Recycling water from sewage into drinking water

”High Risk”

Should be a “last” option not an early option

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Declaration of interest statement

- I do not have any contracts, consultancy arrangement or research grants from any companies that may derive major financial gains from building sewage recycling plants (eg engineering companies such as CH2M Hill, Veolia Water etc) nor from institutions that may be involved with the large sums of monies that will be needed to finance these types of projects (eg Macquarie Bank, Babcock and Brown, and/or water infrastructure funds).

- I declare that I have previously owned a small parcel of shares in AGL (which is in a business partnership with ACTEW and thus derives profits from water supply and use in the ACT in conjunction with ACTEW and the ACT Government).

- In making this submission I am expressing my own opinions on a matter of the very important public interest and concern as a medical and public health expert in the field of microbiology and infectious disease. I am not making any adverse imputations on the possible motives of any party who may be seeking to promote the recycling of treated sewage into water for human use as drinking water. The statements made herein represent my own considered opinions and judgements and do not necessarily represent those of any employer of mine or of any other institution with which I may be, or may have been, affiliated.

This is not an argument against recycling

Just do not use treated sewage as a drinking water source if there are other reasonable options

Only recycle water from sewage into drinking water

- When no other reasonable sources for water
  - Thus only as “last resort”

  and

- When testing is in place that shows the system is working properly all the time
  - This means show you achieve a log 10 reduction for viruses

Fundamental reversal of one of the basic health principles

- The problem with proposals to recycle sewage into our drinking water supply is that this is a fundamental reversal of one of the basic principles that have helped keep our drinking water safe (i.e. keeping sewage out of our catchment area and drinking water).

We have strived to protect our catchments from sewage

WARNING

RECLAIMED EFFLUENT
IN THIS LOCATION
DO NOT DRINK
AVOID CONTACT

We should only do this is if there are no other reasonable options for safer water sources

and no other options that are reasonable from an economic and environmental perspective

If you recycle water from sewage into drinking water then you need “real-time” testing to show the system is working
and reaching specifications all the time

especially for viruses

Issues in Potable Reuse: The Viability of Augmenting Drinking Water Supplies with Reclaimed Water

- Our general conclusion is that planned, indirect potable reuse is a viable application of reclaimed water—but only when there is a careful, thorough, project-specific assessment that includes contaminant monitoring, health and safety testing, and system reliability evaluation.

- Further, indirect potable reuse is an option of last resort. It should be adopted only if other measures—including other water sources, nonpotable reuse, and water conservation—have been evaluated and rejected as technically or economically infeasible.

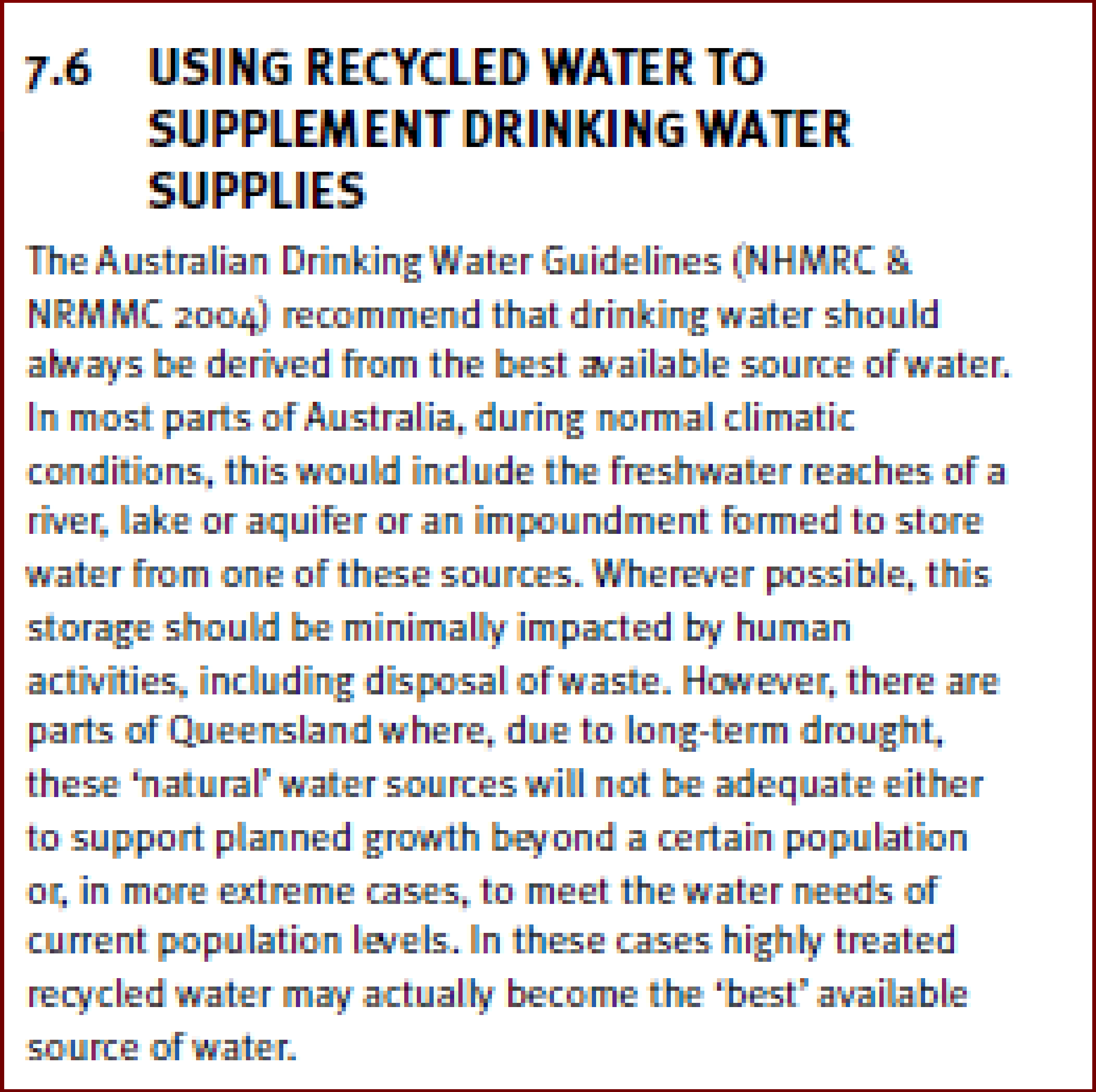
National Academy of Sciences US 1998

“Last resort”

- **indirect potable reuse is an option of last resort. It should be adopted only if other measures—including other water sources, nonpotable reuse, and water conservation—have been evaluated and rejected as technically or economically infeasible.**

National Academy of Sciences US 1998

Use as “last resort”



7.6 USING RECYCLED WATER TO SUPPLEMENT DRINKING WATER SUPPLIES

The Australian Drinking Water Guidelines (NHMRC & NRMMC 2004) recommend that drinking water should always be derived from the best available source of water. In most parts of Australia, during normal climatic conditions, this would include the freshwater reaches of a river, lake or aquifer or an impoundment formed to store water from one of these sources. Wherever possible, this storage should be minimally impacted by human activities, including disposal of waste. However, there are parts of Queensland where, due to long-term drought, these ‘natural’ water sources will not be adequate either to support planned growth beyond a certain population or, in more extreme cases, to meet the water needs of current population levels. In these cases highly treated recycled water may actually become the ‘best’ available source of water.

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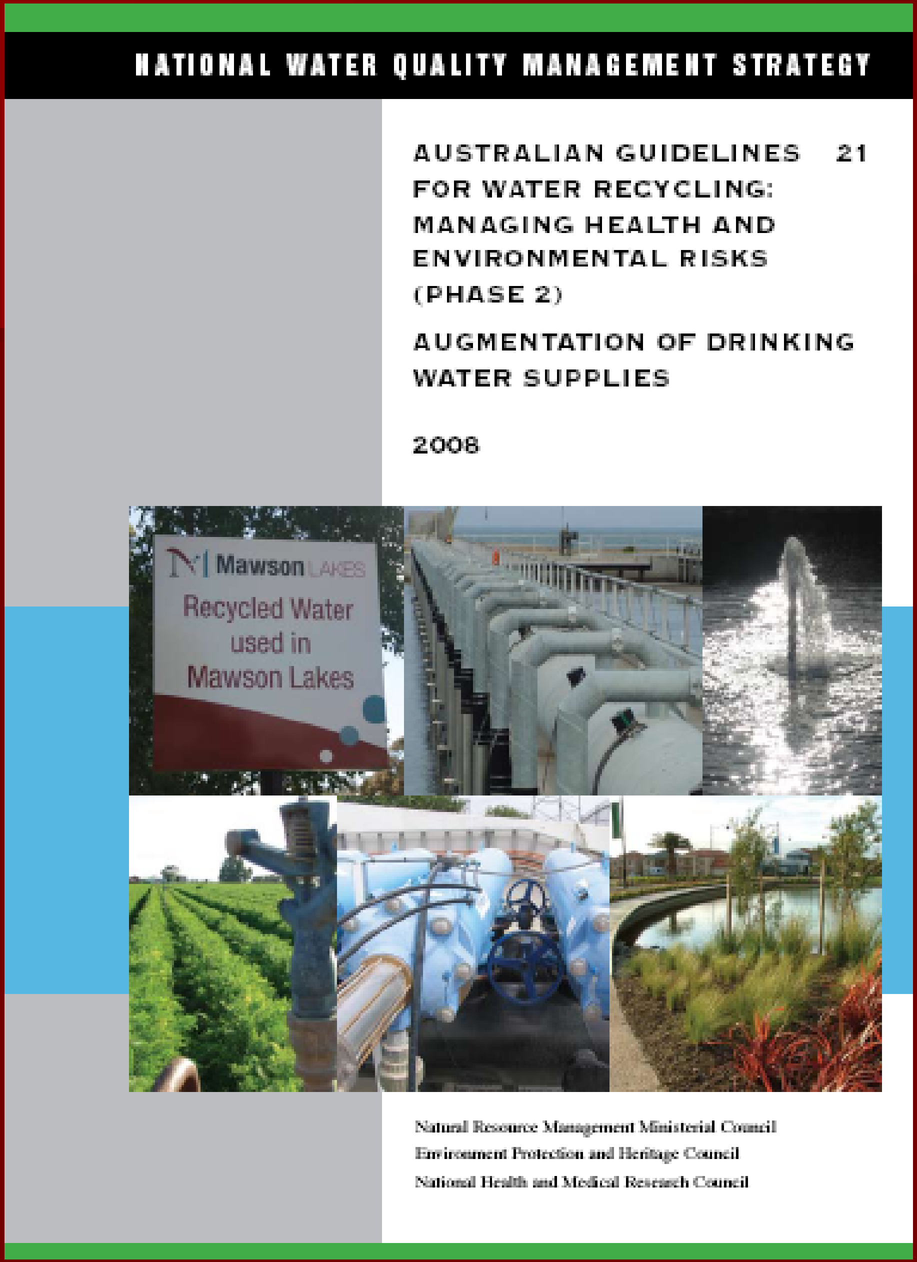


NATIONAL WATER QUALITY MANAGEMENT STRATEGY

AUSTRALIAN GUIDELINES FOR WATER RECYCLING: MANAGING HEALTH AND ENVIRONMENTAL RISKS (PHASE 2)

21

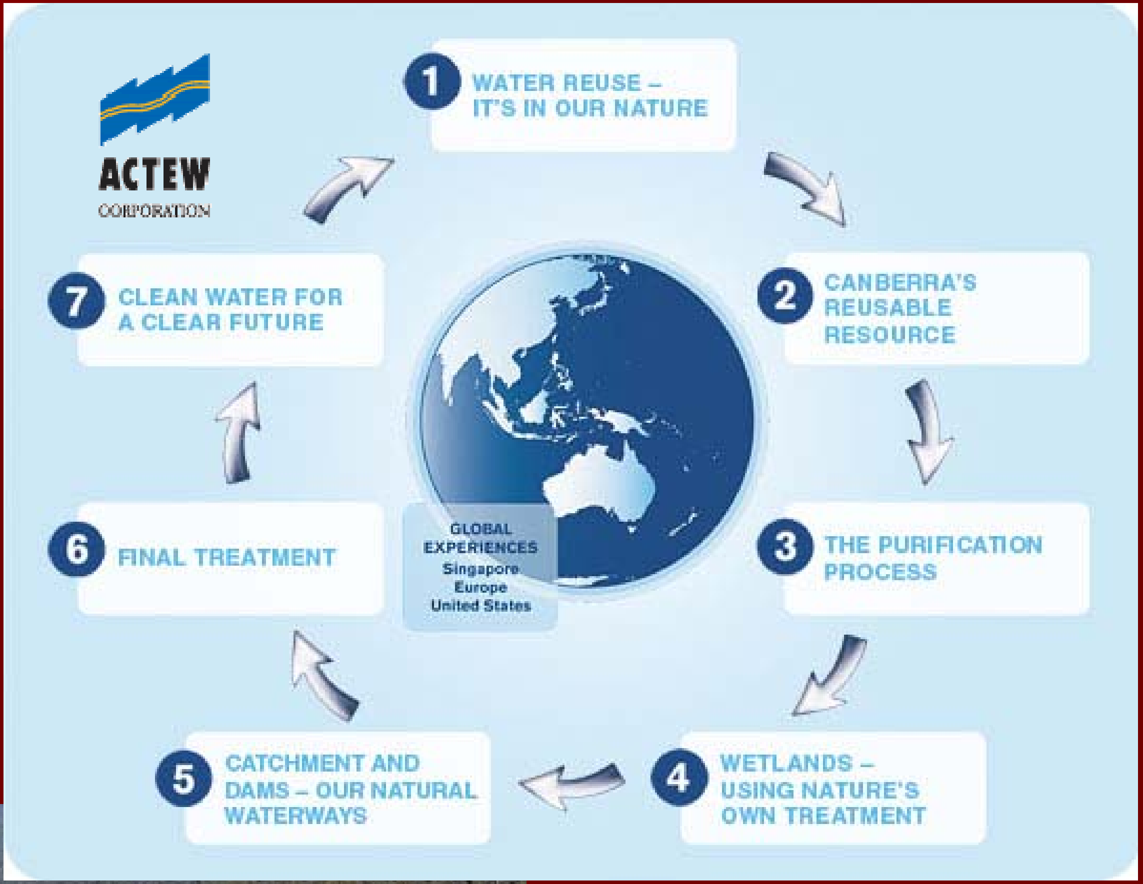
AUGMENTATION OF DRINKING WATER SUPPLIES

2008

Natural Resource Management Ministerial Council
Environment Protection and Heritage Council
National Health and Medical Research Council

Why is there no “last resort” comment in our latest national guidelines?

There are Major local and international marketing campaigns to promote recycling water from sewage into drinking water



ACTEW
CORPORATION

1 WATER REUSE – IT'S IN OUR NATURE

2 CANBERRA'S REUSABLE RESOURCE

3 THE PURIFICATION PROCESS

4 WETLANDS – USING NATURE'S OWN TREATMENT

5 CATCHMENT AND DAMS – OUR NATURAL WATERWAYS

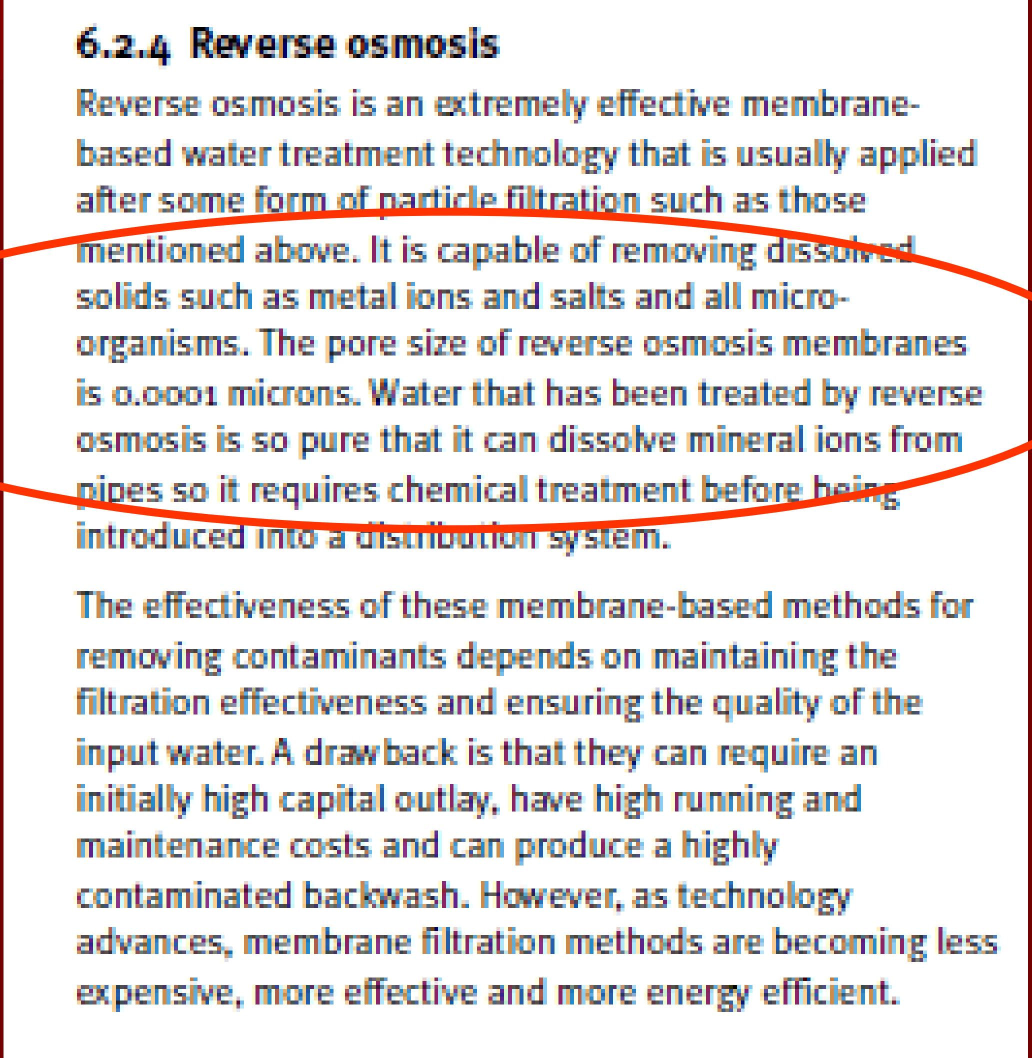
6 FINAL TREATMENT

7 CLEAN WATER FOR A CLEAR FUTURE

GLOBAL EXPERIENCES
Singapore
Europe
United States

water2WATER
safe • secure • sustainable

Reverse osmosis should remove ALL micro-organisms and nearly all drugs



6.2.4 Reverse osmosis

Reverse osmosis is an extremely effective membrane-based water treatment technology that is usually applied after some form of particle filtration such as those mentioned above. It is capable of removing dissolved solids such as metal ions and salts and all micro-organisms. The pore size of reverse osmosis membranes is 0.0001 microns. Water that has been treated by reverse osmosis is so pure that it can dissolve mineral ions from pipes so it requires chemical treatment before being introduced into a distribution system.

