Sydney Water Inquiry

Third Report

Assessment of the contamination events and future directions for the management of the catchment

October 1998

Peter McClellan QC

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The Hon R Carr MP
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Dear Mr Carr

Please find attached, for your consideration, the Sydney Water Inquiry's Third Report – Assessment of the contamination events and future directions for the management of the catchment. My inquiries in relation to the contract for the Prospect water filtration plant are progressing and I will provide you with a separate report in relation to those matters at an early date.

My final report should be completed by the end of November.

Peter McClellan QC

Table of Contents

Chapter 1: Executive summary

There is continuing community concern about the recent contamination of Sydney's water. Since providing the Second Report in September, a great deal of further investigation and research has been undertaken. My inquiries are close to completion and some issues may be authoritatively reported. It is now possible to place the events in an accurate context from a public health perspective.

My investigations have shown that the main catchment for Sydney's water supply is seriously compromised, not only by the presence of *Cryptosporidium* and *Giardia* but in other significant respects. These problems have been identified in previous investigations and are the result of neglect over many decades. The health of the catchment is a fundamental responsibility of our community, both for this, and subsequent generations. I have concluded that immediate action must be taken to establish appropriate management and regulatory structures to ensure the catchment is not further compromised and, if possible, existing problems minimised or removed. Whatever may have been the reluctance to address these issues in the past, recent events have provided an opportunity to effect real change. I have consulted widely about the problems and possible solutions and believe the Catchment Commission model discussed in this report should be acceptable to the community. We must not allow vested interests to inhibit the creation of effective planning, regulatory and management structures for the catchment.

This report provides a detailed account of the scientific problems in identifying *Cryptosporidium* and *Giardia* and the present difficulties in understanding their health consequences. I also discuss the difficulties identified in the laboratory testing results, the performance of the treatment plants and my conclusions in relation to the proposed Catchment Commission.

I have reported earlier on the events surrounding the contamination of Sydney's water supply between 21 July and 4 August, the "First Event", which led to a boil water alert. The Second Report discussed the "Second Event", which started when further contamination was identified on 24 August. This event led to an extended boil water alert being issued which was being progressively lifted when further contamination was reported on 5 September. A two-week boil alert was instituted.

The extensive research which has now been undertaken creates doubt about many of the laboratory results obtained during these events. *Cryptosporidium* and *Giardia* may not have been present in the drinking water in the high numbers originally reported. However, it is clear that having regard to the information available at the time a conservative public health response was appropriate.

On the evening of 11 September levels of *Cryptosporidium* and *Giardia* were detected at six treatment plants. Although these were high levels, a boil water alert was not extended to Illawarra and Woronora. This decision was made by NSW Health in consultation with the Expert Panel after considering the relevant data. Retesting was urgently undertaken at all plants and proved negative. I am satisfied that the decision not to extend the boil water alert was appropriate.

Understanding the science and health issues

It is now apparent that the level of understanding of the health consequences of *Cryptosporidium* and *Giardia* in the water supply by both Sydney Water and NSW Health prior to the First Event has been significantly increased due to the information brought forward since my Inquiry began. I have been able to access international research on water contamination, spoken to experts throughout Australia and have been assisted by a number of scientific advisers. I attended a gathering of scientists and other experts from all parts of the world in Melbourne on Monday 6 October 1998 at a conference to discuss *Cryptosporidium.* The organisers ensured I had an opportunity to discuss all the significant issues with the leaders in the various fields.

My discussions at the conference and other research have demonstrated that there are a great many uncertainties related to *Cryptosporidium* and *Giardia* in a water supply. There are problems with its detection in water and in determining its viability. The medicine is quite unclear and the relationship between the presence of the organism and issues of immunity and infectivity are not well understood. There is no doubt that viable organisms of some strains of *Cryptosporidium* will cause disease which can be life threatening in the immuno-compromised and accordingly public health decisions must be conservative. It does not appear to have such severe consequences for the health of other persons, although it is apparent that a great deal of further research is necessary before a complete picture of the desirable approach to managing drinking water can be determined.

Problems with the laboratory

Extensive scientific work has been undertaken to investigate the various contamination events. Because I had concerns about the validity of some of the test results obtained by Sydney Water's laboratory - Australian Water Technologies (AWT) - and, in particular, the levels of contamination which had been identified, confirmation was sought from laboratories in the USA, France and the United Kingdom. In addition, there has been an independent audit of the AWT laboratory at West Ryde where the testing for contamination levels was conducted.

The audit identified a number of deficiencies in AWT's laboratory operations and record keeping. Quality control failures were found prior to the contamination events but the number of these failures increased significantly as the number of samples being tested increased.

The results of the audit of the AWT laboratory are of great concern. The laboratory was placed under enormous stress by the requests for testing during the various incidents. It is apparent that as the pressure of the demands for laboratory work increased the quality of the work in the laboratory diminished. The conclusion reached by the auditor is that problems in the laboratory operations, coupled with record keeping difficulties, could have resulted in the generation of erroneous data, either positive samples reported as negative or negative samples reported as positive. The deficiencies noted during the audit cast doubt on the reliability of data produced by AWT both prior to and during the period of the contamination events. The auditor concludes that data from the laboratory should not be used to make public health decisions until all deficiencies are corrected and data quality can be assured. I am advised by Sydney Water that an external quality controller has been appointed to oversee this process.

AWT has provided me with a detailed submission which defends the quality of its work. Although I understand the extraordinary burdens the laboratory was required to carry, I accept the auditor’s findings. The work done to check AWT’s results at overseas laboratories, although confirming some results, cast doubt over many others.

It is obvious that effective long-term assurance of the quality of the water supply depends upon effective monitoring and laboratory testing. I do not believe that a laboratory owned by Sydney Water is appropriate to provide testing for public health purposes. I recommend that there be established an independent testing laboratory which provides testing services for all regulatory agencies. The results should be available to both the regulators and the community.

Until a new laboratory is available AWT must continue to perform these tasks with the assistance of appropriate external expertise.

Operation of the treatment plants

Because of the lack of reliable laboratory data it is not presently possible to draw definitive conclusions from recent events with respect to the efficiency of the Prospect plant or the other treatment plants in removing *Cryptosporidium* and *Giardia*. The effectiveness of water treatment plants is conventionally tested by their ability to reduce turbidity in the treated water. By this measure, the Prospect plant has operated satisfactorily.

As I reported in the First Report at the time of the First Event, there were difficulties in the operation of the Prospect plant. These occurred during a period of scheduled maintenance. Although turbidity levels remained well within contract limits, I have little doubt that the plant would have allowed *Cryptosporidium* and *Giardia* to pass into the water distribution system in greater than usual numbers. I now think it unlikely that it could have released *Cryptosporidium* and *Giardia* in any large numbers from the clearwater tanks or at other points of the plant. Although the source of the contamination was from within the catchment, the very high readings found in some parts of the system were (if accurate) most likely caused by the accumulation of organisms in the biofilm or sediments within the pipes which were disturbed by the extensive flushing which was undertaken. These organisms would have built up over time and may have been accumulating before the treatment plant was in operation.

During the time of the Second and Third Events after heavy rainfall, the raw water coming to the Prospect plant had elevated turbidity levels and contained *Cryptosporidium* and *Giardia*. Some of these organisms must have passed through the plant but the actual levels cannot be determined. The problems in the laboratory work are such that the results are unreliable.

I conclude that plants at Greaves Creek, Nepean, North Richmond, Woronora and Linden performed well throughout the period, which may be due in part to the fact that they received water from a relatively unpolluted source. Warragamba and Orchard Hills both experienced operational difficulties when there were high levels of *Cryptosporidium* and *Giardia* and high turbidity levels in late August. These operational matters are being addressed by Sydney Water.

Health impacts

Having regard to the comprehensive data which is now available it is most unlikely that any person suffered illness because of ingesting *Cryptosporidium* and *Giardia* in any of the events. Whether this is due to the strain, the viability of the organisms or some other reason is also not possible to determine on the basis of current scientific knowledge. The lack of infectivity of the organisms has been confirmed by studies in the USA.

The surveillance mechanisms used by NSW Health to detect disease have been shown to be capable of detecting increased cases of *Cryptosporidium* through swimming pool transmission and provide one measure to identify increases in illness.

Current surveillance by NSW Health and the National Centre for HIV Epidemiology and Clinical Research has not identified any increase in cryptosporidiosis cases in persons with HIV in Sydney since the contamination occurred.

Protecting the catchment

I have reported in the Second Report that Warragamba Dam received significant run-off waters immediately before the second contamination event. This caused turbid water apparently containing high levels of *Cryptosporidium* and *Giardia* to be passed to the Prospect plant.

Notwithstanding the difficulties with the laboratory work, it is clear that *Cryptosporidium* and *Giardia* are present in significant numbers in Sydney's drinking water catchment. This has been confirmed by independent laboratory work, which I am satisfied is reliable. It is also apparent that there are a number of other significant problems in the catchment. For a variety of reasons, the catchment is seriously compromised.

The problems of the catchment demand a strong and effective response. A modern treatment plant is not a substitute for proper catchment management. Protecting the catchment provides the best long-term protection for Sydney's drinking water. Following my Second Report, the Premier announced that the Government was prepared to create a Catchment Commission and ensure that it is given appropriate powers and adequate resources.

The essential elements of effective catchment management include the following:

- clear and enforceable water quality objectives for the catchment;

- strong planning controls over the outer catchments which specify that developments must have a neutral or positive impact on water quality;

- a catchment manager with a concurrence power in relation to development;

- independent auditing of catchment health with the auditor reporting to Parliament;

- effective partnerships between local government and the catchment manager;

- adequate resourcing to provide effective management of catchment lands and a capacity to enforce breaches of relevant statutes or regulations; and

- management of inner catchment areas by the National Parks and Wildlife Service for water quality and ecological purposes.

I have concluded that as a first step a State Environmental Planning Policy (SEPP) should be made to control relevant development in the catchment. It should identify the concurrence role of the proposed Catchment Commission and the parameters for permissible development. It should be followed by a new Regional Environmental Plan (REP) which builds upon the work of the Healthy Rivers Commission, incorporates clear development controls and specifies environmental and health standards. The REP should give priority to drinking water quality and provide a binding action plan for all the regulatory bodies at the State and local level.

In my opinion there is a need for independent auditing and regular reporting to the Parliament on the management of Sydney’s drinking water catchment. I believe that the Licence Regulator should be restructured and provided with the necessary statutory powers and resources, together with a clear set of operating objectives to undertake this role. I will discuss the role of the Licence Regulator in more detail in my Final Report.

The Catchment Commission

The proposed Catchment Commission should be an agency or corporation independent of Sydney Water, responsible for delivering water of a defined quality, which controls the relevant infrastructure, including dams, reservoirs and associated land and facilities.

The Commission should be structured to maintain strong linkages between the catchment, dams, water storages and the treatment plants and must be adequately resourced. I am satisfied that staff are available with the commitment and skills to provide effective management. I am mindful that the restructuring of Sydney Water will impose further stress on an organisation which has already suffered significantly. However, I have come to the view that recent events have created a climate within which most members of the community accept the need for a response which involves reform and change.

The contract

The Terms of Reference for the Inquiry require me to "determine whether the current arrangements for water treatment are appropriate, determine who is responsible for the current arrangements and whether their actions were appropriate". In part these issues require an examination of the confidential negotiations which preceded the contract for the Prospect plant and the legal advice given to the Water Board.

Although I have received every cooperation from Sydney Water in the investigation, it was unable, for appropriate commercial reasons, to voluntarily give me copies of material which attracted legal professional privilege. To overcome this difficulty, I decided to ask the Premier for the powers of a Royal Commission to complete the investigation of matters relating to the contract. This

request was immediately granted and I have now obtained access to the documents.

Since my Second Report, considerable work has been undertaken to investigate these issues. Although my terms of reference require me to examine the relevant contractual decision, this has led to a review of the whole decision-making process, including the process followed under the *Environmental Planning and Assessment (EPA) Act 1979* which preceded the decision to execute the contract. I have now been able to review the actions of the Water Board in these matters and I am satisfied the consideration of the project under the EPA Act was both rigorous and complete.

After beginning this investigation, I was reminded that in 1993 I was asked by the Water Board's solicitor to review the requirements of the EPA Act as they applied to the various water treatment projects. In particular, I was asked to consider the effect of section 112 of the Act. The advice I gave is not relevant to the Terms of Reference of the Inquiry or the Commission.

My investigations have raised questions about the internal reporting processes and the exchange of information within Sydney Water, between the engineers and the environmental scientists, regarding the presence of *Cryptosporidium* and *Giardia* in the raw water and its removal through treatment. An issue has also been raised as to the final form of the contract and in particular whether it adequately reflects the obligations which the Board accepted when resolving matters under the EPA Act. These matters are still under review and will be addressed in the next report.

Water quality and monitoring standards

The Final Report will make recommendations about water quality and monitoring standards necessary to restore public confidence in Sydney's drinking water quality. These standards are presently being formulated and reviewed by appropriate experts.

The Inquiry has commissioned studies which will attempt to determine whether Sydney residents have a protective immunity to *Cryptosporidium* and *Giardia* and these results will also be included in that Report.

Operation of the prototype plant and further treatment options

In view of the important role that the Prospect plant plays in providing Sydney's drinking water, I have asked that further testing be undertaken using a prototype plant and seeding it with *Cryptosporidium*. This may provide a more controlled and reliable measure of the Prospect plant's efficiency under various treatment conditions. However, the testing is time consuming and the results will not be available until the Final Report. I have also commissioned an investigation which will assist in determining whether augmentation of the plant is either necessary or justified. I will report on these matters in the Final Report.

The future

The future quality of Sydney's drinking water will rely upon improved catchment management. It will also require effective management of the water supply in the dams, optimum treatment procedures during significant rainfall events and effective maintenance of the distribution system.

My Final Report will address these matters and make recommendations designed to ensure the future quality of Sydney's water.

Chapter 2: *Cryptosporidium* and *Giardia* - A picture of uncertainty

Why is it so hard to find out what was in Sydney's water?

The potential for transmission of *Cryptosporidium* from water to humans has only been understood in recent years, starting from the first documented waterborne outbreak in Texas in 1984 (Rose, 1997). The methods for detecting its presence in water are new and evolving (Fricker *et al* 1997). The detection of both *Cryptosporidium* and *Giardia* relies upon microscopic examination of material, which has been captured and concentrated by some form of filtration. Although many methods have been described in the scientific literature, there is little agreement as to the quality of the methods, their efficiency or reliability. Most methods in use have not been fully validated. The scientific community is in constant debate about the quality and health consequences of the results.

Of particular concern is the ability of analysts to identify *Cryptosporidium* and *Giardia* accurately. Many of the tests that are currently employed rely upon a subjective assessment and mistakes are made. In a recent event in the UK, a water company issued a "boil water" alert after claiming to have found *Cryptosporidium* in the water. Subsequent expert examination showed that the "particle" detected was an algal cell and not a *Cryptosporidium* oocyst. Many algae are of similar size and shape to both *Cryptosporidium* and *Giardia* and may be easily confused without the help of recently developed specialised tests.

Of the six species of *Cryptosporidium* currently defined, only *C. parvum* has been reported to infect humans. Other species that could be detected as *Cryptosporidium* oocysts in waters include: *C. baileyi* and *C. meleagridis* (birds); *C. muris* (rodents); *C. serpentis* (reptiles); and *C. nasorum* (fish). No reliable test exists for the routine identification of specific species of *Cryptosporidium*.

Detecting parasites

There is no method of testing which allows constant monitoring for parasites. Given the likely patchy or clumpy occurrence of parasites in water (Teunis *et al* 1997), reliance on single "grab" samples to assess water quality is a problem, so care is needed to ensure that samples are taken at a sufficient frequency. It is possible to tailor the size and frequency of sampling if the range of likely contamination is known, if assumptions are made about the distribution of parasites within a water body and if the efficiency of the methodology is accounted for (Nahrstedt and Gimbel, 1996).

The methods available for the detection of *Cryptosporidium* oocysts and *Giardia* cysts in water involve three stages:

- sample collection and concentration;

- separation of oocysts from contaminating debris; and

- detection of the oocyst (or its contents) and determination of viability.

No single method is suitable for testing different types of water samples. Different laboratories across the world use different techniques, often resulting in a wide variation in results. There is sometimes complete disagreement between laboratories on whether or not parasites are present and there is often disagreement on the measured concentrations.

In one study in North America, considerable variation was noted between laboratories using the same methodology, with many laboratories recording false positive and negative results (Clancy *et al* 1994). The efficiency with which laboratories recovered *Cryptosporidium* and *Giardia* from water was shown to be about 10%, meaning that 90% of the organisms were not found. This was determined from controlled trials with water intentionally seeded with *Cryptosporidium* and *Giardia*.

Stage 1: Sample collection and concentration

How are samples collected?

The early methods used for the detection of *Cryptosporidium* oocysts used a procedure originally developed for the detection of *Giardia intestinalis* cysts (Badenoch, 1990). In this method, large volumes of water (100-1,000 litres) were concentrated using yarn-wound filters. After concentrating the sample, the filter was cut open and the concentrated material resuspended with the aid of a weak detergent solution.

This method was valuable in establishing that oocysts were present in water samples but it produced mixed results with recovery efficiencies being as low as 1%. The yarn-wound filter method has largely been superseded by other methods that are more efficient. Two new methods of concentrating samples became generally available in the early 1990s. One utilises membrane filtration (Ongerth and Stibbs, 1987) and the other a calcium carbonate flocculation procedure (Vesey *et al* 1993a).

In the membrane filtration method, water is passed through a large flat membrane with the retained material being washed off the surface and collected for further processing. Problems may arise when the membrane becomes blocked resulting in water/solids being lost when the membrane housing is opened. A problem of cross-contamination may also result from the use of a pre-filter (used to reduce membrane blockages) if it is not adequately cleaned between samples.

In the calcium carbonate flocculation method, a floc of finely dispersed calcium carbonate is produced in the water sample by the addition of calcium chloride and sodium bicarbonate, followed by raising the water's pH. The calcium carbonate is then allowed to settle, together with the *Cryptosporidium* and *Giardia* and other particulate matter.

Both of these procedures give higher recovery percentages and are more reliable than the yarn-wound filter method. However, they have their drawbacks. The membrane filter method is only practical for large volumes of water if the sample is relatively clear. The flocculation method can generally only be used on volumes of water less than 20 litres, irrespective of the water quality. The extremes in pH resulting from the flocculation method can also have the effect of killing some oocysts which is a disadvantage if it is important to determine viability.

Further methods of sample concentration have recently become commercially available. Some of these have been incorporated into the US Environment Protection Authority (US EPA) draft method 1622 for detection of *Cryptosporidium* and *Giardia* (US EPA, 1997). Method 1622 allows for various approved steps to be used to process samples. The simplest concentration option is a capsule filter (such as Envirochek™), but it has been noted that the current Envirochek™ filter is only suitable for the concentration of up to 20 litres of water (Matheson *et al* 1998). Recovery efficiencies, which range from 70-80%, have been reported by several other scientists. Although these recoveries may not be achievable for all types of water, they are considerably higher than those obtained by the yarn-wound filters.

The flat bed membrane disk filter mentioned above, has been shown to give recoveries as high as 90% for large volume samples (100-1,000 litres), but in its present format is only suitable for relatively clean waters (see Figure 1 for an overview of both concentration methods).

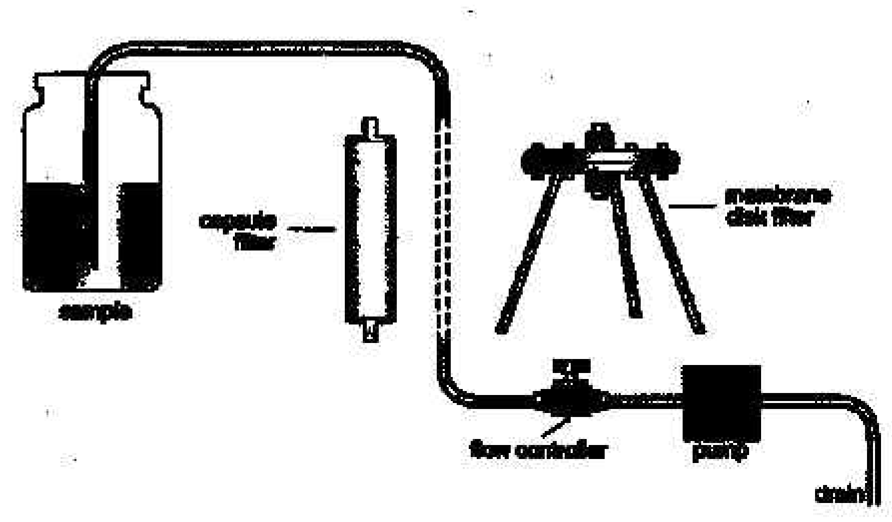

Figure 1 Laboratory filtration system for capsule filter or membrane disk filter (page 43, Method 1622, US-EPA 1997)

Figure 1: Laboratory filtration system for capsule filter or membrane disk filter (page 43, Method 1622, US-EPA 1997)

Stage 2: Separation of oocysts and cysts from background debris

A large amount of extraneous material, which is present in water concentrated with *Cryptosporidium* and *Giardia*, needs to be removed to allow a meaningful assessment of *Cryptosporidium* and *Giardia* numbers. Various techniques are used to achieve this separation.

The major techniques for separating oocysts and cysts from other particles are:

Flotation

This involves flotation of material on a sucrose or Percol-sucrose solution. This technique tends to lose oocysts and cysts, and to concentrate other material which is not required and may interfere with the microscopic examination of parasites. Notwithstanding these limitations, it is a widely used separation process (US EPA, 1996).

Immunomagnetic separation (IMS)

IMS is one of the newer technologies approved in Method 1622 for the separation stage. It involves the at.

During the July to mid September period, over 100 raw and 200 treated water samples were analysed by AWT.

I am satisfied that some of the very high levels reported in finished water are unreliable. The sample taken from the laboratory tap on 4 September which was reported by AWT as having greater than 500 *Cryptosporidium* and greater than 3,500 *Giardia* was re-examined. This did not reveal the presence of any organisms that could be definitively identified as *Giardia*. Similarly in the sample from the laboratory tap taken on 24 August only two *Cryptosporidium* oocysts could be seen. AWT had reported that 1,035 oocysts were present. Many other inconsistencies have been described in Chapter 2.

What happened in July?

Performance at the Prospect plant differed markedly prior to and after the events of 29 July. Traditionally, water demand in Sydney is at its lowest in July so this is the most appropriate time to undertake major maintenance. During most of the month, raw water quality appeared to be good. The plant was being managed to operate economically. As a consequence, the management procedures provided for the following:

- long filter runs of up to seventy hours to conserve energy and backwash treatment and reduce residues;

- the lowest coagulation dosages necessary to achieve an average turbidity of less than 0.1 NTU;

- return of treated backwash water to the head of the works.

I am advised that this form of treatment at Prospect must be carefully managed to prevent any significant passage of parasites through the treatment plant. During July, the plant was undergoing intensive, but scheduled maintenance. As a result of this there were several operational deviations which may have allowed *Cryptosporidium* and *Giardia* to pass through the plant at higher levels than normal. The problems were described in detail in my First Report and include:

- Interruption to the coagulant system which reduced the effectiveness of coagulant mixing occurred on four occasions: 7, 15, 21 and 29 July. This resulted in a sub-optimal coagulation process and a less effective filtration process, which may have allowed passage of the parasites. During these events treated water turbidity increased with a high of 0.24 NTU in the overall finished water and up to 0.4 NTU at an individual filter. This less effective removal of turbidity (although within specification and water quality objectives), and therefore particles, would mean that any *Cryptosporidium* and *Giardia*, if present, would be more likely to pass through the filtration process.

- On 21 July the level in the clearwater tanks was being lowered. Plant inflow and outflow were increased rapidly, which resulted in higher than normal velocities in those tanks. These velocities may have mobilised sediments, which exist in the bottom of the clearwater tanks. Hence, organisms that may have been contained in these sediments would have been introduced into the distribution system. The filtration rate was also increased rapidly, which could have dislodged organisms contained in the filter sand. These matters could not explain the whole of the events.

- On 21 July the level in the clearwater tanks was being lowered. A bypass channel was opened to allow isolation of Clearwater Tank No. 1 for cleaning. Sediments in this bypass channel may have been mobilised into the distribution system. Organisms possibly contained in these sediments would have been introduced into the distribution system.

- On 7 and 8 July, the Upper Canal flow rate was increased. Water quality data indicated that organic material also increased into the Prospect plant. This may have reduced the effectiveness of the coagulation and filtration processes, and allowed some *Cryptosporidium* and *Giardia* to pass through the filters and into the distribution system.

AWS argue that the concerns raised about the operation of Prospect plant during July are not justified. They correctly point out that the plant operated well within specification and within turbidity targets despite the maintenance procedures being undertaken at the time. They also argue that the sediment dislodged from the CWT could not have contained the levels of *Cryptosporidium* and *Giardia* required to provide contamination at the levels found in the distribution system. Specifically they state that "the amount of sediment discharged into the system was very small in comparison to that normally transported into the system". Similarly, AWS argue that sediments in the bypass conduit and the inlet structure could not have been responsible for the Sydney-wide contamination.

