water quality	A location in a sub-catchment with 3 or 4 parameter groups with a very poor WQ rating	Figure 5.2
5.2	Macroinvertebrates	A location in a sub-catchment with an AusRivAS health rating of severely or significantly impaired	Figure 5.3
5.3	Fish	Sub-catchments which have an observed/expected ratio difference upstream and downstream of a dam	Figure 5.5
5.4	Riparian vegetation	Sub-catchments with < 40% native vegetation cover in the riparian zone	Page 68
5.5	Native vegetation	Sub-catchments with < 20% native vegetation cover	Figure 5.12





# Appendix B

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## Documents from SCA

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# Appendix C

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## SCA Data Quality Assurance and Quality Control Processes

### Water Quality

Confidence in results from the various programs depends on the quality of the data and the various steps undertaken to collect those data. Sydney Catchments Authority (SCA) have developed criteria and protocols for auditing of their water quality monitoring program (see Section 14 of the July 2002- Dec 2004 *Water Quality Monitoring Program Report*), and have put in place a comprehensive system for reporting performance against QA/QC processes associated with that program. Both the sampling and analytical programs, which were largely undertaken by contractors external to SCA, have QA/QC processes built in as part of the monitoring contract process. Analytical methods used for routine analytes are all NATA accredited. These programs were audited by Sinclair Knight Merz (SKM). SKM supply monthly reports and a consolidated annual report (SKM/SCA *Water Quality Monitoring Project Annual Report 2002-03*, 2003) which reports on the results of audits, non-conformances and corrective action.

Data transfer from service providers to SCA is automatic and agreed data transfer protocols are in place. Data collected after the formation of SCA (data used for all previous audits) are quality assured for reliability and had been analysed for QA/QC for previous annual reports. SCA is currently checking data quality for historical data prior to June 1999.

The audits were conducted independently of SCA and the respective contractors and covered field sampling and analytical laboratories (second and third-round audits of each laboratory).

Analytical methods used for routine analytes were all NATA accredited and the independent auditors commented on sampling and analytical services above NATA accreditation requirements. Field sampling audits were carried out on seven sites or operations throughout 2002-03. The audit contractor (SKM) indicated that “sampling activities were of high standard and were undertaken in accordance with the AWT procedure manuals and safety plan and SCA contract requirements” (AWT is the sampling contractor). Five of the seven audits “scored a perfect score of 100” and minor suggestions did not compromise sample integrity. Each of the two remaining audits lost only two penalty points on procedural matters. SKM have reported that these issues have been addressed by AWT.

For analytical audits (12 audits reported in 2002-03), “procedures, on most occasions, [met] the contractual and quality requirements established in the respective contracts”, and laboratories performed well in sample traceability, standards preparation and equipment calibration and maintenance. Eight of the procedures had no major or minor findings reported while of the four remaining procedures/laboratories, 10 findings were all minor – relating to analytical methods, sample management and monitoring. Corrective actions have been implemented. The analytical procedures/ laboratories audited covered the following: organisms and metals; algae and chlorophyll; nutrients; water chemistry; microbiology; trace metals; and viruses.

Data from duplicates and blanks were analysed by the Project Manager and data acceptance criteria were established. Field data transfer from service providers to SCA is automatic and agreed data transfer protocols are in place. Acceptance criteria for field duplicates were established during the year using agreed approaches and AWT are now reporting field duplicate data and investigating any data that fall outside these criteria. Results of field and trip blanks are also reported routinely but contamination is “extremely rare”.

The audit process and results instils confidence in the accuracy of results supplied for water quality monitoring.

## **Geographical Information System (GIS)**

There is a fundamental need to make immediate and long-term decisions based upon sound knowledge including geographical information. The SCA has developed a Catchment Information Strategy which includes spatial information under its Healthy Catchments Program. However the SCA is yet to finalise its strategy in regard to its Geographical Information System (GIS). The SCA therefore needs to adopt a GIS data protocol that is consistent with the Australian New Zealand Land Information Council (ANZLIC) Metadata Standard. ANZLIC is a joint initiative of the Australian Government, the New Zealand Government and the governments of the States and Territories of Australia. The core metadata elements of the ANZLIC protocol include a comprehensive item report containing: the title, custodian details, description, currency and status, access, data quality and contact information in relation to every GIS data set. Such a protocol would assist SCA to develop a more coordinated approach to its GIS data collection, use and quality assurance.

# Appendix D

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**List of stakeholders provided with a draft of relevant parts of the report to comment on the accuracy of information and data they provided to the audit:**

- Sydney Catchment Authority
- NSW Fisheries
- National Parks and Wildlife Service
- Department of Infrastructure, Planning and Natural Resources
- Department of Mineral Resources.





# Appendix E

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## **Individuals and organisations who provided a submission to the Sydney Drinking Water Catchment Audit**

### **Individuals**

Mr Ivan Jeray

Mr Mike Thompson

### **Organisations**

Centennial Coal

Department of Infrastructure, Planning & Natural Resources (DIPNR)

Department of Local Government

Department of Mineral Resources (DMR)

Friends of Katoomba Falls Creek Valley

Hawkesbury-Nepean CMB Chair

Lithgow City Council

Ministry of Energy & Utilities

National Parks & Wildlife Service (NPWS)

NSW Agriculture

NSW Department of Health

NSW Fisheries

NSW Minerals Council

Peak Environment Non Government Organisations

Shoalhaven City Council

State Forests of NSW

Sydney Catchment Authority (SCA)

Sydney Water Corporation

Transgrid

Wingecarribee Shire Council

Wollondilly Shire Council





# Appendix F

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## **Roles and Responsibilities of Stakeholders**

### **Sydney Catchment Authority (SCA)**

SCA is responsible, primarily under the Sydney Water Catchment Management Act 1998, for the management of the Catchment, dams and infrastructure that provide Sydney's bulk water supply. SCA's management takes form in a variety of projects and under numerous pieces of legislation.

SCA has further statutory responsibilities set out in three other documents. Their Operating Licence sets out the performance and water quality objectives SCA must meet and is granted by the Governor of NSW. A Water Management Licence is granted to SCA by DIPNR, and SCA must meet licence requirements on monitoring, reporting, and water releases and transfers. The Bulk Water Supply Agreement addresses the supply of raw water to their customers (primarily Sydney Water). This agreement specifies what the quality of the water must be that is supplied to the water filtration plants.