The effectiveness of these membrane-based methods for removing contaminants depends on maintaining the filtration effectiveness and ensuring the quality of the input water. A drawback is that they can require an initially high capital outlay, have high running and maintenance costs and can produce a highly contaminated backwash. However, as technology advances, membrane filtration methods are becoming less expensive, more effective and more energy efficient.

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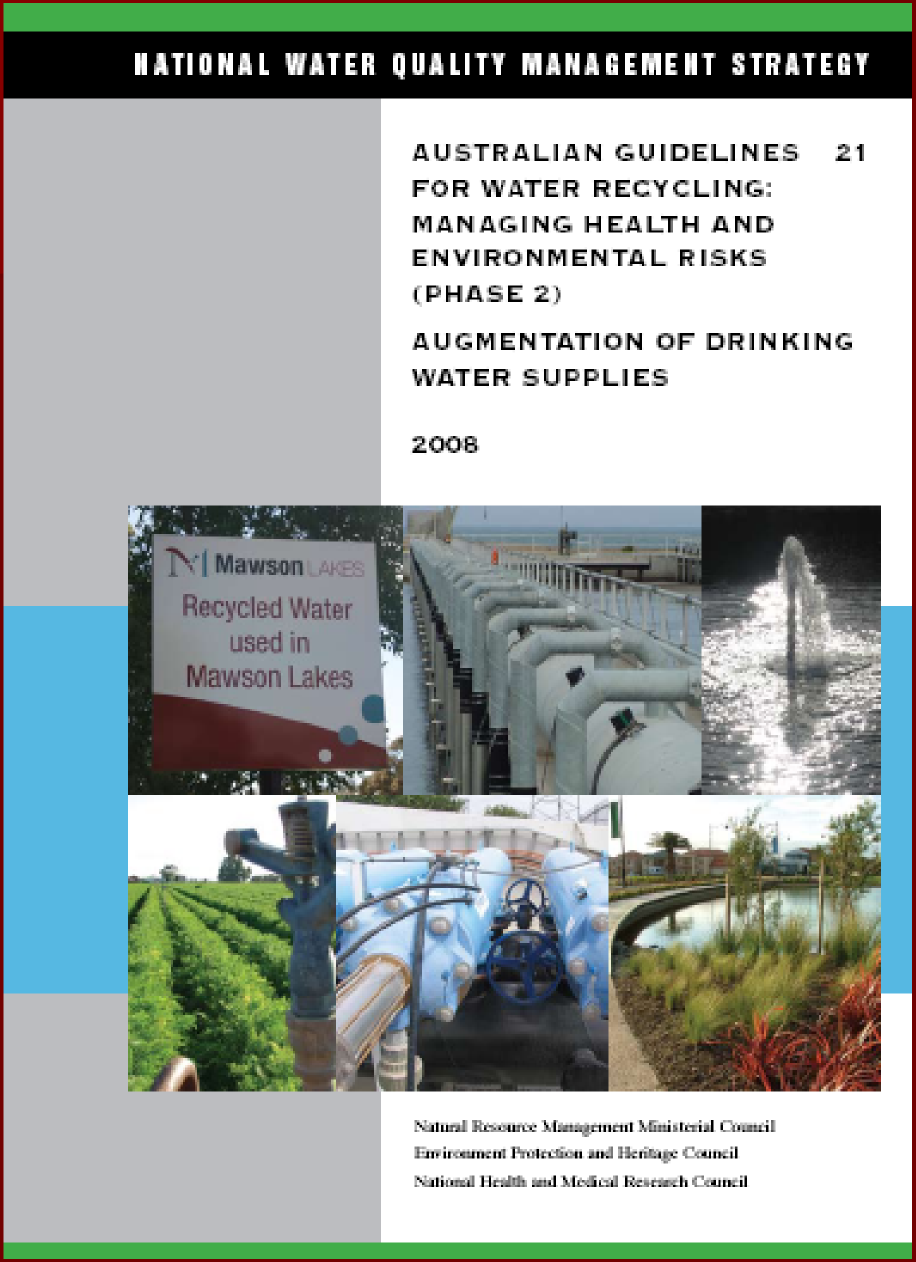
Recycling Guidelines
December 2005



NATIONAL WATER QUALITY MANAGEMENT STRATEGY

AUSTRALIAN GUIDELINES FOR WATER RECYCLING: MANAGING HEALTH AND ENVIRONMENTAL RISKS (PHASE 2)

21

AUGMENTATION OF DRINKING WATER SUPPLIES

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Natural Resource Management Ministerial Council
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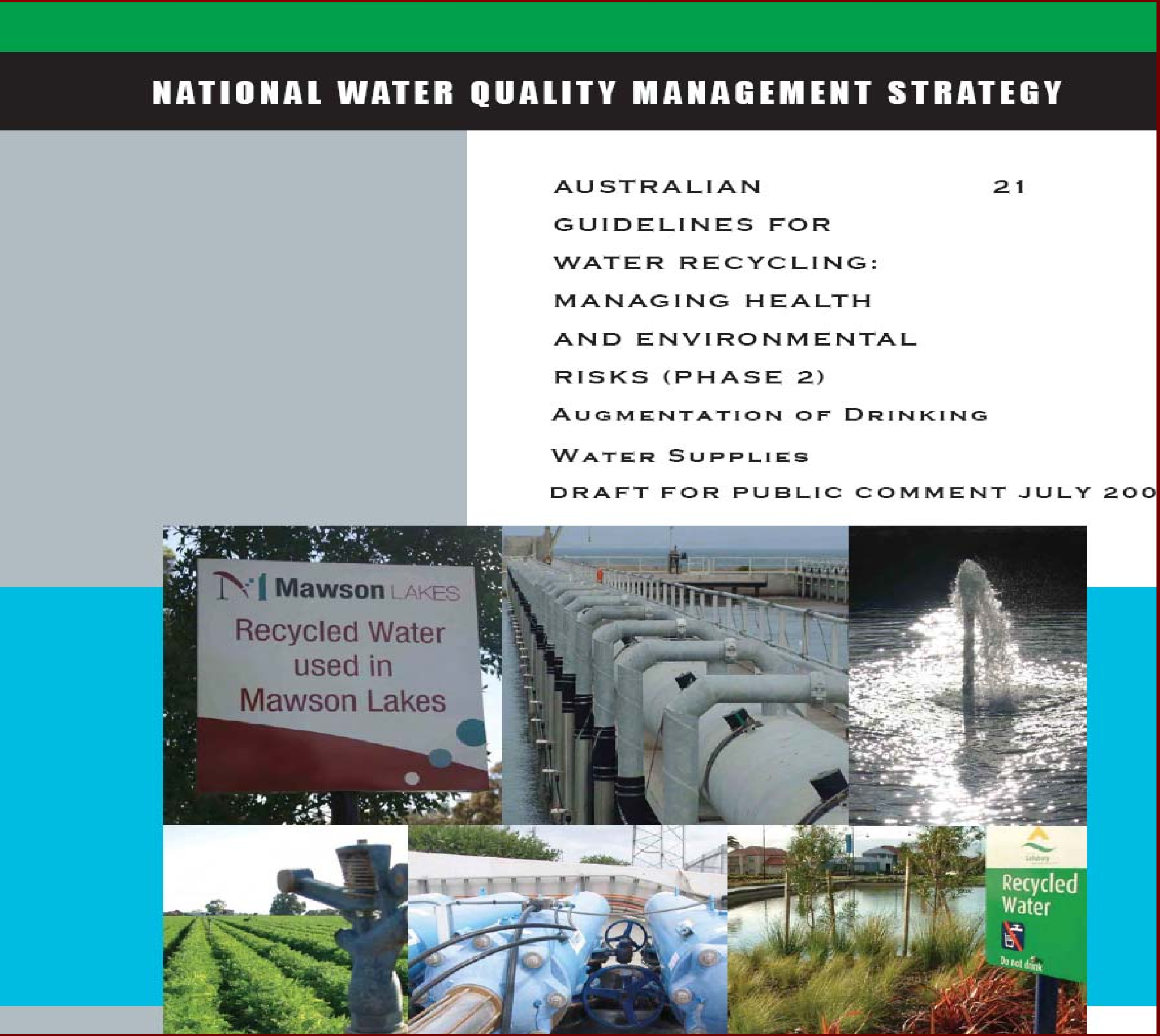


NATIONAL WATER QUALITY MANAGEMENT STRATEGY

AUSTRALIAN 21

GUIDELINES FOR
WATER RECYCLING:
MANAGING HEALTH
AND ENVIRONMENTAL
RISKS (PHASE 2)

AUGMENTATION OF DRINKING
WATER SUPPLIES

DRAFT FOR PUBLIC COMMENT JULY 200


Salisbury
Recycled Water
Do not drink

Much more testing is required if we use much “higher risk” water sources

- Sewage is a much higher risk for water than polluted rivers

- Sewage has a million to a billion *E.coli* per ml compared to 1 to 2 *E.coli* per ml in most rivers (eg Thames River)

National Academy of Sciences

USA 1998

- "The potable reuse industry and the research community should establish the performance and reliability of individual barriers to microorganisms within treatment trains and should develop performance goals appropriate for planned potable reuse."

- "Existing microbial standards for drinking water systems assume that the water source is natural surface or ground water. Treatment standards and goals more appropriate for potable reuse projects need to be developed."

- "Potable reuse project managers should consider using some of the newer analytical methods, such as biomolecular methods, as well as additional indicator microorganisms, such as *Clostridium perfringens* and the F-specific coliphage virus, to screen drinking water sources derived from treated wastewaters."

More lab testing as well as some animal testing is needed

- “These limitations include uncertainty as to whether the concentrates used for testing are truly representative of those in the wastewater; higher than expected occurrences of false negative results; long lag times between sample collection and the availability of results; difficulty in tracing results to particular constituents; and lack of suitability for continuous monitoring. In addition, a truly thorough application of the NRC protocol, which would involve extensive testing of concentrates on live animals, is both expensive and time-consuming.”

- “Given these complications, in waters where toxicological testing appears to be important for determining health risks, emphasis should be placed on live animal test systems that are capable of expressing a wide variety of toxicological effects.”

National Academy of Sciences US 1998

More Safety testing needs to be developed

- “the current approaches to safety testing of reclaimed water, derived mainly from consumer product testing protocols, are inadequate for evaluating reclaimed water and should be replaced by a more appropriate method. Even a brief look at these studies makes clear the need for a new approach.”

National Academy of Sciences US 1998

Epidemiologic Studies re safety are lacking

There are only very limited studies on HEALTH-Effects of reuse of water from sewage

- "Epidemiological data that can be confidently applied to the potable use of reclaimed water are lacking."

National Academy of Sciences US 1998

High numbers of pathogens in sewage

- Bacteria
- Viruses
- Protozoa
- Worms

Sewage much higher levels of virus and bacteria than polluted rivers

- Sewage
  - often between million to billion E.coli per ml (log 6 to log 9)
  - Viruses can be in similar numbers (log 6)

- Rivers (eg Thames)
  - E.coli 100 to 200 E.coli per 100 ml or 1 to 2 per ml (less than log 1 per ml)

- Overall levels of pathogens usually a million times higher in sewage compared to polluted rivers

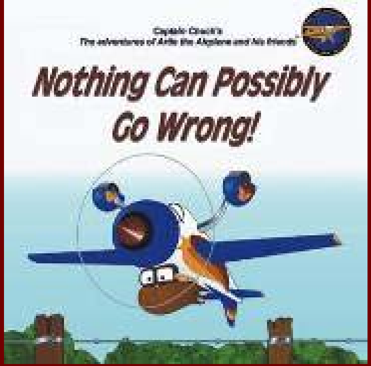
Drugs also a problem

- Drugs
  - Antibiotics
  - Hormones
- Chemicals
- Toxins

Technological fix

- These are Desalination plants
  - Why on coast not sea water or brackish water instead of sewage?

- With any system – things do go wrong
  - Human error causes 80% plus of mistakes



Membranes and reverse osmosis do not remove all drugs and salts

- Salts
    - About 98% removal
- Nitrates
    - Only 50 to 80% removal
- Drugs (eg antibiotics, hormones)
    - Antibiotics only 92% removal by RO

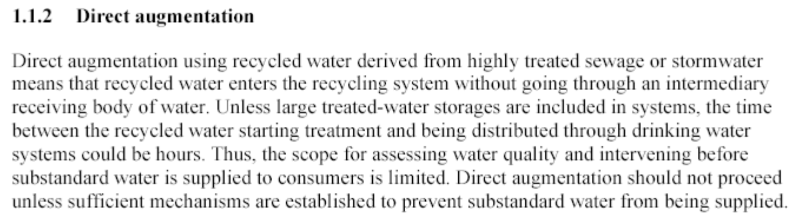
- What about viruses then?
    - Need 99.9999% (log 6) or more removal

“High Risk” proposal

if recycle water from sewage into drinking water

and it is an “added” risk

Politicians love it!



1.1.2 Direct augmentation

Direct augmentation using recycled water derived from highly treated sewage or stormwater means that recycled water enters the recycling system without going through an intermediary receiving body of water. Unless large treated-water storages are included in systems, the time between the recycled water starting treatment and being distributed through drinking water systems could be hours. Thus, the scope for assessing water quality and intervening before substandard water is supplied to consumers is limited. Direct augmentation should not proceed unless sufficient mechanisms are established to prevent substandard water from being supplied.

This is a “high risk” proposal

Risk assessment; Australian Drinking Water Guidelines 2004
Appendix A5

Likelihood

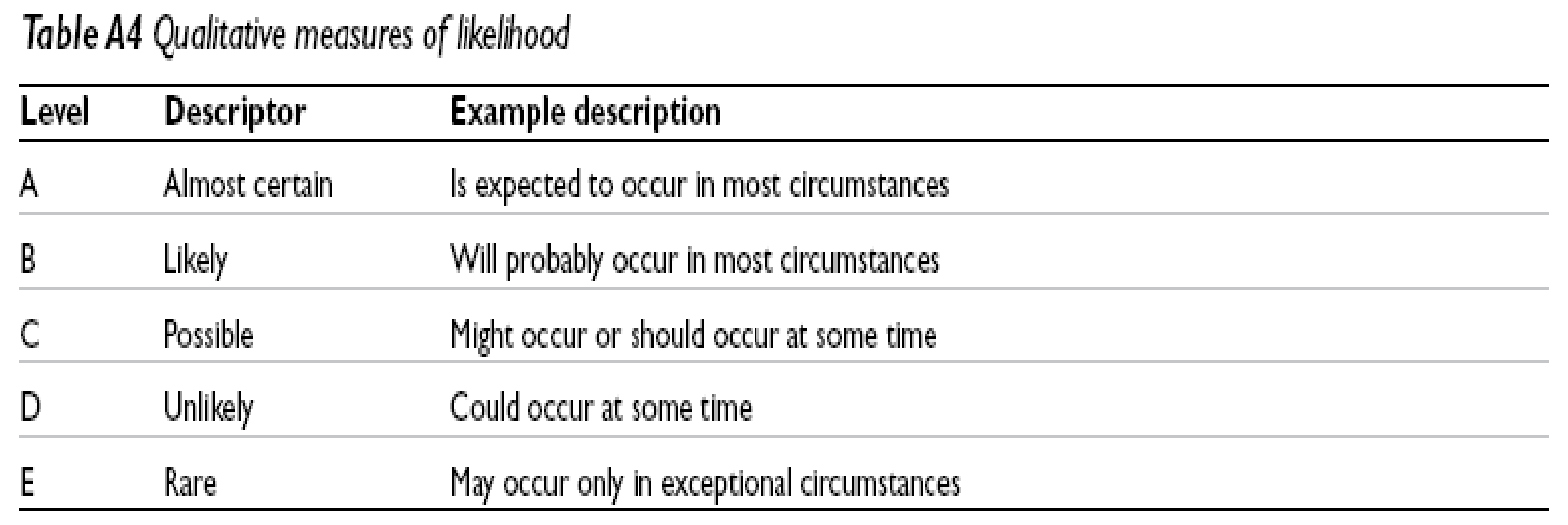


Table A4 Qualitative measures of likelihood

Level	Descriptor	Example description
A	Almost certain	Is expected to occur in most circumstances
B	Likely	Will probably occur in most circumstances
C	Possible	Might occur or should occur at some time
D	Unlikely	Could occur at some time
E	Rare	May occur only in exceptional circumstances