I am now satisfied that the June and July raw events probably mobilised organisms in the raw water. The problems at the plant would be likely to have allowed passage of some organisms, but these levels alone were probably insufficient to have resulted in the extremely high readings found in the distribution system. These high readings are likely to be the result of flushing operations in the distribution system.

What happened in August and September?

Treated water

The extremely high results in finished water found in August and September were recorded during a period when the plant was operating at an optimal level, as measured by both turbidity measurements (0.02 NTU) and particle counts. Filter run times had been reduced, chemical dosing maximised and backwash waters run to waste in response to a request from Sydney Water.

The apparent discrepancy between pathogen levels recorded and the optimal operation of the plant raises significant questions about the reliability of the sampling and testing procedures. For this reason I sought to validate the results in other laboratories.

If extremely high levels of parasites are present in the raw water, a plant operating at 99.9% removal of parasites, will still allow detectable levels through the filters. This may have led to some of the positive findings in the clearwater tanks, distribution chamber and laboratory tap. It does not, however, explain the very high levels reported from some samples of the finished water. As I have already discussed, some of those results could not be verified and some samples were not available for re-examination. Accordingly, it is impossible to assess the plant's efficiency on the basis of the laboratory results.

AWS dispute the AWT laboratory results. They undertook their own testing which showed only low counts in finished water. As I discuss in Chapter 2 these results also need to be understood and their limitations appreciated. AWS believe that there were only very low numbers of *Cryptosporidium* and *Giardia* present in treated drinking water leaving the plant during August and September.

Raw water

Raw water samples have shown high counts with some in excess of 10,000 *Cryptosporidium* and 5,000 *Giardia* per 100 litres in the pipeline and inlet to the plant. AWS have also recorded significant numbers in the raw water but generally at a tenth of the levels shown by AWT.

It is clear that *Cryptosporidium* and *Giardia* are both present in the catchment in significant numbers. They are available to be washed into dams during significant rain events. Unless there is effective management of the catchment and water abstraction from the dams, the pathogens will continue to contaminate raw water at the treatment plants. I conclude that some organisms have passed through the plant. However, it is impossible to authoritatively define the level at which this was occurring.

Because of the difficulties, I have asked that the prototype plant, which was built during the design stage of the plant, be reactivated and seeding trials with *Cryptosporidium* conducted. Trials with *Cryptosporidium* or *Giardia* were never undertaken in the prototype plant. The present trial may demonstrate whether appropriate levels of the organisms are being removed and whether measurements of turbidity and particle removal adequately reflect the rate of removal of the organisms.

Prospect prototype plant

The prototype plant is a small version of the full-scale Prospect Water Filtration Plant. The plant has one filter with an area of one square metre; compared to the full-scale plant which has 24 filters each with an area of 240 square metres. A small-scale plant such as the prototype plant is used by the water industry to test various qualities of raw water entering the plant and various treatment conditions in the plant to estimate how these conditions may affect treatment in the full-scale plant.

What will the prototype plant be able to demonstrate?

The primary objective of the current prototype plant testing program is to create controlled conditions in which to develop a better understanding of the performance of the Prospect plant in removing *Cryptosporidium* and *Giardia* and other particulate material (algae, clay particles, etc) under a variety of treatment conditions. The material inside the prototype filter (a sand medium) and the water treatment chemicals (iron salts, polymers and lime) added in the prototype plant are the same as those used in the Prospect plant. While it is not possible to replicate exactly in the prototype plant all of the raw water quality conditions and treatment conditions occurring at the Prospect plant, the prototype plant allows the filter to be challenged with a high concentration of organisms and provides the flexibility to vary treatment conditions.

How it works

An experiment in which a large number of organisms is added to the prototype plant to quantify their removal through the filter is called a "seeding" experiment. Two kinds of seeding experiments will be performed in the prototype plant: one with the natural, relatively low raw water turbidity of Warragamba Pipeline water, and one with higher raw water turbidity. Each of these experiments will be performed twice to verify that the concentrations of organisms measured in each experiment are valid. The seeding experiment with low turbidity raw water will determine the removal capabilities of the prototype plant under typical raw water conditions. The seeding experiment with higher turbidity raw water will then provide a comparison of the plant's ability to remove organisms when the quality of water entering the plant has been affected by unusual conditions such as a major rainfall event in the catchment.

The first step is to perform experiments without seeding to ensure that the prototype plant is performing appropriately. These unseeded experiments also provide information for the subsequent seeding experiments, so that the correct conditions for the seeding experiments can be estimated.

Once the unseeded experiments are complete, the seeding experiments will be performed with natural raw water turbidity levels. The turbidity of the raw water for these experiments will be approximately 1 NTU. This is the level of turbidity entering the Prospect plant most of the year.

Each seeding experiment requires about three days to complete, in addition to several days of preparation before the experiment, and about two weeks of laboratory work and data analysis after the experiment. During each experiment, samples are collected at six different locations in the prototype plant, with more than 50 samples generated during an experiment. The prototype plant is also monitored for removal of turbidity and particulate material, and other microbiological parameters such as aerobic spores and algae. All of the data generated in a seeding experiment are used to characterise the performance of the filter for removing particles and microbiological contaminants from the water.

Since Warragamba water presently has low turbidity, the high turbidity seeding experiments must be performed using different water than that presently being treated in the Prospect plant. The high turbidity water could be obtained from either of two sources. The first source is from the reservoir but at a location much deeper than the water entering the Warragamba pipelines. At this very deep location, the turbidity is 10 to 20 times higher than the water at shallower depths. This water would be pumped from the bottom of the reservoir into tanker trucks, which would then deliver the water to the prototype plant. Approximately four truckloads of this water would be necessary each day. The water from the tanker trucks would be mixed with the low turbidity Warragamba pipeline water as it enters the prototype plant to produce a turbidity of approximately 10 NTU.

If it is not possible to obtain high turbidity water from the reservoir, then the turbidity of Warragamba pipeline water will be raised artificially at the prototype plant by adding sediments collected from the banks of the reservoir. These sediments will be mixed with the low-turbidity water from the Warragamba pipelines to create a turbidity of approximately 10 NTU entering the prototype plant. Regardless of how the high turbidity water is obtained for the prototype testing, the same type of seeding experiment described above for low turbidity raw water will be repeated with the high turbidity raw water.

Although the prototype plant will undoubtedly provide useful information about the plant, it may not provide conclusive results. The results of these experiments should be available within four weeks. I shall report further on this matter in the final report.

Conclusions

Cascade, Greaves Creek, Nepean, North Richmond, Woronora and Linden treatment plants appear to have performed well although they were not challenged with highly polluted water. However, both Warragamba and Orchard Hills experienced operational difficulties when challenged with high levels of parasites and high turbidity water. Orchard Hills in particular produced poor quality water that was outside the specification for turbidity on several days during August. This may have led to some *Cryptosporidium* and *Giardia* passing into the distribution system. I understand that Sydney Water has identified the relevant shortcomings and is taking action to rectify the problems. Macarthur handled very difficult water well with the exception of a count of 24 *Cryptosporidium* per 100 litres on 28 August. This may have resulted from either extremely contaminated raw water or operational problems although problems in the laboratory cannot be discounted.

The water filtration plant at Prospect operated within the specifications of the contract with Sydney Water during the entire period of the recent events. The contract specification for turbidity was 0.5 NTU while the target level was 0.3.

However, during July and August, various events caused levels of both *Cryptosporidium* and *Giardia* to pass through the plant. It is likely that the low levels of parasites originally identified by AWT were coming through the treatment plant at that time. However, accepting the laboratory results as accurate, it is likely that the higher levels of organisms recorded originated from the sediments and biofilm in the distribution system which built up over time and were mobilised during the flushing operations undertaken in response to the initial positive findings. A regular and routine flushing program should be implemented by Sydney Water to avoid any future build up of organisms.

No treatment plant can guarantee removal of all *Cryptosporidium* and *Giardia*. The levels of parasites normally present in Warragamba water is low and appropriate operation of the plant will allow only very small numbers of *Cryptosporidium* and *Giardia* to pass into the distribution system. However, when there are elevated levels in the raw water, it may be necessary to take special precautions. My final report will discuss management of the water in the dam, appropriate future operation of the plant and the necessity, if any, for augmentation of the plant.

Chapter 4: Health impacts

Can *Cryptosporidium* and *Giardia* make you sick?

How do *Cryptosporidium* and *Giardia* cause disease in humans?

Cryptosporidium and *Giardia* are protozoan parasites which can cause disease in humans. They reproduce in the gut of animals and are shed as oocysts or cysts in faeces as part of their life cycle. People may be exposed to *Cryptosporidium* or *Giardia* if they come into contact with faecal material containing these parasites. Transmission can occur by a number of routes, including person to person (especially in day care facilities), food or beverages, contact with animals, contamination of swimming pools with faecal material and carriage in drinking water.

Cryptosporidium and *Giardia* can cause gastroenteritis, presenting as diarrhoea and other gastrointestinal symptoms. *Cryptosporidium* may cause prolonged and sometimes intractable diarrhoea in people with AIDS. It may result in death in this group.

What diseases do they cause?

Gastroenteritis

Gastroenteritis describes an inflammation of the lining of the intestine. This condition may be caused by non-infectious factors or by infection by harmful microorganisms, including but not limited to *Cryptosporidium* and

Giardia. Gastroenteritis can result in significant loss of fluid and electrolytes (body salts) and can interfere with the absorption of nutrients. There are many different causes of infectious gastroenteritis, which include a range of viruses, bacteria and protozoa such as *Cryptosporidium* and *Giardia*.

Risk of infection

The number of microorganisms required to cause infection varies greatly, and this depends both on the characteristics of the particular strain of microorganism and on the characteristics of the individual. Ingestion of pathogenic microorganisms, such as *Cryptosporidium* and *Giardia* may result in one of three outcomes:

1. passage of the microorganisms through the gut without establishment of an infection or production of symptoms;

2. establishment of an infection which does not cause symptoms of illness;

3. establishment of an infection which causes symptoms of illness.

Studies of a range of microorganisms with human volunteers show that the risk of infection increases with an increasing number of organisms ingested. However, the probability of developing symptoms once infected does not necessarily vary with the number of organisms ingested, but may depend on the particular strain of microorganism. For some strains most infected people will become ill, while for other strains only a small minority of infected people will become ill.

Symptoms of gastroenteritis

The symptoms experienced due to gastroenteritis caused by any of these microorganisms are very similar and commonly include nausea, vomiting, diarrhoea and abdominal pain. The symptoms caused by all the different organisms are so similar that it is very difficult, if not impossible, to distinguish on the basis of symptoms which organism is responsible for an individual’s episode of gastroenteritis.

Making a diagnosis of gastroenteritis

The cause of an episode of gastroenteritis is usually determined by obtaining a faecal sample. The sample is examined under a microscope and/or the organisms are cultured to determine if there are any pathogenic organisms present that may have caused the episode. It is not cost effective to test each faecal sample for all possible organisms because some causes are rare and other organisms are very expensive to detect.

In practice there is considerable variation in the classes of microorganisms that are tested. Most commonly, tests are done for bacterial pathogens such as *Salmonella, Shigella* and *Campylobacter,* but tests for viruses and protozoa are less commonly performed. For any faecal specimen submitted, the tests which are done will depend on the request by the physician ordering the test, the interpretation of this request by the laboratory, and the policy of the laboratory.

The causes of gastroenteritis

Only about 30% of individuals with gastroenteritis who submit a faecal sample to the laboratory have a pathogenic microorganism identified. Of these, the most common organism that causes gastroenteritis is *Campylobacter* which usually causes about 5% of cases, although *Salmonella,* which causes about 1-5%, and *Giardia* which causes between 2-4% are also among the commoner causes. Viruses are also a common cause of gastroenteritis but are not routinely tested for at present.

Giardiasis

Giardia is one of the commonest causes of gastroenteritis. It may be transmitted by direct exposure to faecal material, through person to person contact. *Giardia* infection may also be acquired by ingesting contaminated water or food. Transmission to humans from mammals, such as cows, is believed possible although this has not been well documented. It is believed that transmission from other classes of animal (such as birds and reptiles) to humans is extremely unlikely.

Clinical features

The symptoms experienced by someone who contracts giardiasis are variable and generally appear about one to two weeks after infection. A significant proportion of individuals who are infected will develop no symptoms at all, although this is hard to estimate because these individuals never present to a doctor to have a faecal sample taken.

Of those who experience symptoms, most have a mild and self-limiting disease that does not require treatment and therefore they never come to the attention of medical practitioners.

Possibly about 10% of those infected may have a prolonged illness that may last for weeks or in some cases longer.

Among those with symptoms who also seek medical attention, the frequency of the individual symptoms are; diarrhoea (64-100%), malaise (72-97%), flatulence (35-97%), foul smelling stools (57-79%), abdominal cramps (44-85%), nausea (59-79%), anorexia (41-82%), weight loss (56-73%), vomiting (17-36%) and less commonly fever (0-21%).

Asymptomatic carriage

Individuals may be infected with *Giardia* for prolonged periods without any symptoms. This is particularly common in children and is likely to play a part in the fact that this infection is especially prevalent in childcare facilities. The vast majority of infected children are not adversely affected.

Immuno-compromised patients

Individuals with rare deficiencies in their immune symptoms are predisposed to more severe infection with *Giardia* that may be prolonged. Patients with prior gastric surgery, such as partial or total removal of the stomach, may be more susceptible to giardiers) were free of parasites.

In particular, two samples of raw water from the Prospect plant (28 August) originally reported to have high numbers (280 and 151 *Cryptosporidium* and 98 and 37 *Giardia* in 10 litres) were found to be negative when re-examined by AWT and the US laboratories. These re-examinations were performed one month after the original analysis and sample deterioration could explain the lower results. However, sample deterioration for *Giardia* was not seen in the same series of samples processed and reported above for the First Event.

Further evidence of difficulties comes from the quality control samples. Recoveries of spiked oocysts and cysts from laboratory tap water yielded an unusually low 0.2-0.3% recovery at AWT, 13% and 19% by CEC and 2.6%

at CH Diagnostics. AWT's performance procedure recommends recoveries should be over 50%. The lower than expected recoveries of spiked parasites indicates that the control material may have been significantly overestimated at AWT. Nonetheless, AWT performed far more poorly with these samples than the two US laboratories.

In contrast, AWT's findings of parasites in their water concentrates concurred with the US laboratories, both in spiked control samples (three) and unspiked samples (two).

It follows that there were some serious discrepancies between AWT's original findings and later reanalyses, as well as with its use of quality control materials. It is possible that organisms were mis-identified as *Cryptosporidium* and *Giardia* by AWT during the initial analysis or that samples could have become contaminated during laboratory examination. The large number of positive samples during the Second Event makes the possibility of laboratory cross-contamination less likely. Few of the raw water samples tested positive by FISH, indicating that *Cryptosporidium* may be degraded and non-infectious (Table 2). Furthermore, data presented by AWS on four samples collected within 30 minutes of AWT's (22 and 28 August) showed zero or counts 99% lower than those reported by AWT for the same raw waters at Prospect plant.

It is not possible at this stage to determine if mis-identification or cross-contamination occurred, but further evidence for both possibilities is discussed for the Third Event.

Table 2 AWT *Cryptosporidium* and *Giardia* counts along with FISH for the Second Event

Sample ID	Sample Date	Location	AWT Result per slide read		FISH test for Crypto.
			Crypto.	Giardia	+ve/total tested
98059282	24/08/98	1 Lawson Rd, Paddington	370	22	0/346
98061384	24/08/98	1 Hospital Rd, Tap	270	39	3/270
98060967	24/08/98	Warragamba 33m	552	11	0/517
98061381	24/08/98	Prospect WFP D/S dist. chamber	72	13	0/64
98061389	24/08/98	118 Pacific Ave, Palm Beach	1050	347	0/932
98061382	24/08/98	Prospect WFP, lab tap	863	252	-
98061756	26/08/98	Warragamba DWA2 21m	287	15	4/44 (9%)
98061928	26/08/98	R209/R304 (M0H1)	114	17	4/19 (21%)
98062185	27/08/98	R129 outlet	1526	227	6/53 (11%)
98062187	27/08/98	Prospect WFP raw water	3020	530	66/100 (66%)
98062189	27/08/98	Prospect WFP lab tap finished water	1889	455	72/100 (72%)
98062282	27/08/98	Broughtons Pass Weir site 1	22	8	6/12 (50%)
98047180	28/08/98	Woronora WFP pre NH_3	1	3	1/1
98062286	28/08/98	Macarthur WFP filtered	24	2	14/16 (87%)
98062092	27/08/98	Prospect WFP finished CWT	1348	467	-
98062091	27/08/98	Prospect WFP lab tap finished	70	9	-
98062188	27/08/98	Prospect WFP channel 2 raw	12080	2120	-
98062189	27/08/98	Prospect WFP lab tap finished	9400	2250	-
98062185	27/08/98	Warragamba WFP treated	1526	227	-
98062344	28/08/98	Prospect WFP finished CWT	5	0	0/5

Third Event: 3-19 September

On Saturday 5 September, the boil water notice was issued for the third time for most of Sydney after high numbers were found in the raw and finished water at the Prospect, Warragamba and Orchard Hills plants. Numbers in excess of 500 oocysts and 3,500 cysts per 100 litres were reported in Prospect filtered water (sample #98068786, 4/9/98), when the plant was functioning well for turbidity and particle removal (see Chapter 3). Hence, parasites in excess of 50,000 oocysts and 350,000 cysts per 100 litres must have arrived in the raw waters if the plant was functioning sub-optimally with 99% removal, or at ten-fold higher numbers if removing 99.9%. Raw water in the pipeline was measured by AWT to have 10,000 oocysts and 7,600 cysts (sample #98068774, 4/9/98) (Table 3).

Such high numbers of parasites in raw waters would normally have been associated with other faecal indicator microorganisms, yet consistently low numbers of faecal indicator bacteria were reported by AWT. A possible explanation is that the source of the faecal material was very old, and faecal indicator bacteria had died out. The low levels of faecal sterols measured (some reported in Table 4) support the possibility of a distant source of faecal contamination.

Of the five samples analysed for faecal sterols and parasites, herbivores were the sole source of faeces contamination identified (Table 4). However, of the 42 samples analysed, unambiguous human faecal contamination was noted twice in Warragamba below the thermocline (#98070786 & 98070695) and twice in Cataract in the surface waters above the thermocline

(#98070755 & 98071767) during the Third Event. Only one sample was positive for the human-specific virus (phage) to *B. fragilis* HSP40 (#98058813 from the Second Event).

Table 3 Results during the Third Event

Sample ID	Sample Date	Location	AWT Result per slide read		FISH test for Crypto
98068412	03/09/98	Prospect Nth run upper comp.	173	121	**33% ? ***
98068774	04/09/98	Warragamba pipeline comp.	502/5L	381/5L	**25% ?**
98068691	04/09/98	Orchard Hills WFP raw	15	0	**16% ?**
98068690	04/09/98	U/canal inlet to channel 2	40/5L	10/5L	**14% ?**
98068742	04/09/98	Warragamba raw water	59/18	37/18	**15% ?**
98068771	04/09/98	Warragamba filtered R129	121	250	**10% ?**
98068789	04/09/98	Longworth Ave, Castle Hill	37/10L	1368/10L	**0% ?**

* % ? means that AWT supplied the percentage FISH positive but not the raw data.

Table 4 Concentration of faecal sterols (ng L-1), abundance of bacterial indicators (cfu/100 ml) and proportion of human, herbivore and other faecal contamination ± the range of likely values based on current data, in water samples from Warragamba (DWA) and Cataract (DCA) Dams

Site → / date collected → / indicator ↓ sample no. →	DWA2 57m 13/8 98058813	DWA2 30m 11/9 98070696	DWA1 at Screen 40m 13/9 98070786	DWA2 at 30m 13/9 98070783	DWA2 at 27m 11/9 98070695	DCA1 dam wall 30m 14/9 98071168
coprostanol	54	ND	2	3	6	1
*epi*coprostanol	ND	ND	6	ND	ND	1
cholesterol	729	207	81	4	105	27
5α-cholestanol	160	TR	4	8	7	2
24-ethylcoprostanol	246	TR	1	10	10	4
24-ethyl-*epi*-coprostanol	107	ND	1	5	ND	1
24-ethylcholesterol	826	76	23	2	39	66
24- ethyl-5α-cholestanol	247	ND	2	23	6	5
5β / 5α coprostanol ratio*	0.34	-	0.44	0.31	0.95	0.48
ethylcop / 24-ethyl-5α-cholestanol*	1.00	-	0.70	0.45	1.69	0.87
thermotolerant coliforms	340	3	0.1	0.1	0.1	4.2
faecal streptococci	-	0.4	0.3	0	0.1	0.1
C. perfringens spores	111	2.2	2.8	1.4	1.3	12
B. fragilis HSP40 phage (in 200mL)	+ve	-ve	-ve	-ve	-ve	-ve
Cryptosporidium oocysts	86/L	143/100L	0/6L	0/20L	Not tested	0/9L
Giardia cysts	10/L	75/100L	0/6L	0/20L	Not tested	0/9L
% human (based on biomarkers ONLY)	0	NQ	61	0	18	0
% herbivore (based on biomarkers ONLY)	100	NQ	39	100	82	100
% human input	-	NQ	81± 2	0	23 ± 2	0
% herbivore input	58 ± 14	NQ	19± 2	100	77 ± 2	88± 18
% other input (eg birds)	42 ± 14	NQ	0	0	0	12± 18

ND: below detection (detection limit 1 ng L-1); TR: trace amounts (,5 ng L-1); NQ: not quantifiable
* ratio over 0.5 indicates unambiguous faecal contamination.

It was even more difficult to explain the consistent findings of high numbers of parasites in the Northern Region of the Prospect system, with the highest value recorded being 3,700 oocysts and 13,670 cysts at Castle Hill (#98068789, 4/9/98, Table 5).

AWS's analysis during the Third Event was extensive and while parasites were identified in raw waters at similar levels to AWT (in the hundreds to low thousands per 100 litres), none were reported for finished water (Joint Action Group, AWS-CIRSEE Sampling and Analysis Report, 1998).

The methodologies used by AWS and AWT were different and this may have contributed to the differences in results obtained. In addition, the volume of water examined by AWS for some samples was only 1 litre. Thus levels of *Cryptosporidium* and *Giardia* would need to exceed 100 per 100 litres to give a positive result.

Other samples analysed by AWS/CIRSEE consisted of 10 - 1,000 litre volumes of water being concentrated using a particular type of filter. I have been advised that these filters are not as efficient at recovering *Cryptosporidium* and *Giardia* from large volumes of water as the method used by AWT, and therefore the sensitivity of the analysis may be lower. I have received data from AWS demonstrating the recovery efficiency of its procedure and while the information is not complete, I am advised that inappropriately high numbers of *Cryptosporidium* and *Giardia* were used to perform these experiments. Hundreds rather than hundreds of thousands of oocysts are required to estimate the efficiency of the method used.

Positive findings in six of Sydney's water filtration plants on 11 September 1998, as well as in Sydney's most protected catchment, Cataract Dam, suggest possible mis-identification (Table 5). High numbers were found in treated water from six different water filtration plants at a time when water entering the plants showed nil readings. AWT responded to this concern by re-sampling the following day, and recorded zero parasites in filtered waters. AWT also provided evidence that five negative quality control samples were processed by its laboratory, evenly spread throughout the positive samples. All five were shown to be free of parasites. This of course would not completely exclude the possibility of laboratory contamination giving the positive results.

While the filtration plant data were confirmed immediately with DAPI staining, the Cataract samples were not confirmed until requested by the Inquiry on 21 October 1998. *Cryptosporidium* oocysts were confirmed (DAPI staining) in Cataract, but confirmation of *Giardia* was not possible, due to degradation of internal structures.

Data used to source faecal contamination (faecal sterols) indicated that some (12-20%) human faecal contamination may have occurred above the thermocline in Cataract Dam, but only by herbivores below the thermocline. However, only one sample with predicted positive oocyst-like particles (LIMS No 98070026) was also assayed for faecal sterols. Interestingly, neither herbivore nor human faecal contamination was evident, only cholesterol which may result from algal biomass. Furthermore, attempts to amplify the 18S rDNA from any oocysts within the Cataract sample failed despite a successful PCR reaction for other organisms, supporting the possibility that there were very few or no oocysts present.

Overall, the faecal sterol and human-specific virus work indicated predominantly herbivore faecal contamination in the dams. There was also strong evidence for occasional human faecal contamination. Therefore, the bulk of the *Cryptosporidium* and *Giardia* detected was more likely to have come from catchment animals.