SCA jointly manages the Special Areas with the Department of Environment and Conservation (NSW) under the Special Areas Strategic Plan of Management. The Plan sets the framework for a high level of protection of the natural and cultural heritage in these areas, and maintain the areas as intact buffers for the storages.

Current legislation allows SCA to exercise power under the Protection of the Environment Operations Act 1997, regarding the impact of point sources of pollution on water quality in the Catchment. This is particularly true in the Special Areas where SCA can restrict access and activities.

The SCA must also play a role in overseeing the development of the Catchment, under SEPP58, which assists in protecting Sydney's drinking water supply. Types of development likely to have a large impact, or a lesser impact in a Special Area, must go to SCA's Chief Executive for approval.

### **Department of Infrastructure Planning and Natural Resources (DIPNR)**

DIPNR is a developer of policies for natural resource management and maintains databases on the condition of the State's land, soil, water and vegetation. DIPNR is involved in the planning, policy and regulation in relation to the natural and built environment, rural and urban management (including urban growth, renewal and consolidation) and the development of housing policies. The Department aims to achieve coordinated and sustainable management of the State's natural resources through an integrated catchment management framework.

DIPNR manages the planning and sharing of water across the state, and is preparing the Sydney and Regional Centres Drinking Water Catchments Regional Environmental Plan (REP) for the catchments providing water to Sydney and adjacent regional centres. This REP will provide catchment management strategies to improve the planning, management and knowledge base for water quality protection in the catchments. State Environmental Protection Policy 58 (SEPP 58) 'Protecting Sydney's Water Supply' is currently in place to perform this function until the REP is finalised. DIPNR also administers water management licences issued under the Water Act 1912, such as for surface water or groundwater extractions.

Along with local councils and catchment management committees, DIPNR is responsible for producing the Catchment Blueprints which are aimed at natural resource management at a sub-catchment level.

## **Department of Environment and Conservation**

The Department of Environment and Conservation (NSW) is a new government department formed in September 2003, and joins together the Environment Protection Authority (EPA), the National Parks and Wildlife Service (NPWS), the Botanic Gardens Trust and Resource NSW. The Department of Environment and Conservation (NSW) does not encompass, but shares links with, the SCA.

The EPA works towards protection and improvement of water quality for coastal marine, estuarine, inland and groundwater and recognises the value of water ways to: aquatic and riparian ecosystems and habitats; public health and public amenity; and economic development. The EPA is the issuer and regulator of licences for polluting activities in NSW and undertakes a public education role in relation to pollution.

The NPWS is responsible for maintaining the parks and reserves in NSW. They also jointly manage with the SCA the catchment's Special Areas, under the Special Areas Strategic Plan of Management.

## **NSW Department of Health (DOH)**

The primary aim of NSW Health is to protect the health of the public, and thus they have a role ensuring safe drinking water. DOH monitors the quality of drinking water via information provided by the agencies it regulates, and develops standards and guidelines for the treatment of waste water.

It manages the testing program established to verify *Cryptosporidium* and *Giardia* testing results supplied by Sydney Water, the SCA and independent laboratories.

The Chief Health Officer of DOH has the power to restrict or prevent the use of water considered unfit for human consumption.

## **Department of Mineral Resources (DMR)**

The DMR is responsible for approving, regulating and monitoring mining and associated activities in NSW. They have a role in the rehabilitation of abandoned and derelict mine sites, and are currently rehabilitating some priority sites in the Catchment with SCA.

## **NSW Agriculture**

NSW Agriculture conducts agricultural research and provides practical and sustainable farm production and environmental advice to commercial farmers, graziers, horticulturists, agribusiness and other groups. This collaborative effort draws together a comprehensive range of information and knowledge which can also be disseminated through best management practices guidelines. There are extensive areas of agriculture in the Catchment.

## **NSW Fisheries**

NSW Fisheries manages the living aquatic resources of NSW. It focuses on managing commercial and recreational fishing, protecting key fish habitats, conserving aquatic biodiversity and promoting ecologically sustainable development. It carries out scientific research, and provides management, advisory and compliance services. It advises the government on the use and conservation of living aquatic resources. In consultation with industry and the community, NSW Fisheries develops policies and regulations on resource sharing and allocation. NSW Fisheries have undergone substantial fish sampling in the Catchment and are currently investigating the effects on fish of the barriers (dams, weirs etc.) in the Catchment.

## **Local Councils**

Local councils determine and approve proposed developments and prepare local environment plans. Under the Environment Planning & Assessment Act (EP&A Act), local Councils must prepare Local

Environmental Plans (LEPs) and assess development applications (DAs). If councils are to approve a development that doesn't require development consent, they must still take full account of its likely effect on the environment.

Although the EPA is responsible for granting works approvals and licences, local councils play a major role in regulating pollution control. Under the *Protection of the Environment Operations Act 1997* (POEO Act), councils have the power to issue notices ordering pollution control measures for premises or activities which are not the subject of an EPA licence.

Councils provide major infrastructure services such as sewerage and drainage connection to residents land, and regulates on-site effluent disposal in unsewered areas. Councils require approval from the Minister for the construction or extension of dams, water treatment works and flood retaining basins.

Local councils are represented on Catchment Management Boards.

### **Catchment Management Authorities (CMAs)**

The Government recently announced the establishment of 13 CMAs across the State. The Sydney Drinking Water Catchment falls across two CMAs, the Hawkesbury–Nepean CMA and the Southern Rivers CMA.

The CMAs are to be established from January 2004 as independent statutory bodies. The CMAs will build on the work of the Catchment Management Boards and related committees in developing catchment action plans and working with local landholders in developing Property Vegetation Plans.

### **Department of Energy, Utilities and Sustainability**

The Department promotes the sustainable supply and use of energy and urban water in NSW. They are involved in managing the water supply for country towns and sewerage schemes in the Catchment.

### **Independent Pricing and Regulatory Tribunal of NSW (IPART)**

IPART's historical role was the setting of prices for service providers, but has recently expanded to include industry and licence reviews. IPART monitor prices, and now also industry performance against licence provisions, including the water quality and environmental impacts of the water supply industry. IPART has reviewed SWC's licence and reviewed SCA's water management licence in 2002. It made a recommendation that no changes to the licence occur, but that SCA develop with SWC and DIPNR a Demand and Supply Management Strategy.