This is a “high risk” proposal impact

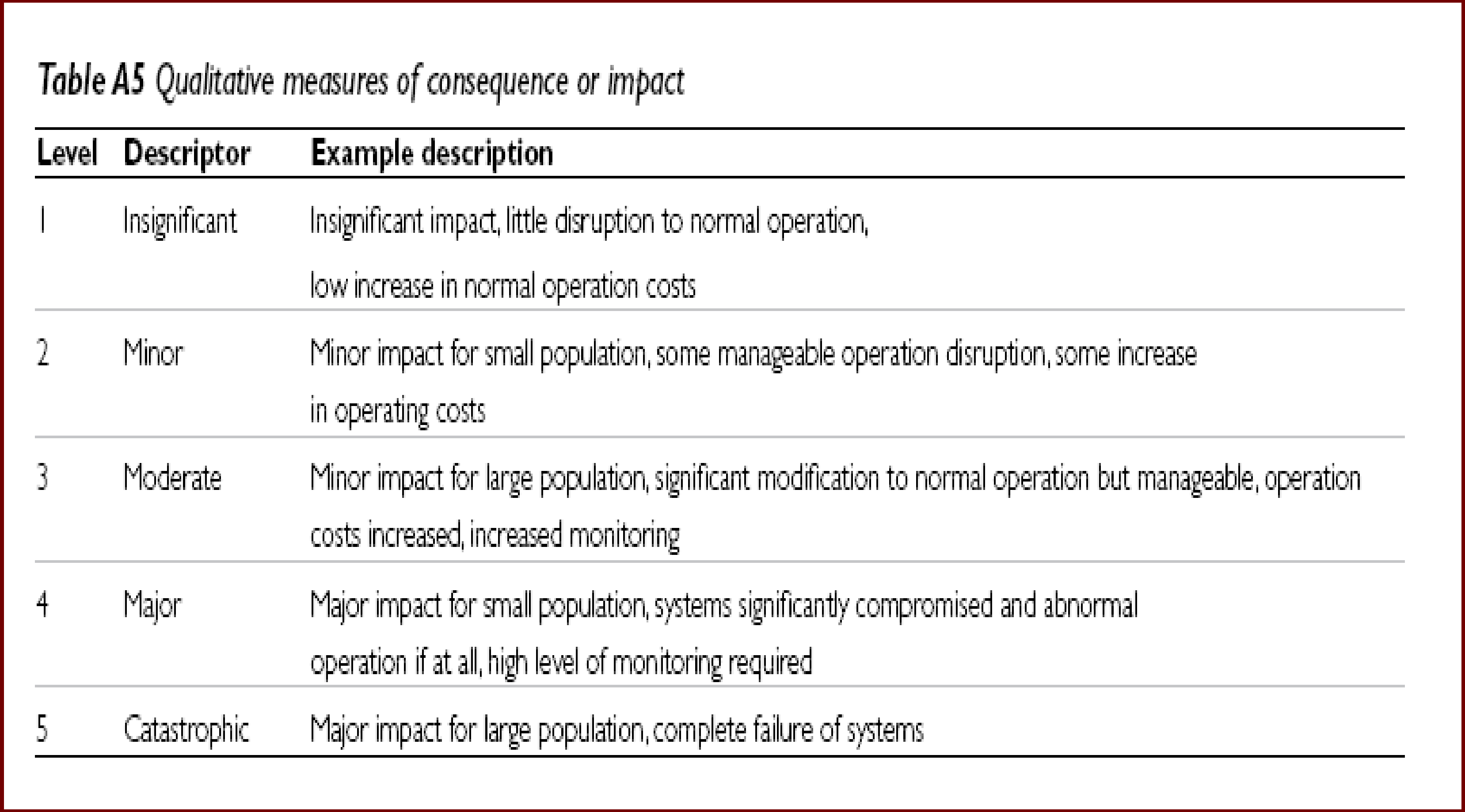


Table A5 Qualitative measures of consequence or impact

Level	Descriptor	Example description
1	Insignificant	Insignificant impact, little disruption to normal operation, low increase in normal operation costs
2	Minor	Minor impact for small population, some manageable operation disruption, some increase in operating costs
3	Moderate	Minor impact for large population, significant modification to normal operation but manageable, operation costs increased, increased monitoring
4	Major	Major impact for small population, systems significantly compromised and abnormal operation if at all, high level of monitoring required
5	Catastrophic	Major impact for large population, complete failure of systems

This is a “high risk” proposal

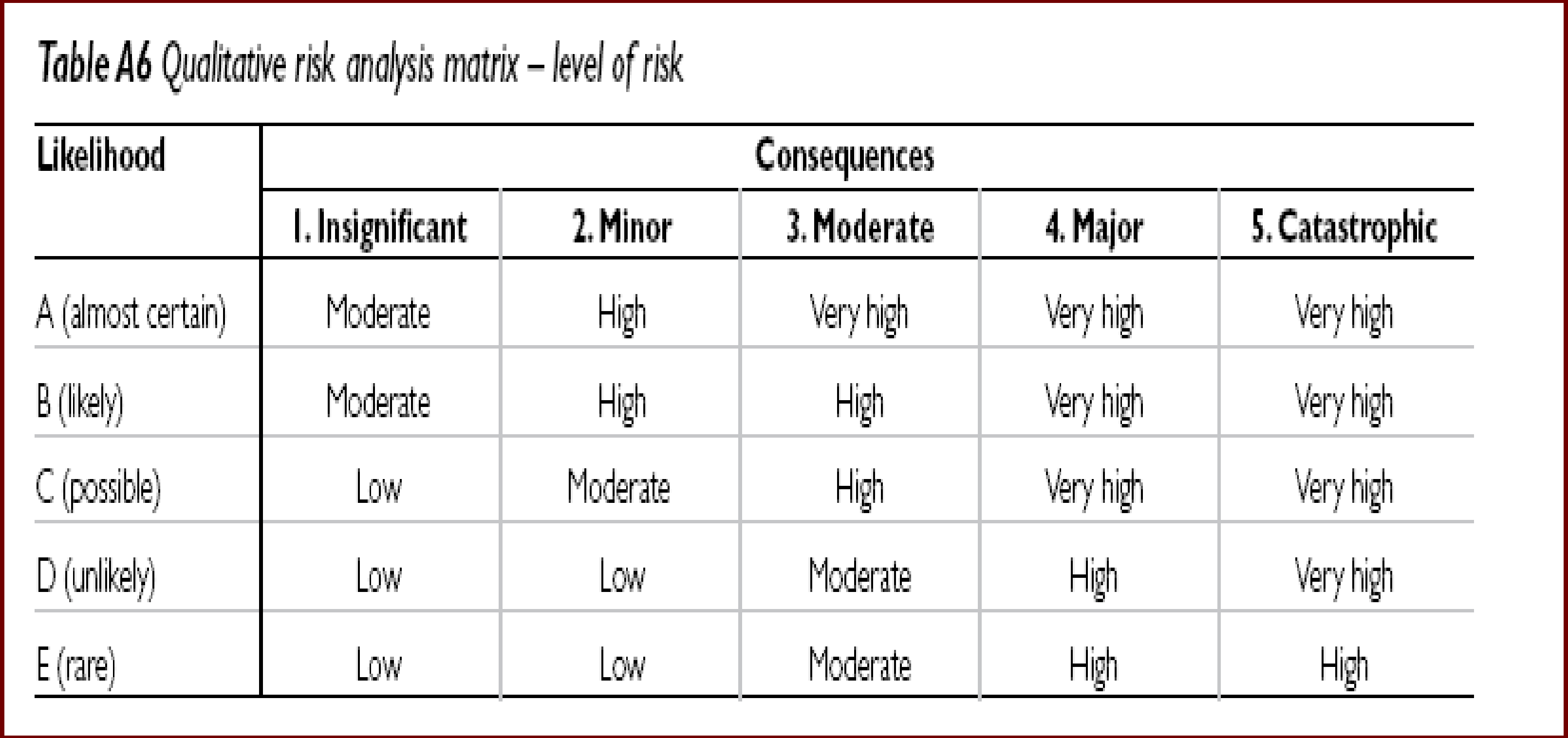
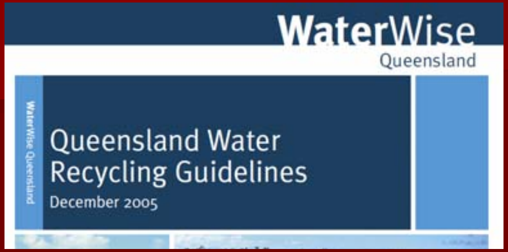


Table A6 Qualitative risk analysis matrix – level of risk

Likelihood	**Consequences**				
	1. Insignificant	**2. Minor**	**3. Moderate**	**4. Major**	**5. Catastrophic**
A (almost certain)	Moderate	High	Very high	Very high	Very high
B (likely)	Moderate	High	High	Very high	Very high
C (possible)	Low	Moderate	High	Very high	Very high
D (unlikely)	Low	Low	Moderate	High	Very high
E (rare)	Low	Low	Moderate	High	High

High Risk procedure



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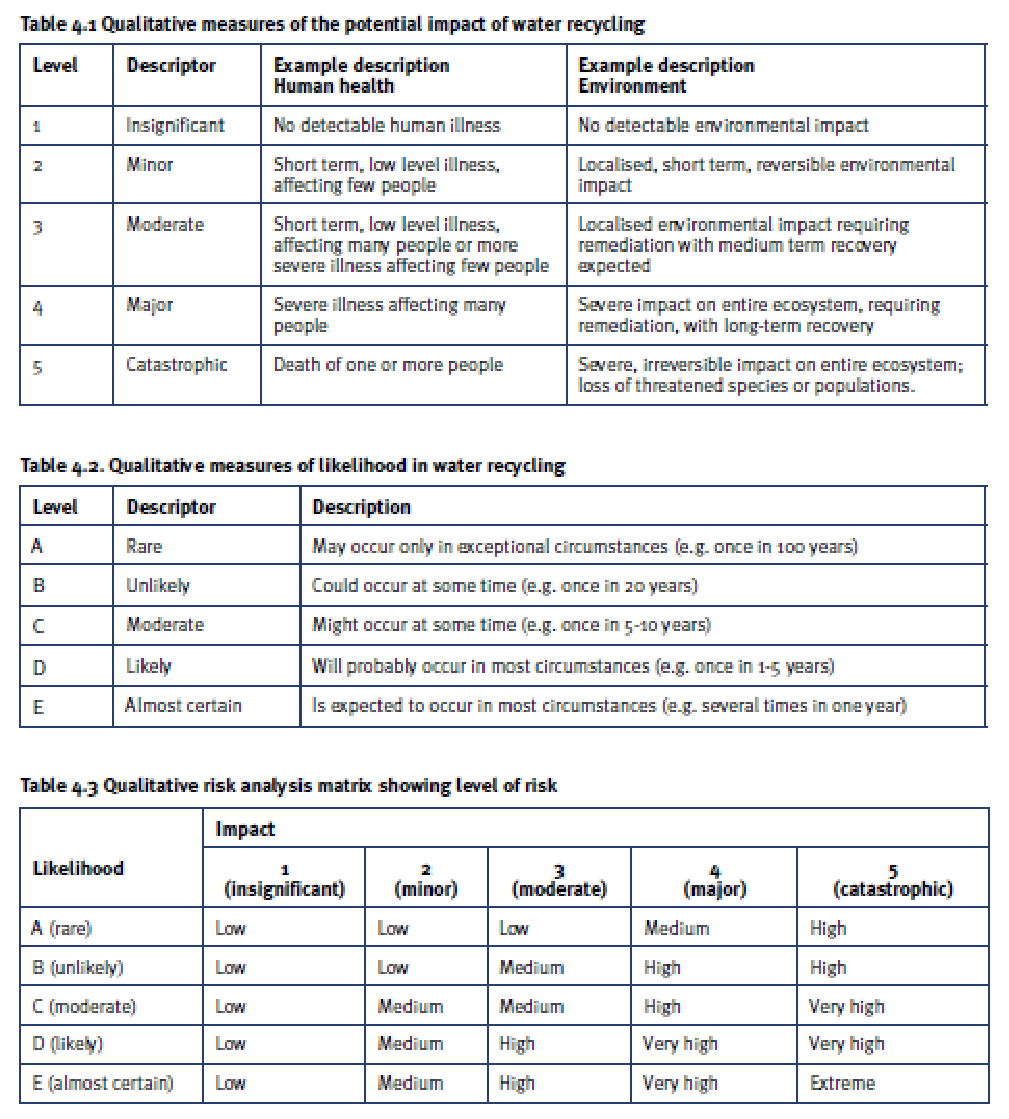


Table 4.1 Qualitative measures of the potential impact of water recycling

Level	Descriptor	Example description Human health	Example description Environment
1	Insignificant	No detectable human illness	No detectable environmental impact
2	Minor	Short term, low level illness, affecting few people	Localised, short term, reversible environmental impact
3	Moderate	Short term, low level illness, affecting many people or more severe illness affecting few people	Localised environmental impact requiring remediation with medium term recovery expected
4	Major	Severe illness affecting many people	Severe impact on entire ecosystem, requiring remediation, with long-term recovery
5	Catastrophic	Death of one or more people	Severe, irreversible impact on entire ecosystem; loss of threatened species or populations.

Table 4.2. Qualitative measures of likelihood in water recycling

Level	Descriptor	Description
A	Rare	May occur only in exceptional circumstances (e.g. once in 100 years)
B	Unlikely	Could occur at some time (e.g. once in 20 years)
C	Moderate	Might occur at some time (e.g. once in 5-10 years)
D	Likely	Will probably occur in most circumstances (e.g. once in 1-5 years)
E	Almost certain	Is expected to occur in most circumstances (e.g. several times in one year)

Table 4.3 Qualitative risk analysis matrix showing level of risk

Likelihood	Impact				
	1 (insignificant)	2 (minor)	3 (moderate)	4 (major)	5 (catastrophic)
A (rare)	Low	Low	Low	Medium	High
B (unlikely)	Low	Low	Medium	High	High
C (moderate)	Low	Medium	Medium	High	Very high
D (likely)	Low	Medium	High	Very high	Very high
E (almost certain)	Low	Medium	High	Very high	Extreme

No appropriate international epidemiology data to assess safety

- Doing this on faith
- Need at least log 9.5 reduction for viruses (Australian guidelines 2008)
    - 10 billion fold reduction
    - Extrapolated data being used to assess whether this is achieved

Everyone else drinks recycled sewage if downstream anyway

- Not by choice!
- Only 1 liter per year versus 700 liters if recycle into drinking water (log 3 increased risk)
- Usually Major and prolonged natural Safety barriers before ingested from rivers
- But lots of people get sick from water from rivers!

Pumping recycled water from sewage into drinking water is rarely done elsewhere in the world

- Singapore uses recycled water for industry not drinking
- USA. California little rain and long legislated retention times, major dilutions, variable percentages used.
- Windhoek – almost no rain and how can you do appropriate safety studies applicable to developed world

There are other safer uses for recycled water rather than using it as drinking water

- Use recycled water from sewage for industry
  - Singapore
  - Luggage point
  - Steel works in NSW

- Irrigation
  - After appropriate safety levels achieved

- What we save by this reuse means that there is that much less need for potable water to be taken from reservoirs

A needless risk for the population; we have enough water in Canberra

- Average year 800 GL available
  - 500 Gl in ACT
  - 300 Gl inflow via Murrumbidgee

- Usage low
  - 70 Gl no restrictions
  - 50 Gl levels 3

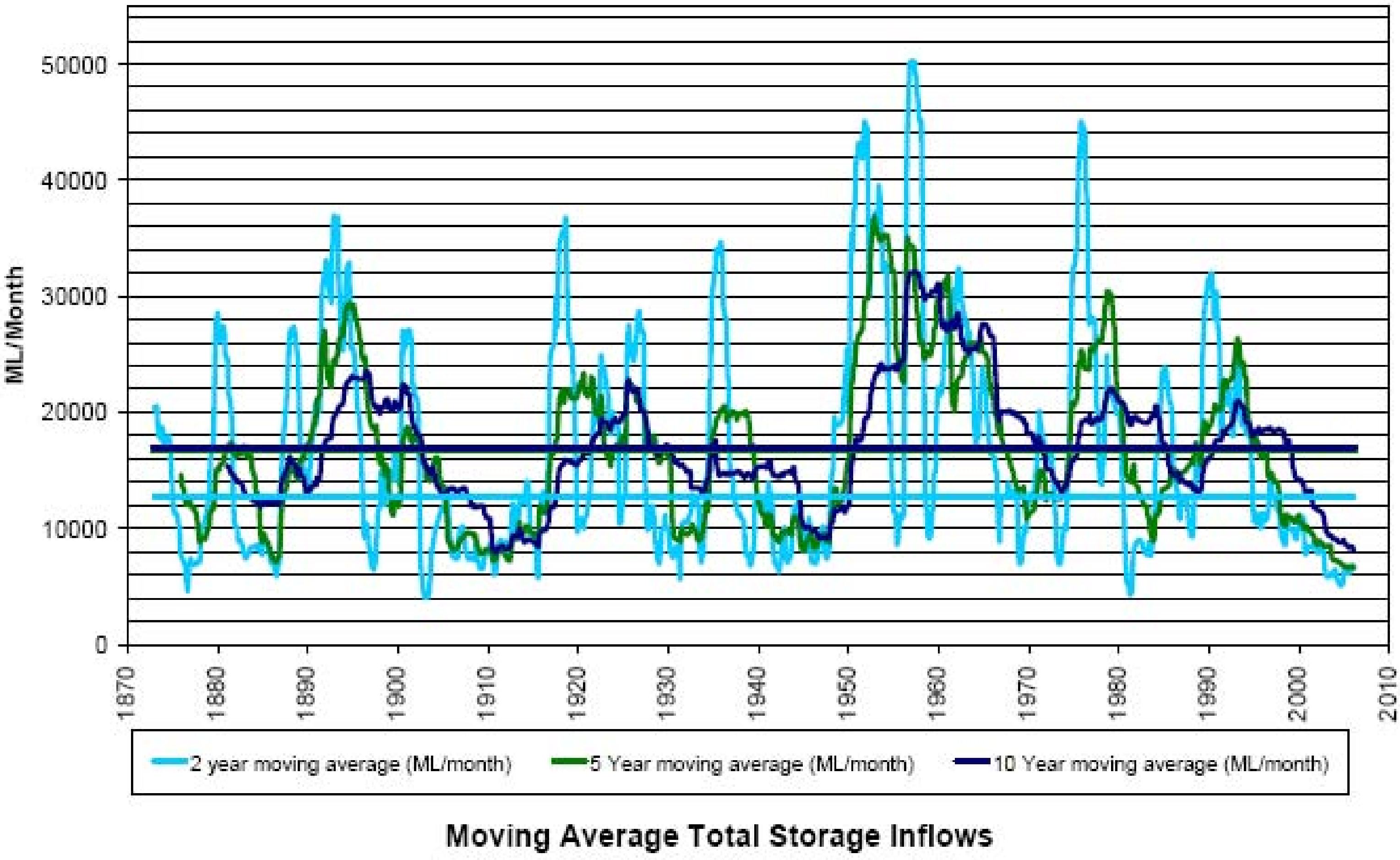
  - Of this 35 Gl is returned to rivers (ie only net 35/800 removed or 5%)
  - Downstream nearly all use is agriculture including 2,000 GL for rice farming
  - Recycle proposal is 9-18 GL per year

The claim is that Canberra is not going to be planning to recycle sewage into drinking water anymore

However Canberra is now getting a “salt reduction” plant instead!