Table 5 Filtration plant and Cataract results for 11 September

LIMS No	Sample Date	Sample Location (20L & 100L raw and filtered waters respectively)	AWT Result per slide read	
Filtration plant samples			***Crypto.***	***Giardia***
98068785	04/09/98	Prospect WFP raw water	0	0
98068786	04/09/98	Prospect WFP finished water (paired result with raw water given above)	>500	>3500
98070627	11/09/98	Woronora WFP raw water (20L)	0	0
98070628	11/09/98	Woronora WFP filtered water	55	61
98070629	11/09/98	Illawarra WFP raw water (20L)	0	0
98070630	11/09/98	Illawarra WFP filtered water	141	107
98070680	11/09/98	Macarthur WFP raw water (20L)	0	0
98070681	11/09/98	Macarthur WFP filtered water	59	52
98070682	11/09/98	Nepean WFP raw water (20L)	0	0
98070683	11/09/98	Nepean WFP filtered water	106	97
98070672	11/09/98	Warragamba pipeline HWP (20L)	33	33
98070675	11/09/98	Warragamba WFP filtered R129	193	214
98070676	11/09/98	Orchard Hills R209/304	268	305
Cataract Dam samples				
98070024	9/09/98	Cataract Dam 10m	14/16L	43/16L
98070025	9/09/98	Cataract Dam 20m	9/8L	20/8L
98070026	9/09/98	Cataract Dam 30m	-	-
98070027	9/09/98	Cataract Dam composite 10-30m	428/8L	137/8L

Mouse infectivity tests

As previously indicated, there has been much discussion in the scientific literature regarding the viability and infectivity of *Cryptosporidium*. If a *Cryptosporidium* oocyst is shown to be empty by DAPI staining, then it must be dead since viable *Cryptosporidium* oocysts should contain four sporozoites. If it is shown to contain sporozoites, it is potentially alive. The situation is further complicated by the fact that DAPI fails to stain all oocysts and therefore it is possible that viable, infectious oocysts may be recorded as being non-viable.

In addition to the FISH tests used at Macquarie University, parasites from the three remaining stored samples of high counts were sent to Arizona for infectivity assessment. Estimated doses of oocysts delivered to individual mice and results are provided in Table 6. No mouse receiving Sydney parasites became infected, whereas the control samples performed well, indicating that the dose required for about 50% infection with seven-month-old oocysts was about 150.

Nowhere in the world have environmental oocysts been reported to cause infection in mice. While the mice infectivity test is perhaps the only valid measure of potentially human infective oocysts, it is important to note that large numbers of oocysts are required for the test to be sufficiently representative. For example, if the Sydney environmental oocysts were some months old, but preserved to maintain activity, then from the results with stored calf oocysts, one might expect a dose of some 125 oocysts (if 25% of 98068774 were viable) to produce infection in about 10% of inoculated mice. Hence, having material to only inoculate a few mice greatly reduced the probability of demonstrating the presence of infectious oocysts.

Table 6 Results from the mice infectivity tests

Sample ID (FISH positive)	Source	Oocyst Dose	Mice Challenged	Percent Infected
98068774 (25%)	Warragamba pipeline 4/9/98	500	3	0
98061382 (not tested)	Prospect WFP finished water 24/8/98	250	3	0
98061928 (21%)	Orchard Hills R209/304 26/8/98	300	2	0
PC 1*	Calf faeces	600	12	92
PC 2	Calf faeces	300	10	90
PC 3	Calf faeces	150	10	40
PC 4	Calf faeces	50	11	0
NC 1	Bacteria	0	5	0

* PC = positive control oocysts were seven-month-old oocysts harvested from a calf from Camden, Sydney, stored at 4ÞC and with 69% "viable" with PI.
NC = negative control, containing water bacteria only.

What has been done to check the results?

Audits of the AWT and Macquarie University laboratories

An initial audit of AWT and Macquarie University laboratories was undertaken in August and followed up in September. The first audit was designed to determine if the methodologies used by the laboratory were appropriate. The audit concluded that the staff understood the scientific methodology they were using and could reliably recognise *Cryptosporidium* and *Giardia*. The audit, however, identified a number of deficiencies at AWT and Macquarie University with regard to the quality control system used by the laboratory.

The more intensive second audit of AWT focussed on the technical competency of the staff and the laboratory's quality procedures. Significant deficiencies were noted in both the way that analysts performed their tasks and in the quality control program. It was also noted the laboratory had made no attempt to correct the deficiencies highlighted in the first audit. As such, the auditor concluded that:

- data from the laboratory should not be used to make public health decisions until all deficiencies are corrected and data quality can be assured;

- immediate focus of the laboratory should be on correcting all deficiencies as soon as possible - to facilitate this, an external Quality Assurance officer should be appointed to oversee this process;

- the laboratory should participate in an expanded external Quality Assurance scheme which will allow confidence in the data generated; and

- a full audit of the laboratory once all deficiencies have been corrected should be conducted to ascertain that data quality is reliable.

Audit findings and AWT's response (AWT, 1998)

The second audit revealed the following deficiencies:

1. serious potential for cross contamination between samples in the laboratory. In fact some "negative control" samples, which were deliberately introduced into the laboratory, produced positive readings;

2. lack of method performance - of 85 entries on performance samples examined, 62 (73%) were below the stated 50% recovery and recoveries ranged from 0-133% for *Cryptosporidium* and 0-184% for *Giardia*;

3. LIMS labels incorrectly applied, incomplete and unvalidated data sheets, data crossed out and re-entered without explanation;

4. no validation data for methods used; and

5. deficiencies noted cast doubt on the reliability of data for management decisions.

In relation to the first three findings, AWT agreed, but noted that:

- 2% of negative control samples (out of 150) returned positives of only 1 or 2 parasites per 100 litres, and 8.6% positive controls out of 150 gave negative results;

- seed material needs to be evaluated (by flow cytometry) prior to use and a more reliable source of seed needs to be found; and

- a new full-time quality control officer has been found and will start shortly.

The matters raised in points 1-5 are extremely serious. Such findings should have led to immediate and thorough investigations. However, there was no effective response by the laboratory. The auditor's finding that there is no specific quality assurance plan remains the case. Furthermore, complete training of competent staff will take months.

In response to the auditor's concern about the lack of validation data, AWT disagreed, and said that:

- significant method validation data exist, but are commercial-in-confidence;

- their testing procedure is undergoing constant improvement, with rigorous validation applied at each step;

- improvements are expected to continue for the next nine months to a year, before seeking formal accreditation with NATA; and

- earlier validation data had been published by Macquarie University, and will made public in November 1998.

Perhaps the most serious issue on which AWT disagreed with the auditor was the reliability of data for management decisions. AWT listed the following confirmations in support of their data:

- confirmatory slide reading undertaken at Macquarie University and Thames Water;

- inter-laboratory comparisons of concentrated and unconcentrated water samples;

- FISH and RT-PCR testing;

- positive and negative control samples; and

- internal checks, such as process triggers (eg high positive or low positive/negative after a high positive).

It is my view that the confirmations at Macquarie University and Thames Water were appropriate, but only validated the final step of AWT's method. It was inappropriate that no action was taken when negative controls were positive, or when performance was below the 50% recovery mark. Furthermore, to use untrained staff on a critical step of the process (concentration) without adequate quality control of that process, was a fundamental error. As discussed previously, AWT's own reanalysis showed negative results from previously positive samples, and positive samples from a range of different treatment plants when no positives were found in their raw waters (Table 5).

It must be remembered that AWT was resourced to handle 10 samples or less on average per week at the time of the contamination events. Yet during the incident, it was required to handle up to 60 per day. A summary of the number of samples analysed per day and the resources allocated to this is shown on the next page. I have great sympathy for laboratory staff over the increased demand caused by the contamination events. Nonetheless, by late August and into September, the quality system in the laboratory had broken down. Repeat examination of some slides reported by AWT as having high levels of both *Cryptosporidium* and *Giardia* did not confirm the presence of *Giardia* at all and in one sample, only two *Cryptosporidium* oocysts were found in a sample reported to have in excess of 1,000. There is clear evidence that significant mistakes were being made.

(see commencement of appendices for this page)

Conclusions

There is no agreement about the quality of the data generated by tests for the detection of *Cryptosporidium* and *Giardia*. Various methods are in use throughout the world, but few procedures have been fully validated and there is significant uncertainty regarding their efficiency or reliability. Different laboratory techniques yield different recovery rates. Comparison of the levels recorded in Sydney with those reported from overseas has limited value. While the techniques used by AWT during recent events have the capability of producing good recoveries, on several occasions poor recoveries were recorded. These difficulties in accurately assessing the numbers of parasites present in water samples lead to uncertainty about the health consequences. There is no reliable test to identify infectious species.

There was definitely *Cryptosporidium* and *Giardia* in raw and treated water in both the First and Second Events although the levels recorded are questionable. This was, in part, because of the variable recovery efficiencies obtained and some mis-identification of particulates in some samples.

Despite these uncertainties, the various public health responses throughout the contamination incidents were appropriate. They required a conservative public health approach.

Many oocysts identified during the First Event were degraded and their species could not be determined.

The laboratory results from the Third Event are the most unreliable and were the least validated by external laboratories. Re-examination of some samples suggests that AWT had incorrectly identified other cells as *Cryptosporidium* and *Giardia*.

AWT was under considerable pressure to analyse large numbers of samples. This led to a complete breakdown of an already poor quality control procedures. Staff with insufficient training and experience were performing analyses. These problems were identified during audits of the AWT laboratories.

Because of the uncertainty of the analytical results from AWT and AWS, it is not possible to use this data to meaningfully assess the performance of the treatment plants during the contamination events. The series of events that occurred in Sydney have demonstrated many of the problems that relate to the detection of *Cryptosporidium* and *Giardia* in water.

I recommend that a suitably qualified independent laboratory be established to provide accurate data for regulatory authorities.

It will be necessary to identify an appropriate laboratory which must have adequate resources. Whether it is provided by Government or an existing commercial laboratory is utilised, needs further consideration. This must take place without delay.

AWT must continue to perform these tasks until the new laboratory is available. It will need the assistance of appropriate external expertise during the interim period.

In the longer term, the AWT laboratory, with adequate training and quality management, should perform analytical work for Sydney Water to assist in its management responsibilities.

Chapter 3: Sydney's water treatment plants

Modern water treatment plants are designed to produce clean and safe drinking water. Drinking water is not sterile, nor is it the intention of water treatment to produce sterile water. Water treatment operates by the physical removal of particulate matter and disinfection of bacteria and viruses using chlorine. The removal of particulate matter can be achieved by many different processes, none of which guarantees the removal of all particles. Although water treatment plants can be expected to remove most particles, some will pass through. If both *Cryptosporidium* and *Giardia* are present in the raw water, some organisms can be expected to pass through the plants. Readings of 1,000 oocysts per 100 litres of raw water were reported during the recent events. These levels are exceptional in any catchment and have occurred only sporadically during the recent events in Sydney. As I have indicated elsewhere in this report, I have some doubt about the reliability of some of these high levels. However, there is no doubt that high levels of both *Cryptosporidium* and *Giardia* were present in the catchment during recent events, and, after the heavy rainfall, were introduced to the Sydney plants especially those sourcing water from Warragamba.

Previous testing in the catchment has not detected parasites at the levels being detected in recent events. This may be due in part to improved methods of detection but is also likely to reflect deterioration in the catchment. Catchment management is fundamental to ensuring the quality of a water supply system.

How is Sydney's drinking water treated?

Sydney Water Corporation (SWC) provides approximately 1,500 million litres (i.e. megalitres) of water each day (ML/day) to more than 3.8 million people in the Sydney, Blue Mountains and the Illawarra regions. A network of nine major dams plus several minor storage reservoirs is used to collect and store water which, in turn, is delivered to a network of over 20,000 km of water mains, 165 pumping stations and 261 service reservoirs.

The water supply is drawn from catchments on four main river systems - the Upper Nepean, the Warragamba, the Shoalhaven and the Woronora - with minor supplies drawn from the Hawkesbury River, and tributaries of the Grose, Fish and Duckmaloi Rivers.

Since late 1996 all of Sydney's water supply has been filtered. Eleven water treatment plants are used to filter drinking water supplied to Sydney, Illawarra and the Blue Mountains. Seven of these facilities are owned and operated by Sydney Water. These are located at Orchard Hills, Cascade, North Richmond, Nepean, Warragamba, Linden and Greaves Creek.

The remaining four privately-owned and operated plants at Prospect, Macarthur, Illawarra and Woronora provide filtered water under contract to Sydney Water. These four plants provide more than 90% of Sydney's drinking water.

The location of the major water filtration plants is shown in Map A in the Appendices.

Water treatment methods

"Conventional" water treatment includes a series of steps including coagulation, flocculation, sedimentation, filtration and disinfection. There are several other forms of water treatment which incorporate some or all of these steps. Water treatment plants in Sydney generally use alternatives to conventional treatment because the water quality is deemed to contain low levels of pathogens and to be of consistently high quality.

A process of contact or direct filtration treats all of Sydney's water, with the exception of water supplied through the North Richmond and Nepean plants.

North Richmond, which has a "run of river" water supply uses dissolved air flotation and a clarification process followed by filtration using granular activated carbon contactors. Nepean, which has high levels of colour and turbidity from time to time, uses a process of absorption clarification and filtration.

Disinfection for all plants is achieved after filtration by a chlorination process and fluoride is added for the protection of dental health.

My next report will provide explanations for the choice of treatment facilities at the Prospect plant.

Coagulation and flocculation

The particles that are being removed from drinking water range in size from one tenth to one hundred thousandth of a millimetre (100 to 0.01 microns). The larger the particles the more easily they are removed. Removal is achieved with the smaller particles by making them stick together by a process known as coagulation. The small particles (colloids) usually have a negative charge. By adding a suitable compound with a large positive charge, the negatively charged particles are attracted and will clump together. These compounds are called coagulants and are usually ferric (iron) or aluminium salts that dissolve in water to form positive ions which attract the negatively charged particles. This process is sometimes enhanced by the addition of positively charged (cationic) polymers. After the coagulant is added and mixed in the water, small groups of colloids start forming structures called floc.

Flocculation is the next stage where the size of the floc is increased, making it easier to remove by the filtration or settling process. The flocculation process is frequently aided by slow stirring of the water using large paddles, which causes the floc particles to gently collide and stick together. If the water is agitated too hard the larger floc will be ripped apart. Addition of a polymer during the flocculation stage is frequently used to strengthen the large floc.

Clarification/settling and filtration

Sometimes known as "conventional filtration", this process achieves removal of particulate matter by two steps. The first step is a settling process where coagulants are added to the water and floc is formed as described above. Following formation of the floc the water travels through settling tanks where most of the floc is removed by gravity. The settling tanks may take the form of horizontal flow chambers where the water travels slowly through the chamber with several hours detention time. Alternatively, they may be more compact structures called clarifiers where the water is allowed to slowly rise through a vertical chamber and the clarified water is decanted from the surface into troughs. Whatever floc remains after settling is screened out by means of filters containing single, dual or multiple layers of media. Alternatives to conventional clarifiers are absorption clarifiers or roughing filters that consist of either a coarse artificial or granular media. Such clarifiers and roughing filters remove large floc prior to polishing filtration. For large municipal plants rapid gravity filters are most frequently used for this purpose. The filters are regularly backwashed to remove accumulated floc.

Direct or contact filtration

In the process of contact filtration (sometimes known as in-line filtration) a coagulant is added to the water immediately ahead of the filters in order to form a floc which is then trapped by the filter. Flocculation tanks are frequently added prior to the filters to provide a longer detention thus allowing more time for the floc to increase in size. This latter process is known as direct filtration. Direct and contact filtration processes differ from conventional filtration by eliminating the settling stage. Although more cost effective than the conventional settling/filtration method, the process requires optimal performance at all times and requires careful control in systems where the source water quality varies greatly. Modern instrumentation and control technology provide for reliable operation and management of filtration plants using the direct or contact filtration process.

Dissolved air flotation (DAF)

This method relies on flotation of particles instead of settling as described in the settling/filtration process. Prior to flotation, the water must first be treated with coagulants to allow the flocculation process to take place. Air is dissolved in water to create microscopic bubbles. The air/water solution flows up through the flotation chamber carrying floc to the top of the tank where it can be skimmed off. The floc moves upward as the air bubbles attach to the floc, making it lighter than water. Flotation is frequently used where algae and colour are of more concern than silt or clay particles and is often used for treatment of "run of the river" water. DAF is effective for the removal of some 90-99% of *Cryptosporidium* and *Giardia* (Plummer, *et al* 1995).

Granular Activated Carbon (GAC) Contactors

GAC contactors are sometimes used as a supplement to the filtration process. The activated carbon absorbs organic micro-pollutants and taste and odour compounds.

Sydney's treatment plants and their performance July - September 1998

Details of all water filtration plants (WFPs) in the Sydney, Blue Mountains and Illawarra regions are summarised in Table 1.

TABLE 1
Water Filtration Plants

Plant	Capacity (ML/day)	Ave Flow (ML/day)	Pop. Served	Owner/operator	Source Water	Process
Prospect	3,000	1,200	2,740,000	Australian Water Services	Warragamba Dam	Contact Filtration
Orchard Hills	210	70	192,000	Sydney Water	Warragamba Dam	Direct Filtration
Macarthur	280	100	150,000	Macarthur Water	Broughtons Pass	Contact Filtration
Illawarra	210	120	230,000	Wyuna Water	Avon Dam	Contact Filtration
Woronora	220	100	180,000	Wyuna Water	Woronora Dam	Contact Filtration
Cascade	54	10	25,000	Sydney Water	Upper Cascade Dam	Direct Filtration
North Richmond	54	20	35,000	Sydney Water	Hawkesbury River	DAF, Dual Media Filtration, GAC
Nepean	36	25	15,000	Sydney Water	Nepean Dam	Clarification, Filtration
Warragamba	25	4	8,000	Sydney Water	Warragamba Dam	Direct Filtration
Linden	6	6	10,000	Sydney Water	Woodford Creek Dam	Direct Filtration
Greaves Creek	6	4	8,000	Sydney Water	Greaves Creek Dam	Contact Filtration
TOTAL	4,101	1,659	3,593,000			

Impacts on plant performance

Treatment plant performance is affected by raw water quality. Increases in colour and turbidity may change the conditions required for coagulation. Similarly, very low turbidity waters can be difficult to coagulate effectively. The quality of water in the catchment has a marked effect on drinking water quality.

The bulk water supply for the Sydney region is drawn from the catchments of four major river systems - the Warragamba, Upper Nepean, Woronora and Shoalhaven. These catchments extend over 16,000 square kilometres and extend beyond the Sydney Greater Metropolitan Region. Minor supplies are also drawn from the Hawkesbury River at Richmond, tributaries of the Grose River within the Blue Mountains, and the Fish and Duckmaloi Rivers at Oberon.

I have described the catchment in more detail in Chapters 5 and 6 of this report.

The catchments that provide the water for Sydney are of varying quality and some, notably the Warragamba catchment, are in poor condition and deteriorating as a result of development and agricultural practices over many decades. There is an urgent need to address this issue as demands on water increase. Within this catchment there are several sources of pollution. Some, but not all will contribute pathogens to the water body. In particular, these include sewage from residential premises and animal grazing. Other discharges, such as those from mining and industry, contribute chemical contaminants to the catchment, which may also be of health concern.

Water treatment is not designed to remove 100% of pathogens. Increased levels of pathogens accumulating in the catchment will lead to an increased risk of contamination of Sydney's drinking water. If contamination of the catchment is not effectively controlled through strong planning and regulatory action, then further contamination events will occur.

Rainfall

A significant factor in raw water quality is intense rainfall particularly after periods of drought. Rainfall, and/or snow melts, have been a consistent contributor to most overseas contamination incidents. During these events contaminated material is swept into streams, rivers and storage facilities.

Some of the rainfalls in the Warragamba catchment during the recent events are set out in Table 2.

Table 2 Rainfall in Sydney's catchments during the parasite events (in millimetres)

Date	Bowral	Camden	Katoomba	Wollongong
23.06.98	50.4	49.0	49.0	
21.07.98	28.0	17.0	19.0	
07.08.98	25.6	25.0	39.0	40.6
08.08.98	114.8	62.0	159.0	136.4
16.08.98	21.8	44.0	39.8	79.6
17.08.98	39.2	58.0	44.2	32.0
18.08.98	60.8	50.0	17.2	316.0
19.08.98	34.6	4.0	1.0	99.0

Both the 23 June and 21 July rain events resulted in increased flows into Warragamba and increases in the water levels within the dam. The 23 June inflow was the first since July 1997. The rain resulted in the dam receiving 16,750 megalitres (ML) of water and rising 0.22 metres. This and the rain on 21 July may have had a contributory role in the First Event and may explain subsequent events.

The rainfall in August resulted in flood peaks and high inflows which dramatically increased water levels and caused the dam to spill. Large areas of the foreshore of the dam were re-flooded during these events. This would undoubtedly have caused the transport of a large volume of animal faecal matter which was deposited on the foreshore of the dam adjacent to the water level during the preceding years. This material had the potential to carry huge numbers of *Cryptosporidium* and *Giardia* into Warragamba Dam.

Role of dams in water supply systems

Dams play an important part in the water supply system. In addition to storing water, dams provide a barrier to contaminated material by allowing it to settle out as sediment. Some unfiltered systems such as Melbourne rely for water quality on healthy catchments and long holding times of three to five years in a series of dams. These long holding periods not only allow solid material to settle, but mean that some particles such as the cysts and oocysts can be killed by harmless microorganisms. Both *Cryptosporidium* and *Giardia* will eventually die in water, although this may take many months or even years.

Dams, however, have the potential to maintain concentrated pockets of *Cryptosporidium* and *Giardia*. Water may pass through a dam rapidly, a process known as "bypassing" or "streaming". This may mean that a dam with a general holding time of three years could, under some circumstances, allow water to pass through in a matter of days.

It is also necessary to understand how particles can be distributed in dams. This is largely determined by water temperature, wind, sun and rain. These create density differences through the water column, which separate and partition the matter within the dam.

A sharp temperature gradient, known as a thermocline, normally separates the waters of Warragamba into layers. Mixing occurs in late winter after the upper layer cools to the temperature of the lake bottom. The water supply for the Prospect, Orchard Hills and Warragamba plants is abstracted through open mesh screens at three separate outlet chambers in the Warragamba Dam wall. They may be positioned to draw water from different depths and layers in the dam depending on water quality.

The region of the thermocline is usually avoided in selecting the depth for abstraction of bulk water because it is known to accumulate large amounts of particulate matter and microorganisms. This material can result in unpleasant taste and odour. In August and September *Cryptosporidium* and *Giardia* appear to have accumulated within the thermocline.

Internal waves which pass along the thermocline, known as seiches, are created by varying wind and heat applied to the different layers in stratified water bodies. Seiches are a common occurrence in large lakes and oceans and can result in water from above and below the thermocline reaching the dam offtake zone.

There is evidence that a seiche was occurring in the dam during July and August and the thermocline was periodically rising and falling through the depth of the operating screens.

As I indicated in my Second Report, this phenomenon is likely to have resulted in slugs of *Cryptosporidium* and *Giardia* entering the Warragamba pipeline and impacting upon Prospect, Warragamba and Orchard Hills Plants.

The passage of floodwater in the dam was tracked during August. The *Cryptosporidium* and *Giardia* content of this turbid run-off water and of other waters was also monitored. This clearly demonstrated the presence of floodwater-borne contaminants into the bulk water distribution system supplied from Warragamba dam. It is likely to explain the events of August and September.

From 22 August to 4 September an internal wave periodically raised the thermocline to the level of the operating offtakes and turbid water entered the bulk supply in pulses with periods of between four and 48 hours.

From 25 August to 4 September the concentration of *Cryptosporidium* and *Giardia* in the bulk supply downstream of Warragamba Dam was measured intensively with some locations monitored four times daily. On several occasions the numbers of protozoan cysts recorded in the bulk water swung wildly from zero per 100L to 1,000 then back to zero within hours. *Cryptosporidium* and *Giardia* are also not homogenously distributed in a body of water and occur in clumps, which could assist in explaining the variability of the results.

During the June event the cold water inflow did not reach the dam wall and mixed with water in storage. The inflow experienced in late June may have mobilised *Cryptosporidium* and *Giardia* within the dam during July. During July, one off-take was operating at 32-40 metres, and the thermocline was at 40 metres. The first positive test for the pathogens was sampled at 48 metres on 31 July. There had been little monitoring in the dam previously and it had not been tested at varying depths.

Regular sampling of Warragamba dam since mid-September has not produced any evidence of high concentrations of *Cryptosporidium* and

Giardia in this zone and the dam seems more evenly mixed. This is probably because the parasites have become more evenly distributed and are therefore not present in clumps of high concentrations.

Can the plants cope?

The ability of the plants to cope with *Cryptosporidium* and *Giardia* will depend on a number of factors including design, operating regimes, equipment failure, maintenance requirements and recycling of backwash waters.

Sydney's WFPs were not specifically designed to remove *Cryptosporidium* and *Giardia*. I will discuss this in more detail in my next report.