### **NSW Rural Fire Service (RFS)**

RFS are responsible for the coordination and planning of bushfire fighting and hazard reduction operations throughout NSW. At the local government scale, there are Bushfire Management Committees included in the above role, including representatives from NPWS and SCA. SCA has worked with the RFS on improving their fire management practices.

### **NSW Rural Lands Protection Boards (RLPB)**

They are involved in the control of pest animal species and livestock diseases. They also have an advisory role to landholders. SCA and the NPWS have worked with RLPB to ensure the coordination of pest control strategies in the Catchment.

## **NSW Rural Assistance Authority**

This authority administers assistance measures to rural producers and small businesses. Conservation funding exists, for example, to encourage improved and sustainable land management. Projects include woody weed control and livestock effluent control. The authority also manages the Water Reform Structural Adjustment Program. The Program's aims include the adoption of improved irrigation practices, increased water use efficiency on farms, and minimising negative impacts from irrigation upon the NSW environment.

## **State Forests of NSW**

State Forests are responsible for sustainably managing more than 2 million hectares of public native forests and a large area of planted forests in NSW. Included in State Forests' aims is the management of forests for which it is responsible and providing benefits to the NSW public now and in the future. There are moderate areas of State Forests in the Catchment.

## **Dams Safety Committee**

Its statutory function is to ensure all prescribed dams in NSW are safe and maintained. The Committee must also ensure that mining operations near dams do not affect the integrity of the dam or create significant water loss from a storage.

## **NSW Healthy Rivers Commission (HRC)**

HRC's role is to independently assess selected NSW rivers and make recommendation to the government on appropriate management strategies for ecological, social and economic benefits. The Hawkesbury-Nepean, Shoalhaven and Woronora Rivers have all been assessed by the HRC, and recommendations made in the inquiries were accepted by the government.

Guidelines specified by the HRC also make up part of SCA's assessment of catchment water quality.

## **NSW State Algal Coordinating Committee (SACC)**

SACC's main role is implementing the NSW Algal Management Strategy which is aimed at minimising the occurrence and impacts of algal blooms in NSW, specifically on the algal contingency planning and response areas. The strategy includes CMBs, government, industry and the public stakeholders. They also oversee the Regional Algal Coordinating Committees (RACC). RACCs have a more focused research and monitoring roles, and the Metropolitan/South Coast RACC is particularly active in the Hawkesbury-Nepean.

SCA has adopted the SACC guidelines for cyanobacteria concentrations in recreational waters.

## **NSW Heritage Council**

The Council's main role is the implementation of the Heritage Act 1977. This includes management design and implementation for heritage listings and an advisory role on matters affecting heritage sites. Heritage Council listings include both built and key natural environments. The Wingecarribee Swamp in the Catchment is a state listed natural site. There are many built sites of state and local heritage significance in the Catchment, including Avon, Cataract and Cordeaux Dams.

## **Universities**

Universities are often involved in providing expertise and research support for SCA. For example, UNSW and Macquarie and Sydney Universities have all been involved in research on pathogens. UWS has assisted in creating carbon and nutrient budgets, and Wollongong University has assisted with sediment budgets.

## **Sydney Water Corporation (SWC)**

SWC is the SCA's major bulk water customer, supplying the Sydney, Illawarra and Blue Mountains regions with drinking water. SWC operate nine water filtration plants (WFPs) in the Catchment and, under the Bulk Water Supply Agreement between SWC and SCA, specify the quantity and quality of the raw water the WFPs should receive.

## **Industry**

Industry in the Catchment is diverse and includes: mining and extractive industry, forestry and horticulture, livestock and commercial industries, and telecommunication and energy-based industry. Some of these activities are regulated and licensed. When this is the case, the operators have an obligation to comply with the licence conditions. All industry is also required to submit for initial development approval. Within the Catchment, SEPP 58 applies to developments with a high potential threat to water quality, particularly in the special areas, and these developments are obligated to undergo a more rigorous approval process. Industry also has an intrinsic role to minimise pollution.

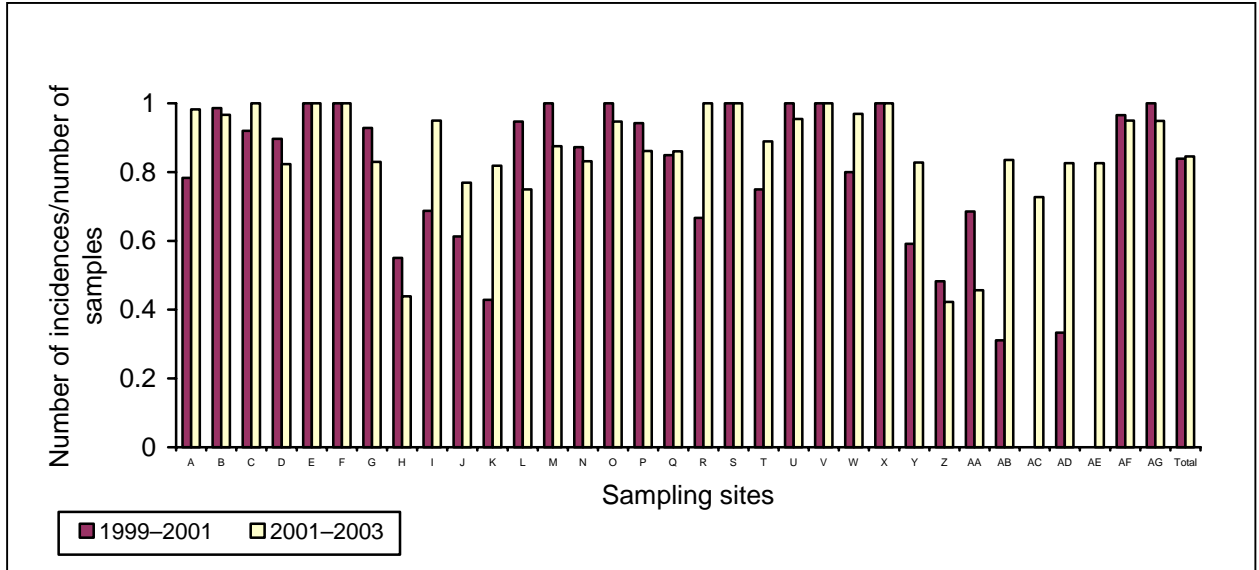
## **Residents**

Individuals must seek Council approval to conduct water supply work, draw water from a council water supply, conduct sewerage or storm-water works, or connect a private drain or sewer to a public drain or sewer. Residents can have a role in community groups which are active in decision making. All residents have an intrinsic role to minimise pollution.