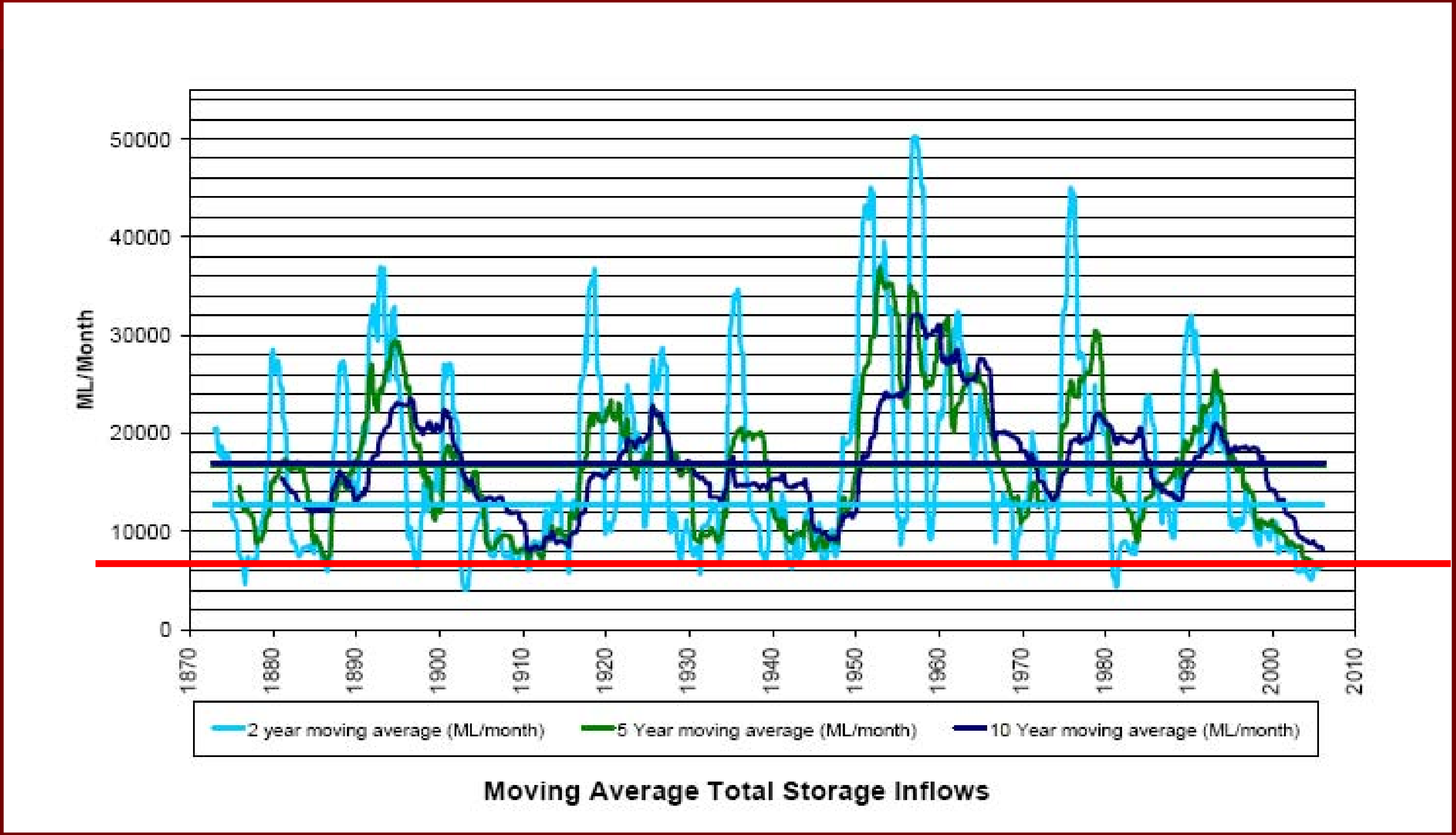
Same plant just different name

Moving Average monthly Inflows into Corin, Bendora and Googong Dams (Canberra reservoirs)



Moving Average Monthly Inflows to Corin, Bendora and Googong Dams

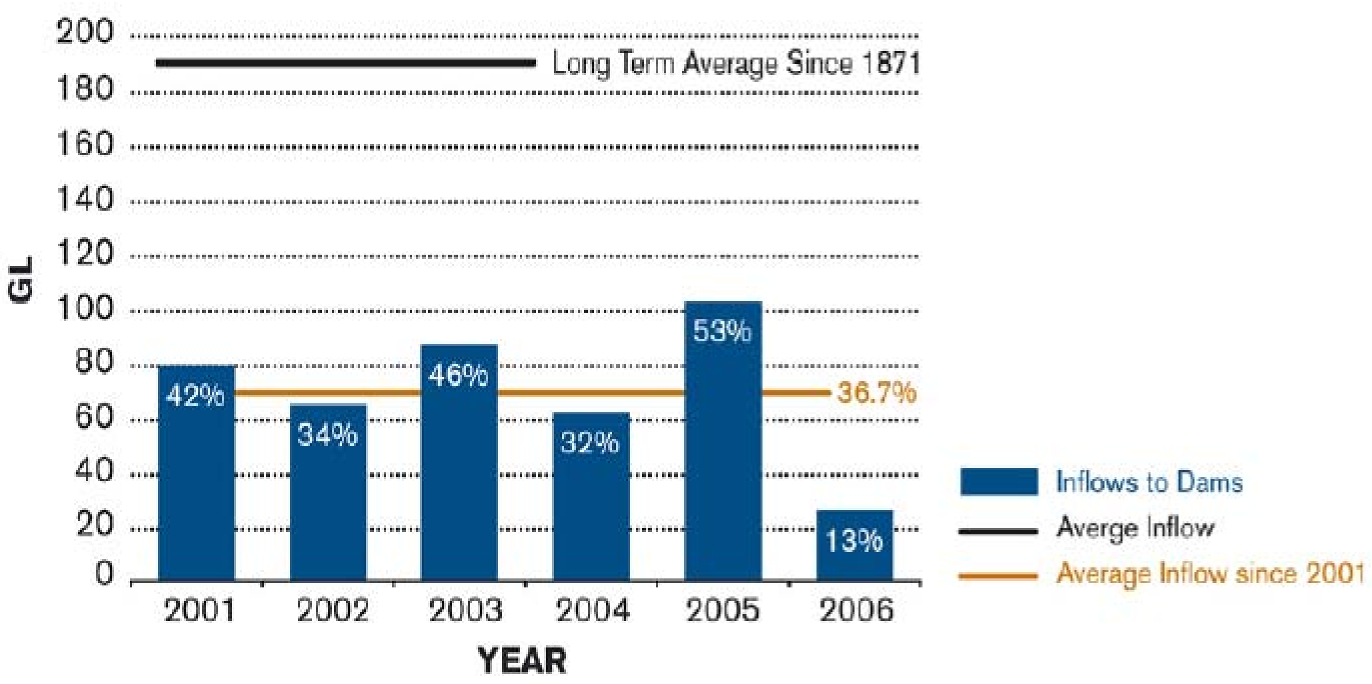
red line is min requirement for Canberra with water restrictions
50 GL/Yr or 4,000 ML per month



Moving Average Total Storage Inflows

Inflows to Corin, Bendora and Googong Dams (2001-2006)

ACTEW figures and graphs. Note this excludes Cotter dam which receives about 25% of Cotter catchment area rainfall



Inflows to Corin, Bendora and Googong Dams (2001-2006)

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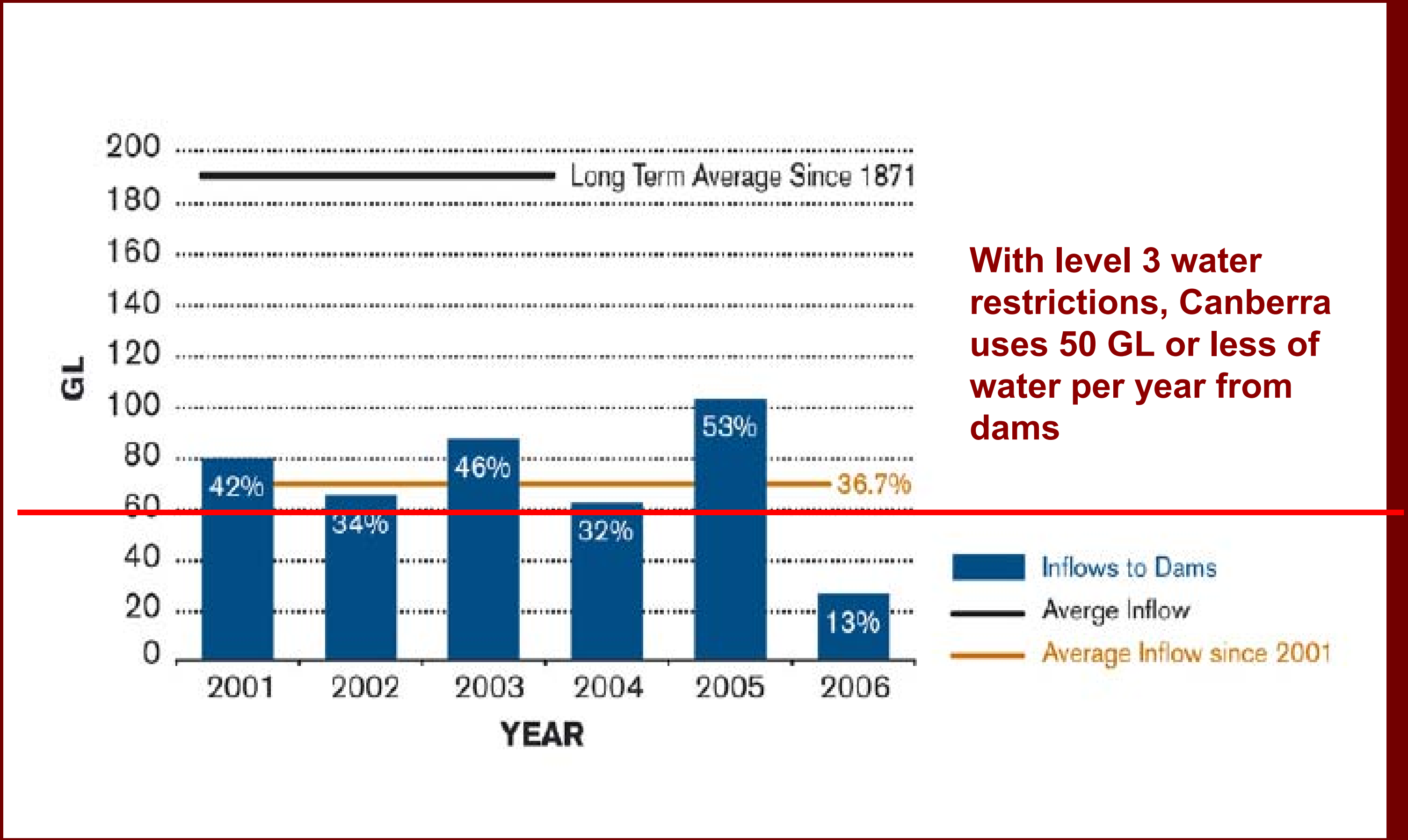

50 Gl

With level 3 water restrictions, Canberra uses 50 GL or less of water per year from dams

This is a very high energy proposal – it is not green or environmentally friendly

- Canberra proposal
  - Large increase in Greenhouse gas production per year
  - pumped over 13 km and uphill (260 m lift)
  - carbon neutral only if more than an additional 300,000 trees per year are planted.

Often may be really “Direct” recycling into our potable system

- Unless into a full and very large Dam
- But what about droughts when Dams empty?
- Natural barriers in droughts compromised
- What about temperature streaming and layering of water

What about industrial and chemical waste

Discharge pretreatment

(WHO document)

- When recharging aquifers for human consumption it is important to develop efficient pretreatment programs for industrial discharges into the sewerage, so that effluents have relatively “controlled” characteristics. Although this is not part of recharge legislation, it is definitely an essential component. The presence of industrial discharges into the sewer system is a concern, because they carry compounds that are hard to determine and remove, and that have unpredictable and even unknown effects, so they must be segregated from the water before infiltration. Because there is reuse of treated wastewater for human consumption, regardless of whether it is intentional or unintentional, the discharge of toxic compounds must be regulated so that only domestic water is used.

- http://www.who.int/water_sanitation_health/wastewater/wsh0308/en/index.html

Procedures for testing micro-organisms are inadequate

Viruses are Major concern

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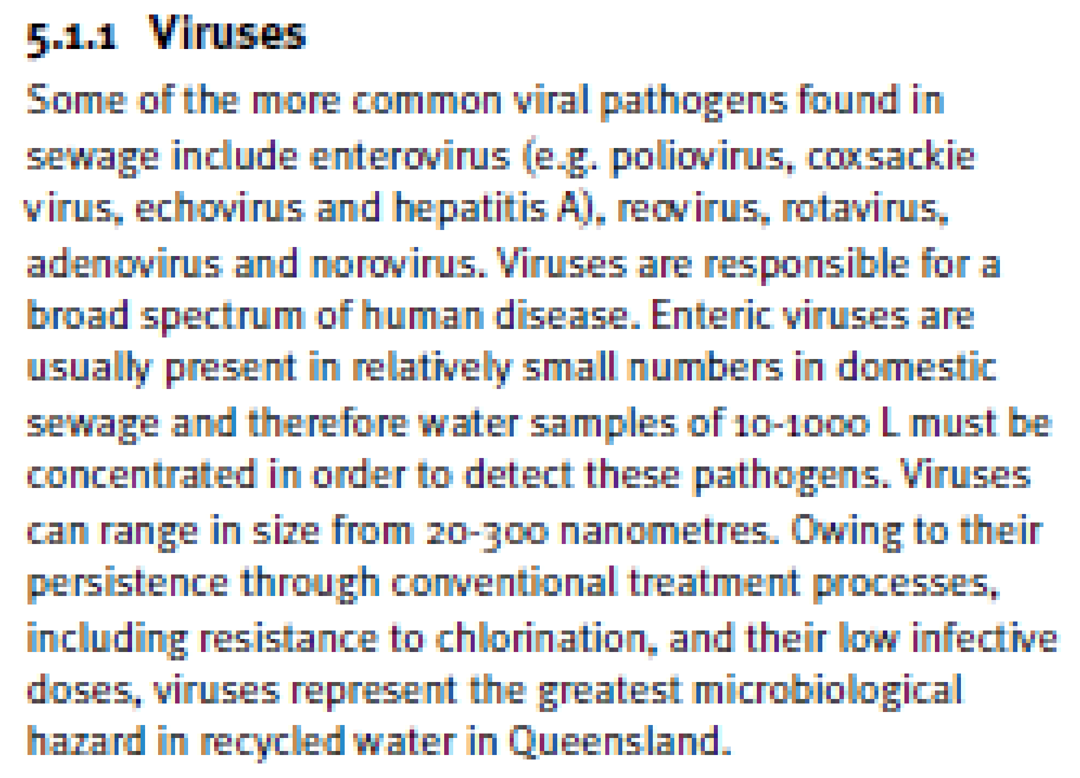
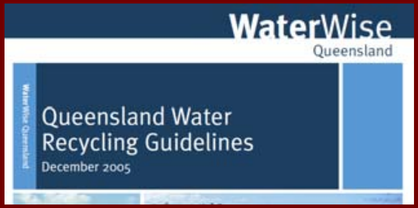


5.1.1 Viruses

Some of the more common viral pathogens found in sewage include enterovirus (e.g. poliovirus, coxsackie virus, echovirus and hepatitis A), reovirus, rotavirus, adenovirus and norovirus. Viruses are responsible for a broad spectrum of human disease. Enteric viruses are usually present in relatively small numbers in domestic sewage and therefore water samples of 10-1000 L must be concentrated in order to detect these pathogens. Viruses can range in size from 20-300 nanometres. Owing to their persistence through conventional treatment processes, including resistance to chlorination, and their low infective doses, viruses represent the greatest microbiological hazard in recycled water in Queensland.

Microbiological indicators

Need many more than standard E.coli



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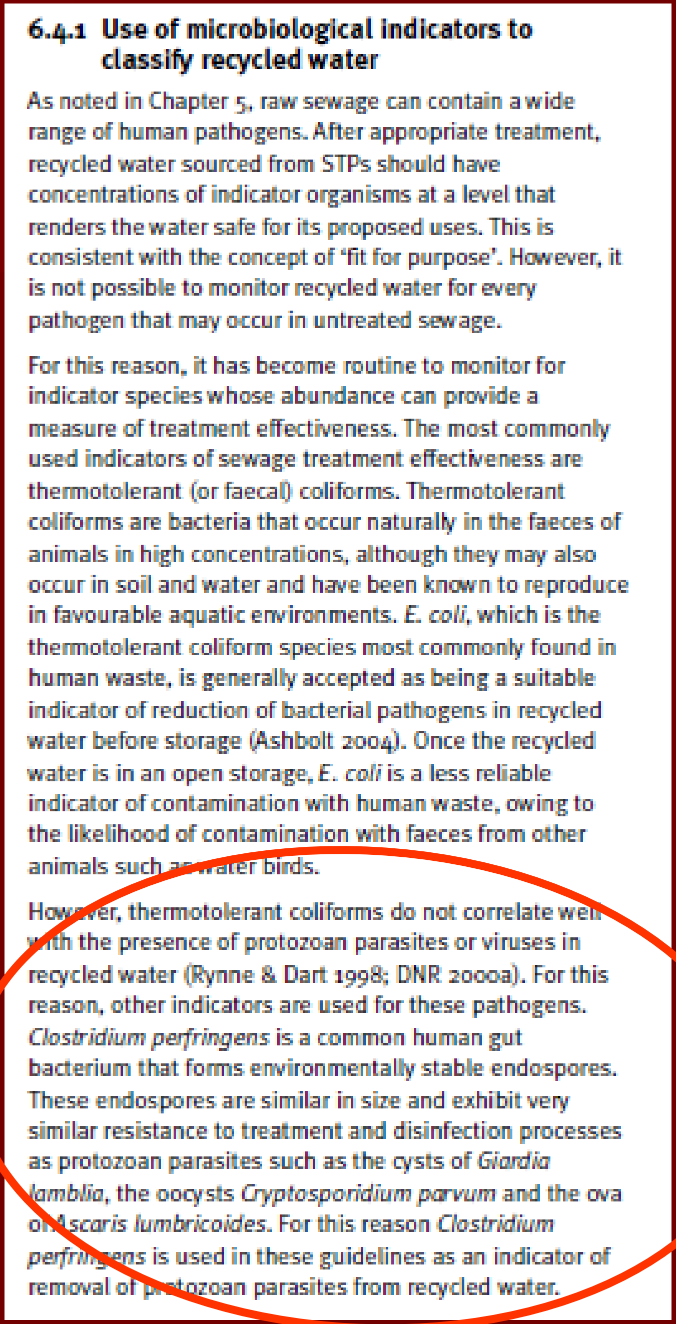


6.4.1 Use of microbiological indicators to classify recycled water

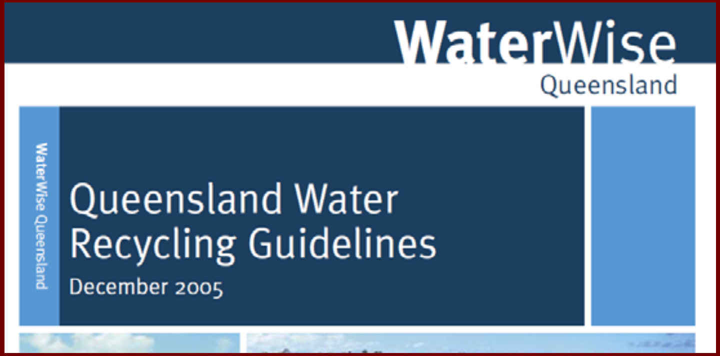
As noted in Chapter 5, raw sewage can contain a wide range of human pathogens. After appropriate treatment, recycled water sourced from STPs should have concentrations of indicator organisms at a level that renders the water safe for its proposed uses. This is consistent with the concept of 'fit for purpose'. However, it is not possible to monitor recycled water for every pathogen that may occur in untreated sewage.