Operating regimes are important for plant efficiency especially as it is more difficult to coagulate less turbid water. This may lead to a reduction of the ability of filters to remove *Cryptosporidium* and *Giardia*. Operating elements which are important in achieving good results include:

- filter run times;
- backwash procedures;
- coagulation dosage and
- filter startup.

These processes can be optimised to reduce the risk of *Cryptosporidium* and *Giardia* passing into the drinking water supply. Filter run times may be controlled to reduce the chances of particle "breakthrough" which can occur when filters are operated for an extensive period.

Backwash procedures can also be designed to achieve maximum cleaning of the filters. The combined air and water procedure used at Prospect is accepted as probably the most efficient procedure available. Adequate treatment of filter backwash waters is important to plant efficiency. With contact filtration plants it is essential to prevent the build-up of high levels of parasites within the plant. Coagulation dose and adequate mixing of coagulant with incoming water is also essential for effective filtration. These two processes must be carefully controlled for contact filtration to work effectively. The filtration process is most susceptible to particle breakthrough during the initial period immediately after backwashing, known as the ripening period. There is some evidence that by reducing the flow of water through the filter during this ripening period, the likelihood of *Cryptosporidium* and *Giardia* passing through is reduced. The setting of inappropriate treatment regimes or the inability to change settings quickly to meet varying conditions can significantly weaken the barriers to *Cryptosporidium* and *Giardia*.

Equipment failure or maintenance requirements, which weaken the process and place pressure on ongoing operations are also a potential problem. Plant failure has been associated with many of the overseas water contamination incidents.

How do we evaluate performance?

It is extremely difficult to detect *Cryptosporidium* and *Giardia* in an accurate and timely manner to enable verification of a plant's removal capacity. The performance of most plants is determined by removal of turbidity or particles. Within the industry these measures have been regarded as surrogates for parasite removal. Measurement of the number and size distribution of particles passing through a treatment plant is generally thought to give a good indication of the likelihood of *Cryptosporidium* and *Giardia* being present in treated drinking water. This is measured through use of particle counters placed on the outlet from individual filters rather than only at the outlet to the treatment plant. This allows the performance of individual filters to be monitored.

Monitoring by regular sampling of comparable raw and treated water with specific testing for *Cryptosporidium* and *Giardia* should provide the most accurate measure of the plant's capacity to remove them. However, as outlined in Chapter 2 of this Report there are considerable concerns about the accuracy of many test results undertaken during July, August and September. They cannot be relied on to provide a definitive tool for evaluating plant performance.

Plants operating at effective levels of 99.9% removal (3 log) still allow passage of some pathogens. These may settle in biofilm and sediment deposits within the distribution system. In addition, Sydney's major plants have only been operating for two years before which pathogens had free passage. This could have contributed to the residues within the system. *Cryptosporidium* in particular can survive for long periods in water and remain alive and potentially infectious. Dead *Cryptosporidium* oocysts can still be detected using the methods routinely used for examining water. Oocysts detected in Sydney's drinking water may well have been in the distribution system for some time and in view of the lack of illness, may have been dead.

Drought conditions over the last four to five years have inhibited regular flushing of the distribution system and encouraged the build-up of deposits.

The heavy program of flushing introduced during the period July-September and the ongoing programs initiated by Sydney Water have reduced this source of possible contamination in the distribution system.

Under their contracts the privately owned plants are required to achieve a turbidity of not more than 0.5 NTU in their filtered water. However, this obligation is only applicable provided that the raw water supplied by Sydney Water does not exceed 40 NTU.

In the event that Sydney Water supplies raw water which does not comply with specified criteria for such water, the private operators are obliged only to "use its best endeavours" to meet the Water Quality Criteria. Sydney Water is liable for any additional costs incurred by operators in doing so.

If the private operators fail to meet the Water Quality Criteria the contracts provide for penalties by way of a reduction in the tariff payable to them by Sydney Water.

The contracts also provide for "Water Quality Objectives". In doing so, the contracts require plants to be designed so that they will be capable of yielding water which satisfies the Water Quality Objectives. The contracts require the private operators to "endeavour" to operate the plant so that the treated water satisfies the Water Quality Objectives. They are not, however, obliged to do so. The Water Quality Objectives include a goal of less than 0.3 NTU turbidity.

How did Sydney's plants perform?

Greaves Creek WFP

The Greaves Creek WFP is located at Medlow Bath in the Blue Mountains and the raw water treated at the plant is sourced from Lake Greaves. The plant has a maximum operating capacity of 6 ML/day; however, it currently operates below capacity at approximately 4 ML/day. The contact filtration treatment process at the Greaves Creek plant includes:

- dosing with lime, ferric chloride and polymer for coagulation and pH correction;

- coagulation and flocculation in flow splitter;

- dividing water through flow splitter to feed six dual media filters;

- dosing with chlorine, fluoride and lime in mixing chamber.

A total of 13 tests were carried out during July, August and September for treated water and all were negative.

Linden WFP

The Linden WFP is located at Linden in the Blue Mountains and treats water from Lake Woodford. The plant has an operating capacity of 6 ML/day; however, the plant is only brought into operation during peak demand periods. The direct filtration process includes:

- aeration of raw water for the oxygenation of iron at an aeration chamber;

- dosing of ferric chloride and polymer for coagulation and lime for pH adjustment;

- flash mixing to assist the coagulation process;

- flocculation at a flocculation chamber encouraged by agitation of flocculator paddles;

- filtration at three open rapid gravity filters with gravel, sand and anthracite media;

- dosing with lime at the clear water tank to ensure a neutral pH;

- dosing with chlorine and fluoride before entering the storage reservoirs.

All tests carried out at the plant were negative.

Warragamba WFP

The Warragamba WFP is located in Warragamba and treats water from the dam. The plant has a maximum operating capacity of 25 ML/day; however, the plant currently runs at between 2 to 7 ML/day. The treatment process is by direct filtration and includes:

- dosing of ferric chloride and polymer for coagulation;

- flocculation in three flocculation chambers;

- filtration in six open gravity filters with gravel, sand and anthracite media;

- dosing with caustic soda for pH adjustment;

- dosing with chlorine and fluoride.

Source water from Warragamba Dam was heavily polluted during August and September and treated water tested positive on four occasions.

Date	*Cryptosporidium* /100L	*Giardia*/100L
29 August	1526	227
9 September	45	104
11 September	313	438
13 September	2	0

Because of the problems with the reliability of some results, I have considerable doubt about the accuracy of the readings on 11 September. A positive reading of high numbers was obtained for all treatment plants tested that day. Later testing of the comparable raw water samples revealed a nil result. Further treated water samples taken later that day also proved negative. The turbidity at the plant peaked at 3.29 NTU for the raw water and at 0.13 NTU for treated water. I am of the view that the positive readings are probably explained by contamination of samples within the laboratory.

Sydney Water's investigations of the operation of this plant revealed a number of significant problems which would allow the passage of the parasites:

- inappropriate chemical dosing rates had been set;

- poor performance at plant's start-up and at the end of the filter backwash cycle;

- automatic shutdown allows the passage of water through filters;

- automatic flocculation system was unsatisfactory.

These deficiencies resulted in the plant exceeding its turbidity specification on two occasions during August. On 29 August treated water turbidity peaked at 2.79 NTU and remained above specification for one hour. On 30 August turbidity reached 2.29 NTU and continued above specification for four hours. The high positive result on 29 August is possibly a consequence of the plant's failure to cope with highly contaminated water.

Because of these events, I am advised that Sydney Water has changed the plant to a manual operation and instituted a number of changes to improve the plant's performance. An action plan to modify equipment to enhance removal of *Cryptosporidium* and *Giardia* is in place.

Nepean WFP

The Nepean WFP is located near Bargo in the Southern Highlands and treats water from the Nepean Dam. The plant was upgraded in 1993 and now has a maximum operating capacity of 36 ML/day. The plant operates at a capacity anywhere from 9 ML/day to full capacity. The process includes:

- caustic soda and potassium permanganate dosing;
- dosing of ferric chloride and polymer for coagulation;
- flash mixing to assist the coagulation process;
- upflow absorption clarification through polystyrene media (sometimes referred to as roughing filters);
- filtration through five gravity filters utilising gravel, sand and anthracite media;
- post-dosing of chlorine, carbon dioxide, fluoride and lime.

The only positive result in finished water was on 11 September. I have previously indicated this result cannot be relied upon and should be ignored. Raw water tested positive on only one occasion with 20 *Cryptosporidium* and no *Giardia* on 15 September.

Cascade WFP

The Cascade WFP is located at Katoomba in the Blue Mountains. The raw water treated at the plant is sourced from the Upper Cascade Dam which is supplemented by supply from the Middle Cascade and Lower Cascade Dams, as well as the Fish River Pipeline and Greaves Creek.

The plant has a maximum operating capacity of 54 ML/day; however, it usually operates at a capacity of 7 to 13 ML/day.

The plant is a direct filtration plant and the process includes:

- dosing with lime, ferric chloride, polymer and potassium permanganate;
- coagulation and flocculation in rapid mix tanks and flocculation basins;
- filtration through dual media filters;

• dosing with chlorine, fluoride and lime in mixing chamber (carbon dioxide has been used and may be used again in future).

All tests in both raw and treated water were negative.

North Richmond WFP

The North Richmond WFP is located in North Richmond and treats water sourced from the nearby Hawkesbury River. The maximum operating capacity of the plant is 54 ML/day; however, it generally operates at a capacity of 20 to 25 ML/day. The treatment process, which involves dissolved air flotation and clarification includes:

• screening to remove solids;

• dosing of ferric chloride, caustic soda and a flocculant;

• coagulation and flocculation followed by removal of suspended solids by clarification or DAF;

• filtration by dual media filters and granulated activated carbon filters;

• dosing with chlorine, fluoride and caustic soda.

Treated water samples tested positive with low counts on three occasions. The plant was not tested on 11 September.

Positive treated water samples at North Richmond WFP

Date	*Cryptosporidium* /100L	*Giardia*/100L
20 August	1	0
22 August	1	0
29 September	1	0

The highest positive reading in raw water was 80 *Cryptosporidium* per 100 litres.

Orchard Hills WFP

Orchard Hills WFP is located approximately 5 km south-east of the Penrith Central Business District. The plant treats raw water from Warragamba Dam and supplies filtered water to Penrith, Emu Plains, St Marys, Cranebrook, Erskine Park and the Lower Blue Mountains. It also has the capability of pumping treated water to the Upper Blue Mountains area in case of an emergency or during operational maintenance.

The average daily flow of the plant is 70 ML/day and the design capacity 210 ML/day. The contact filtration treatment process is:

- provision for pre-dosing of lime and potassium permanganate if required;
- mixing of ferric chloride and polymer at the flash mixer;
- coagulation and flocculation of suspended solids;
- filtration by 10 deep bed filters;
- lime dosing to correct and buffer pH.

The plant draws its water from Warragamba, which was heavily polluted in August. A total of eight raw and 44 finished water samples were analysed during August and September. The highest raw water level recorded was 92 *Cryptosporidium* and the finished water tested positive on five occasions.

Positive treated water samples at Orchard Hills WFP

Date	*Cryptosporidium* /100L	*Giardia*/100L
26 August	114	17
27 August	930	60
4 September	10	0
10 September	29	38
11 September	263	305

As indicated earlier, the 11 September result is unreliable and the other high readings may be questionable. However, the plant had experienced considerable difficulties during August. It exceeded turbidity specifications on eight days with a high of 1.99 NTU on a number of occasions and for periods in excess of two hours. These included 26 and 27 August when high positives were recorded. However, turbidity specifications were not exceeded on 11 September. On 27 August raw water in the Warragamba pipeline recorded 1280 *Cryptosporidium* and 2120 *Giardia*.

Sydney Water’s investigation of the plant’s operation reveals the following weaknesses:

- poor performance at plant start-up;

- problems with the automatic backwash cycle when filters are ramped and flows increase, and with the end of the backwash cycle when filter media is unsettled.

I am advised that Sydney Water has introduced modified backwash procedures to reduce the chance of break-through and is now sending ripening filter water to waste rather than passing it back through the filtration process. Sydney Water is now staffing the plant on a 24-hour basis rather than depending on automatic operation. It is also developing a number of plant modifications and instituting an action plan to combat the passage of *Cryptosporidium* and *Giardia*.

Woronora WFP

Wyuna Water Pty Ltd began operating the Woronora Water Filtration Plant in 1996. Wyuna Water is jointly owned by Compagnie Generale des Eaux and Australian Infrastructure Development Corporation (AIDC). The plant is located at Woronora Reservoir about 15 km south-west of the Sutherland Central Business District.

The plant treats raw water from Woronora Dam and supplies filtered water to the Sutherland Shire and Helensburgh region south of Sydney.

The average daily flow of the plant is about 100 ML/day and the design capacity is 220 ML/day. The process is direct filtration treatment and comprises the following:

- pre-dosing of lime;

- provision for pre-dosing of potassium permanganate if required;

- mixing of ferric chloride and polymer at the flash mixer;

- coagulation and flocculation of suspended solids;

- filtration by nine dual media deep bed filters;

- lime dosing and carbon dioxide to correct and buffer pH;

- dosing with chlorine followed by ammonia to form chloramines for disinfection.

Treated water at the plant returned three positives.

Positive treated water results at Woronora WFP

Date	*Cryptosporidium* /100L	*Giardia*/100L
28 August	2	4
6 September	2	7
11 September	55	61

The suspect result of 11 September should be discarded. The highest level recorded in the raw water was 40 *Cryptosporidium* on 5 September.

Macarthur WFP

Macarthur Water Pty Ltd began operating the Macarthur Water Filtration Plant in 1996. Macarthur Water is owned by North West Water Australia. The plant is located on Wilton Road, between Brighton’s Pass and Appin about 20 km south of the Campbelltown Central Business District.

The plant treats raw water from Broughton’s Pass Weir, sourced from Cataract, Cordeaux or Nepean Dams and supplies filtered water to the Campbelltown, Camden and Appin regions south-west of Sydney.

The average daily flow of the plant is about 100 ML/day and the design capacity is 280 ML/day. The process is contact filtration and comprises the following:

- pre-dosing of lime;
- provision for pre-dosing of potassium permanganate if required;
- mixing of ferric chloride and polymer at the flash mixer;
- coagulation and flocculation of suspended solids;
- filtration by 12 dual media deep bed filters;
- lime and carbon dioxide dosing to correct and buffer pH;
- dosing with chlorine followed by ammonia to form chloramines for disinfection.

The plant was sourcing water mainly from Cataract during the period and consequently was treating heavily contaminated and turbid water. Five positive tests in treated water were recorded.

Treated water results at Macarthur WFP

Date	*Cryptosporidium* /100L	*Giardia*/100L
20 August	5	0
28 August	24	2
4 September	0	1
11 September	59	52
16 September	1	0

The result of 11 September should be ignored in assessing the plant's performance. Raw water entering the plant was measured at a maximum of 360 *Cryptosporidium* on 9 September and a reading of 720 *Giardia* on 6 September.

Illawarra WFP

Wyuna Water began operating the Illawarra Water Filtration Plant in 1996. The plant located at Kembla Grange about 10 km south of the Wollongong Central Business District.

The plant treats raw water from Avon Dam and supplies filtered water to the Illawarra region south of Sydney.

The average daily flow of the plant is about 120 ML/day and the design capacity is 210 ML/day. The process is direct filtration and comprises the following:

- pre-dosing of lime;
- provision for pre-dosing of potassium permanganate if required;
- mixing of ferric chloride and polymer at the flash mixer;
- coagulation and flocculation of suspended solids;
- filtration by 10 dual media deep bed filters;
- lime and carbon dioxide dosing to correct and buffer pH;
- chlorine dosing for disinfection.

The plant recorded three positives in treated water:

Treated water results at Illawarra WFP

Date	*Cryptosporidium* /100L	*Giardia*/100L
30 July	52	2
9 September	1	0
11 September	141	107

The result of 11 September should be ignored in any evaluation of the plant's performance. The maximum count in raw water at the plant was 10 *Cryptosporidium* on 5 September and appears to be inconsistent with the higher treated water results on 30 July (52 *Cryptosporidium*, 2 *Giardia*). I have asked for the further examination of the plant's operation on 30 July to ascertain reasons for that result.

Prospect WFP

Australian Water Services (AWS), formerly New South Wales Water Services commenced operation of the Prospect Water Filtration Plant in 1996. AWS is jointly owned by Lend Lease Ltd and Suez Lyonnaise des Eaux and P&O. The plant is built on the southern shore of Prospect Reservoir at Wetherill Park about 15 kms west of the Parramatta Central Business District.

The plant treats raw water from Warragamba Dam and the Upper Nepean Catchments via the Upper Canal and supplies filtered water to most of the Sydney metropolitan area.

The average daily flow of the plant is about 1,200 ML/day and the design capacity is 3,000 ML/day. The process is contact filtration and comprises the following:

- pre-dosing of lime and sulphuric acid;
- provision for pre-dosing of chlorine and potassium permanganate if required;
- mixing of ferric chloride and polymer at the flash mixer;
- coagulation and flocculation of suspended solids;
- filtration by 24 single media deep bed filters;
- lime dosing to correct and buffer pH;

● dosing with chlorine followed by ammonia to form chloramines for disinfection.

The Prospect plant was intensively investigated. Both raw and finished water were tested on a regular basis at Prospect during August and September and intermittently during July. Table 3 outlines the finished water results. Samples were taken from the clearwater tanks (CWTs), the laboratory tap (LT) and the distribution chamber (DC) some 800m downstream of the plant. Analysis of samples from these different points has confused the picture. Initially AWT were taking samples from the distribution chamber whilst AWS were sampling at the laboratory tap. Different results were obtained and this led to a dispute as to whether water was entering the pipeline below the plant. Both companies then sampled at the laboratory tap. This was an inappropriate sampling point for microbiological analysis because of the long length of pipework between the water and the laboratory tap. Both companies are now sampling at the outlet of the clearwater tanks.

Table 3 *Cryptosporidium* and *Giardia* in treated water samples at the Prospect plant taken by AWT

Date	DC		CWT		LT	
	C/100L	G/100L	C/100L	G/100L	C/100L	G/100L
29 July			765 2/per grm *	230 3/per grm *		
30 July	325	75				
31 July					1	10
13 August	50	22			12	5
14 August	15 27	16 13				
21 August	10	9			28	2
24 August	72	13			1035	302
25 August					11	0
26 August	32 140	0 60	4	1	20 31	4 12
27 August	99 52	6 11	1348	467	70 450 9400	9 130 2250
28 August			0	5	25	0
4 September					500	3500
6 September					0	9
9 September					25	30
10 September					47	63
11 September					39	32
13 September					34	7
14 September					2	7
18 September					2	0

* From sediment in clearwater tank no.1.

During the July to mid September period, over 100 raw and 200 treated water samples were analysed by AWT.

I am satisfied that some of the very high levels reported in finished water are unreliable. The sample taken from the laboratory tap on 4 September which was reported by AWT as having greater than 500 *Cryptosporidium* and greater than 3,500 *Giardia* was re-examined. This did not reveal the presence of any organisms that could be definitively identified as *Giardia*. Similarly in the sample from the laboratory tap taken on 24 August only two *Cryptosporidium* oocysts could be seen. AWT had reported that 1,035 oocysts were present. Many other inconsistencies have been described in Chapter 2.

What happened in July?

Performance at the Prospect plant differed markedly prior to and after the events of 29 July. Traditionally, water demand in Sydney is at its lowest in July so this is the most appropriate time to undertake major maintenance. During most of the month, raw water quality appeared to be good. The plant was being managed to operate economically. As a consequence, the management procedures provided for the following:

- long filter runs of up to seventy hours to conserve energy and backwash treatment and reduce residues;

- the lowest coagulation dosages necessary to achieve an average turbidity of less than 0.1 NTU;

- return of treated backwash water to the head of the works.

I am advised that this form of treatment at Prospect must be carefully managed to prevent any significant passage of parasites through the treatment plant. During July, the plant was undergoing intensive, but scheduled maintenance. As a result of this there were several operational deviations which may have allowed *Cryptosporidium* and *Giardia* to pass through the plant at higher levels than normal. The problems were described in detail in my First Report and include:

- Interruption to the coagulant system which reduced the effectiveness of coagulant mixing occurred on four occasions: 7, 15, 21 and 29 July. This resulted in a sub-optimal coagulation process and a less effective filtration process, which may have allowed passage of the parasites. During these events treated water turbidity increased with a high of 0.24 NTU in the overall finished water and up to 0.4 NTU at an individual filter. This less effective removal of turbidity (although within specification and water quality objectives), and therefore particles, would mean that any *Cryptosporidium* and *Giardia*, if present, would be more likely to pass through the filtration process.

- On 21 July the level in the clearwater tanks was being lowered. Plant inflow and outflow were increased rapidly, which resulted in higher than normal velocities in those tanks. These velocities may have mobilised sediments, which exist in the bottom of the clearwater tanks. Hence, organisms that may have been contained in these sediments would have been introduced into the distribution system. The filtration rate was also increased rapidly, which could have dislodged organisms contained in the filter sand. These matters could not explain the whole of the events.

- On 21 July the level in the clearwater tanks was being lowered. A bypass channel was opened to allow isolation of Clearwater Tank No. 1 for cleaning. Sediments in this bypass channel may have been mobilised into the distribution system. Organisms possibly contained in these sediments would have been introduced into the distribution system.

- On 7 and 8 July, the Upper Canal flow rate was increased. Water quality data indicated that organic material also increased into the Prospect plant. This may have reduced the effectiveness of the coagulation and filtration processes, and allowed some *Cryptosporidium* and *Giardia* to pass through the filters and into the distribution system.

AWS argue that the concerns raised about the operation of Prospect plant during July are not justified. They correctly point out that the plant operated well within specification and within turbidity targets despite the maintenance procedures being undertaken at the time. They also argue that the sediment dislodged from the CWT could not have contained the levels of *Cryptosporidium* and *Giardia* required to provide contamination at the levels found in the distribution system. Specifically they state that "the amount of sediment discharged into the system was very small in comparison to that normally transported into the system". Similarly, AWS argue that sediments in the bypass conduit and the inlet structure could not have been responsible for the Sydney-wide contamination.

I am now satisfied that the June and July raw events probably mobilised organisms in the raw water. The problems at the plant would be likely to have allowed passage of some organisms, but these levels alone were probably insufficient to have resulted in the extremely high readings found in the distribution system. These high readings are likely to be the result of flushing operations in the distribution system.

What happened in August and September?

Treated water

The extremely high results in finished water found in August and September were recorded during a period when the plant was operating at an optimal level, as measured by both turbidity measurements (0.02 NTU) and particle counts. Filter run times had been reduced, chemical dosing maximised and backwash waters run to waste in response to a request from Sydney Water.

The apparent discrepancy between pathogen levels recorded and the optimal operation of the plant raises significant questions about the reliability of the sampling and testing procedures. For this reason I sought to validate the results in other laboratories.

If extremely high levels of parasites are present in the raw water, a plant operating at 99.9% removal of parasites, will still allow detectable levels through the filters. This may have led to some of the positive findings in the clearwater tanks, distribution chamber and laboratory tap. It does not, however, explain the very high levels reported from some samples of the finished water. As I have already discussed, some of those results could not be verified and some samples were not available for re-examination. Accordingly, it is impossible to assess the plant's efficiency on the basis of the laboratory results.

AWS dispute the AWT laboratory results. They undertook their own testing which showed only low counts in finished water. As I discuss in Chapter 2 these results also need to be understood and their limitations appreciated. AWS believe that there were only very low numbers of *Cryptosporidium* and *Giardia* present in treated drinking water leaving the plant during August and September.

Raw water

Raw water samples have shown high counts with some in excess of 10,000 *Cryptosporidium* and 5,000 *Giardia* per 100 litres in the pipeline and inlet to the plant. AWS have also recorded significant numbers in the raw water but generally at a tenth of the levels shown by AWT.

It is clear that *Cryptosporidium* and *Giardia* are both present in the catchment in significant numbers. They are available to be washed into dams during significant rain events. Unless there is effective management of the catchment and water abstraction from the dams, the pathogens will continue to contaminate raw water at the treatment plants. I conclude that some organisms have passed through the plant. However, it is impossible to authoritatively define the level at which this was occurring.

Because of the difficulties, I have asked that the prototype plant, which was built during the design stage of the plant, be reactivated and seeding trials with *Cryptosporidium* conducted. Trials with *Cryptosporidium* or *Giardia* were never undertaken in the prototype plant. The present trial may demonstrate whether appropriate levels of the organisms are being removed and whether measurements of turbidity and particle removal adequately reflect the rate of removal of the organisms.

Prospect prototype plant

The prototype plant is a small version of the full-scale Prospect Water Filtration Plant. The plant has one filter with an area of one square metre; compared to the full-scale plant which has 24 filters each with an area of 240 square metres. A small-scale plant such as the prototype plant is used by the water industry to test various qualities of raw water entering the plant and various treatment conditions in the plant to estimate how these conditions may affect treatment in the full-scale plant.