# Appendix G



**Figure 1 – The number of incidences of total cyanobacteria per number of samples**

**Table 1 – Percentage of total cyanobacteria and toxic cyanobacteria in the Sydney Drinking Water Catchment for the current audit period (1/7/01–30/6/03)**

Code	SCA Code	Station Name	Total Cyanobacteria				Toxic Cyanobacteria			
			High	Medium	Low	Very Low	High	Medium	Low	Very Low
A	DAV7	Lake Avon at the Upper Avon Valve	14	66	18	2	0	0	0	100
B	DBP1	Bendeela Pondage	68	23	6	3	0	3	19	78
C	DCA1	Lake Cataract at Dam Wall	25	75	0	0	0	0	0	100
D	DCO1	Lake Cordeaux at Dam Wall	24	41	18	17	0	0	0	100
E	DFF	Fitzroy Falls composite	91	9	0	0	0.7	32	48	19.3
F	DFF6	Lake Fitzroy Falls at Midlake	92	8	0	0	3	38	24	35
G	DGC1	Lake Greaves at Dam Wall	1	41	40	18	0	0	0	100
H	DLC1	Lake Lower Cascade at 50m upstream	0	10	34	56	0	0	0	100
I	DNE2	Lake Nepean at 300m upstream of Dam Wall	10	70	15	5	0	0	0	100
J	DPAE	Bendeela picnic area	50	17	10	23	0	4	9	87
K	DTA1	Lake Yarrunga at 100m from Dam Wall	45	9	27	19	0	0	14	86
L	DTA3	Lake Yarrunga at Kangaroo and Yarrunga Junction	42	25	8	25	0	0	11	89
M	DTA5	Lake Yarrunga at Shoalhaven River	13	25	50	12	0	0	25	75
N	DTA8	Lake Yarrunga at Kangaroo River, Bendeela PS	54	15	14	17	0	1	13	86
O	DTA10	Lake Yarrunga at Kangaroo arm, Reed Island	47	21	26	6	0	0	6	94
P	DTC1	Lake top Cascade at 100m upstream of Dam Wall	7	57	21	15	0	0	0	100
Q	DWA2	Lake Burragorang at 500m upstream of Dam Wall	36	32	18	14	0	3	3	94
R	DWA9	Lake Burragorang at 14km upstream of Dam Wall	72	27	0	1	0	0	22	78
S	DWA12	Lake Burragorang at 9km upstream of Coxs River	67	33	0	0	0	0	8	92
T	DWA19	Lake Burragorang at Kembula River arm	70	15	4	11	0	0	4	96
U	DWA21	Lake Burragorang at Coxs arm 37 km upstream of Dam Wall	86	9	0	5	0	6	11	83
V	DWA27	Lake Burragorang at Wollondilly arm 23 km upstream of Dam Wall	77	23	0	0	0	8	0	92
W	DWA39	Lake Burragorang at Wollondilly arm 40 km upstream of Dam Wall	30	42	24	4	0	0	0	100
X	DWI1	Wingecarribee Lake at outlet	98	2	0	0	0	5	38	57
Y	DWO1	Lake Woronora at Dam Wall	0	55	28	17	0	0	0	100

**Table 1 – Percentage of total cyanobacteria and toxic cyanobacteria in the Sydney Drinking Water Catchment for the current audit period (1/7/01–30/6/03) (continued)**

Z	HBP	HBP1 and HBP2 taps	0	13	30	57	0	0	11	89
AA	HFF4	NPWS picnic shelter tap at Fitzroy Falls	0	21	25	54	0	9	24	67
AB	HOP6	Oberon pipeline, Leura	14	40	30	16	0	0	0	100
AC	HPR1	Upper Canal at Prospect WFP	0	41	32	27	0	0	0	100
AD	HUC1	Upper Canal at Broughtons Pass	4	48	30	18	0	0	0	100
AE	HUC3	Upper Canal at Kenny Hill	0	35	48	17	0	0	0	100
AF	RPR1	Lake Prospect at Midlake	63	20	12	5	0	0	0	100
AG	RPR3	Lake Prospect near RWPS	66	20	9	5	0	0	3	97

**Table 2 – Volume (ML) of water licensed to be extracted for each river and creek in the Sydney Drinking Water Catchment and the use of the water extracted**

	Boro Creek	Bungonia Creek	Coxs River	Endrick River	Jerrabattgulla Creek	Kangaroo River	Little River	Mongarlowe River	Mulwatee River	Nattai River	Nerrimunga Creek	Ohares Creek	Reedy Creek	Shoalhaven River	Werriberri Creek	Wingecarribee River	Wollondilly River	Woronora River
<b>Irrigation</b>	60	34	3540	15	102	5426	31	241	695	222	271	216	262	10380	708	912	7603	72
<b>Domestic</b>	0	1	10	0	1	12	0	2	2	0	0	0	0	27	2	3	28	0
<b>Farming</b>	0	0	10	0	0	25	0	0	5	0	0	0	0	50	0	0	10	0
<b>Industrial</b>	0	0	148	0	0	21	0	46	5	0	0	0	0	84	0	76	257	0
<b>Mining</b>	0	0	73	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
<b>Pisciculture</b>	0	0	2	0	0	0	0	3	0	0	0	0	0	3	0	18	18	0
<b>Railway</b>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<b>Recreation High security</b>	0	0	50	0	0	0	0	0	0	0	0	0	0	63	0	0	0	0
<b>Recreation Low security</b>	0	4	0	0	0	8	0	0	84	0	0	0	0	19	0	0	88	0
<b>Stock</b>	0	0	43	0	5	72	0	9	0	10	0	6	0	139	12	10	99	0
<b>Town water supply</b>	0	0	70	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0
<b>Total</b>	60	39	3946	15	108	5563	31	301	791	232	271	222	262	10789	722	1019	8108	72