For this reason, it has become routine to monitor for indicator species whose abundance can provide a measure of treatment effectiveness. The most commonly used indicators of sewage treatment effectiveness are thermotolerant (or faecal) coliforms. Thermotolerant coliforms are bacteria that occur naturally in the faeces of animals in high concentrations, although they may also occur in soil and water and have been known to reproduce in favourable aquatic environments. *E. coli*, which is the thermotolerant coliform species most commonly found in human waste, is generally accepted as being a suitable indicator of reduction of bacterial pathogens in recycled water before storage (Ashbolt 2004). Once the recycled water is in an open storage, *E. coli* is a less reliable indicator of contamination with human waste, owing to the likelihood of contamination with faeces from other animals such as water birds.

However, thermotolerant coliforms do not correlate well with the presence of protozoan parasites or viruses in recycled water (Rynne & Dart 1998; DNR 2000a). For this reason, other indicators are used for these pathogens. *Clostridium perfringens* is a common human gut bacterium that forms environmentally stable endospores. These endospores are similar in size and exhibit very similar resistance to treatment and disinfection processes as protozoan parasites such as the cysts of *Giardia lamblia*, the oocysts *Cryptosporidium parvum* and the ova of *Ascaris lumbricoides*. For this reason *Clostridium perfringens* is used in these guidelines as an indicator of removal of protozoan parasites from recycled water.

Microbiological indicators

Need viral testing



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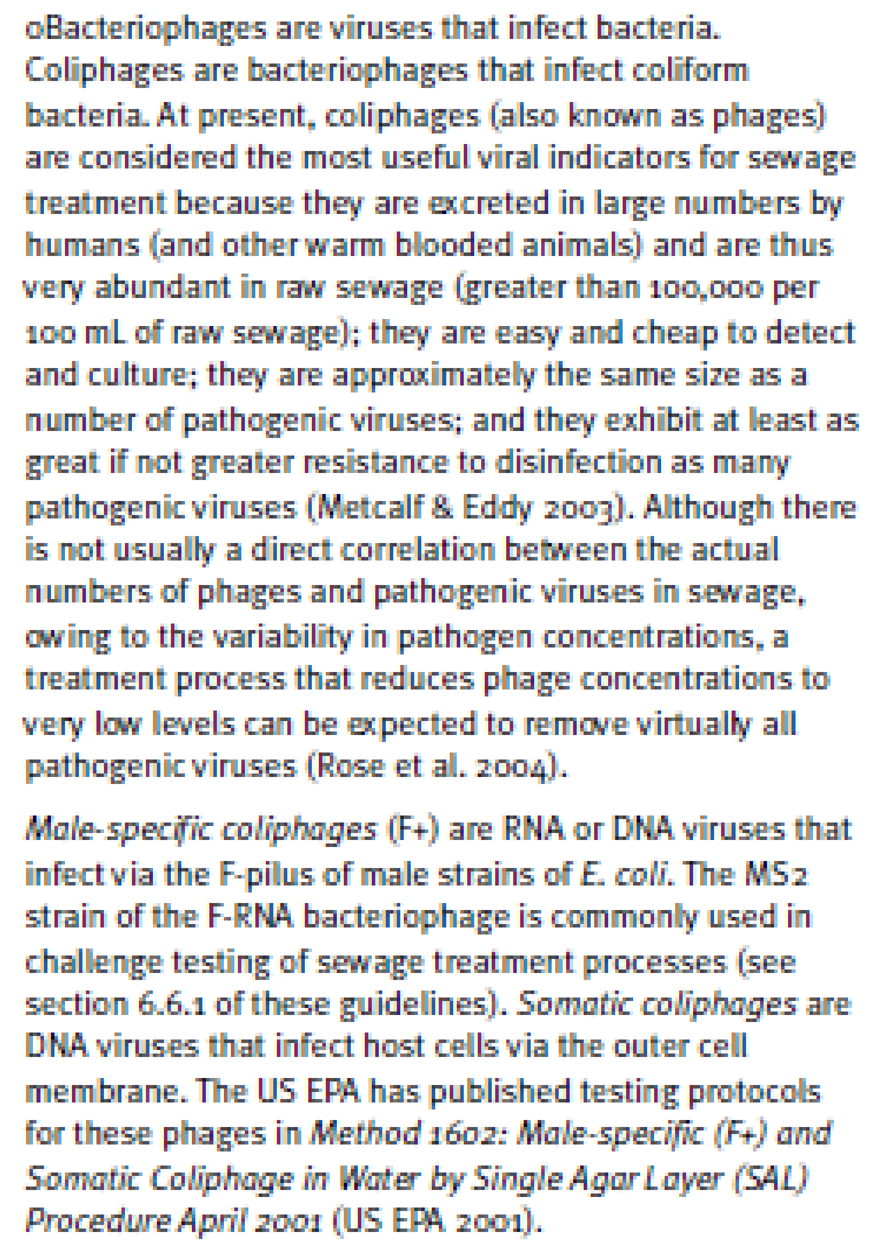
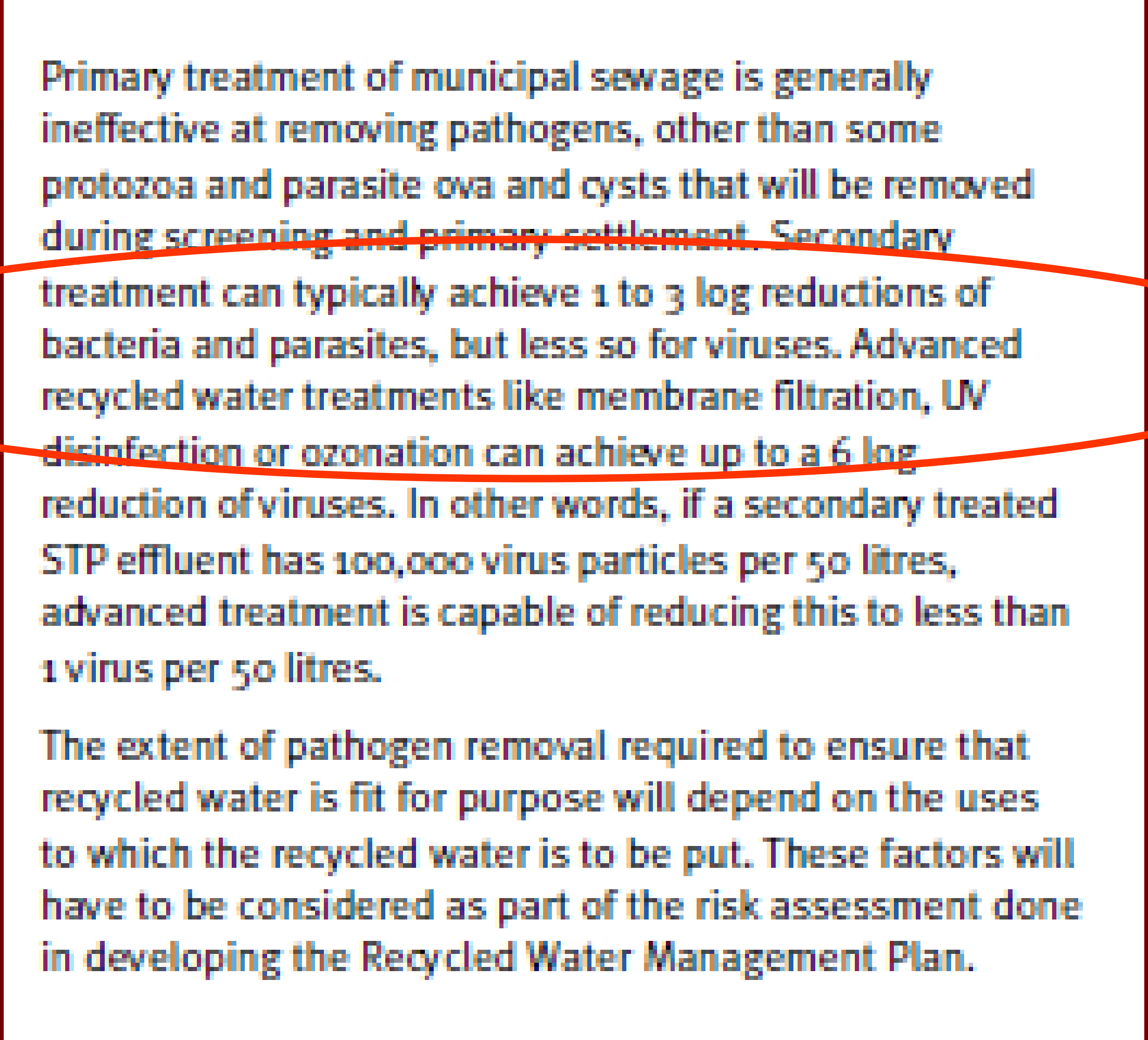


oBacteriophages are viruses that infect bacteria. Coliphages are bacteriophages that infect coliform bacteria. At present, coliphages (also known as phages) are considered the most useful viral indicators for sewage treatment because they are excreted in large numbers by humans (and other warm blooded animals) and are thus very abundant in raw sewage (greater than 100,000 per 100 mL of raw sewage); they are easy and cheap to detect and culture; they are approximately the same size as a number of pathogenic viruses; and they exhibit at least as great if not greater resistance to disinfection as many pathogenic viruses (Metcalf & Eddy 2003). Although there is not usually a direct correlation between the actual numbers of phages and pathogenic viruses in sewage, owing to the variability in pathogen concentrations, a treatment process that reduces phage concentrations to very low levels can be expected to remove virtually all pathogenic viruses (Rose et al. 2004).

Male-specific coliphages (F+) are RNA or DNA viruses that infect via the F-pilus of male strains of *E. coli*. The MS2 strain of the F-RNA bacteriophage is commonly used in challenge testing of sewage treatment processes (see section 6.6.1 of these guidelines). *Somatic coliphages* are DNA viruses that infect host cells via the outer cell membrane. The US EPA has published testing protocols for these phages in *Method 1602: Male-specific (F+) and Somatic Coliphage in Water by Single Agar Layer (SAL) Procedure April 2001* (US EPA 2001).

Viruses need to be removed by RO



Primary treatment of municipal sewage is generally ineffective at removing pathogens, other than some protozoa and parasite ova and cysts that will be removed during screening and primary settlement. Secondary treatment can typically achieve 1 to 3 log reductions of bacteria and parasites, but less so for viruses. Advanced recycled water treatments like membrane filtration, UV disinfection or ozonation can achieve up to a 6 log reduction of viruses. In other words, if a secondary treated STP effluent has 100,000 virus particles per 50 litres, advanced treatment is capable of reducing this to less than 1 virus per 50 litres.

The extent of pathogen removal required to ensure that recycled water is fit for purpose will depend on the uses to which the recycled water is to be put. These factors will have to be considered as part of the risk assessment done in developing the Recycled Water Management Plan.

How good are processes at removing viruses?

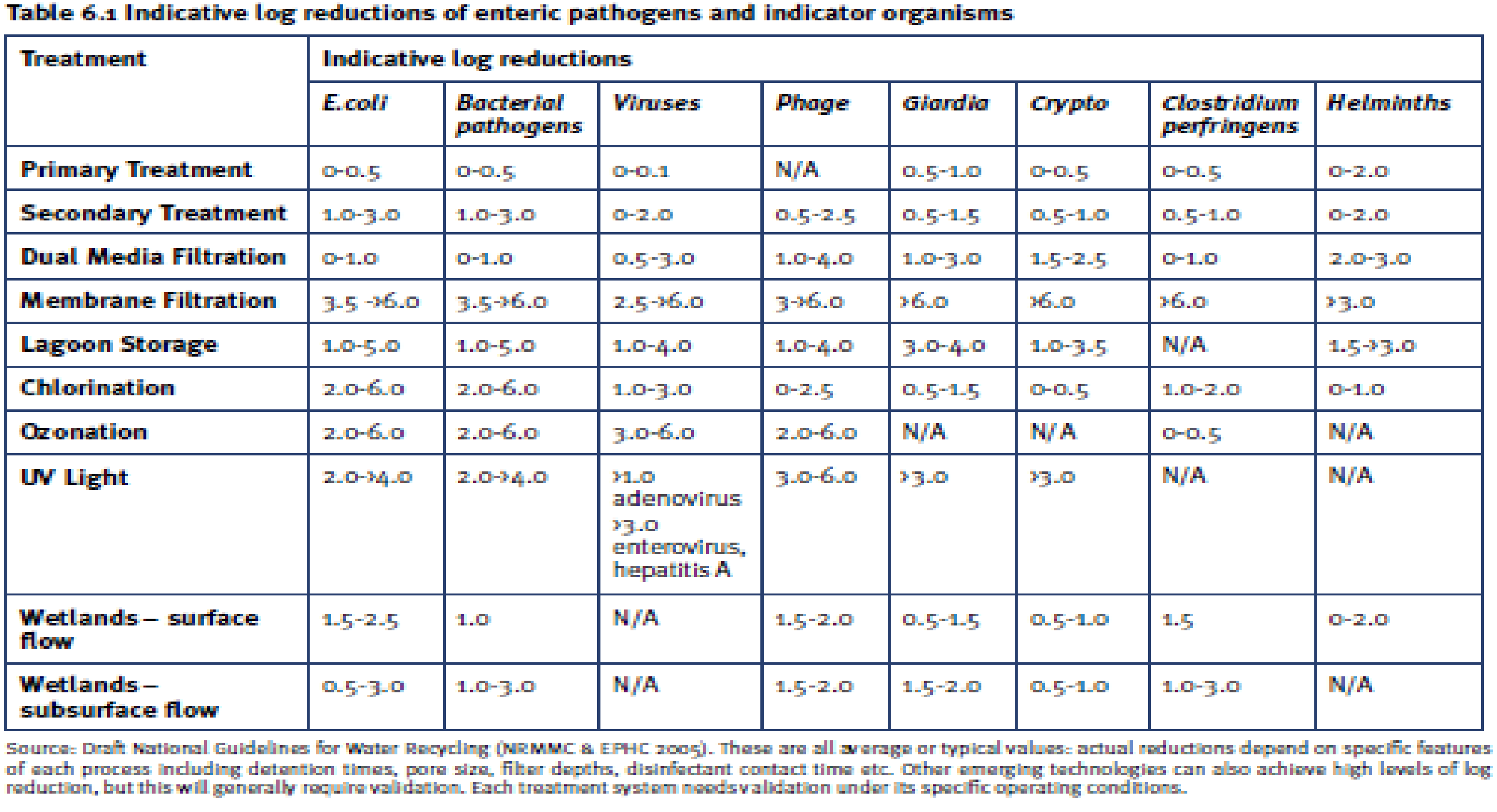


Table 6.1 Indicative log reductions of enteric pathogens and indicator organisms

Treatment	Indicative log reductions							
	E.coli	*Bacterial pathogens*	*Viruses*	*Phage*	*Giardia*	*Crypto*	*Clostridium perfringens*	*Helminths*
Primary Treatment	0-0.5	0-0.5	0-0.1	N/A	0.5-1.0	0-0.5	0-0.5	0-2.0
Secondary Treatment	1.0-3.0	1.0-3.0	0-2.0	0.5-2.5	0.5-1.5	0.5-1.0	0.5-1.0	0-2.0
Dual Media Filtration	0-1.0	0-1.0	0.5-3.0	1.0-4.0	1.0-3.0	1.5-2.5	0-1.0	2.0-3.0
Membrane Filtration	3.5 ->6.0	3.5->6.0	2.5->6.0	3->6.0	>6.0	>6.0	>6.0	>3.0
Lagoon Storage	1.0-5.0	1.0-5.0	1.0-4.0	1.0-4.0	3.0-4.0	1.0-3.5	N/A	1.5->3.0
Chlorination	2.0-6.0	2.0-6.0	1.0-3.0	0-2.5	0.5-1.5	0-0.5	1.0-2.0	0-1.0
Ozonation	2.0-6.0	2.0-6.0	3.0-6.0	2.0-6.0	N/A	N/A	0-0.5	N/A
UV Light	2.0->4.0	2.0->4.0	>1.0 adenovirus >3.0 enterovirus, hepatitis A	3.0-6.0	>3.0	>3.0	N/A	N/A
Wetlands – surface flow	1.5-2.5	1.0	N/A	1.5-2.0	0.5-1.5	0.5-1.0	1.5	0-2.0
Wetlands – subsurface flow	0.5-3.0	1.0-3.0	N/A	1.5-2.0	1.5-2.0	0.5-1.0	1.0-3.0	N/A

Source: Draft National Guidelines for Water Recycling (NRMMC & EPHC 2005). These are all average or typical values: actual reductions depend on specific features of each process including detention times, pore size, filter depths, disinfectant contact time etc. Other emerging technologies can also achieve high levels of log reduction, but this will generally require validation. Each treatment system needs validation under its specific operating conditions.

N/A = not available.