What will the prototype plant be able to demonstrate?

The primary objective of the current prototype plant testing program is to create controlled conditions in which to develop a better understanding of the performance of the Prospect plant in removing *Cryptosporidium* and *Giardia* and other particulate material (algae, clay particles, etc) under a variety of treatment conditions. The material inside the prototype filter (a sand medium) and the water treatment chemicals (iron salts, polymers and lime) added in the prototype plant are the same as those used in the Prospect plant. While it is not possible to replicate exactly in the prototype plant all of the raw water quality conditions and treatment conditions occurring at the Prospect plant, the prototype plant allows the filter to be challenged with a high concentration of organisms and provides the flexibility to vary treatment conditions.

How it works

An experiment in which a large number of organisms is added to the prototype plant to quantify their removal through the filter is called a "seeding" experiment. Two kinds of seeding experiments will be performed in the prototype plant: one with the natural, relatively low raw water turbidity of Warragamba Pipeline water, and one with higher raw water turbidity. Each of these experiments will be performed twice to verify that the concentrations of organisms measured in each experiment are valid. The seeding experiment with low turbidity raw water will determine the removal capabilities of the prototype plant under typical raw water conditions. The seeding experiment with higher turbidity raw water will then provide a comparison of the plant's ability to remove organisms when the quality of water entering the plant has been affected by unusual conditions such as a major rainfall event in the catchment.

The first step is to perform experiments without seeding to ensure that the prototype plant is performing appropriately. These unseeded experiments also provide information for the subsequent seeding experiments, so that the correct conditions for the seeding experiments can be estimated.

Once the unseeded experiments are complete, the seeding experiments will be performed with natural raw water turbidity levels. The turbidity of the raw water for these experiments will be approximately 1 NTU. This is the level of turbidity entering the Prospect plant most of the year.

Each seeding experiment requires about three days to complete, in addition to several days of preparation before the experiment, and about two weeks of laboratory work and data analysis after the experiment. During each experiment, samples are collected at six different locations in the prototype plant, with more than 50 samples generated during an experiment. The prototype plant is also monitored for removal of turbidity and particulate material, and other microbiological parameters such as aerobic spores and algae. All of the data generated in a seeding experiment are used to characterise the performance of the filter for removing particles and microbiological contaminants from the water.

Since Warragamba water presently has low turbidity, the high turbidity seeding experiments must be performed using different water than that presently being treated in the Prospect plant. The high turbidity water could be obtained from either of two sources. The first source is from the reservoir but at a location much deeper than the water entering the Warragamba pipelines. At this very deep location, the turbidity is 10 to 20 times higher than the water at shallower depths. This water would be pumped from the bottom of the reservoir into tanker trucks, which would then deliver the water to the prototype plant. Approximately four truckloads of this water would be necessary each day. The water from the tanker trucks would be mixed with the low turbidity Warragamba pipeline water as it enters the prototype plant to produce a turbidity of approximately 10 NTU.

If it is not possible to obtain high turbidity water from the reservoir, then the turbidity of Warragamba pipeline water will be raised artificially at the prototype plant by adding sediments collected from the banks of the reservoir. These sediments will be mixed with the low-turbidity water from the Warragamba pipelines to create a turbidity of approximately 10 NTU entering the prototype plant. Regardless of how the high turbidity water is obtained for the prototype testing, the same type of seeding experiment described above for low turbidity raw water will be repeated with the high turbidity raw water.

Although the prototype plant will undoubtedly provide useful information about the plant, it may not provide conclusive results. The results of these experiments should be available within four weeks. I shall report further on this matter in the final report.

Conclusions

Cascade, Greaves Creek, Nepean, North Richmond, Woronora and Linden treatment plants appear to have performed well although they were not challenged with highly polluted water. However, both Warragamba and Orchard Hills experienced operational difficulties when challenged with high levels of parasites and high turbidity water. Orchard Hills in particular produced poor quality water that was outside the specification for turbidity on several days during August. This may have led to some *Cryptosporidium* and *Giardia* passing into the distribution system. I understand that Sydney Water has identified the relevant shortcomings and is taking action to rectify the problems. Macarthur handled very difficult water well with the exception of a count of 24 *Cryptosporidium* per 100 litres on 28 August. This may have resulted from either extremely contaminated raw water or operational problems although problems in the laboratory cannot be discounted.

The water filtration plant at Prospect operated within the specifications of the contract with Sydney Water during the entire period of the recent events. The contract specification for turbidity was 0.5 NTU while the target level was 0.3.

However, during July and August, various events caused levels of both *Cryptosporidium* and *Giardia* to pass through the plant. It is likely that the low levels of parasites originally identified by AWT were coming through the treatment plant at that time. However, accepting the laboratory results as accurate, it is likely that the higher levels of organisms recorded originated from the sediments and biofilm in the distribution system which built up over time and were mobilised during the flushing operations undertaken in response to the initial positive findings. A regular and routine flushing program should be implemented by Sydney Water to avoid any future build up of organisms.

No treatment plant can guarantee removal of all *Cryptosporidium* and *Giardia*. The levels of parasites normally present in Warragamba water is low and appropriate operation of the plant will allow only very small numbers of *Cryptosporidium* and *Giardia* to pass into the distribution system. However, when there are elevated levels in the raw water, it may be necessary to take special precautions. My final report will discuss management of the water in the dam, appropriate future operation of the plant and the necessity, if any, for augmentation of the plant.

Chapter 4: Health impacts

Can *Cryptosporidium* and *Giardia* make you sick?

How do *Cryptosporidium* and *Giardia* cause disease in humans?

Cryptosporidium and *Giardia* are protozoan parasites which can cause disease in humans. They reproduce in the gut of animals and are shed as oocysts or cysts in faeces as part of their life cycle. People may be exposed to *Cryptosporidium* or *Giardia* if they come into contact with faecal material containing these parasites. Transmission can occur by a number of routes, including person to person (especially in day care facilities), food or beverages, contact with animals, contamination of swimming pools with faecal material and carriage in drinking water.

Cryptosporidium and *Giardia* can cause gastroenteritis, presenting as diarrhoea and other gastrointestinal symptoms. *Cryptosporidium* may cause prolonged and sometimes intractable diarrhoea in people with AIDS. It may result in death in this group.

What diseases do they cause?

Gastroenteritis

Gastroenteritis describes an inflammation of the lining of the intestine. This condition may be caused by non-infectious factors or by infection by harmful microorganisms, including but not limited to *Cryptosporidium* and *Giardia*. Gastroenteritis can result in significant loss of fluid and electrolytes (body salts) and can interfere with the absorption of nutrients. There are many different causes of infectious gastroenteritis, which include a range of viruses, bacteria and protozoa such as *Cryptosporidium* and *Giardia*.

Risk of infection

The number of microorganisms required to cause infection varies greatly, and this depends both on the characteristics of the particular strain of microorganism and on the characteristics of the individual. Ingestion of pathogenic microorganisms, such as *Cryptosporidium* and *Giardia* may result in one of three outcomes:

1. passage of the microorganisms through the gut without establishment of an infection or production of symptoms;

2. establishment of an infection which does not cause symptoms of illness;

3. establishment of an infection which causes symptoms of illness.

Studies of a range of microorganisms with human volunteers show that the risk of infection increases with an increasing number of organisms ingested. However, the probability of developing symptoms once infected does not necessarily var

Chapter 5: Sydney's catchments and current management arrangements

Which catchments provide Sydney's drinking water?

The water supply for the Sydney region is drawn from the catchments of four major river systems - the Warragamba, Upper Nepean, Woronora and Shoalhaven. These catchments extend over 16,000 square kilometres and surround the Sydney Greater Metropolitan Region. Minor supplies are also drawn from the Hawkesbury River at Richmond, tributaries of the Grose River within the Blue Mountains, and the Fish and Duckmaloi Rivers at Oberon.

During normal rainfall periods, up to 97% of Sydney's drinking water is supplied from the Warragamba and Upper Nepean hydrological catchments, which are part of the Hawkesbury Nepean catchment. In extended periods of low rainfall such as the recent 1992 to 1998 drought, these supplies are augmented by transfers from the Shoalhaven River.

Water from the Warragamba catchment is stored in Lake Burragorang behind the Warragamba Dam. Lake Burragorang supplies up to 80% of Sydney's drinking water needs, via the Prospect, Orchard Hills and Warragamba Water Filtration Plants. The Warragamba catchment extends over 9,050 square kilometres and includes the regional centres of Goulburn, Bowral, Mittagong and Lithgow.

Four dams are located in the Upper Nepean catchment - Cataract, Cordeaux, Avon and Nepean. Water is diverted to Sydney Water's customers from the Upper Nepean storages via the Prospect, Macarthur, Nepean and Illawarra Water Filtration Plants. The Upper Nepean catchment extends over approximately 900 square kilometres of mostly bushland.

Up to 80% of Sydney's drinking water is supplied through the Prospect Water Filtration Plant. This water comes from both the Warragamba and Upper Nepean water supply systems.

The Inquiry has focussed its investigations on the Warragamba and Upper Nepean hydrological catchments as the primary source of Sydney's water supply and the sole source of water flowing through the Prospect Water Filtration Plant.

Nevertheless, many of the Report's findings in relation to catchment management and protection based on the Warragamba and Upper Nepean catchments would also apply to the smaller catchments supplying drinking water to the remaining parts of Sydney or to other communities.

The Warragamba and Upper Nepean hydrological catchments (hereafter referred to in this report as "the catchment") cover about half of the Hawkesbury Nepean catchment and are shown in Map B in the Appendices.

To protect the quality of drinking water supplies, land surrounding Sydney's drinking water storages have been strictly protected. These areas are known as Water Supply Special Areas. The level of protection provided to these lands depends on both the size of the hydrological catchment and pre-existing land uses. For the Upper Nepean dams, which were completed early this century, almost the entire hydrological catchment has been reserved for water quality protection. However, in the Warragamba Special Area, the size of the catchment and pre-existing land uses has meant that less than a third of the entire Warragamba hydrological catchment is reserved as a Special Area.

In the case of the Warragamba catchment, this has resulted in two distinct parts of the catchment - the Inner Catchment and the Outer Catchment - that have quite different physical characteristics and ownership, regulatory and management regimes.

The Inner Catchment

The "Inner Catchment" is those parts of the catchment surrounding the water storage areas, classified as Special Areas, as shown in Map B in the Appendices. They are primarily owned by Sydney Water or the National Parks and Wildlife Service (NPWS). Public access to and development of the areas is strictly controlled and they are generally in good condition, with some areas of relatively pristine wilderness.

The Inner Catchment comprises the 3,500 square kilometres classified as the Water Supply Special Areas. These are:

- the areas around and including Lake Burragorang, which is the reservoir behind Warragamba Dam (approximately 2,600 square kilometres); and

- the areas around and including the Upper Nepean Dams (includes the entire Upper Nepean catchment of approximately 900 square kilometres).

Land tenure

A range of land tenures exists in the Warragamba Inner Catchment including Sydney Water freehold land, NPWS land, Crown land and private freehold land.

About 73% of the Warragamba Inner Catchment (1,900 square kilometres) is owned by NPWS and jointly managed with Sydney Water. This is reserved as part of the Blue Mountains, Kanangra Boyd, Nattai and Thirlmere Lakes National Parks and the Bargo, Burragorang, Nattai and Yerranderie State Recreational Areas. It includes part of the Nattai and Kanangra-Boyd Wilderness Areas.

Sydney Water owns another 18% of the Inner Catchment upstream of Warragamba Dam (approximately 470 square kilometres) under freehold title.

About 13% of the Warragamba Inner Catchment is private freehold land. There are some small private land pockets within the NPWS land and two quite large areas of private freehold land on the perimeters of the Inner Catchment - one in the south around the Wollondilly River and near

Wombeyan Caves, and the other to the east around the residential areas of The Oaks and Oakdale.

The remainder of the Warragamba Inner Catchment is Crown land held under private leaseholds or managed by Sydney Water or other State or local government agencies.

The catchment upstream of the Upper Nepean dams is largely Sydney Water freehold land. There are also a number of private landholdings situated at the southern and south-western end of the Inner Catchment around Robertson and Mittagong.

Almost 90% of the native vegetation of both the Warragamba Inner Catchment and the Upper Nepean Catchment remains intact.

The tenure of the Inner Catchment lands is shown in Map C in the Appendices.

Land use

When the Warragamba Special Area was declared it already contained a range of land uses, such as mining and agriculture, which are inconsistent with good water catchment management. Since declaration, public access to the Special Areas has been restricted.

However, a diverse range of land uses continue to exist in the Warragamba Inner Catchment, including agriculture, coal mining, light industry, commercial and residential, in addition to conservation. These activities occur on private land, Crown land, national park estate and Sydney Water land.

Sydney Water grants conditional leases and licences and rights for a range of activities including grazing, rights-of-way, agriculture, research and limited residential occupation.

Along the periphery of the Upper Nepean Catchment, some private land uses such as rural residential and agricultural development exist. Mining and utility easements also exist throughout the Upper Nepean catchment. Many of the mining activities and utility developments existed before the declaration of the Special Area. Sydney Water has limited ability to control these activities, as a number of government and non-government agencies have statutory rights, under various statutes, to override Sydney Water’s powers to exclude or control these activities.

The Outer Catchment

The Outer Catchment is the area of the catchment outside the Warragamba Special Area which supplies drinking water to Sydney. For Warragamba Dam, 70% (over 6,000 square kilometres) of the catchment falls outside the Special Area.

Within the Outer Catchment, approximately 44% of the land is forested, 53% is agricultural and 3% is urbanised. It includes part of the Nattai and Kanangra-Boyd Wilderness Area.

A range of land uses exists within the Warragamba Outer Catchment including: residential development; major urban centres and associated infrastructure (including sewage treatment plants and waste management facilities); small-lot rural subdivision; a range of intensive agricultural activities (predominantly livestock, vegetable growing and poultry farming); coal mining; public roads; and utility easements.

The Outer Catchment is managed by a range of agencies by methods including direct regulation, development controls, education and on-ground works.

How is the Inner Catchment managed and regulated?

Currently Sydney Water and NPWS jointly manage the Warragamba Inner Catchment lands. The Special Areas Strategic Plan of Management proposes that this arrangement be extended to the Upper Nepean Catchment.

Sydney Water has primary responsibility for regulation and management of the Special Areas. Its functions are supported by legislation, regulation and the terms of its Operating Licence.

The *Water Board (Corporatisation) Act 1994* provides for the declaration of Special Areas where the Minister is satisfied that making an order is necessary for either or both of the following: protecting the quality of stored waters; and maintaining the ecological integrity of an area consistent with Sydney Water’s obligations for the management of water storages.

Sydney Water’s Operating Licence specifies that the Corporation must regularly review the plans of management for water storage catchments with relevant agencies, principally having regard to the protection of the quality of stored waters and the maintenance of the ecological integrity and values of the Special Areas.

Sydney Water controls activities in the Special Areas through its exercise of the Sydney Water (Catchment Management) Regulation 1995. The Regulation provides Sydney Water with the ability to control or prohibit activities within designated areas that may adversely affect the quantity or quality of stored waters and the ecological integrity of these areas. This applies in varying degrees to all land (private freehold, Sydney Water freehold, Crown land and national parks estate) within the Special Areas.

The Warragamba Inner Catchment lands are classified by the Sydney Water (Catchment Management) Regulation 1995 as Schedule 1 lands and Schedule 2 lands. Broadly speaking, Schedule 1 lands are located adjacent to the storages and they are controlled much more strictly, given the higher risks to stored water quality. Upstream of Warragamba Dam, Schedule 1 lands are those areas within 3 kilometres of the full supply level of Lake Burragorang and Schedule 2 lands are the remainder of the lands in the Inner Catchment. Upstream of the Upper Nepean dams, all of the catchment is classified as Schedule 1. Map B in the Appendices shows the location of the Schedule 1 and 2 lands.

Sydney Water principally manages the protection of the Inner Catchment through an exclusion policy (keeping sources of risk out) and troubleshooting (involving ongoing efforts to actively remove potential sources of risk). Its efforts to protect drinking water quality there have included:

- restricting access;

- fire management activities to ensure that the effects of bushfire on water quality are minimised;

- removing pests and weeds;

- soil conservation works;

- advocating appropriate development and land management practices to agencies and private landholders; and

- actively managing to protect biodiversity, ecological integrity and other cultural values (such as items of Aboriginal and European cultural significance).

The Regulation empowers Sydney Water to exclude a range of activities in the Special Areas, including forestry operations, driving vehicles or riding animals, bringing in non-native plants and animals, swimming, boating, damaging plants and using buildings for animals within 100 metres of water.

The Regulation allows Sydney Water to prohibit people entering or remaining on Schedule 1 lands. Sydney Water exercises this power by prohibiting all access to Schedule 1 lands with the exception of two short bushwalking access corridors.

Some interest groups have attempted to increase access to the Inner Catchment. Their efforts have not been successful. Pressure to allow recreational access, particularly for fishing on the lake, canoeing, four-wheel vehicle driving, horse riding and ecotourism, has been substantial. Conversely, many conservation groups have lobbied for increased protection of these lands.

The National Parks and Wildlife Service is the other body primarily involved in regulating and managing the Inner Catchment. It has care, control and management of the 75% of the Inner Catchment that is national park estate. Its management of these areas is guided by statutory plans of management prepared through public consultation processes. Outside the reserve areas, NPWS has responsibility for the protection of native plants and fauna, Aboriginal cultural heritage and for the implementation of joint plans of management with Sydney Water.

Operational agreements between Sydney Water and NPWS have applied in the Blue Mountains National Park and the Nattai Reserves system for some time. Under these agreements, NPWS is responsible for basic land management, fire management, natural and cultural heritage and introduced species management. Sydney Water is responsible for catchment management associated with water quality and yield, maintenance of catchment facilities, and assisting with introduced species management.

Management of the Inner Catchment gives greater priority to some management practices compared to other parts of the national park estate. There is a greater emphasis on fire suppression strategies and post-fire rehabilitation, given the potential for adverse effects on water quality, and on feral animal eradication.

Sydney Water and NPWS have jointly developed a Strategic Plan of Management for the Special Areas. They undertook extensive consultation with representatives of key interest groups and held community workshops. The Plan provides the basis for the joint management of the Special Areas, including the principles governing their management, key actions to be undertaken in the next 5-10 years and indicators by which the effectiveness of joint management can be assessed. The Plan states that there will be no substantive changes to access or permitted activities in Special Areas until further scientific information becomes available to rigorously assess their potential impacts on the ecological integrity of the areas affected and on stored water quality.

How is the Outer Catchment managed and regulated?

The management of the Inner Catchment as a "closed" system with primarily reserved lands means that it offers limited risks to the raw water. The more significant risk to water quality lies in the Outer Catchment, where there are a larger number of significant potential sources of contamination and more complex and fragmented regulatory and management arrangements.

Where the Inner Catchment is subject to a clearly defined set of regulations and is predominantly managed by two agencies, Sydney Water and NPWS, management and regulation is more complex in the Outer Catchment.

The following agencies or groups are primarily involved in management of the Outer Catchment.

Sydney Water	Contributes to strategic-level environmental planning. Exercises concurrence powers for development applications. Undertakes water quality monitoring.
Department of Land & Water Conservation	Part of water quality standards setting process, through Water Management Committees. Regulates water use through licences. Regulates Sydney Water's access to water in its area of operations. Regulates land clearance and activities in and near rivers. Undertakes soil erosion works. Facilitates landholder best practice through education. Provides administrative support to Catchment Management Committees. Manages Crown land. Audits catchment condition through State of Rivers reports. Undertakes water quality monitoring.
Environment Protection Authority	Part of water quality standards setting process, through Water Management Committees. Regulates point discharges through licences. Enforces specific regulations (eg, *Clean Waters Act 1970*). Some monitoring of non-point discharges. Audits catchment condition through State-wide State of the Environment reports. Develops general water quality monitoring protocols.
NSW Health	Emergency powers in relation to unfit drinking water. Advises on public health aspects of drinking water supplies and sewerage services.
National Parks & Wildlife Service	Manages the national parks estate. Responsibilities for biodiversity, threatened species and Aboriginal cultural heritage on and off-park.
Department of Urban Affairs & Planning	Undertakes strategic environmental planning for the region. Develops State-wide and regional planning instruments. Approves local environmental plans. Determines/approves some proposed developments.
Department of Mineral Resources	Regulates mining activities. Applies environmental controls and monitoring on mining industry.
NSW Agriculture	Promotes sustainable agricultural land use. Undertakes farmer education in best practice. Issues guidelines on intensive agricultural activities.
NSW Fisheries	Manages commercial and recreational fishing activities. Protects significant fish habitats.

Local Councils	Determine/approve most proposed developments. Prepare local environmental plans. Audit catchment condition through local-level State of the Environment reports. Own and manage sewage treatment plants outside Sydney Water's area of operations. Regulate on-site sewage disposal.
Licence Regulator	Audits SW's performance against its Operating Licence, including its plan of management for Special Areas.
Independent Pricing & Regulatory Tribunal	Makes recommendations on pricing structures for water services.
Hawkesbury Nepean Catchment Management Trust	Undertakes planning, educational and advisory functions. Coordinates activities of various agencies and bodies. Provides some input to environmental planning. Reports on catchment condition.
Community bodies	Three Catchment Management Committees (Upper Nepean, Wollondilly and Coxs River) coordinate the management of sub-catchments. A variety of other community bodies (such as Landcare) participate in catchment management activities.
Private landholders	Undertake responsibilities for land/water management as per regulations and their own efforts towards best practice.

The management and regulatory arrangements in the catchment are obviously complex. There are a large number of government and non-government agencies operating with fragmented responsibilities, potential overlaps and gaps. No one body is responsible for ensuring the catchment is managed to minimise contamination of the available waters.

Chapter 6: Possible sources of contamination

What are the possible sources of contamination in the catchment?

It is critical that a greater understanding is developed about the potential sources of *Cryptosporidium* and *Giardia* in the catchment. As discussed earlier, human and animal faecal matter are the sources of *Cryptosporidium* and *Giardia*. They can exist for long periods in cold water, in riverbeds and lake sediment. The Inquiry has undertaken a preliminary investigation of possible sources of *Cryptosporidium* and *Giardia* in the catchment concentrating on the major sources of animal and faecal matter. Map D, which is located in the Appendices, indicates the possible sources of contamination.

The Inner Catchment includes a considerable proportion of freehold land used for cattle grazing, extending to the banks of Lake Burragorang. This means that significant quantities of cattle manure enter the water system directly. It also contains residential development areas such as The Oaks and Oakdale villages, located 8 kilometres from the dam wall, which contribute raw sewage from time to time. Native animals, such as kangaroos, and feral animals, such as pigs and deer, are both potential sources of contamination and have been reported in high numbers during the recent drought. The continuation of human and animal activity in the Inner Catchment is of concern given its intended role as the natural filtration system for the wider catchment.

While the risk of contamination in the Inner Catchment requires attention, it is the current state of the Outer Catchment that concerns me most as a potential long-term source of contamination.

The Outer Catchment includes major cities such as Goulburn and Lithgow and other smaller urban centres such as Bowral, Mittagong, Moss Vale and Marulan. In addition, there are many small rural settlements and individual properties dotted throughout the catchment, which together can produce significant pollution in the form of sewage and stormwater run-off that enters the water supply. Risk assessments by the Environment Protection Authority (EPA), recently confirmed by the Inquiry, have ranked the sewage treatment plants and on-site systems as the highest risk source in the catchment. There is also significant agricultural activity in the Outer Catchment. In addition to cattle grazing, contamination sources include intensive developments such as piggeries and poultry farming.

Urban growth and animal farming in the Outer Catchment is projected to intensify in the coming years, further contributing to the degradation of water quality in the catchment. Without effective long-term planning and management, there is serious doubt as to the capacity of the catchment system to control the contamination loads being contributed to the various tributaries and sub-catchments upstream of Warragamba Dam.

Sydney Water studies have demonstrated that high loadings of faecal matter in the catchment have the capacity to result in levels of contamination in the dam water which impose difficulties for effective water treatment. This was shown by the recent rainfall events in August 1998, where highly turbid floodwater from the Outer Catchment reached the dam wall within a week. Any intensification in land use in the catchment will cumulatively increase the level of pollution and place further pressure on Sydney’s drinking water system.

This Report concentrates on potential sources of *Cryptosporidium* and *Giardia* from within the catchment. However, similar findings and conclusions have been reached in relation to other types of pollution that occur in the catchment. In particular, the August 1998 Healthy Rivers Commission Report on the Hawkesbury Nepean River and the 1993 EPA Inventory of Pollutant Sources in the Hawkesbury Nepean Catchment found that the hydrological catchment is highly polluted by a wide variety of contaminants (HRC 1998, EPA 1993).