**Table 3 – Percentage exceedence at lake and reservoir locations for current audit period**

Code	SCA Code	Station Name	Turbidity (<10NTU)	Conductivity (<30 µS/cm)	pH (6.5–8.5)	Total Al (<0.055 mg/L)	Total Fe (<0.3 mg/L)	Total P (<10 µg/L)	Filtered P (<5 µg/L)	Total N (<350 µg/L)	Oxidised N (<10 µg/L)	Ammonia (<10 µg/L)	Dissolved Oxygen (85–110%)	Chlorophyll-a (<5 µg/L)
A	DAV7	Lake Avon at the Upper Avon Valve	1	0	9.7 +	4.1	16.4	1.8	0	1.8	50	51.8	39 -	31.6
C	DCA1	Lake Cataract at Dam Wall	2.8	0	46 +	34.9	50.8	0	0	15.9	18.2	77.3 -	58.6	20.7 +
D	DCO1	Lake Cordeaux at Dam Wall	6.4	0	14.1 +	17.2	34.5 +	2.6	0	21.1	42.1	94.7 -	72 +	39.1 +
F	DFF6	Lake Fitzroy Falls at Midlake	0.9	0	0	59.5 -	7.1	100 -	17.6	100 -	85.3 -	96.6 -	11.3	100 -
G	DGC1	Lake Greaves at Dam Wall	3	0	27.9 +	98	94.1	0	2.6	25.6	64.1 -	66.7 -	22.9 +	26.7 -
H	DLC1	Lake Lower Cascade at 50m upstream	0.7	0	0	0	0	0	0	7.3	100	68.3 -	25.8 -	3.4
I	DNE2	Lake Nepean at 300m upstream of Dam Wall	0.3	0	9.9	12.5 +	18.8 +	2.1	0	16.7	97.9	58.3 -	63.7	5.7
K	DTA1	Lake Yarrunga at 100m from Dam Wall	30.2	0	10.9	81.9	84	69.1	32.1	69.1	74.5 +	90.9	67.4 +	26.7 -
L	DTA3	Lake Yarrunga at Kangaroo River and Yarrunga Junction	24.1 +	0	12.1	76.3	84.6	82.8 -	53.6	70.7	69	87.9	76.3	34.8 +
M	DTA5	Lake Yarrunga at Shoalhaven River	37.6	0	5.8	89.8	91.8	56.7	42.9	70 -	80	96.7	58.3	16.4
N	DTA8	Lake Yarrunga at Kangaroo River, Bendeela PS	16.4	0	4.5	82.8	92.9	93.3	80	50	73.3 +	80 -	36	70.3 +
O	DTA10	Lake Yarrunga at Kangaroo arm, Reed Island	20.7	0	10.1	94.9	97.4	100	66.7	76.2 -	76.2 -	81 -	51.8	70
P	DTC1	Lake Top Cascade at 100m upstream of Dam Wall	0.2	0	1.6	0	0	12.5	2.6	45	87.5	37.5	27.6 -	21.9 +
Q	DWA2	Lake Burragorang at 500m upstream of Dam Wall	0.5	0	0	3.7	0	0.2	0.2	1.9 +	65 +	4.3	61.1 +	2.6
R	DWA9	Lake Burragorang at 14km upstream of Dam Wall	0.5	0	0	1.4	0	0	0	2.4 +	59.7 +	2.4	69.3	0.3
S	DWA12	Lake Burragorang at 9km upstream of Coxs River	1.5	0	0.7	5.6	1.5	1.8	0	3.6 +	58.5	7.8	72.6 +	0.8
T	DWA19	Lake Burragorang at Kedumba River arm	14.5	0	3.2	37.7 -	37.7 -	67.5 -	22.9 +	18.1	37.3	34.9 -	25.3	51.4
U	DWA21	Lake Burragorang at Coxs Arm 37km upstream of Dam Wall	7.6	0	0	16.7	28.8 -	65.6 -	16.7 +	12.2	15.6 +	27.8 -	20.1 +	31.6
V	DWA27	Lake Burragorang at Wollondilly Arm 23 km upstream of Dam Wall	0.1	0	0	2.1	0.8	0.2	0.2	3.4 +	62.8	12.2	67.6 +	0
W	DWA39	Lake Burragorang at Wollondilly Arm 40 km from Dam Wall	3.2	0	0	61.1 -	0.9	35.6 -	1.8 +	4.9 +	37.4	7.4	9.4	16.8 +
X	DWI1	Wingecarribee Lake at outlet	8.3	0	0	52.2	4.5	100 -	18.9	96.2 -	43.4 -	68.8 -	16	86
Y	DWO1	Lake Woronora at Dam Wall	5.5	0	54.1	32.9	2.5	0	0	3.2	95.2	64.5	36.3	2.4
AF	RPR1	Lake Prospect at Midlake	2.8	0	1.9	0	0	3.7	1.2	2.5	9.9 +	17.3	24.5	4.7
AG	RPR3	Lake Prospect near RWPS	1.4	0	0	16 +	0	5.3	0 +	0	0	0	13.3	13.3

**Notes:** pH and dissolved oxygen percentage indicates outside guideline range.

ANZECC and ARMCANZ 2000 guideline values in parentheses.

Red cells indicate 75–100%, orange 50–75% and yellow 25–50% exceedence of guidelines. - = increased percentage exceedence from previous audit period and + = decreased percentage exceedence from previous audit period.