WaterWise
Queensland

Queensland Water Recycling Guidelines
December 2005

Queensland was not going to use recycled water from sewage for drinking water

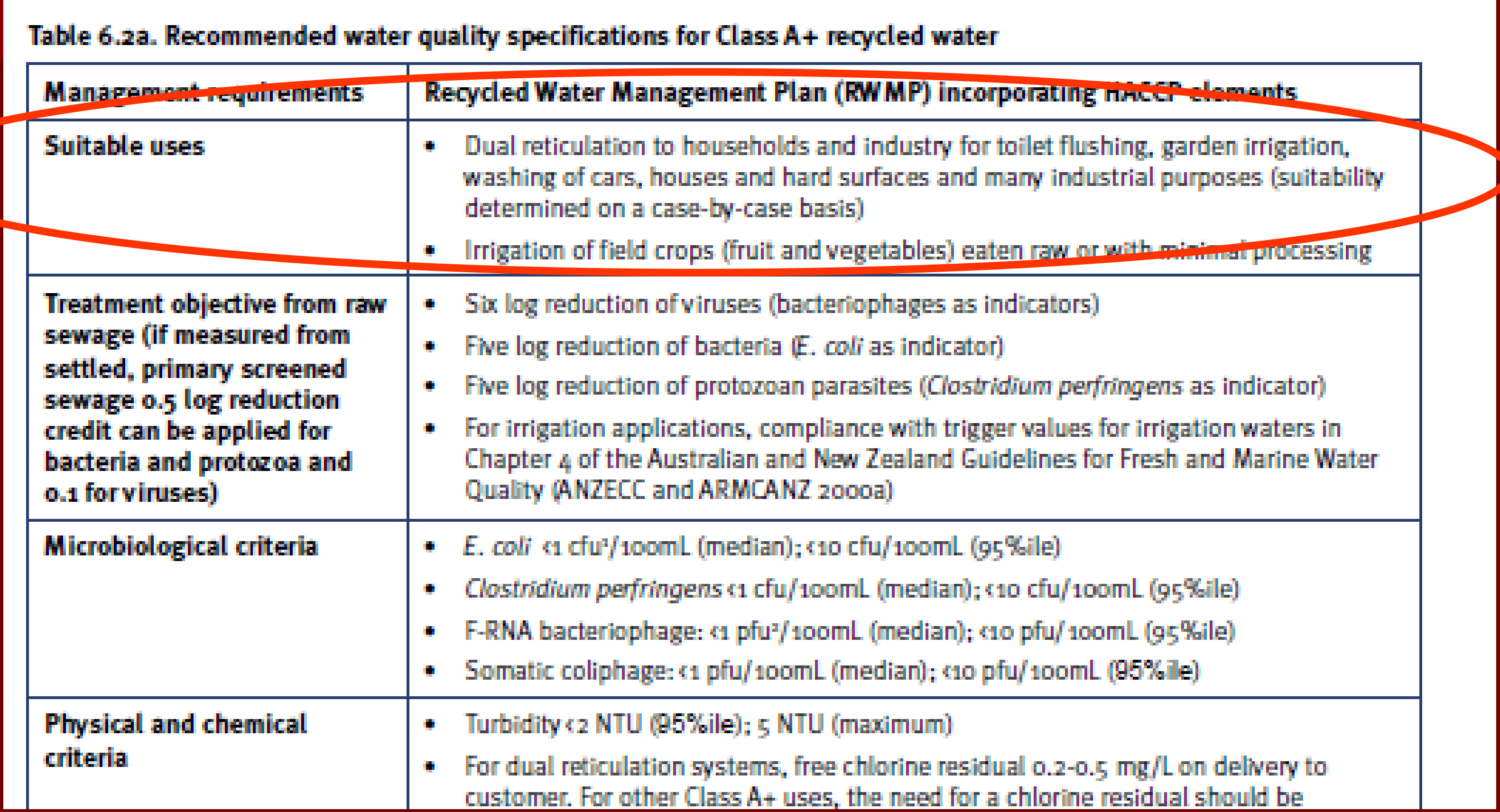


Table 6.2a. Recommended water quality specifications for Class A+ recycled water

Management requirements	Recycled Water Management Plan (RWMP) incorporating HACCP elements
Suitable uses	- Dual reticulation to households and industry for toilet flushing, garden irrigation, washing of cars, houses and hard surfaces and many industrial purposes (suitability determined on a case-by-case basis) - Irrigation of field crops (fruit and vegetables) eaten raw or with minimal processing
Treatment objective from raw sewage (if measured from settled, primary screened sewage 0.5 log reduction credit can be applied for bacteria and protozoa and 0.1 for viruses)	- Six log reduction of viruses (bacteriophages as indicators) - Five log reduction of bacteria (*E. coli* as indicator) - Five log reduction of protozoan parasites (*Clostridium perfringens* as indicator) - For irrigation applications, compliance with trigger values for irrigation waters in Chapter 4 of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000a)
Microbiological criteria	- *E. coli* <1 cfu^1/100mL (median); <10 cfu/100mL (95%ile) - *Clostridium perfringens* <1 cfu/100mL (median); <10 cfu/100mL (95%ile) - F-RNA bacteriophage: <1 pfu^2/100mL (median); <10 pfu/100mL (95%ile) - Somatic coliphage: <1 pfu/100mL (median); <10 pfu/100mL (95%ile)
Physical and chemical criteria	- Turbidity <2 NTU (95%ile); 5 NTU (maximum) - For dual reticulation systems, free chlorine residual 0.2-0.5 mg/L on delivery to customer. For other Class A+ uses, the need for a chlorine residual should be

WaterWise
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Queensland Water Recycling Guidelines
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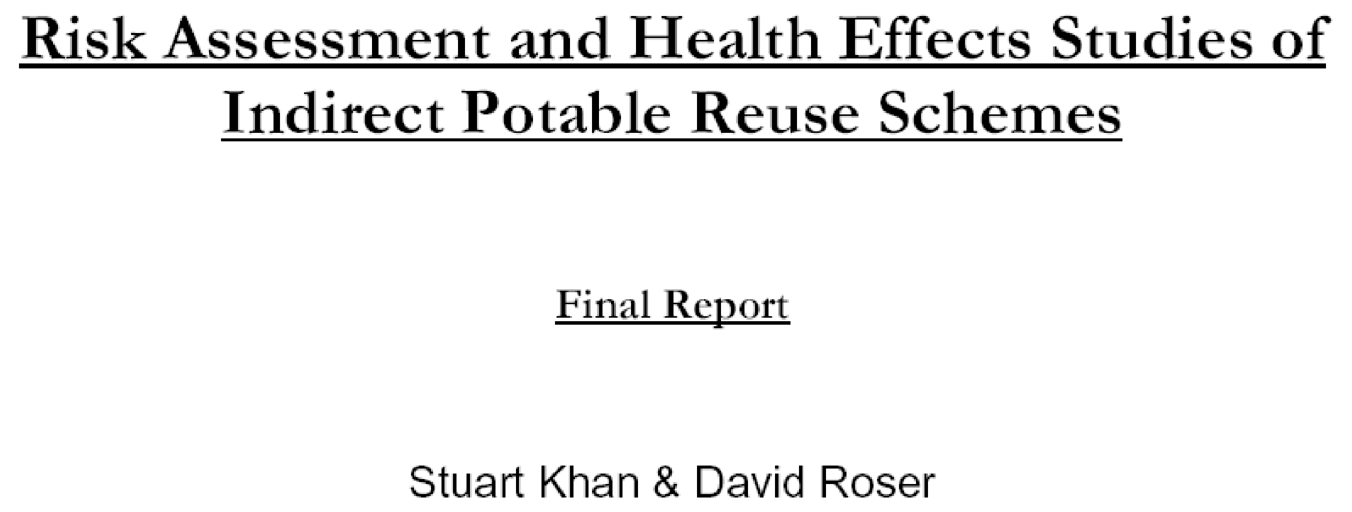
Australian safety reports



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Final Report

Stuart Khan & David Roser

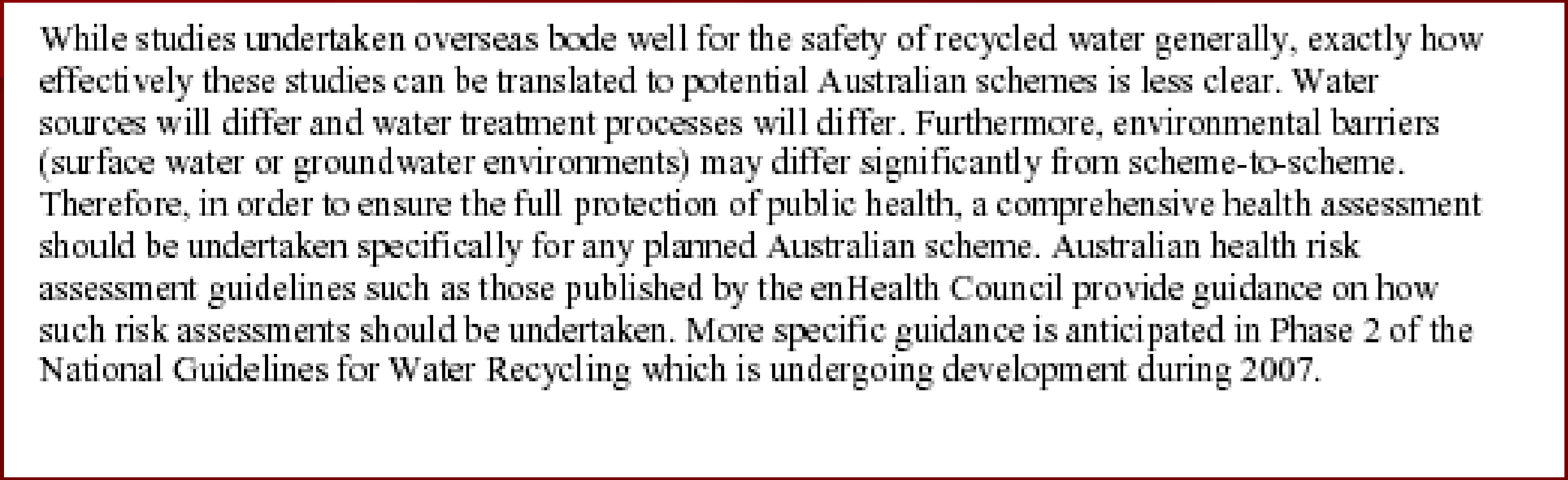
UNSW
THE UNIVERSITY OF NEW SOUTH WALES

CENTRE FOR WATER AND WASTE TECHNOLOGY
School of Civil and Environmental Engineering

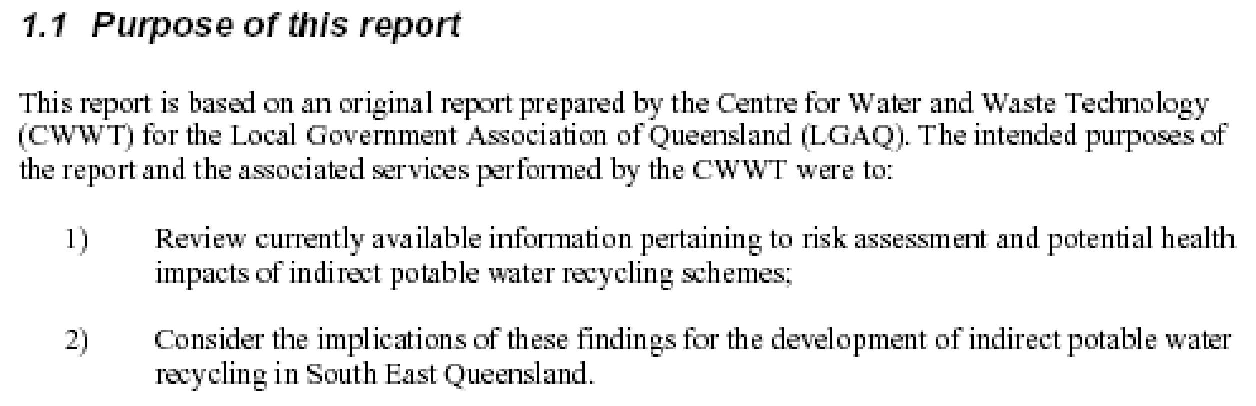
Centre for Water and Waste Technology
School of Civil and Environmental Engineering
University of New South Wales
NSW, 2052, Australia.

CWWT Report 2007/08
18 April 2007

Concludes overall likely “safe”



While studies undertaken overseas bode well for the safety of recycled water generally, exactly how effectively these studies can be translated to potential Australian schemes is less clear. Water sources will differ and water treatment processes will differ. Furthermore, environmental barriers (surface water or groundwater environments) may differ significantly from scheme-to-scheme. Therefore, in order to ensure the full protection of public health, a comprehensive health assessment should be undertaken specifically for any planned Australian scheme. Australian health risk assessment guidelines such as those published by the enHealth Council provide guidance on how such risk assessments should be undertaken. More specific guidance is anticipated in Phase 2 of the National Guidelines for Water Recycling which is undergoing development during 2007.



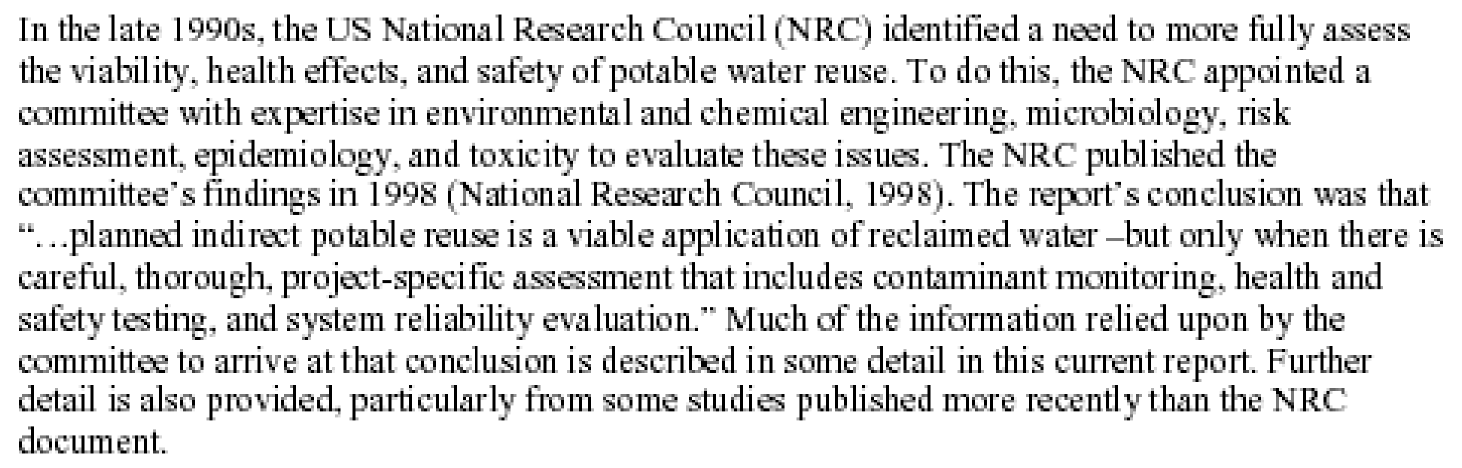
1.1 Purpose of this report

This report is based on an original report prepared by the Centre for Water and Waste Technology (CWWT) for the Local Government Association of Queensland (LGAQ). The intended purposes of the report and the associated services performed by the CWWT were to:

1) Review currently available information pertaining to risk assessment and potential health impacts of indirect potable water recycling schemes;

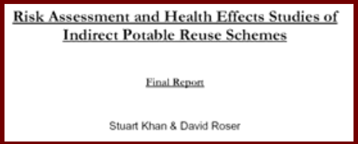
2) Consider the implications of these findings for the development of indirect potable water recycling in South East Queensland.

Mostly taken from NRC report



In the late 1990s, the US National Research Council (NRC) identified a need to more fully assess the viability, health effects, and safety of potable water reuse. To do this, the NRC appointed a committee with expertise in environmental and chemical engineering, microbiology, risk assessment, epidemiology, and toxicity to evaluate these issues. The NRC published the committee's findings in 1998 (National Research Council, 1998). The report's conclusion was that "…planned indirect potable reuse is a viable application of reclaimed water –but only when there is careful, thorough, project-specific assessment that includes contaminant monitoring, health and safety testing, and system reliability evaluation." Much of the information relied upon by the committee to arrive at that conclusion is described in some detail in this current report. Further detail is also provided, particularly from some studies published more recently than the NRC document.

- Bit a bit selective - left out "last resort" caveat from UNSW report!



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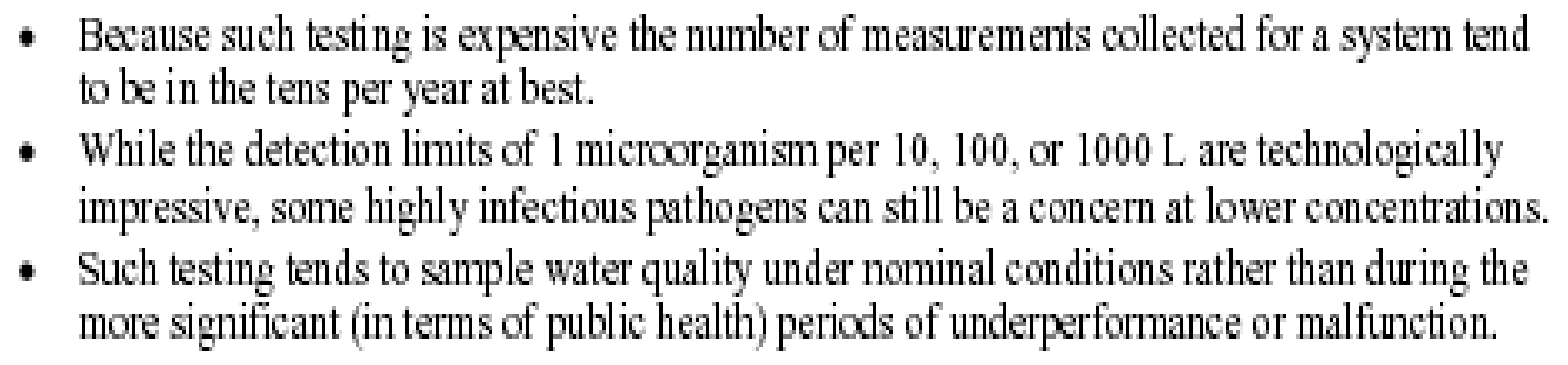
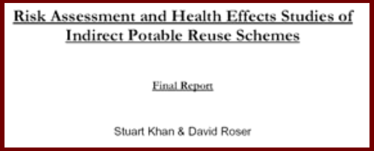
Evaluation for pathogens



- Because such testing is expensive the number of measurements collected for a system tend to be in the tens per year at best.
- While the detection limits of 1 microorganism per 10, 100, or 1000 L are technologically impressive, some highly infectious pathogens can still be a concern at lower concentrations.
- Such testing tends to sample water quality under nominal conditions rather than during the more significant (in terms of public health) periods of underperformance or malfunction.