Cryptosporidium and *Giardia* are significant because they are indicators of faecal contamination, which can carry a wide range of constituents that are of concern to human health. While *Cryptosporidium* and *Giardia* are important, they are but two of a wide variety of pathogens that can occur in polluted water, including viruses and bacteria. Also of concern are pesticides, nitrates and phosphorous causing toxic algal blooms and industrial pollutants such as acid that can drain from mines. Numerous development activities in the catchment contribute additional pollutants. Such activities range from road use, which results in oil and grease being deposited by cars, to mining, which can result in mine tailings run-off. All of these can compromise the natural purification processes for which water storage areas such Warragamba Dam are designed.

Any strategic response put forward to address the presence of *Cryptosporidium* and *Giardia* in the catchment must also address the cumulative risk posed by these other contaminants. As discussed in the final chapter, an effective response will depend on regulation of high-risk activities and on effective land use planning and development control.

What specific sources of *Cryptosporidium* and *Giardia* are of concern?

Cryptosporidium and *Giardia* are associated with two primary sources of contamination. The first category of sources is discharges from point sources such as sewage management systems and agricultural facilities such as the Goulburn Livestock Saleyards.

The second category is diffuse sources such as stormwater and run-off of animal matter from pastures and bushland. The flood events that occurred in the catchment in early and mid August 1998 demonstrated how intense rainfall can scour the catchment, washing the accumulated animal and human matter, as well as other pollutants, into the water system. The August rains were preceded by an extended period of drought in the catchment that led to a build-up of considerable faecal material on the surrounding lands. The refilling of Warragamba Dam after the drought resulted in some 1,800 hectares of foreshore, and the associated faecal matter, being inundated.

Sewage treatment plants

Sewage treatment plants (STPs) are ranked as the highest risk source for *Cryptosporidium* and *Giardia*, both in terms of potential parasite numbers and strains likely to be infectious to humans. STPs are of concern because they can release significant amounts of poorly treated effluent during periods of rainfall or plant failure. STPs are also a concern in relation to viral pathogens that can be contained in human faecal matter.

Nine STPs are located in the Warragamba catchment, with one operated by Sydney Water and the remainder by local councils.

The EPA regulates sewage treatment plants by the issue of licences and other regulatory instruments under the pollution control legislation. The EPA conducts inspections of STPs, negotiates pollution reduction programs, conducts compliance audits and issues legal notices. Its enforcement powers include the issue of penalty infringement notices and prosecutions.

At Goulburn STP, during dry conditions, the treated effluent is pumped onto designated areas and does not go directly into the Wollondilly River. However, there are limited storage facilities for its partially treated effluent and no wet weather storage at the irrigation area. This means that during heavy rain, the irrigated effluent, including the partially treated effluent, can be washed into the Wollondilly River. The effluent management facilities are currently being upgraded in consultation with the EPA.

The other eight STPs - Lithgow, Wallerawang, Bundanoon, Berrima, Bowral, Mittagong, Moss Vale and Mount Victoria - discharge effluent directly into tributaries of Warragamba Dam. The EPA advises me that the Lithgow STP has been performing relatively poorly and that it has been involved in extensive negotiations with the council to improve the plant's performance. The effluent from this plant, however, flows into Lake Lyell before entering the Coxs River. The Wallerawang STP also performs relatively poorly, although the discharge goes to Lake Wallace and Lake Lyell before entering the Coxs River.

Wingecarribee Shire Council is intending to upgrade the small STP at Bundanoon, which is performing satisfactorily. Council has no plans to upgrade the small Berrima plant, which is also reported to be performing well. The EPA has required council to upgrade the Bowral and Mittagong STPs by July 2001 and 2000 respectively. The Moss Vale STP was upgraded in 1995. Sydney Water has recently upgraded the Mt Victoria STP.

Discharges of poorly treated or untreated sewage from Mittagong, Bowral and Goulburn STPs occurred during the August rainfall events. There were power failures in Berrima, Bundanoon, Moss Vale, Bowral and Mittagong which all overflowed raw sewage into the Wingecarribee River in late August 1998. While all of these sewage inputs occurred far from Warragamba Dam, computer modelling of storm water, contaminated by the storm event, indicated that the travel time to the offtake at the dam wall was only about one week.

In addition to these large STPs, there are several other ‘package STPs’ located throughout the catchment which aerobically treat wastewater for irrigation. These package plants are regularly used by businesses such as service stations, for example, those located at Marulan and Penrose. The Marulan package STP has experienced some problems with run-off from its irrigation areas during wet weather. The EPA has recently required its irrigation system to be upgraded. There is also a package STP operating at Mt Piper Power Station.

The Inquiry has commissioned faecal coliform testing throughout the catchment. The highest level was found at the inlets downstream of the Nattai River, which carries effluent from the Mittagong and Moss Vale STPs, and Werri Berri Creek, which has septic seepage flowing into it from the unsewered area of The Oaks and Oakdale.

Sewer overflows

Sewer overflows occur at designed release points installed as part of the sewerage system to prevent wastewater from backing up in people’s homes and properties. The ecological impacts of sewer overflows in receiving waters largely depends upon the total amount of contaminants discharged, their location in the river system and the frequency of occurrence. While wet weather overflows are of less concern than dry weather overflows (caused predominantly by pipes being blocked by tree roots), during extended or heavy rain, flow can enter the system through illegal stormwater connections or seep through cracks in pipes.

Sewer overflows are not currently regulated, although a process of licensing sewer overflows in the Sydney Water operational area is under way. Sydney Water has prepared Environmental Impact Statements (EISs) for each of its sewerage systems as a basis for EPA licensing of the overflows. The intent of the EISs is to assess the environmental, recreational and public health impacts of the overflows and to propose management strategies and targets to be incorporated in the licences.

While there is no record kept of sewer overflows, it is likely that a significant number occurred in the catchment during the heavy rains.

On-site sewage management facilities

On-site sewage management facilities serve single residences in unsewered areas. The basic function of these systems is to treat all the wastewater produced by a household and distribute it to adjacent land. There is a broad range of on-site systems available, including septic tanks with associated absorption fields and composting toilets. Users of on-site systems in the catchment include:

- households in unsewered villages such as The Oaks and Oakdale in Wollondilly;
- rural residents such as the 40 homes of Darkes Forest;
- mining operations such as the various collieries that operate in the Upper Nepean Catchment;
- the many picnic areas that are often located near the dam facilities, such as the picnic areas adjacent to Cataract Dam; and
- Sydney Water administrative offices, cottages and field huts.

Discussions with the councils that cover the catchment suggest that around 21,500 on-site systems occur in the catchment area, as outlined below.

Local Government Area	Number of individual systems in the catchment	Comments
Wollondilly Shire	11,000	Includes The Oaks and Oakdale.
Wingecarribee Shire	5,000	Systems are predominantly on-site disposal with trenches. Only 5-10% are currently aerated systems.
Wollongong City	40-60	40 homes in Darkes Forest and eight at Mount Kembla. There are up to 10 mining operations in the area and two utility facilities that have on-site systems.
Oberon Shire	1,000	There are two villages in the shire, one of which, Blackspring, is unsewered.
Mulwaree Shire	3,000	Around 1,800 of these are registered and largely located in Marulan, which has a septic system draining into a communal area.
Lithgow City	800	There are an estimated 120 aerated systems with the rest being septic.
Goulburn City	100	99% of council area is reticulated. Only a small area out of town remains unsewered.
Blue Mountains City	700	80% of these systems are on-site disposal with absorption trenches with the other 20% being pump out septic tanks.

The urbanised areas in the Warragamba Inner Catchment appear to present a significant risk to contamination of the water supply. As noted, the highest coliform values were observed at the inlets downstream of the Nattai River, which carries effluent from the Mittagong and Moss Vale STPs and Werri Berri Creek, from which unsewered villages have direct drainage.

The unsewered villages of The Oaks and Oakdale, located west of Camden, have been identified as major risks of faecal contamination from septic tanks. This situation has been of particular concern as the area is located only eight kilometres from the Warragamba dam wall. In response to this, an accelerated program for sewering the villages of The Oaks and Oakdale has been approved by the Minister for Urban Affairs and Planning, to commence in 1999. At this stage, the Government has allocated $871,000 to Sydney Water to develop the design options for the treatment works and to commence the EIS process, including community consultation. Other unsewered urban areas are located at Taralga, Tarago, Hartley, Yerrinbool, Nattai Village, Yerranderrie Village, Sutton Forest and Kangaloon.

Regulation of on-site septic systems is the responsibility of local councils. In response to concern that some on-site systems were failing to satisfy environmental and health performance criteria, the NSW Government recently released a package of reforms aimed at improving the performance of these systems. The reforms consist of a new set of environment and health protection guidelines as well as amendments to the Local Government (Approvals) Regulation 1998. The objective of the reforms is to put in place a sound framework for ecologically sustainable on-site sewage management practices and regulatory strategies. The package includes measures to provide local councils with more accurate figures on the number of on-site systems operating in their areas.

Agriculture

Extensive agricultural activities are undertaken in the catchment, including sheep and cattle grazing, poultry farms, chicken hatcheries and piggeries, dairies, saleyards and abattoirs.

Number of animals in the catchment area

	Wingecarribee	**Blue Mountains**	**Goulburn**	**GT Lithgow**	**Mulwaree**	**Oberon**	**Wollondilly**
	60209.7HA	2950HA	4663.4HA	84316.3HA	271111.7H	114542.2H	28981.7HA
Livestock	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**	**Number**
Sheep	22,091	970	5,285	82,076	619,019	27,1330	16,544
Cattle	48,779	1,403	1,091	30,767	61,937	40,865	19,944
Pigs	12,100	70	0	336	0	5	27,170
Deer	911	0	350	300	873	18	670
Stud Horses	538	4	1	151	356	109	534
Chickens	16,173	0	0	0	9,600	1,300	294,6362
Other poultry inc geese, game birds, ducks turkeys	0	0	0	60	0	0	288,220

Source: *AgStats* 1996

Cattle grazing, including along unfenced riverbanks, occurs extensively throughout the catchment with a large concentration in the Wollondilly catchment. During the recent heavy rainfall events, it is likely that run-off of animal manures and soil loads would have occurred from grazing lands denuded of pasture by 3-6 years of drought and from river banks subject to removal of riparian vegetation. The protection offered by riparian vegetation is crucial to water quality as it acts as a buffer zone in deterring livestock from walking in waterways and in stabilising the riverbank area.

Cattle faecal matter has been found to protect oocysts which makes it likely that run-off from agricultural land could be a significant source of *Cryptosporidium* (Le Chevallier *et al* 1998). Some seasonality has been noted in the number of oocysts in the environment and this has generally been associated with calving/lambing incidents. Calves and lambs are known to produce prolific numbers of oocysts, with as many as 10 million oocysts per gram of faeces being excreted from infected calves (Fayer *et al* 1997). While oocysts produced by cattle are less likely to be dangerous to human health than oocysts sourced from human effluent, waterborne outbreaks of disease have been reported from these sources, particularly in the United Kingdom and New Zealand (Shianna *et al* 1998).

Dairy farms are concentrated around the Wingecarribee local government area. Animal pollution from these farms mainly consists of run-off from milking sheds and pens and may be exacerbated by wet weather conditions, especially if pen bunding is poorly implemented or non-existent.

The EPA regulates a number of the larger agricultural activities in the catchment by the issue of licences and other regulatory instruments. It also periodically inspects potential sources of pollution that may not hold an EPA licence. Generally these facilities are regulated by local councils. Non-mandatory guidelines are issued by NSW Agriculture.

The Goulburn Livestock Saleyards have no effluent or manure collection facilities in place and discharges occur in wet weather to the Wollondilly River, which is located one kilometre from the Saleyards. An EPA notice has been issued to the council requiring it to install further facilities by the end of 2000. Livestock selling yards are also located at Moss Vale and Taralga. There is also a wool scouring operation and an abattoir at Goulburn.

Intensive horticulture using animal manure as fertiliser is also undertaken, for example, the orchards in the Upper Cordeaux, the flower and vegetable gardens around Werri Berri and potato growing around Kangaloon and Robertson.

Agricultural activities can contribute to water pollution, not only by the production of animal and chemical contaminants, but also by disturbance of vegetation near waterways. Such disturbance removes the natural barriers to pollutants entering waterways. The Department of Land and Water Conservation is responsible for regulating vegetation clearance that may be associated with agricultural activities. *The Native Vegetation Conservation Act 1998* prevents inappropriate clearing through the use of licences to clear vegetation and provides for the protection of "State Protected Land" which includes steep mapped land, land near prescribed streams and environmentally sensitive land. The *Rivers and Foreshores Improvement Act 1948* requires a permit to excavate or remove material in, or within 40 metres of the bank or shore of a river, lake or estuary.

Biosolids

Sewage treatment requires the removal of solids to provide a clear effluent of suitable quality for discharge to the environment. These wastewater solids can be further processed to produce biosolids which contain useful amounts of plant nutrient and organic matter.

There are four options for the disposal of biosolids:

- disposal to receiving waters;
- disposal to the air through incineration;
- disposal to dedicated landfill; or
- processing to provide a useful organic soil conditioner.

Sydney Water has settled on the last option and in 1997/98 processed enough sewage to provide 173,466 tonnes of product to the following markets:

- agriculture - 117,220 tonnes;
- horticulture/landscaping - 43,175 tonnes;
- forestry - 3,280 tonnes;
- land rehabilitation - 9,020 tonnes;
- research - 30 tonnes; and
- landfill - 741 tonnes.

The sludge may be composted, although the majority used is treated with lime and given up to 20 days retention time in an aerobic digester at 30Þ C. This treatment is considered sufficient to kill pathogens and other harmful organisms.

While the pathogens are killed, research has shown that *Giardia* cysts are still capable of detection in biosolids for up to six months and at high levels (McInnes *et al* 1997). *Cryptosporidium* oocysts survive better than *Giardia* cysts and therefore are likely to be detectable for an even longer period of time.

Sydney suffered a significant outbreak of cryptosporidiosis in late 1997 and early 1998 and its sewage is likely to have been heavily contaminated with the pathogen. Furthermore, background levels of *Giardia* are always present in sewage, so large numbers of both organisms would be expected in biosolids produced during this time.

Investigations of biosolid application in the Warragamba catchment has revealed that a total of 5,378 tonnes was applied during 1997/98. A total of 5,328 tonnes was applied to three grazing properties and 50 tonnes to the degraded Woodlawn mining site. All of these applications were subject to EPA licences and met their conditions. However these conditions do not include any criteria for *Cryptosporidium* and *Giardia*.

Sydney Water and NSW Agriculture have undertaken research which shows that biosolids improve infiltration of water into the soil and reduce erosion. Close monitoring of water quality downstream of large biosolid applications has not shown any deterioration in water quality, however this research did not include testing for the pathogens. As a result, Sydney Water argue that, even if present, the pathogens would be unlikely to move into the environment.

While Sydney Water may be correct, the levels of *Giardia* identified in biosolids by other studies (2,000-100,000 per gram dry weight) provide a vast potential reservoir of inactive pathogens which could be released by rain and washed into watercourses and reservoirs.

I have asked for further research to be undertaken on this issue. It could explain the extremely high numbers, but lack of disease, during the Sydney events.

Stormwater run-off

As well as sewerage systems which take wastes from homes and businesses, there is a separate drainage system that carries away excess water from gardens, roads, footpaths and roofs of buildings in urbanised areas. Stormwater, or urban run-off, refers to the rain run-off from all sources. In most cities and suburbs, there are roadside drainage pits where rainwater run-off can enter the underground stormwater drainage system.

Most drainage water flows directly into waterways, causing pollution. In some cases, stormwater run-off can be more toxic than treated sewage released from STPs. The pollution contained in urban stormwater can include: sediment from development and new construction; oil, grease and toxic material left on roads by cars, such as lead, zinc and copper; nutrients and pesticides from lawn management and gardening; and viruses and bacteria from failing septic systems. The faeces of domesticated animals such as dogs may also be a major source of pollutants in stormwater, and also a potential source of *Cryptosporidium* and *Giardia*. Sewer overflows may also be picked up and transported by stormwater.

Responsibility for the management of stormwater is fragmented between State and local government bodies. Stormwater systems in the catchment are primarily managed by local councils, although Sydney Water has responsibility for a limited number of stormwater pipes. The EPA has recently developed a policy framework and best practice guidelines requiring councils to develop stormwater management plans.

Native and feral animals

Feral deer, pigs, goats, wild dogs, feral cats, foxes, horses and cattle infest parts of the catchment. Studies are being done to see if they carry human-infective *Cryptosporidium* and *Giardia*, but no conclusive results are available. Nonetheless, such animals are all potential carriers of these parasites, as are native animals such as kangaroos, wallabies, possums and koalas (Gasser and Morgan 1998).

The National Parks and Wildlife Service has responsibility for feral animal control on the national park estate. It is also involved in joint control programs with Sydney Water in Inner Catchment lands. It is difficult to assess either the number of feral animals in the catchment or the effectiveness of control programs.

Little information is available to assess the number of native species to determine whether there has been any significant variation in numbers leading up to the contamination event. However, large numbers of kangaroos have been reported around the foreshores of Lake Burragorang as a result of the recent drought.

Mining

As previously noted, contamination by faecal matter is not the only threat to drinking water quality. Mining is a significant additional source of pollution that must be considered.

Mining has been undertaken in the Inner Catchment since the turn of the century, with two coal mines operating in the Warragamba Special Area today. In addition to surface facilities, surface-based mining exploration and subsidence monitoring is undertaken across the Special Area. All these activities have the potential to pollute streams or watercourses. Coal mining involves underground mining methods and significant surface-based infrastructure. There are six unworked coalmines with current leases in the Nattai River area which remain unrehabilitated and pose a threat to water quality. A number of shale, clay and sand extraction leases exist in the Upper Nepean Special Areas.

Mining also occurs in the Outer Catchment area and includes coal mining around Lithgow and base metal mining at Woodlawn, south of Goulburn. These mines produce run-off that could potentially pose a risk to water quality

Mines are regulated by a number of government agencies and may require licences from the EPA, the Department of Land and Water Conservation and the Department of Mineral Resources.

Other sources

There are a number of other sources of faecal contamination that pose a threat to the catchment. These include:

- public toilets located at recreation facilities on the river system, for example, at Avon, Cataract, Cordeaux and Nepean dams which are visited by approximately 1,000,000 people annually;

- illegal fishing in Lake Burragorang and Cataract;

- possible accumulation of *Cryptosporidium* and *Giardia* in sediments in Lake Burragorang; and

- swimming pool and water treatment plant discharges, both of which can contain concentrated sources of *Cryptosporidium* and *Giardia* - swimming pools are located at Nattai, Wollondilly and Coxs River (EPA 1993).

Which of these sources pose the highest risk in the catchment?

This discussion does not provide a definitive list of possible sources of contamination in the catchment. Rather, it is an indication of the current state of the catchment in terms of the potential for significant contamination of the raw water that is supplied to Sydney’s major water filtration system at Prospect.

Further research is now required to create an accurate picture of the catchment’s health. This work will need to analyse the risk posed by possible sources of contamination and review the following:

- magnitude of contamination;
- frequency of the discharge (continuous vs run-off related);
- type of contamination (animal or human); and
- distance from the lake and travel times during events.

Given the lack of data about the catchment and the current monitoring regimes, it is currently not possible to isolate the source or sources of contamination for the recent events. However, it is clear that the catchment has a number of significant potential and active sources of contamination that require urgent attention.

The Inquiry has commissioned work to rank the sources of risk in the catchment that pose the greatest threat of contamination by *Cryptosporidium* and *Giardia* at levels which threaten public health.The results of this work in terms of non-point and point sources are listed below (AWT 1998a).

Non point sources include:

- grazing in Burragorang, Werri Berri Creek, Nattai, Coxs and Wollondilly Rivers;
- two unsewered areas in Werri Berri Creek and Nattai River; and
- run-off from bushland in Wollondilly.

In terms of risk, it would appear that sewered and unsewered urban areas require most attention. In addition, grazing and other farming activities, particularly in the Werri Berri and Nattai River areas, are significant in view of their proximity to Warragamba dam and the water supply intake structures.

Point sources include:

- sewage treatment plant effluent;
- sewage treatment plant overflows;
- package sewage treatment plants;
- swimming pool backwash water;
- water treatment plant backwash water; and
- concentrated agricultural animal facilities.

Some of the specific sources have been identified as follows:

- STP effluent in Nattai;
- STP effluent in Coxs;
- STP effluent in Burragorang;
- STP effluent in Wollondilly;
- package STPs in Wollondilly;
- package STPs in Coxs;
- STP overflows in Burragorang;
- STP overflows in Coxs;
- swimming pools backwash water in Nattai;
- water treatment backwash in Wollondilly;
- water treatment backwash in Coxs;
- swimming pool backwash in Wollondilly;
- piggeries and abattoirs in Wollondilly.

It is significant that of the 13 point sources identified, the top 8 (representing 23 individual discharge points) are either sewage treatment plant effluent or overflows.

The risk ranking should not be taken to indicate the precise order of sources that are known to present the highest risks. However, it is obvious that action in the short term must address the sources of greatest concern in the catchment.

Conclusion

It is apparent that Sydney's catchment is seriously compromised. It contains a number of major sources of potential contamination both of *Cryptosporidium* and *Giardia* and of other pollutants. The state of the Outer Catchment and its planning and regulation is of particular concern and requires immediate attention. The recent contamination events have demonstrated the need to ensure that an effective planning and regulatory framework is in place to control future development and give priority to the protection of water quality.

Chapter 7: Catchment management regulations and structures

In the Inquiry's Second Report, I suggested that the Government should consider reviewing current water protection measures. The Government has since announced that it will review the structural and legislative controls that impact upon the management of Sydney's drinking water catchments. The Premier indicated that the Government was prepared to establish a Catchment Commission and ensure that it was given the necessary powers and provided with adequate resources to protect the catchment. A Task Force chaired by The Cabinet Office was established to undertake this review and bring forward legislative changes.

I have no doubt of the need for a Catchment Commission and will discuss its structure at the conclusion of this chapter. I favour a model where the Commission would be tasked to protect the water quality in the Inner and Outer Catchments and given management responsibilities for the Inner Catchment and powers to oversight a new strong and strategic Regional Environmental Plan for the whole catchment. The staff and resources currently allocated by Sydney Water for catchment and storage management should be transferred to the Catchment Commission. It would have responsibility for the catchments supplying the majority of Sydney's drinking water together with the relevant infrastructure.

I have come to the view that there are a number of major weaknesses in the current catchment management arrangements which create a potential threat to Sydney's drinking water. The same problems have generally been identified in a number of earlier reviews. All have called for better processes for identifying appropriate environmental standards and improved regulatory and institutional structures. They have also identified the need to minimise conflicts within and between agencies and establish coherent policies.

Healthy Rivers Commission Inquiry

The most recent review was conducted by the Healthy Rivers Commission which published its Independent Inquiry into the Hawkesbury Nepean River System in August this year.

It provides a clear statement of the weaknesses in the current water management arrangements. I endorse its findings.

The Commission noted that there are some 50 major statutes dealing with or affecting water in NSW. These statutes are administered by nine departments, agencies, commissions and corporations along with numerous local authorities. Responsibility for water related catchments is fragmented and accountability is unclear. It is obvious that it is only the goodwill of agencies attempting to make the system work which minimises regulatory inconsistencies.

This situation is reflected in Sydney's drinking water catchment, with five Ministers responsible for legislation controlled by the following:

- Department of Land and Water Conservation;
- Sydney Water Corporation;
- Environment Protection Authority;
- Department of Urban Affairs and Planning;
- National Parks and Wildlife Service;
- Healthy Rivers Commission;
- Independent Pricing and Regulatory Tribunal;

- Local councils;
- Hawkesbury Nepean Catchment Trust;
- Catchment Management Committees;
- NSW Fisheries;
- Department of Agriculture;
- Department of Mineral Resources.

The Healthy Rivers Commission found that:

- there is a widespread perception that because everyone is apparently responsible for river health, no-one in fact can be held responsible;
- there is no adequately directive framework within which agencies and councils can act severally and collectively;
- a new empowered authority must be created as there is no entity clearly accountable for the river with the powers to enforce the "rights of the river"; and
- improvements to coordinating machinery alone - as distinct from explicit accountability - will not resolve critical issues of leadership, exercise of powers, whole of government strategies or reconciliation of conflict.

Previous reviews of water management

Several major reviews have been conducted into the management and regulation of the "water industry" since 1984, culminating in the Healthy Rivers Commission Inquiry.

It is beyond the scope of this Inquiry to discuss in detail the outcomes of these reviews. However, a number of their recommendations are relevant to informing management and regulatory issues relating to the catchment and the problems underpinning the recent contamination events.

In chronological order, the most relevant findings of these reviews are summarised below.

Paterson Review 1984

The Paterson Review found that there was a lack of accountability, a fragmentation of responsibility, inefficiency, inadequate statutory provisions and conflict between public agencies. It found that the water resource ownership and management function should be at arms length from local distribution whether that distribution is for town supply, industrial or agricultural use.