**Table 4 – Percentage of samples collected in exceedence at catchment locations for current audit period**

Code	SCA Code	Station Name	Turbidity (<15NTU)	Conductivity (<350 µS/cm)	pH (6.5-8.5)	Total Al (<0.055 mg/L)	Total Fe (<0.3 mg/L)	Total P (<20 µg/L)	Filtered P (<15 µg/L)	Total N (<250 µg/L)	Oxidised N (<15 µg/L)	Ammonia (<13 µg/L)	Dissolved Oxygen (85-110%)	Chlorophyll-a (<5 µg/L)
CA	E083	Coxs River at Kelpie Point	0	0	0	7.7 +	0 +	0	0	6.9 +	19.2 +	3.8	11.1	0
CB	E130	Kowmung River at Cedar Ford	0	0	11.5	8 +	4.2	0	0	26.9 -	24 +	4	29.2 -	0
CC	E157	Kedumba River at Maxwells Crossing	7.1 +	3.6	3.6	38.5 +	24 +	22.2 +	3.8	81.5	96.2	42.3 -	23.1	7.7
CD	E203	Gibbergunyah Creek at Mittagong STP	4.8	76.2	0	95	45	100	85	100	100	100	78.9	15
CE	E206	Nattai River at The Crags	0	71.4 -	0	21.4 +	7.1 +	100	100	100	85.7	67.9 -	29.6 -	7.1 +
CF	E210	Nattai River at Smallwoods Crossing	14.3	4.8	0	73.7 -	72.2	28.6 -	5.3	76.2 -	73.7 -	47.6 -	36.8 -	16.7
CG	E243	Little River at Fireroad	0	0	19.2	41.7 -	52.2 -	3.8	0	42.3 -	58.3 -	54.2 -	8.3	13
CH	E332	Wingecarribee River at Berrima	26.3	5.3	5.3	90.5	57.1	100	52.4 -	100	90.5	81 -	31.6	100
CJ	E409	Wollondilly River at Murrays Flat	0	96.2	23.1	18.5 +	18.5 +	100	100	100	85.2	81.5 -	76 -	66.7 -
CK	E450	Wollondilly River at Golden Valley	0	82.4	5.9	29.4	11.8 +	5.9	0	100	5.9 +	11.8	5.9	0
CL	E457	Mulwarree River at Towers Weir	0	100	33.3 -	66.7	100 -	100	100	100	66.7 +	100 -	100 -	33.3
CM	E488	Wollondilly River at Jooriland (Fowlers Flat)	8.7	60.9	13.6	60	21.1 +	13 +	5	78.3	35	25	19	15
CN	E531	Werriberri Creek at Werombi	3.5	62.8	4.7	50 +	100	8.3	0	54.2	85	75 -	90.5	10.5
CO	E601	Nepean River at Inflow to Lake Nepean	0 +	0	0	62.5	100	12.5 +	0	100	100	12.5	0	0
CP	E602	Burke River at inflow to Lake Nepean	0	0	8	52 +	92	0	0	4 +	20	20	20	0
CQ	E706	Kangaroo River at Hampden Bridge	3.1 +	0	3.1	88.9	100	42.4	9.1	90.9	93.9	75 -	14.8	6.7
CR	E822	Mongarlowe River at Mongarlowe	3.8	0	0	73.1 +	53.8	7.7 +	3.8	15.4 +	15.4	26.9 -	15.4 +	3.8
CS	E847	Shoalhaven River at Fossickers Flat	4.2 +	0	0	60 +	36 -	12 +	4	32 +	32	36 -	8	0
CT	E851	Shoalhaven River at downstream Tallowa Dam	28 -	0	0	96.4	100	21.4	0	100	100	92.9	7.7	10.7
CU	E860	Shoalhaven River at Mount View	8 +	0	4	53.8 +	53.8	15.4 +	15.4 +	38.5	11.5	26.9 -	0	0
CV	E861	Shoalhaven River at Hillview	11.5 +	0	0	59.3 +	40.7 +	18.5 +	0	33.3 +	7.4 +	29.6 -	15.4	7.4
CW	E891	Gillamatong Creek at Braidwood	19.2 +	92.3	0	11.5 +	65.4	46.2	26.9	84.6 -	34.6	30.8 -	92.3	7.7

**Notes:** pH and dissolved oxygen percentage indicates outside guideline range.

ANZECC and ARMCANZ 2000 guideline values in parentheses

Red cells indicate 75–100%, orange 50–75% and yellow 25–50% exceedence of guidelines. - = increased percentage exceedence from previous audit period and + = decreased percentage exceedence from previous audit period.

**Table 5 – Recorded (✓) fish species within streams and rivers above water storages; Upper Shoalhaven River (USR), Mongarlowe River (MR), Kangaroo River (KR), Wingecarribee River (WR), Woronora River (WO), and Coxs River (CX); below water storages; Lower Shoalhaven River (LSR), Lower Nepean River (LNR), Woronora River (WO) and Lower Cataract River (LCR) and within water storages; Warragamba (WA), Nepean (NE), Avon (AV), Cordeaux (CO), Cataract (CA), Wingecarribee (WI), Fitzroy Falls (FF) and Prospect (PR) Reservoirs, Lake Yarrunga (LY) and Woronora Dam (WD). Areas above and below water storages have been colour coded to match the particular storage. MR, AV, PR and CO had no accompanying data supplied.**