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Often still positive viral testing results after going through a system that includes RO

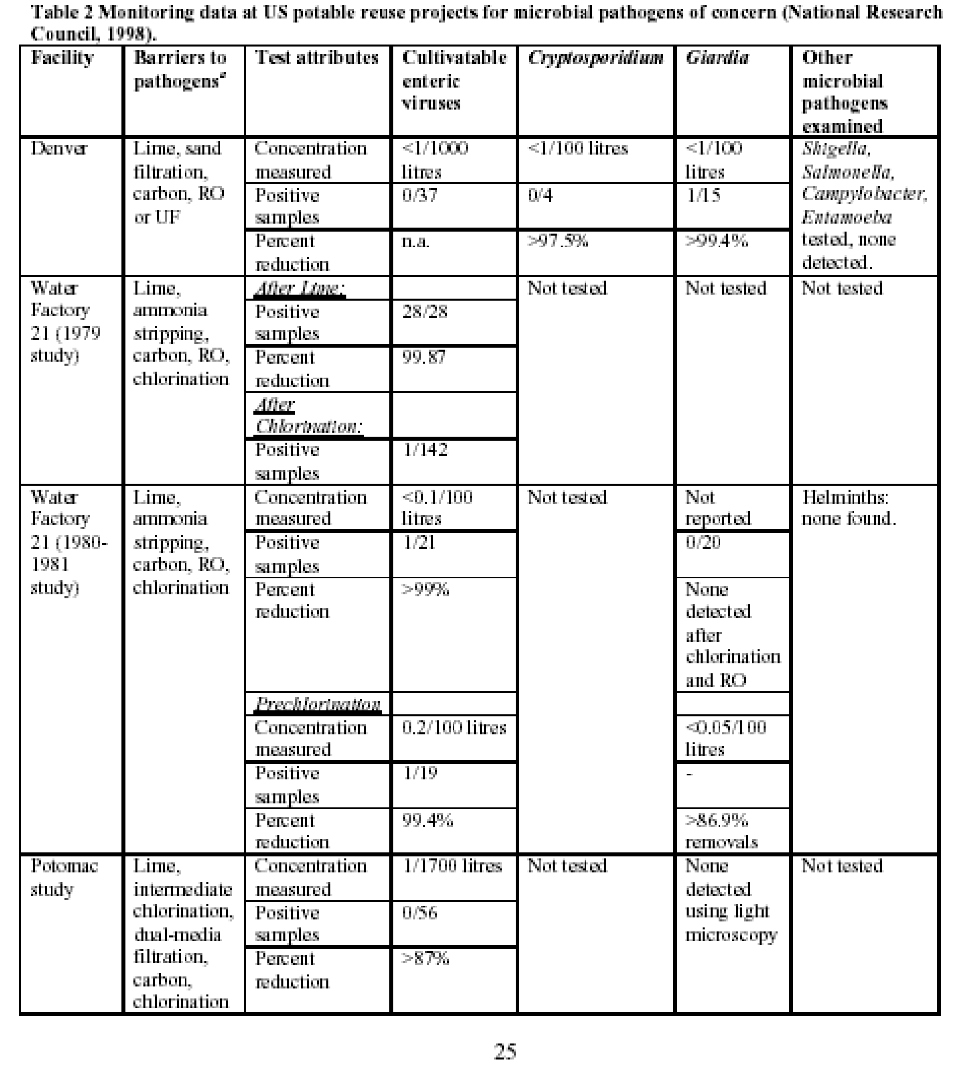

Table 2 Monitoring data at US potable reuse projects for microbial pathogens of concern (National Research Council, 1998).

Facility	**Barriers to pathogens**[a]	**Test attributes**	**Cultivatable enteric viruses**	***Cryptosporidium***	***Giardia***	**Other microbial pathogens examined**
Denver	Lime, sand filtration, carbon, RO or UF	Concentration measured	<1/1000 litres	<1/100 litres	<1/100 litres	*Shigella*, *Salmonella*, *Campylobacter*, *Entamoeba* tested, none detected.
		Positive samples	0/37	0/4	1/15	
		Percent reduction	n.a.	>97.5%	>99.4%	
Water Factory 21 (1979 study)	Lime, ammonia stripping, carbon, RO, chlorination	*After Lime:*		Not tested	Not tested	Not tested
		Positive samples	28/28			
		Percent reduction	99.87			
		After Chlorination:				
		Positive samples	1/142			
Water Factory 21 (1980-1981 study)	Lime, ammonia stripping, carbon, RO, chlorination	Concentration measured	<0.1/100 litres	Not tested	Not reported	Helminths: none found.
		Positive samples	1/21		0/20	
		Percent reduction	>99%		None detected after chlorination and RO	
		Prechlorination				
		Concentration measured	0.2/100 litres		<0.05/100 litres	
		Positive samples	1/19		-	
		Percent reduction	99.4%		>86.9% removals	
Potomac study	Lime, intermediate chlorination, dual-media filtration, carbon, chlorination	Concentration measured	1/1700 litres	Not tested	None detected using light microscopy	Not tested
		Positive samples	0/56			
		Percent reduction	>87%			

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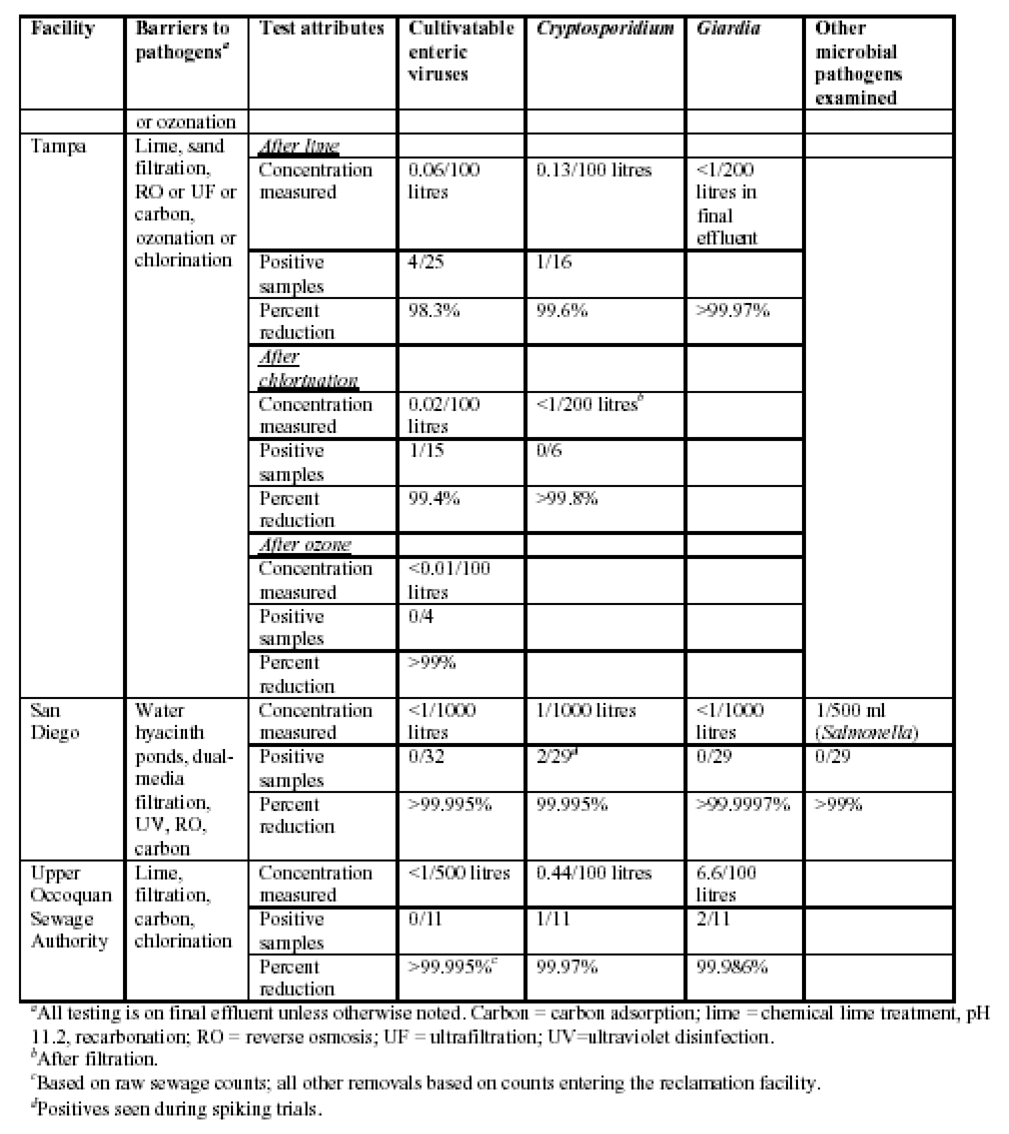

Facility	**Barriers to pathogens**[a]	**Test attributes**	**Cultivatable enteric viruses**	***Cryptosporidium***	***Giardia***	**Other microbial pathogens examined**
	or ozonation					
Tampa	Lime, sand filtration, RO or UF or carbon, ozonation or chlorination	*After lime*				
		Concentration measured	0.06/100 litres	0.13/100 litres	<1/200 litres in final effluent	
		Positive samples	4/25	1/16		
		Percent reduction	98.3%	99.6%	>99.97%	
		After chlorination				
		Concentration measured	0.02/100 litres	<1/200 litres[b]		
		Positive samples	1/15	0/6		
		Percent reduction	99.4%	>99.8%		
		After ozone				
		Concentration measured	<0.01/100 litres			
		Positive samples	0/4			
		Percent reduction	>99%			
San Diego	Water hyacinth ponds, dual-media filtration, UV, RO, carbon	Concentration measured	<1/1000 litres	1/1000 litres	<1/1000 litres	1/500 ml (*Salmonella*)
		Positive samples	0/32	2/29[d]	0/29	0/29
		Percent reduction	>99.995%	99.995%	>99.9997%	>99%
Upper Occoquan Sewage Authority	Lime, filtration, carbon, chlorination	Concentration measured	<1/500 litres	0.44/100 litres	6.6/100 litres	
		Positive samples	0/11	1/11	2/11	
		Percent reduction	>99.995%[c]	99.97%	99.986%	

[a] All testing is on final effluent unless otherwise noted. Carbon = carbon adsorption; lime = chemical lime treatment, pH 11.2, recarbonation; RO = reverse osmosis; UF = ultrafiltration; UV=ultraviolet disinfection.

[b] After filtration.

[c] Based on raw sewage counts; all other removals based on counts entering the reclamation facility.

[d] Positives seen during spiking trials.

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How good is RO etc for enteric viruses?

- 7 examples in report
- Viral Log reduction (complete system) ranges 87% to 99.995% (log 1 to log 5)
- Negative Enterovirus samples ranged from 0/37, 0/56, 0/4, 0/32, 0/11
- Positive samples
  28/28 (lime), 1/142, 1/21,1/19, 4/25, 1/15

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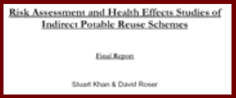
How good is RO for Giardia?

- Reduction from 86.9% to 99.9997% (log 1 to log 6)
- Reduction 99.4%, NT, 86.9%, none (microscopy), 99.7%, 99.9997%, 99.986%
- Positive Samples 1/15, 0/20, 0/29, 2/11



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Singapore NEWater
only 21 Enterovirus tests

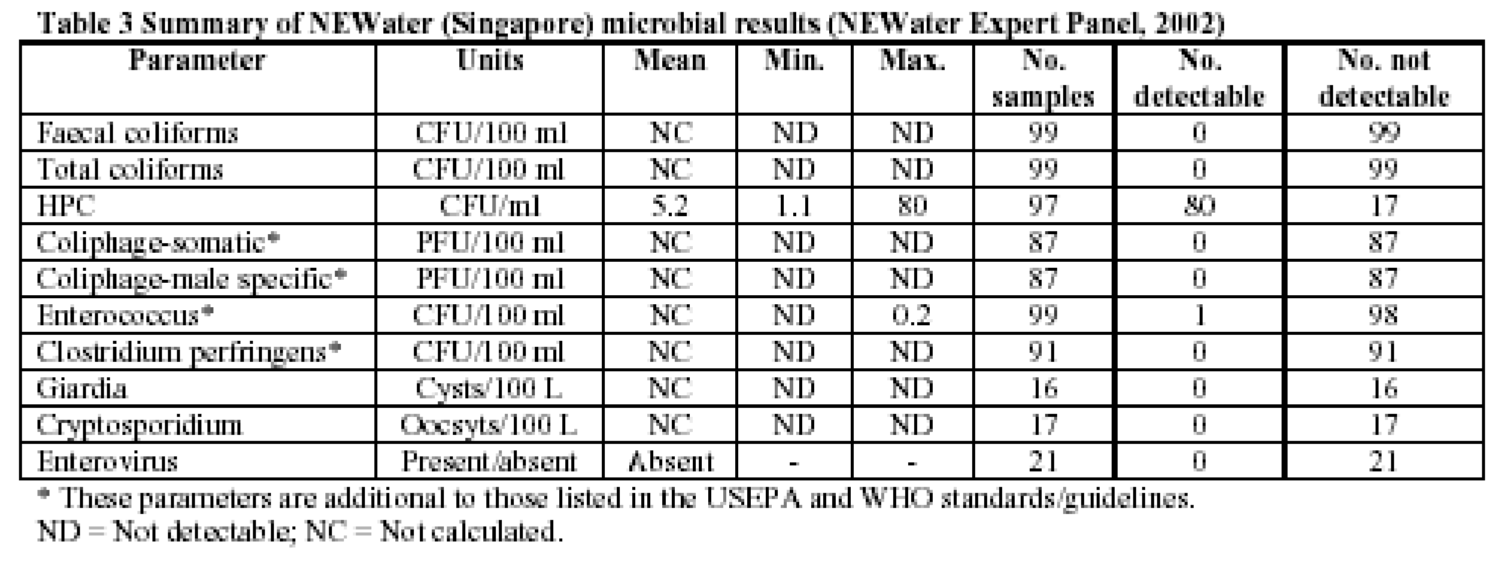
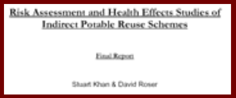


Table 3 Summary of NEWater (Singapore) microbial results (NEWater Expert Panel, 2002)

Parameter	Units	Mean	Min.	Max.	No. samples	No. detectable	No. not detectable
Faecal coliforms	CFU/100 ml	NC	ND	ND	99	0	99
Total coliforms	CFU/100 ml	NC	ND	ND	99	0	99
HPC	CFU/ml	5.2	1.1	80	97	80	17
Coliphage-somatic*	PFU/100 ml	NC	ND	ND	87	0	87
Coliphage-male specific*	PFU/100 ml	NC	ND	ND	87	0	87
Enterococcus*	CFU/100 ml	NC	ND	0.2	99	1	98
Clostridium perfringens*	CFU/100 ml	NC	ND	ND	91	0	91
Giardia	Cysts/100 L	NC	ND	ND	16	0	16
Cryptosporidium	Oocsyts/100 L	NC	ND	ND	17	0	17
Enterovirus	Present/absent	Absent	-	-	21	0	21

* These parameters are additional to those listed in the USEPA and WHO standards/guidelines.
ND = Not detectable; NC = Not calculated.



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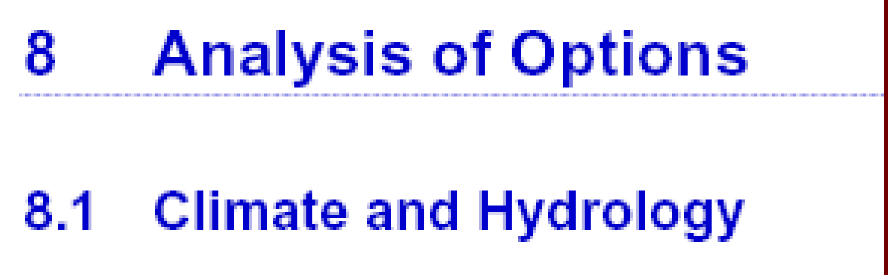
If "High Risk" then benefits need to far outweigh this risk

- Not the Case in Canberra
- Appears minimal long tern water security benefits compared to other options
- And poor economic benefits

Water Security for the ACT and Region

Recommendations to ACT Government

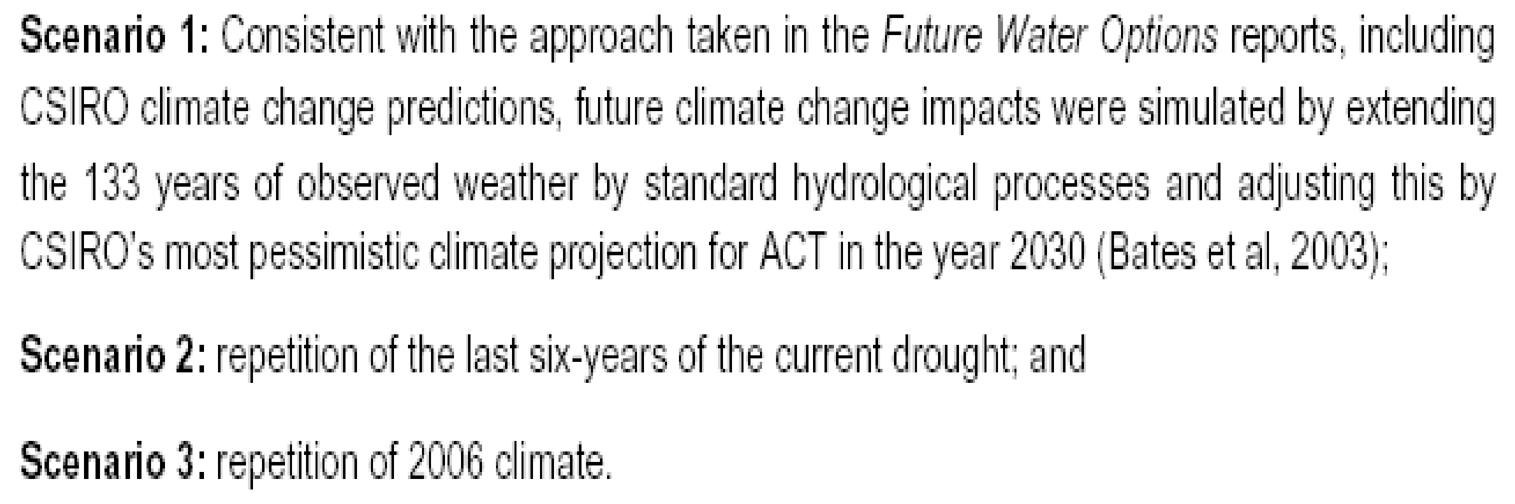
July 2007



8 Analysis of Options

8.1 Climate and Hydrology

Scenario's (all pessimistic)



Scenario 1: Consistent with the approach taken in the *Future Water Options* reports, including CSIRO climate change predictions, future climate change impacts were simulated by extending the 133 years of observed weather by standard hydrological processes and adjusting this by CSIRO's most pessimistic climate projection for ACT in the year 2030 (Bates et al, 2003);

Scenario 2: repetition of the last six-years of the current drought; and

Scenario 3: repetition of 2006 climate.