The Government Pricing Tribunal Review into Water Related Services 1993

This report focused on water pricing. The Government Pricing Tribunal noted that the Water Board had experienced unacceptably large increases in its costs in recent years. The Tribunal noted that some of the cost blow out was related to meeting higher environmental standards, which may be acceptable to the community that is paying the bill. It was, however, noted that other costs had been imposed because of the uncertainties and conflicts in the institutional arrangements surrounding the business of supplying water, sewerage and stormwater services.

The Tribunal recommended that:

"as a matter of urgency, institutional arrangements need to be clarified with respect to the responsibilities, powers and activities of the various regulatory operators involved in water services. This extends to the way in which environmental regulation takes place."

The Tribunal strongly supported a revision of institutional arrangements to establish clear lines of responsibility and accountability for water management in its broadest sense.

"In the absence of clarifying and changing institutional arrangements, the Tribunal believes that the delivery of water services will be more costly than necessary, and unlikely to best meet the environmental outcomes and other standards that the community wants."

Significantly, the Tribunal noted that, as Sydney Water withdraws from regulatory activities that conflict with its function as an operator, it would be appropriate for transitional arrangements to be put in place until the new regulatory/institutional arrangements are properly established and functioning.

The Pricing Tribunal also reached the following conclusions:

- roles are not spelt out clearly in licensing agreements;

- no organisation could be held accountable for water quality issues - responsibilities for monitoring water quality, and for taking coordinated action where problems arise, need to be specified far more clearly than at present;

- there is a substantial overlap of functions between the then Department of Water Resources, the then Department of Conservation and Land Management and the Environment Protection Authority - duplication existed in collecting information on instream water quality;

- while the Board has clear, commercial objectives of maximising the value of the business, other operators self impose standards and have no clear measure of their commercial success in undertaking these tasks;

- accountability is weak because of the unclear assignment of roles and poor incentives - no single organisation can be held responsible for the whole range of activities relating to water quality within the catchment;

- there are frequent conflicts of interest, as the (then) Department of Water Resources, the Sydney Water Board and local councils all combine regulatory and operational functions - conflicts of interest are, in general, undesirable, because they impede transparency in decision making and provide opportunities for pressure by vested interests and for ad hoc political intervention in decision making;

- the multiplicity of bodies involved in the regulation of water and land imposes large costs on industry where new developments are being considered - the Tribunal proposed looking at developments as a whole through the implementation of "one stop shop" arrangements.

The Tribunal argued for the following regulatory model:

- clear separation between operators and regulators or managers - operators should not be able to set their own standards;

- development of new arrangements for setting standards for instream water quality, to encourage the benefits of higher standards being weighed against the costs;

- clear allocation of responsibility and powers for managing water, whether through improved coordination or re-arrangement of functions; and

- sufficient funding to enable regulators and managers to carry out their responsibilities; regulators and managers should be able to recover their costs through fees from licensing abstractions and discharges.

Joint Parliamentary Select Committee Upon the Sydney Water Board, 1994

The Parliamentary Inquiry chaired by Dr Peter Macdonald MP described the regulation of the industry as being fragmented and ineffective. It referred to "unproductive inter-agency rivalries" and to agencies having "strong and conflicting powers".

Many groups argued for catchment management to be the basis for urban development strategies. As Mr Jeff Angel, of the Total Environment Centre submitted to the Committee:

"Rather than being an adjunct to planning, water should be right in the core of planning." (*Hansard*, 26 August 1993 p33)

The Inquiry recommended that institutional arrangements should be changed so that one body is principally responsible for coordinating activities of government which have an impact on water quality and quantity. The body should report directly to the Parliament. It recommended that the functions and administration of the Water Administration Ministerial Corporation should be clearly separated from the functions and administration of the Department of Water Resources, with that department focusing on operations. The Ministerial Corporation’s powers should be exercised by the Office of Water.

Weaknesses in the management of Sydney’s catchment

Despite the efforts of various Governments over the past decade, there has been little progress in addressing the concerns consistently identified in the earlier reviews.

The major weaknesses in the catchment have not been addressed. They may be summarised as follows:

- there is no clear understanding about the health of the catchment;

- there is an absence of an audit of catchment health;

- there is an absence of an agreed set of objectives to govern the management of the catchment - one study in 1994 identified 154 government programs in the catchment with little or no coordination among these projects;

- there is poor coordination in decision making by the large number of agencies involved in managing the catchment;

- there are difficulties in enforcing relevant statutory and other regulatory provisions which control activities in the catchment;

- there is a lack of consistency in planning and development approvals employed by the ten councils in the catchment;

- there is a dominance of land use planning with inadequate attention given to other natural resources such as water; and

- there is a clear need for a custodian for both the minor systems and the catchment which feeds it.

Since the 1980s there have been many changes and reforms to the institutional arrangements for water management, many of which have not survived. The Water Resources Council was established in 1989 with the role of planning, coordination and conflict resolution. It was abolished in 1995 and replaced with a council of Chief Executive Officers (CEOs), comprising the CEOs of the water agencies and the Government Pricing Tribunal. An Office of Water was established in 1994, followed by the establishment of a Catchment Assessment Commission in early 1995. The Catchment Assessment Commission was represented on the council of CEOs and the Office of Water served as a secretariat to the Council. While the Catchment Assessment Commission reported directly to the Premier, it had no legislative base.

The Catchment Assessment Commission was abolished in mid-1995 and the Healthy Rivers Commission established. The Office of Water was also disbanded at about the same time. The Healthy Rivers Commission was subsequently established under the *Pollution Control Act* 1970 reporting to the Minister for the Environment.

Recent Government initiatives

Several initiatives have been introduced to improve some aspects of catchment management. New legislation introduced since the Water Board was corporatised has strengthened some regulatory controls over the Corporation. New environmental legislation has been introduced, including the *Protection of the Environment Operations Act 1997* and the *Contaminated Land Management Act 1997*. The *Water Legislation Amendment Act 1997* has also been introduced.

There have also been significant indications of policy changes which seek to address threats to water quality in the catchment. These include the following:

- Sydney Water and the National Parks and Wildlife Service have successfully produced a Joint Plan of Management for the Inner Catchment areas;

- the introduction of the Local Government (Approvals) Amendment (Sewage Management) Regulation 1998 requires local council approval to operate septic tanks and small sewage management systems and also requires local council supervision of the operation of these systems;

- the Waterways Package, introduced in May 1997, includes a requirement, backed by funding, that councils with towns of over 1,000 people should prepare urban stormwater management plans;

- NSW Agriculture has introduced a Strategic Plan for Sustainable Agriculture in the Sydney Region, which refers to protection of water quality and also the use of biosolids in land use practices;

- effective partnerships are being formed between State and local government and the community through the establishment and work of bodies such as the Hawkesbury Nepean Catchment Management Trust and the various Catchment Management Committees that operate within the catchment;

- work is under way to coordinate current data available on catchment management, including the establishment of specific databases by the Trust which contain information on the catchment’s geomorphology, councils’ State of the Environment Reports, State of the Catchment Management Plans and Local Government Management Plans.

I am aware of the Government’s longer term water reform agenda which will determine water quality and environmental flow objectives for the State’s rivers. Water Management Committees are being established throughout the State to combine the skills and knowledge of community members, interest groups and Government agencies. As part of the reforms, the Healthy Rivers Commission has already conducted major inquiries into several rivers in the State, including the Hawkesbury Nepean River.

The initiatives outlined above, and the water reforms in particular, have prospects of making improvements to the management of the State's catchments and water quality issues. However, it will be at least several years before the reforms become effective.

The catchments that supply Sydney's water are unique. They provide drinking water for over four million people. Any threat to their health will obviously have significant public health and financial implications. I am strongly of the view that the health of Sydney's drinking water is sufficiently important to warrant immediate action.

The size of the population that relies on the catchment and the intensity of the development pressures within it, make it essential that a purpose built solution be developed for Sydney's drinking water catchments. A generic model may need to be developed for the State as a whole, but Sydney is a special case. I understand that representatives of the local government authorities and catchment bodies currently operating within the broader Hawkesbury-Nepean catchment agree with this view.

What needs to be done to ensure the health of the catchment?

It is beyond my terms of reference to deal with the broad spectrum of issues which face water management generally. However, in relation to the catchments supplying Sydney's drinking water, several conclusions are apparent.

Despite the recent Government initiatives, many of the existing regulatory and institutional arrangements remain a problem.

Within the current planning framework there is a clear tendency to focus on land management issues and to treat water quality issues as a secondary consideration, normally as a constraint on development. Under the current arrangements, the catchment is managed to allow a range of activities. Water quality considerations may be diminished in favour of agricultural, urban and rural residential, forestry, mining and other developments. As discussed earlier in this report, some of these developments are significant potential sources of faecal and other contamination.

In my view, this situation cannot be allowed to continue. If development proceeds at the current rate, the risk to the quality of the raw water and therefore the health of four million people will be unacceptably threatened. From now, water quality should be the primary consideration in decision-making affecting the catchment. This has significant implications for proposed future developments in the catchment. Given the ongoing pressures for development, there must be broadly based support for such a move from affected communities, local councils and State Government agencies.

It is clear that an approach is required which seeks to minimise the existing threats to the catchment and control future development. This approach must involve clear direction from the Government, be adequately resourced and bring together the relevant State, local government and community interests.

Determination of water quality objectives and catchment strategies

For many decades, the catchment has been managed with no overall direction being provided from within government for either water quality objectives or broader catchment strategies. Management activities have been undertaken by a range of agencies, councils and bodies in an ad hoc manner, rather than following an agreed set of goals with identifiable priorities.

There is a need to develop directions, catchment-wide strategies and water quality objectives to guide management activities and development decisions in the catchment. The Healthy Rivers Commission is best positioned to assist in the task, as it has already undertaken a comprehensive review of the entire Hawkesbury Nepean catchment. It should be directed to undertake an expedited inquiry to identify the water quality objectives and broad strategic-level goals for the hydrological catchment.

It is critical that the recommendations be formulated in consultation with the community, and with the Government agencies and councils which will be responsible for implementing the objectives and strategies.

The objectives and strategies should be given statutory force by inclusion in a Regional Environmental Plan for the catchment. This will ensure they are applied when consent authorities review existing development activities and that they guide their future development decisions.

A Regional Plan for the catchment

The impact of urban growth will be the critical factor in the catchment’s future environmental health. Development is primarily regulated by environmental planning instruments and the decisions made by local government in relation to subdivisions and other development applications.

At the time of corporatising Sydney Water, it was clear that there were significant concerns about the effectiveness of planning controls in the Outer Catchment areas. The Parliamentary debate on corporatisation identified the need to ensure that adequate direction was provided to local government authorities responsible for the management of development in the Outer Catchment, which is primarily private land.

I have been advised that the intention at that time was to protect the Outer Catchment through a Regional Environmental Plan (REP). It was intended that, while this was being completed, development applications would be referred to Sydney Water for concurrence to ensure that water issues were adequately considered.

Sydney Water was subsequently granted referral and concurrence powers. However, despite the obvious need for a strong REP for this area, no REP has ever eventuated. Sydney Regional Environmental Plan 20 covers only a minor part of the Warragamba catchment. There is no coherent planning framework in place for the Outer Catchment areas, four years after corporatisation of the Board. It is clear that governments of both persuasions have found it difficult to progress effective planning because of pressures from rural and development interests. I am sure that, following recent events, the need to sustain the quality of the catchment will now prevail. It must be seen as an enduring and inter-generational issue for the State.

Directions under section 117(2) of the *Environmental Planning and Assessment Act 1979* have been issued which seek to ensure the protection of drinking water catchments, by requiring councils to consult with Sydney Water where a draft Local Environmental Plan affects its catchments or changes provisions relating to water catchment protection. However, a direction only operates when a new plan is in preparation and it can have no impact on existing problem land uses such as unsewered rural towns, rural residential development, intensive agricultural activities, mines and quarries and waste management. These make significant contributions to water quality problems in the catchment.

It is clear that Sydney's drinking water quality cannot be adequately protected in the long term by the existing controls. Current land use planning and controls have difficulty providing the structure to ensure that development within the catchment takes place without threatening water quality. There must be new controls on the types of developments permitted in the entire hydrological catchments and especially in the Outer Catchment.

My discussions with the Hawkesbury Nepean Catchment Management Trust and representatives from the Local Government and Shires Associations confirm that local government and the various catchment management bodies have contributed significantly to an increased community appreciation of the need to act to protect the catchment. Without the support of these community groups and the community as a whole, catchment protection initiatives are unlikely to succeed. This, however, does not substitute for strong direction from Government on catchment protection measures.

I appreciate the advice from the Local Government and Shires Associations that their member councils accept the need for strong State Government involvement in these areas. They seek the support of the Government to address the existing risks in the catchment including the problem of unsewered residential development.

I am satisfied that a new set of planning controls should be developed for the management of Sydney's drinking water catchments. The effective management of the Outer Catchment lands depends on:

- a clear articulation of catchment-wide strategies and water quality objectives, developed through the Healthy Rivers Commission's consultative inquiry process, and endorsed by the State Government;

- the development of effective arrangements between State and local government planning and regulatory bodies;

- effective enforcement of controls involving cooperative action between State and local government bodies;

- a combination of prescriptive and incentive based measures that seek to remedy existing threats to drinking water quality (such as upgrading of Sewage Treatment Plants) and address diffuse pollution sources; and

- resources being provided for planning within the catchment.

The Minister for Urban Affairs and Planning should develop a new Regional Environmental Plan (REP), covering the Warragamba and Upper Nepean hydrological catchments (both Inner and Outer) that supply the vast majority of Sydney's drinking water. The new REP should be a prescriptive instrument that:

- incorporates the broad catchment-wide strategies developed through the Healthy Rivers Commission inquiry process and endorsed by the Government;

- controls the actions and decisions of the State agencies and local government authorities in the catchment;

- incorporates the water quality objectives developed through the Healthy Rivers Commission which will be binding on agencies;

- specifies that consent authorities must not approve a development application unless it has neutral or positive impacts on water quality in the catchment;

- specifies that all new Local Environmental Plans (LEPs) must be consistent with the REP;

- specifies that councils will be required to review existing LEPs within a prescribed timeframe to ensure consistency with the REP;

- requires councils to develop amelioration plans, in consultation with the Government, within a prescribed timeframe, to develop strategies to address existing developments which pose significant threats to drinking water quality;

- incorporates the Special Areas Strategic Plan of Management jointly developed by Sydney Water and the National Parks and Wildlife Service; and

- is oversighted by the Catchment Commission.

This new REP should be innovative in form. It should be an amalgam of prescriptive development controls with broad catchment-wide strategies, and should integrate traditional land use planning with resource management goals.

I stress the need to involve the catchment community and the wider Sydney community both in the development of catchment strategies and water quality objectives by the Healthy Rivers Commission, and in the development of the REP.

I am conscious that, as the current contamination events become less immediate, the need for effective responses may be seen as less urgent. This must not happen. If legislation is enacted in response to the contamination events, public confidence would be enhanced by the inclusion of a statutory deadline for the completion of the REP.

As an interim measure, I recommend that the Minister give consideration to making a State Environmental Planning Policy (SEPP) which relates to the hydrological catchment and provides the parameters for acceptable development based on current information on water quality. It should identify the concurrence role of the Catchment Commission and development consent arrangements, including development permissible with the consent of council, State significant developments for the consent of the Minister and prohibited uses.

Assessment of the health of the catchment

There are significant gaps in the data and information systems relating to Sydney's drinking water catchment, the rivers and their uses, and the knowledge to predict the cumulative impacts of past and current levels of activities on water quality and the health of the catchment.

To develop appropriate management regimes for both the Inner and Outer Catchments, the Catchment Commission needs to conduct a full assessment of the present state of the catchment. This must incorporate both ecological information and an evaluation of the pressures posed by development in the catchment. Such an assessment offers the best prospect of ensuring that the cumulative impacts of development on catchment health are addressed.

Such an assessment is urgently required to guide management strategies and assure the general public of the continuing high quality of its drinking water or, if the circumstances warrant, provide an early warning of deteriorating water quality, the likely causes and the priorities for effective action.

A number of the written and oral submissions made to the Inquiry reinforced the view that Sydney Water has not successfully addressed the perception that it withholds information from the public and catchment management bodies about the health of the catchment. It is a matter of concern that this perception is also held by the regulatory agencies within the Government. The Catchment Commission's assessment must, in contrast, be transparent, drawing upon information held across government, local government and the community and provide its findings back to all parties.

An important information source is the data from monitoring regimes conducted to determine the cleanliness of raw water at various points in the catchment and water entering the water filtration plants. In the Second Report, I recommended that there should be greater coordination within Government of the collection of data on water quality for use by all relevant agencies. The Catchment Commission should have the responsibility for conducting water quality monitoring in the catchment under the supervision of the EPA. I will discuss monitoring regimes in my final report.

I recommend that the Catchment Commission be required to report regularly to the Parliament on its assessment of the health of the catchment and especially on the achievement of the water quality objectives in the REP. This should be in the form of a "State of the Catchment" report.

Improved management of the Inner Catchment

Much of the land in the Warragamba Special Area is reserved under the *National Parks and Wildlife Act 1974.* These lands are jointly managed by Sydney Water and the National Parks and Wildlife Service.

The Inner Catchment is the first and most critical barrier in Sydney Water's multiple barrier approach to water quality protection. It acts as a filtration system for water entering the storages. The greater the integrity of the Special Areas, the more effectively they act as a barrier.

The protection of the Special Areas has been managed principally through an exclusion policy (keeping out sources of risk) and trouble-shooting (efforts to remove potential sources of risk).

However, some parts of the Special Areas are subject to a variety of land tenures which are not consistent with protecting water quality. Some tenures, for example mining, override Sydney Water's control of the Special Areas.

Following corporatisation of Sydney Water, the Inner Catchment lands were to be managed in accordance with a joint Plan of Management to be entered into by the Corporation with the National Parks and Wildlife Service. As a result, a Special Areas Strategic Plan of Management has been prepared in consultation with representatives of key interest groups as well as experts in ecology, water quality, catchment management and public health. Under the Plan, access will only be allowed if it is clear that no risk will occur to the integrity of the catchment. I agree with this approach.

I am advised that the relevant Ministers have endorsed the Plan of Management. I commend the Plan. Action must now take place to release and implement it and provide appropriate resources.

The Plan of Management has statutory force under the *National Parks and Wildlife Act 1974*, for those parts in the national park estate. It should also be incorporated in, and enforced through, the proposed REP as part of the whole of catchment approach.

Because of the various land tenures in the Special Areas, it is critical that the REP provides strong direction about permissible activities in these areas. I also believe it is appropriate to give one agency specific responsibility for managing Government-owned land in the Inner Catchment. In my view, the National Parks and Wildlife Service is best placed to manage these areas for both water quality and broader ecological considerations, provided it is resourced adequately.

I recommend that Sydney Water's lands and the regulatory powers that underpin their management should be transferred to the proposed Catchment Commission, with areas subsequently to be declared as national parks/nature reserves and managed by the National Parks and Wildlife Service consistent with the Special Areas Strategic Plan of Management.

Improvement of regulatory and enforcement powers in the Inner Catchment

Sydney Water staff currently lack the means to effectively enforce protection measures in the Special Areas such as illegal access, dumping of refuse and sewage.

At present, Sydney Water controls activities occurring within the Special Areas through its exercise of the Sydney Water Corporation Limited (Catchment Management) Regulation 1995. The Regulation provides Sydney Water with the power within designated areas to control or prohibit activities which may adversely affect the quantity or quality of stored waters and the ecological integrity of the areas. This applies in varying degrees to all land within the Special Areas (private freehold, Sydney Water freehold, Crown land and national park estate).

Initially there was some opposition to the Regulation, and arguments against it continue. The exercise of Sydney Water's controls on access to the catchment has been controversial as demands from recreational users to visit these areas for bushwalking, riding, fishing and abseiling and other activities have increased. These arguments have, quite rightly, failed to convince Sydney Water and the National Parks and Wildlife Service to allow greater access.

However, a number of enforcement powers have not been provided to Sydney Water staff. In particular, a proposal to introduce on-the-spot fines for illegal access to Special Areas was withdrawn in August 1995 by Sydney Water on the basis of hostile feedback received from stakeholder groups. Evidence from Sydney Water field staff has shown that exclusion of human activity from the areas immediately around the storage areas is rendered significantly more difficult without powers to issue fines, or even to compel people to provide their name and address. This situation must be reviewed upon the creation of the Catchment Commission.

I also suggest that arrangements be put in place to enable Catchment Commission officers to draw upon the enforcement powers of other regulatory agencies, such as Department of Land and Water Conservation, Environment Protection Authority and National Parks and Wildlife Service, and to allow officers of those agencies to enforce the Commission's regulations. This would significantly enhance cooperative enforcement efforts in the Inner Catchment.

Coordination of agencies regulating the Outer Catchment

The major regulators for the Outer Catchment are the Environment Protection Authority (EPA), the Department of Land and Water Conservation (DLWC), Sydney Water and local government. Despite progress in a number of areas, I am not satisfied that there is either the resources or the will between these agencies to cooperate to ensure that there is an effective regulatory framework for the management of Sydney's drinking water catchment.

Although there is a number of agencies apparently accountable for various components of catchment health, no one agency is responsible for considering the catchment as a whole unit. There is a lack of accountability regarding the specific powers of each of the various agencies. For example, duplication and confusion amongst the agencies has made it difficult, if not impossible, for any agency or a member of the public to obtain a comprehensive picture of the health of the catchment, especially in relation to water quality data. It is my belief that the establishment of the proposed Catchment Commission will help resolve these problems.

However, the establishment of the Catchment Commission is insufficient to address the need to strengthen the protection of the Inner and Outer Catchments. I believe that the proposed REP and creation of the Catchment Commission will provide the most effective means for ensuring a whole of catchment approach which brings together the efforts of State agencies, local government and community bodies involved in the management of the catchment.

Some of the previous reviews have argued for the establishment of a "super regulator." While this may be a useful development in the longer term, a change of this nature at this time would place the future of the catchment in uncertain hands for many years as bureaucratic processes are established. I do not believe that this can be justified given the need for early action.

I am of the view that the EPA should be the primary environmental regulator in the catchment. Its role should be strengthened. Any diminution of its powers has the potential to undermine an important part of the regulatory framework.

The EPA should be given a strong mandate and resources to address both point source and diffuse pollution sources within the catchment. It should also be the agency charged with providing primary assistance to the Healthy Rivers Commission to facilitate development of clear water quality objectives within a prescribed timeframe for incorporation within the proposed REP.

The EPA must have the power to coordinate regulation of water quality within the catchment across State and local government agencies. It must exercise that power in conjunction with the Catchment Commission to establish an agreed water quality program for the catchment. This objective must not be diminished by the competing interests of the regulators.

There would also be benefit in unifying the environmental health responsibilities of NSW Health and the EPA to ensure better coordination based on agreed water quality data.

A further option for coordinating the regulatory responsibilities and efforts of the various agencies involved in the catchment would be the use of the proposed new Protection of the Environment Policies (PEPs) as an instrument to influence decision-makers on existing practices or operations. The PEPs will not be available until the proposed *Protection of the Environment Operations Act* commences in mid-1999, but work could commence on an interim PEP that could be gazetted shortly after commencement of the Act. Another option would be for the EPA to use section 12 of the *Protection of the Environment Administration Act* 1991 to direct public authorities on any environmental related matters arising from this report that Government believes would be usefully supported by a statutory direction. If applied, these mechanisms would be complementary to the proposed REP.

Addressing of gaps in regulatory and concurrence powers

Prior to corporatisation, Sydney Water held regulatory responsibilities with regard to water quality and selected development approval powers. In outlining the benefits of corporatising Sydney Water in 1992, the then Government stressed the need to minimise conflicts between commercial and environmental goals by separating regulatory powers from the management and operation of the Corporation. This separation was claimed to enhance the protection of public health, through the setting of standards by separate regulatory agencies such as the EPA, NSW Health and DLWC and through the independent enforcement of these standards.

Consistent with the principles of corporatisation, activities of a regulatory nature previously undertaken by the Corporation were transferred to other agencies. They include:

- compliance with the National Health and Medical Research Council Guidelines for Drinking Water Quality was transferred to NSW Health;

- trade waste disposal was transferred to the EPA;

- regulating and inspecting the construction and fitting of infrastructure and plumbing on properties is now the responsibility of owner/developers; and

- setting standards in relation to infrastructure and plumbing is now the responsibility of local councils and the private sector.

Despite the theoretical benefits of shifting regulatory powers to the regulatory agencies, there is little evidence to suggest that Sydney Water is in fact subject to more stringent standards following corporatisation. I will discuss this issue further in later reports.

Sydney Water has traditionally had referral and concurrence powers, whereby it had to be consulted on certain development applications (referral clauses) or could veto certain other proposals (concurrence clauses). There are currently 97 referral and concurrence clauses in Local Environmental Plans and other planning instruments that allow Sydney Water to influence development applications. Of these, Sydney Water has advised that 18 clauses relate to the protection of Sydney's drinking water.