Exotic Species		Above Water Storage						Below Water Storage				Water Storage									
		USR	MR	KR	WR	WO	CX	LSR	LNR	WO	LCR	WA	NE	AV	CO	CA	WI	FF	PR	LY	WD
Common carp	<i>Cyprinus carpio</i>	✓		✓				✓				✓				✓	✓		✓	✓	
Goldfish	<i>Carassius auratus</i>	✓		✓	✓			✓				✓				✓					
Mosquito fish	<i>Gambusia holbrooki</i>	✓	✓		✓					✓	✓	✓			✓					✓	
Redfin perch	<i>Perca fluviatilis</i>											✓									
Brook trout	<i>Salvelinus fontinalis</i>											✓									
Brown trout	<i>Salmo trutta</i>	✓	✓					✓				✓	✓	✓	✓	✓					
Rainbow trout	<i>Oncorhynchus mykiss</i>				✓							✓	✓	✓	✓		✓				
Japanese weatherloach	<i>Misgurnus anguillicaudatus</i>				✓																
Native Species		USR	MR	KR	WR	WO	CX	LSR	LNR	WO	LCR	WA	NE	AV	CO	CA	WI	FF	PR	LY	WD
Australian bass	<i>Macquaria novemaculeata</i>	✓		✓				✓		✓										✓	
Yellow finned bream	<i>Acanthopagrus australis</i>							✓													
Bullrout	<i>Notesthes robusta</i>							✓													
Freshwater catfish	<i>Tandanus tandanus</i>							✓								✓			✓	✓	
Murray cod	<i>Maccullochella peelii</i>															✓					
Trout cod (endangered)	<i>Maccullochella macquariensis</i>															✓					
Long-finned eel*	<i>Anguilla reinhardtii</i>	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓
Short-finned eel	<i>Anguilla australis</i>	✓	✓				✓	✓	✓											✓	
Freshwater herring	<i>Potamalosa richmondia</i>							✓													
Climbing galaxias*	<i>Galaxias brevipinnis</i>		✓								✓	✓									
Mountain galaxias*	<i>Galaxias olidus</i>	✓	✓		✓		✓					✓				✓					
Coxs gudgeon	<i>Gobiomorphus coxii</i>	✓		✓	✓			✓	✓	✓										✓	
Dwarf Flat-headed gudgeon	<i>Philypnodon</i> sp1			✓				✓			✓									✓	
Flat-headed gudgeon	<i>Philypnodon grandiceps</i>	✓		✓	✓		✓	✓	✓	✓	✓	✓					✓		✓	✓	
Western carp gudgeon	<i>Hypseleotris</i> spp																			✓	
Striped gudgeon	<i>Gobiomorphus australis</i>							✓		✓	✓										
Common jollytail	<i>Galaxias maculatus</i>							✓													
Short headed lamprey	<i>Mordacia mordax</i>							✓													
Freshwater mullet	<i>Myxus petardi</i>							✓													
Striped mullet	<i>Mugil cephalus</i>		✓					✓													
Golden perch	<i>Macquaria ambigua</i>															✓					
Macquarie perch* (vulnerable)	<i>Macquaria australasica</i>		✓						✓		✓	✓	✓	✓	✓	✓					
Silver perch (vulnerable)	<i>Bidyanus bidyanus</i>													✓		✓					
Australian smelt*	<i>Retropinna semoni</i>	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓			✓	✓	✓
Observed / Expected		0.32	0.27	0.27	0.23	0.05	0.14	0.64	0.27	0.27	0.32	0.27	0.14	0.05	0.14	0.14	0.05	0	0.09	0.32	0.05
Exotic Species / Native Species		0.57	0.33	0.33	0.8	-	1.0	0.19	-	0.17	0.14	1.16	0.37	0.5	0.37	1.67	0.5	-	0.5	0.29	-
Exotic Species as % of total		36	25	25	44	0	50	16	0	14	13	54	40	25	40	38	33	-	25	18	0

Notes: Observed / Expected – number of taxa observed / number of taxa expected, Exotic Species / Native Species – number of exotic fish species / number of native fish species, \*Migratory native species

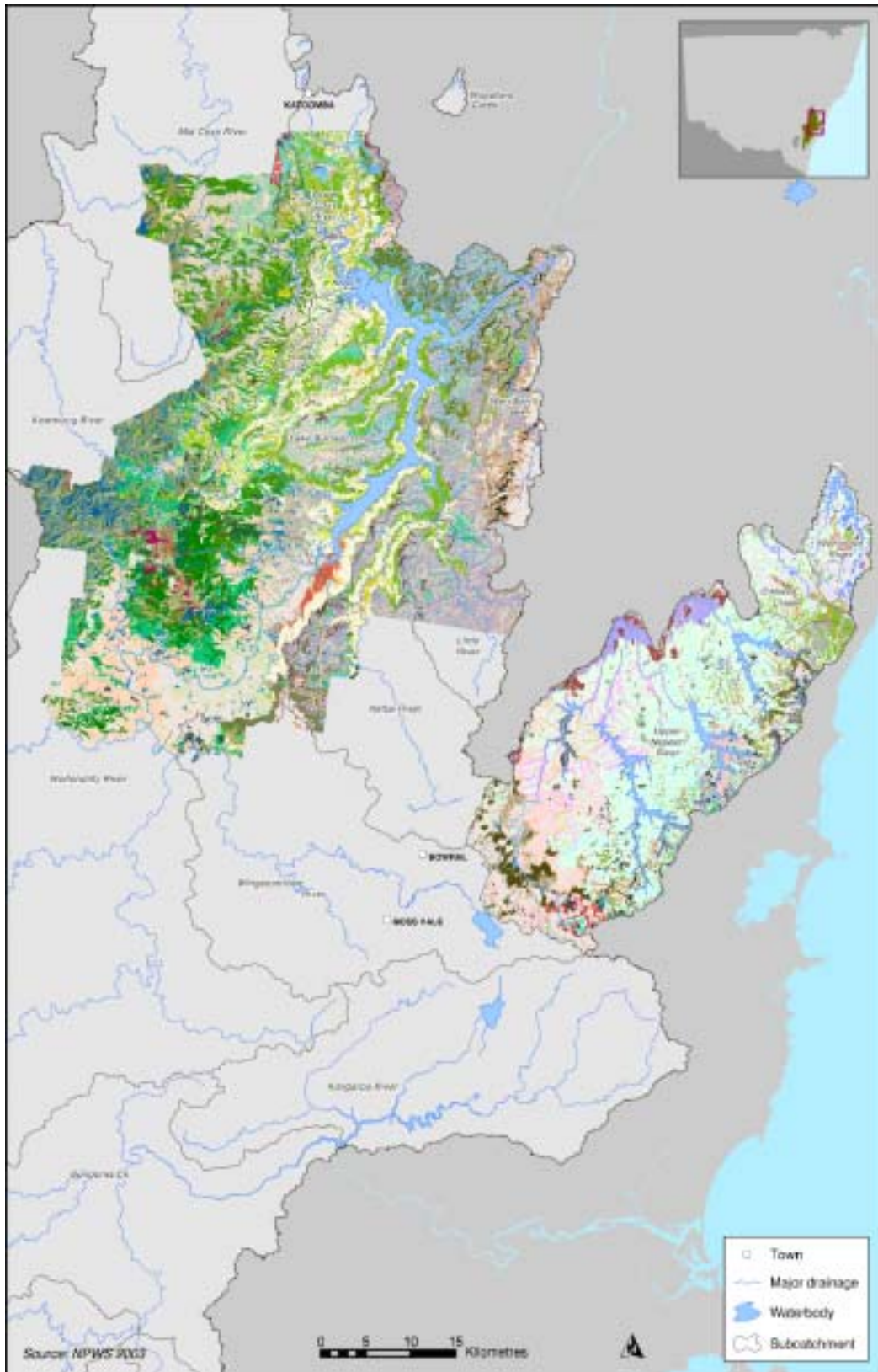
**Table 6 – Code, station name and year sampled of macro invertebrate sampling sites used in the report**