Under a Government initiative to streamline the processes by which development applications are considered, agencies have been requested to review the need for existing referral and concurrence powers. Agencies have been encouraged to work with local government and other agencies to adopt a more strategic approach to safeguarding agency interests. For example, agencies have been asked to consider whether it is appropriate to incorporate their requirements into planning instruments and provide councils with guidelines.

I understand that Sydney Water has reviewed its referral and concurrence powers and concluded that 79 clauses are no longer needed. Of the 18 clauses which it classifies as relating to drinking water protection, Sydney Water has concluded that all should be retained to safeguard Sydney's water quality.

The recommendations resulting from the State-wide review of referral and concurrence provisions are currently being considered by the Government.

The Catchment Commission will require significant powers to influence and control the nature, scale and location of development that is proposed within both the Inner and Outer Catchment areas. This can only be achieved if the Commission has clear concurrence powers in relation to development which could impact on the catchment. This would enable the Commission to exercise an appropriate role in relation to water quality in the Outer Catchment.

Community participation and education

There are currently three Catchment Management Committees (CMCs) operational in the catchment: the Coxs River CMC, the Wollondilly CMC and the Upper Nepean CMC. They undertake a valuable role in coordinating activities of agencies, councils and others in the catchment. They work cooperatively to improve current agricultural and other land use practices impacting on the catchment. I commend their activities and urge the State Government to continue to support them. It may be necessary to review some aspects of their operations, for example, to ensure that the Committees' membership is balanced between representatives of competing interests, and that they are adequately resourced.

The Hawkesbury Nepean Catchment Management Trust does not currently operate in the Warragamba catchment, having responsibility for areas below the wall at Warragamba Dam. However, I understand that action is being taken to expand the Trust's area of operations to include the Wollondilly and Coxs River CMCs. This means that it will have jurisdiction over the whole catchment.

The Trust and the CMCs can ensure appropriate communication between the community in the catchment and the Catchment Commission. The Commission, once established, should consider establishing a forum with representatives of the Trust and CMCs to provide it with advice on specific issues as well as its general work program.

I understand that the role of the Hawkesbury Nepean Catchment Management Trust will be reviewed over the next six to nine months. This review should take into account the new responsibilities of the Catchment Commission.

I have been advised that, with the change in Sydney Water's focus following corporatisation, there has been less emphasis on educating and advising the public on issues associated with catchment management. The Catchment Commission should give attention to the need to ensure that the public and residents in the catchment are given the best available advice about living in sensitive catchment areas.

Audit of the implementation of objectives and strategies

When establishing the Sydney Water Corporation, a need was identified to create an independent statutory body to advise the Minister and the Parliament on the Corporation's performance against its Operating Licence. A Licence Regulator was established to fulfil this role and commissions an annual audit of the Corporation against the Operating Licence requirements.

The former Chairman of the Licence Regulator, Dr Peter Crawford, made the following observation regarding the effectiveness of its operation:

"The Licence Regulator is responsible for ensuring an independent operational audit of performance by Sydney Water against its Licence, then advising the Minister on desirable responses to deficiencies. There is a strong, but erroneous impression that the public can have confidence in the aggregate performance of Sydney Water resulting from each annual audit, including the way in which it is meeting and balancing its three overriding objectives."

He went on to recommend:

"The Licence Regulator will not be able to provide the required assurance to the community if its purpose is so narrowly construed as to enable Sydney Water to secure a perfect report card on the same examination each year. Rather the objective must be to provide an independent assessment of value to the Minister, Government, the community and Sydney Water in refining targets, identifying and reducing shortcomings and enhancing performance ... It is clear that with policy direction clearly established by the

Act/Government/Minister, the Licence Regulator exists to assess objectively and independently whether the operations of the regulated entity are in fact consistent with that policy framework."

It is apparent that the Licence Regulator has experienced considerable difficulty in defining an effective audit role for itself in the face of resistance from both Sydney Water and the primary regulators, who perceived its role as a duplication of their own.

In my opinion, there must be an independent audit body which has the ability to critically review and report on the performance of all parties in meeting the endorsed water quality objectives and the catchment-wide strategies incorporated in the proposed REP. I believe this is critical to restoring public confidence in the water supply, establishing confidence in the Catchment Commission and reinforcing the effectiveness of the regulatory framework.

In my opinion, the Licence Regulator should be restructured and provided with the statutory powers and resources necessary to achieve this function and given a clear set of operating objectives. I will comment on this further in relation to the general regulation of Sydney Water.

In relation to the catchment, the Licence Regulator should be required to undertake an independent audit of the operations of the proposed Catchment Commission and the activities of the primary regulators, namely the EPA and DLWC, with respect to their catchment activities. In particular, the agencies would be audited against their performance in implementing the proposed REP.

Provision of sufficient resources for catchment protection

Sydney Water’s focus on catchment protection has diminished as the focus on commercial production has increased. This trend was part of a move in the early 1990s "to return to basics" and was reinforced with the change in culture accompanying corporatisation. I understand there was and is strong resistance to this change by many staff within the agency.

The change in focus has been accompanied by changes in the number of staff allocated within Sydney Water to catchment management. Since the early 1980s, the number of staff employed to manage Sydney Water’s catchment responsibilities increased from 22 to a peak of 44 in 1992-93, and returned to the current level of 24 people.

Prior to corporatisation, Sydney Water's structure included a Catchment Services Unit comprising staff who worked mainly on "on-the-ground" activities in the Inner Catchment, from fire management and road building to collection of firewood for picnic areas.

Since corporatisation, many of the "on-the-ground" catchment activities have been contracted to other organisations, or undertaken by the National Parks and Wildlife Service under operational agreements. The remaining catchment management activities are performed by staff in the Production and Strategic Resources Planning units of Transwater, which is a subsidiary body responsible for the wholesale water supply side of Sydney Water's operations. Functions performed include strategic planning for the catchment and some on-the-ground work such as patrolling for illegal access.

Strategic planning activities include influencing decision-makers in the Outer Catchment such as agencies, councils and landholders. This occurs through participation on Catchment Management Committees, negotiations for modifications to development proposals, funding demonstration projects of best practice in land management to reduce pollution of waterways and other community-based activities.

While these functions are important and should be continued, the combined effect of the restructure and reduction in staff has been a loss of people in the organisation with a long and detailed knowledge of catchment management, particularly in the Inner Catchment lands. This is especially significant in view of the lack of coordinated quantifiable data about the health of the catchment and the likely risks to the catchment, making greater reliance on corporate memory more necessary.

The reduction in field-based staff has also resulted in a perception within the community and from some within Sydney Water that enforcement of controls within the catchment has slipped. There does seem to be some evidence of this.

The future effectiveness of catchment staff would increase by their transfer to the Catchment Commission with a clear mission to protect drinking water quality. This role would be reinforced by the Minister defining the future needs of the catchment by making a catchment-wide REP.

It is unclear whether the reduction in staff resources has been accompanied by any reduction in financial resources allocated to the catchment since corporatisation. Sydney Water has advised me that its expenditure on the protection of the raw water supply has been steady over the last six years, averaging $3.7 million per year. Additional funds are made available for specific initiatives, such as providing new or upgraded sewage treatment services to currently unsewered residential areas ($6 million allocated to the program in 1998/99).

I am not in a position to judge whether this level of resourcing is sufficient for the proper management of the catchment to protect water quality and achieve other objectives. The absence of an annual audit of water quality and other outcomes, showing trend information, means that the task of determining appropriate resource levels would be extremely difficult. Nevertheless, there can be no doubt that adequate resources will be critical for the success of the Catchment Commission.

To assist in the process of resourcing the Commission and identify the mechanism and appropriate level of funding, I recommend that the Government initiate an inquiry by the Independent Pricing and Regulatory Tribunal (IPART). IPART should also be asked to address how the costs should be reflected in pricing regimes.

A clear advocate for, and steward of, the catchment

There is currently no agency within the Government which is clearly focussed on the health of the catchment, with a CEO who begins and ends each day with the sole task of ensuring that catchment protection prevails over often compelling commercial or broader development interests.

There is a need for an integrated approach which reflects the complex relationships between land, soil, water and biodiversity protection and that balances competing ecological, social and economic demands. However, I am strongly of the view that the protection of the water quality for more than four million people requires a body which does not have to make tradeoffs between competing land and water uses or between drinking water quality and socio-economic considerations. Its input into the decision making process will have a single focus.

It is my view that the proposed Commission should be responsible for providing water quality of a prescribed standard and controlling relevant infrastructure. It should be structured to maintain strong linkages between the catchment, dams, water storages and treatment plants. It would be responsible for the Inner Catchment (managed by the National Parks and Wildlife Service) and have a concurrence power over development within the whole catchment which has the potential to impact adversely on water quality. It should have the power to enforce existing laws and regulations designed to protect water quality.

The staff currently in Sydney Water working on catchment issues, storage management and on supplying water to the treatment plants should be transferred to the new organisation. I am confident that the skill and dedication of these people will help make the Commission an effective advocate for the catchment.

In summary, I believe that the Commission should have the following functions and powers:

- to be accountable to a Minister and have a statutorily defined set of objectives to protect drinking water quality and manage the health of the catchment;

- to oversight the implementation of the proposed Regional Environmental Plan;

- to exercise a concurrence power over development where a council is the consent authority;

- to be consulted on proposed developments where the Minister is the consent authority;

- to independently report to Parliament on a regular basis on its assessment of the health of the catchment;

- to undertake research on the health of the catchment;

- to be responsible for the Inner Catchment (managed by NPWS), with enhanced regulatory and enforcement powers in both the Inner and Outer Catchments;

- to own and maintain the relevant infrastructure;

- to use Catchment Management Committees and other mechanisms to ensure community participation in its activities;

- to undertake an educative role with the community;

- to have its performance audited by the Licence Regulator; and

- to have power to ensure compliance with existing laws and regulations.

Adequate resourcing of the proposed Commission will be critical to its success, both in relation to land management practices in the Inner Catchment and also in relation to its ability to impact upon development in the outer areas. This will require a reassessment of the resources currently applied to these areas by Sydney Water and other land management and regulatory agencies. The IPART review will facilitate this process.

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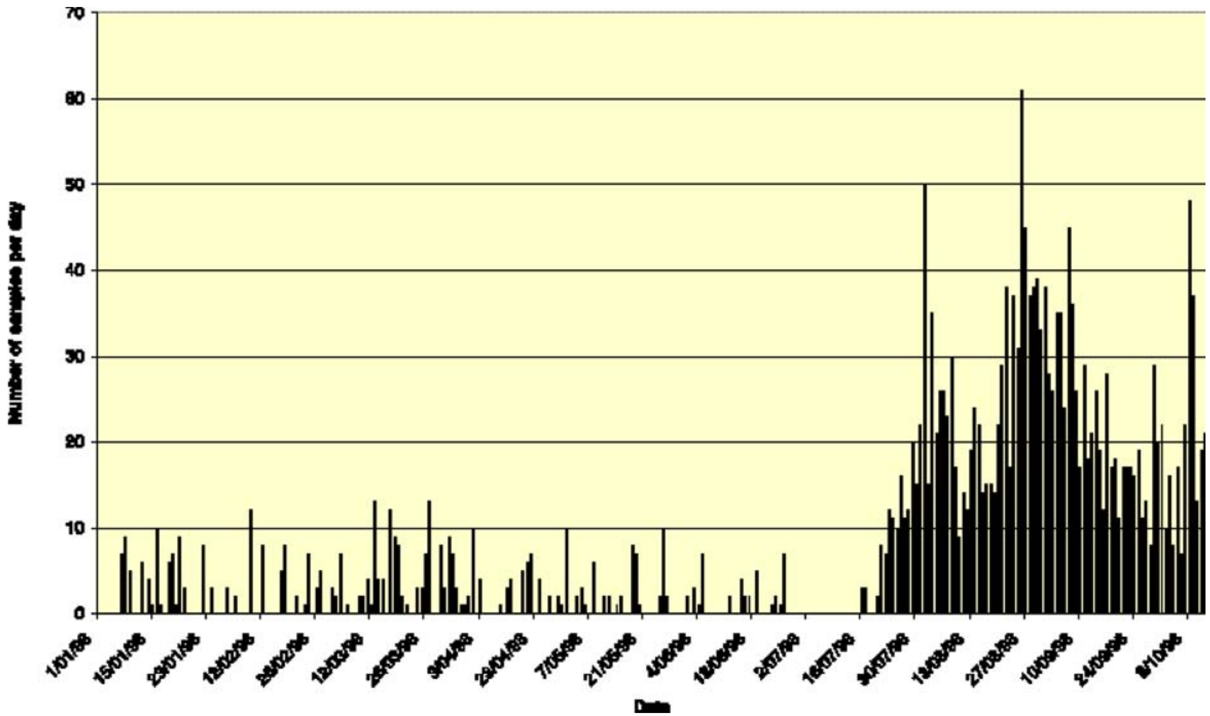
Number of samples per day analysed by the AWT laboratory and the resources allocated

SAMPLE VOLUMES (01 January 1998 to 10 October 1998)

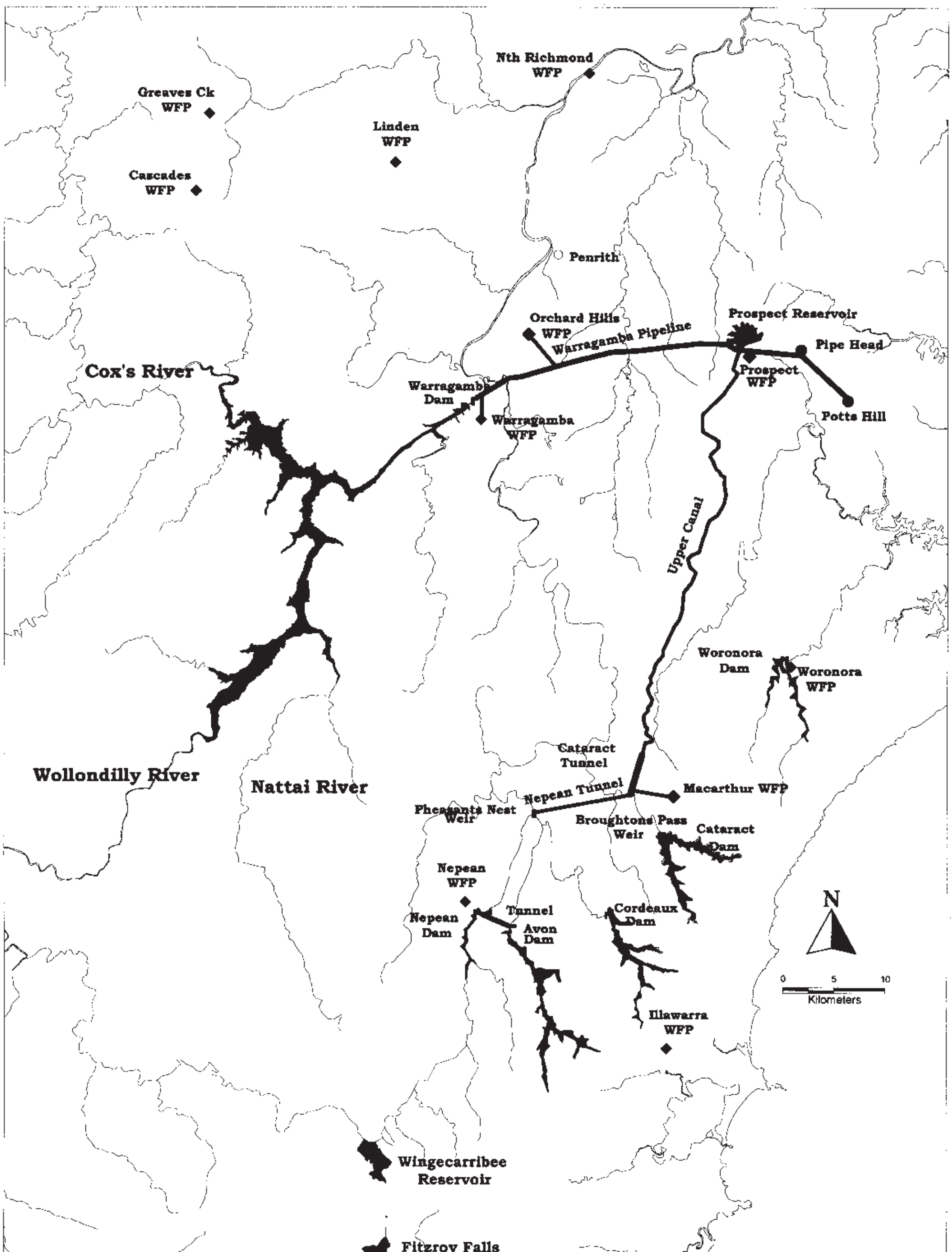


STAFF	Jan 1998	End Jul 1998	End Aug 1998	Mid Sep 1998	End Sep 1998
Full-time	5	5	10	13	13
Casual	-	-	4	4	4

EQUIPMENT	Jan 1998	21 Aug 1998	27 Aug 1998	18 Sep 1998	25 Sep 1998
Flow cytometer	1	1	1	2	2
Flat bed filters	2	3	3	5	6
Microscopes	2	2	3	3	3

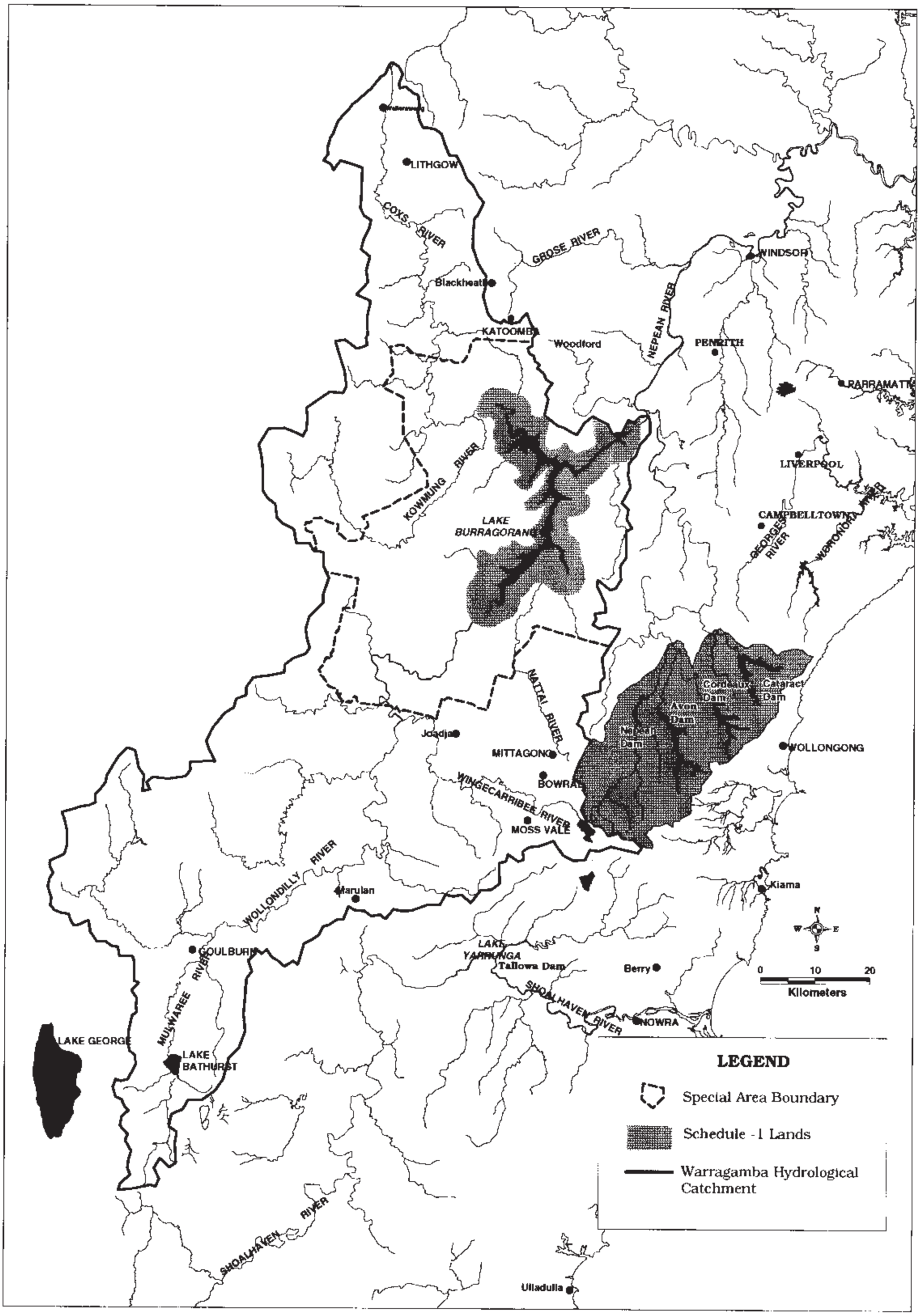
Map A

Major Water Filtration Plants
Sydney Water Supply System



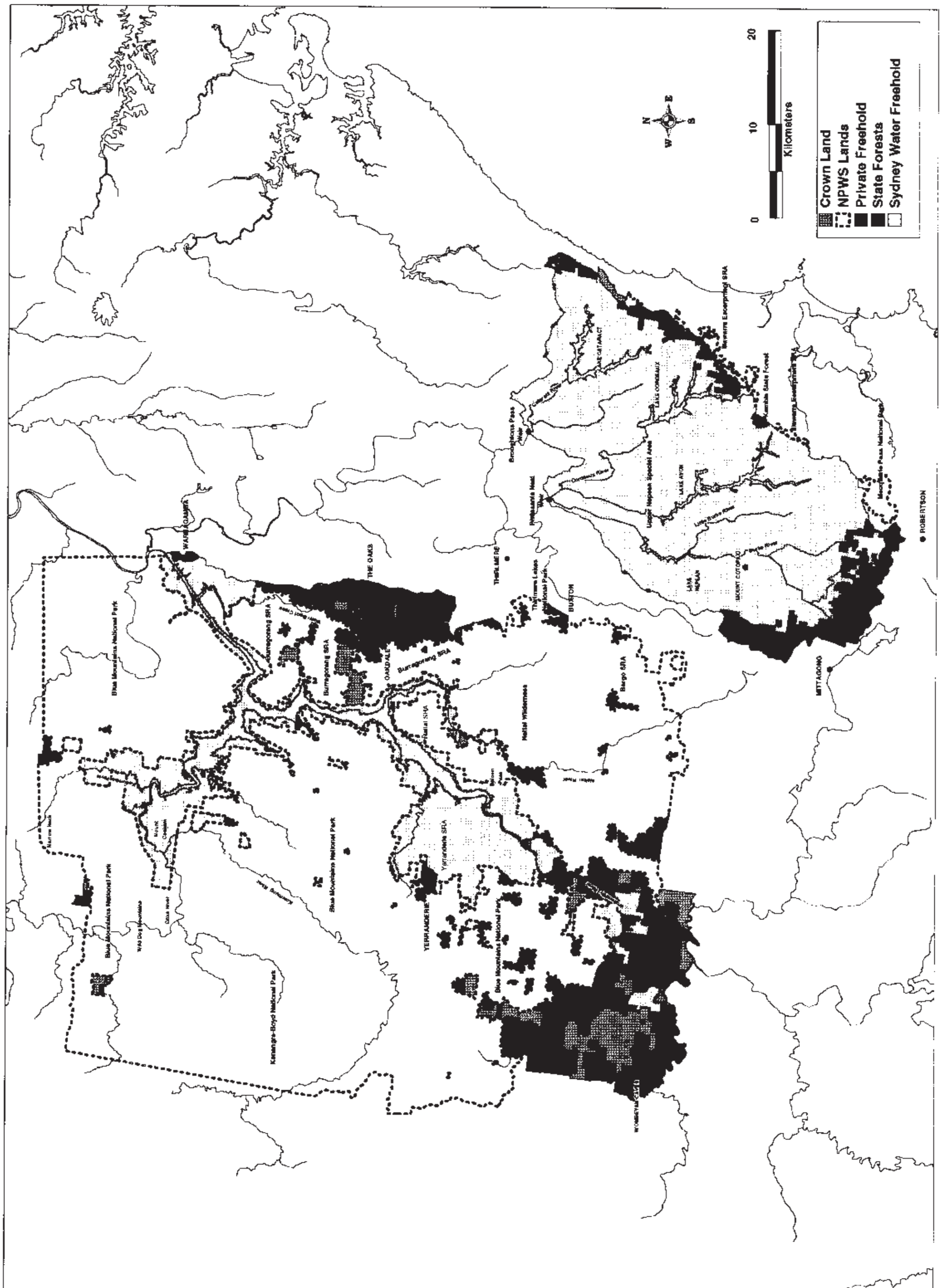
Map B

Sydney's Water Supply Catchments - Warragamba and Upper Nepean



Map C

Tenure Details in the Inner Catchments



Map D

Sydney's Water Supply Catchments - Warragamba and Upper Nepean Possible Sources of Contamination