SCA Station			
Code	Name	Year Sampled	Station Name
MA	A5	2001 & 2002	Mulwaree River at Lake Bathurst
MB	A6	2001 & 2002	Tarlo River at Tarlo
MC	E086	2001 & 2002	Coxs River at Kelpie Point
MD	E130	2002 only	Kowmung River at Cedar Ford
ME	E157	2001 & 2002	Kedumba River at Kedumba crossing
MF	E206	2001 & 2002	Nattai River at The Crags
MG	E210	2002 only	Nattai River at the causeway
MH	E409	2002 only	Wollondilly River at Murrays Flat
MI	E457	2001 & 2002	Mulwaree River at The Towers
MJ	E488	2002 only	Wollondilly River at Jooriland
MK	E6133	2002 only	Goondarin Creek at top of Cordeaux Dam
ML	E706	2002 only	Kangaroo River at Hampton Bridge
MM	E822	2002 only	Mongarlow River at Mongarlowe
MN	E8311	2002 only	Corang River at Meangora
MO	E8361	2001 & 2002	Nerrimunga Creek at Minshall Trig
MP	E847	2001 & 2002	Shoalhaven River at Fossikers Flat
MQ	E861	2001 & 2002	Shoalhaven River at Hillview
MR	E890	2001 & 2002	Boro Creek at Marlowe
MS	E891	2001 & 2002	Gillamatong Creek at Braidwood
MT	GO515	2001 & 2002	Woronora River at the Needles
MU	MMP02	2002 only	Tonalli River upstream of Basin Creek
MV	MMP03	2002 only	Werriberri Creek at Serenity Park
MW	MMP04	2002 only	Blue Gum Creek along fire trail W41
MX	MMP05	2002 only	Little River at fire trail W41
MY	MMP06	2001 & 2002	Shoalhaven River at Yarra Glen
MZ	MMP07	2002 only	Jinden Creek at Jinden Ridge Rd
NA	MMP08	2002 only	Boggy Creek upstream of Shoalhaven River
NB	MMP09	2001 & 2002	Jerrabattgulla Creek at Warragandra
NC	MMP10	2002 only	Shoalhaven River at Berlang
ND	MMP12	2002 only	Endrick River at Nerriga
NE	MMP14	2002 only	Kowmung River at Kowmung fire trail
NF	MMP16	2001 & 2002	Witts Creek at Krawaree Rd crossing
NG	MMP17	2001 & 2002	Shoalhaven River at Farrington crossing
NH	MMP18	2002 only	Back Creek at Wallace Gap Rd
NI	MMP19	2002 only	Bombay Creek at Bombay fire trail
NJ	MMP20	2002 only	Nepean River at Maguires crossing
NK	MMP27	2001 & 2002	Wollondilly River at Goonagulla
NL	MMP30	2002 only	Black Bobs Creek at Bunny Galore
NM	MMP32	2002	Durrans Durra Creek at Euradux
NN	MMP34	2002 only	Boro Creek at Lower Boro

**Table 6 – Code, station name and year sampled of macro invertebrate sampling sites used in the report (continued)**

NO	MMP36	2002 only	Cedar Creek at Hayes crossing
NP	MMP37	2001 & 2002	Coxs River at McKanes Bridge
NQ	MMP38	2002 only	Farmers Creek at Great Western Highway
NR	MMP39	2001 & 2002	Woodford Creek at Woodford Dam
NS	MMP40	2001 & 2002	Yosemite Creek upstream of Minnihaha Falls
NT	MMP41	2001 & 2002	Kedumba River at Scenic Railway
NU	MMP42	2002 only	Brogers Creek at Priddles Lane crossing
NV	MMP43	2001 & 2002	Kangaroo River at Upper Kangaroo
NW	MMP45	2002 only	Werriberri Creek at top of Warragamba
NX	MMP48	2002 only	Jerrara Creek at Jerrara Rd
NY	MMP50	2002 only	Wollondilly River at Gundowringa
NZ	MMP51	2001 & 2002	Jacqua Creek at Lumley Rd
OA	MMP52	2002 only	Nadgigomar Creek at Oallen Ford
OB	MMP53	2002 only	Woronora River at Eckersley Ford
OC	MMP55	2001 & 2002	Little River at Six Foot Track
OD	MMP56	2002 only	Jenolan River at Camping Area
OE	MMP57	2001 & 2002	Werriberri Creek at The Oaks
OF	MMP58	2002 only	Little River at Buxton
OG	Mong1	2001 & 2002	Mongarlowe River at Charleyong
OH	N92	2001 & 2002	Cardeaux River at Pheasents Nest
OI	R13	2001 & 2002	Mongarlowe River at Monga
OJ	R21	2001 & 2002	Waratah Rivulet at Flat Rock crossing
OK	R7	2001 & 2002	Mulloon Creek at Tawarri
OL	R8	2001 & 2002	Currembene Creek at Krawaree Rd crossing
OM	Reed1	2001 & 2002	Reddy Creek at Mayfield Rd
ON	U10	2001 & 2002	Wingecarribee River at Berrima
OO	Uwol1	2001 & 2002	Wollondilly River at Baw Baw Bridge
OP	Winge2	2001 & 2002	Wingecarribee River at Greenstead
OQ	E860	2002 only	Shoalhaven River at Mount View





**Figure 2 – Map showing the extent of available detailed native vegetation classification within the Warragamba and Woronora Special Areas**

**Note:** The map is an extract from two reports assessing the vegetation of the Warragamba, Woronora and Metropolitan Special Areas of the Sydney Drinking Water Catchment. These reports have described and mapped all the native vegetation communities across the Special Areas including comprehensive information on disturbance and condition. An electronic data layer is available in ArcView, ArcInfo and MapInfo formats. Copies of the report and digital data can be obtained from Katrina Nunn, Conservation Programs and Planning Division, Department of Environment and Conservation phone (02) 9585 6678.