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Future water demand in Canberra

If future climate was similar to 2006, the unrestricted demand for water (i.e. free of drought restrictions) will continue at just above 70 GL/yr. The red shaded area shows an estimate of climate similar to 2006, whereas the orange shows climate similar to that of the past six years.

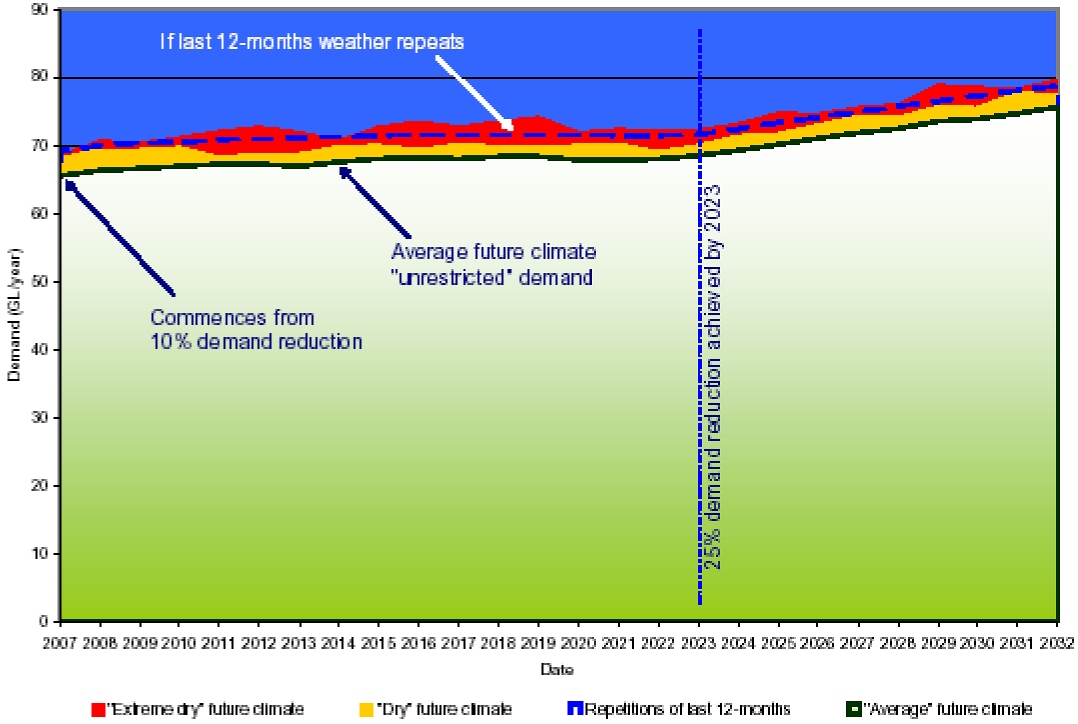

Figure 8:1: Future Water Demand

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Probability of restrictions

Canberra - scenario 1 with 30% long term reduction in inflows

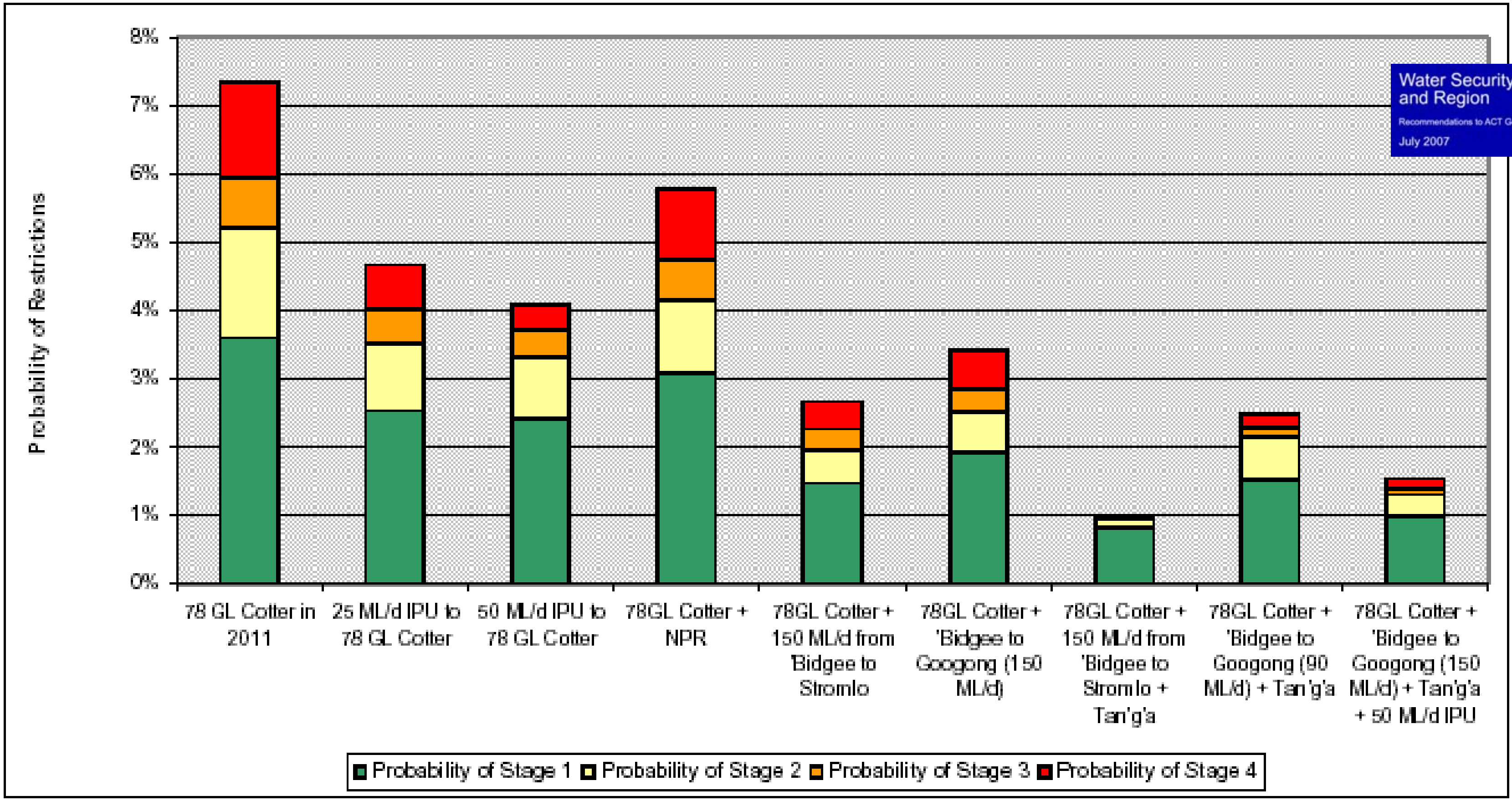

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Figure 8.3: Combined options - overall probability of restrictions

Recycling doesn’t decrease probability of restrictions


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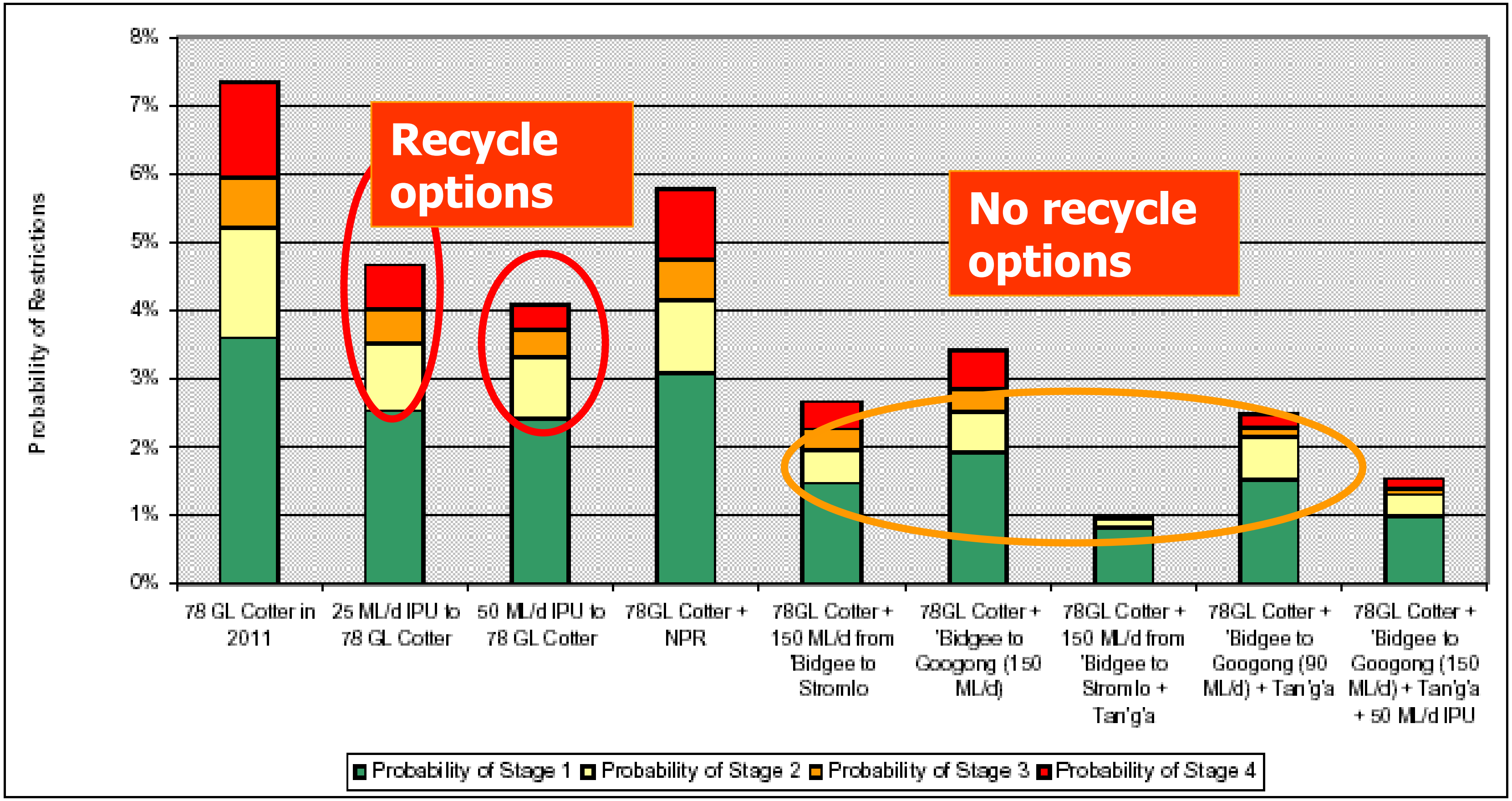
Recycle options

No recycle options

Figure 8.3: Combined options - overall probability of restrictions

Scenario 2 – current drought continues forever with 60% decrease in inflows

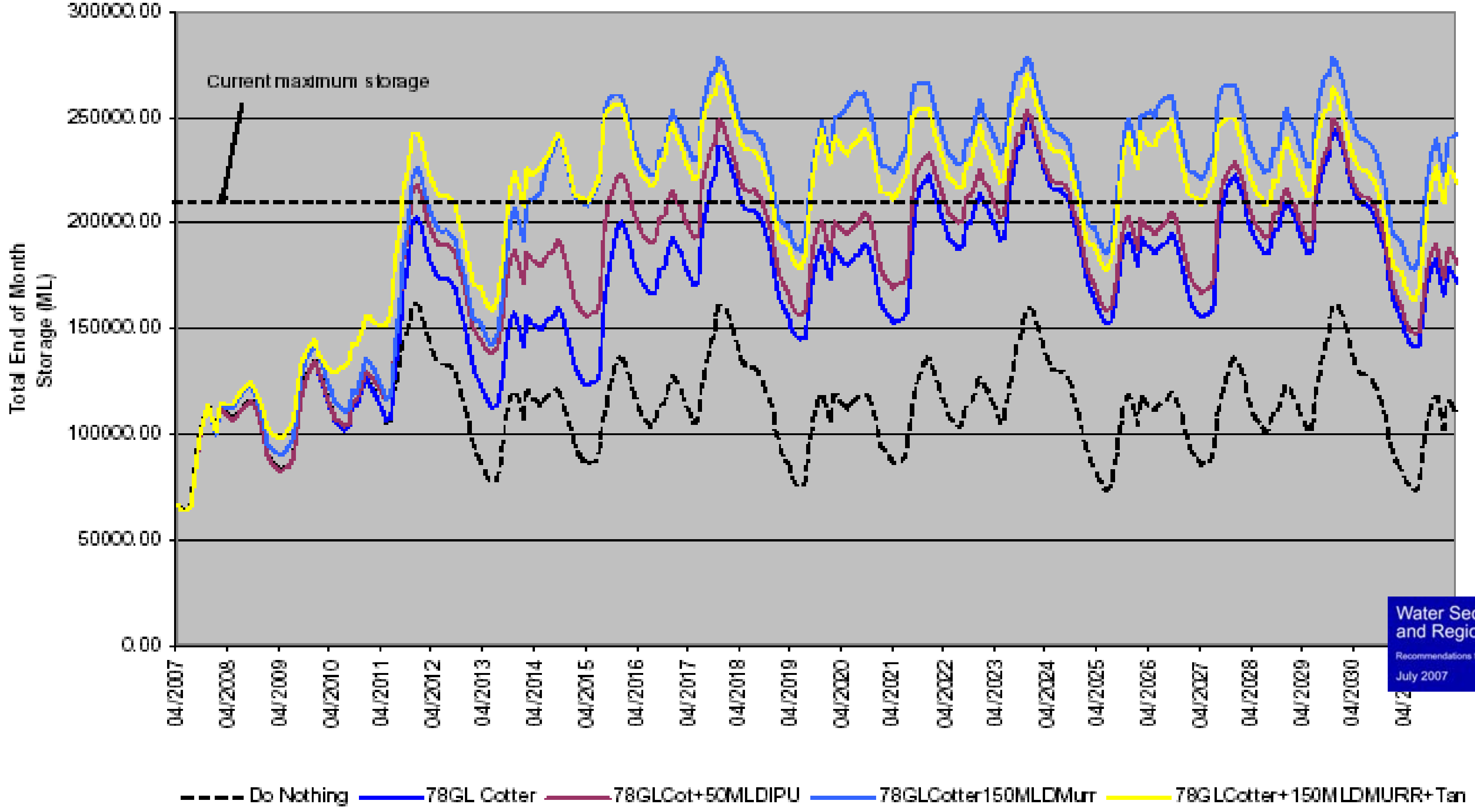

Figure 8.5: Predicted storage levels if the last six-years of drought continues

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Recycling into drinking water option makes minimal difference to short or long term storage levels

(Compare the dark blue to crimson lines)


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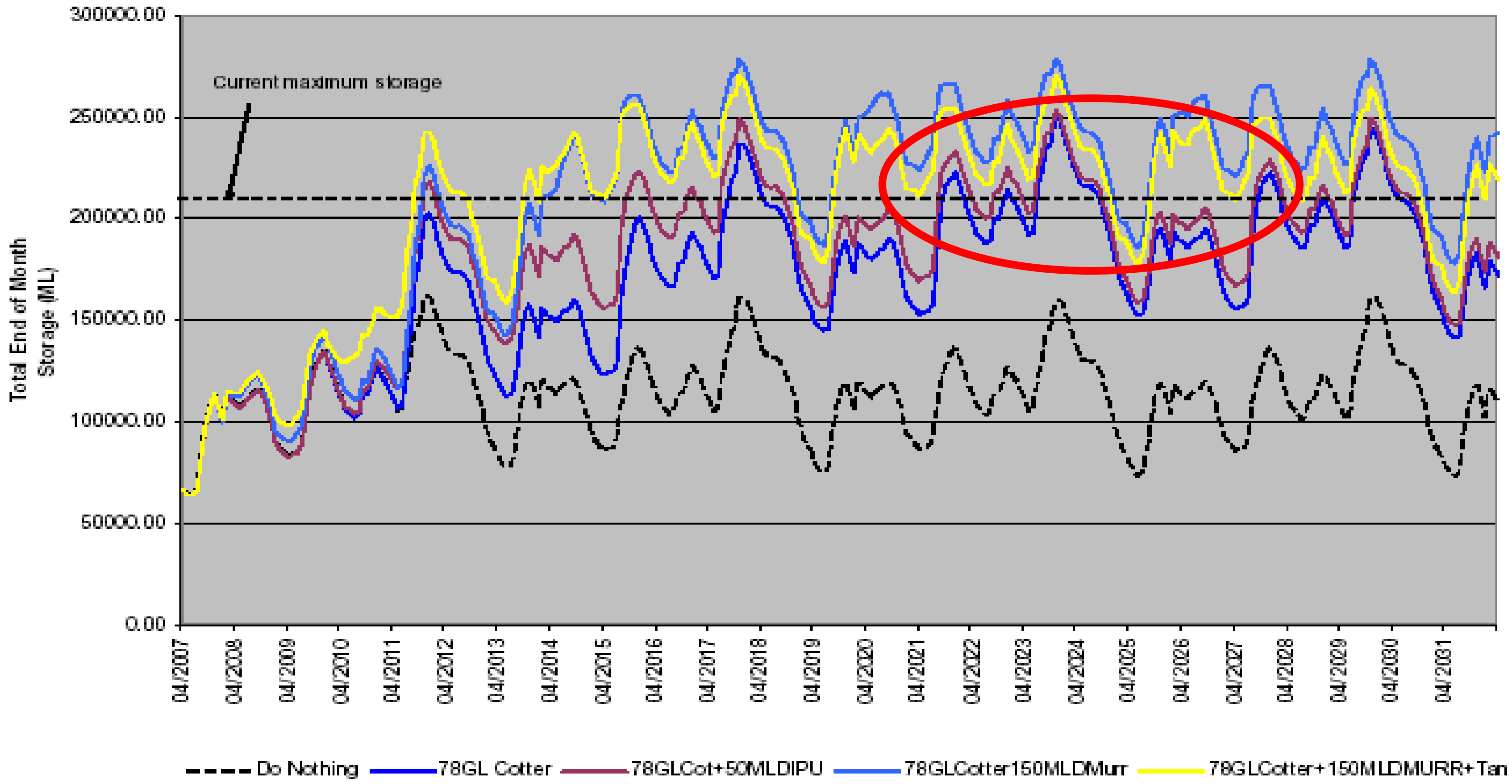

Figure 8.5: Predicted storage levels if the last six-years of drought continues

Scenario 3 – 2006 poor rainfall continues forever and thus a 90% reduction in inflows

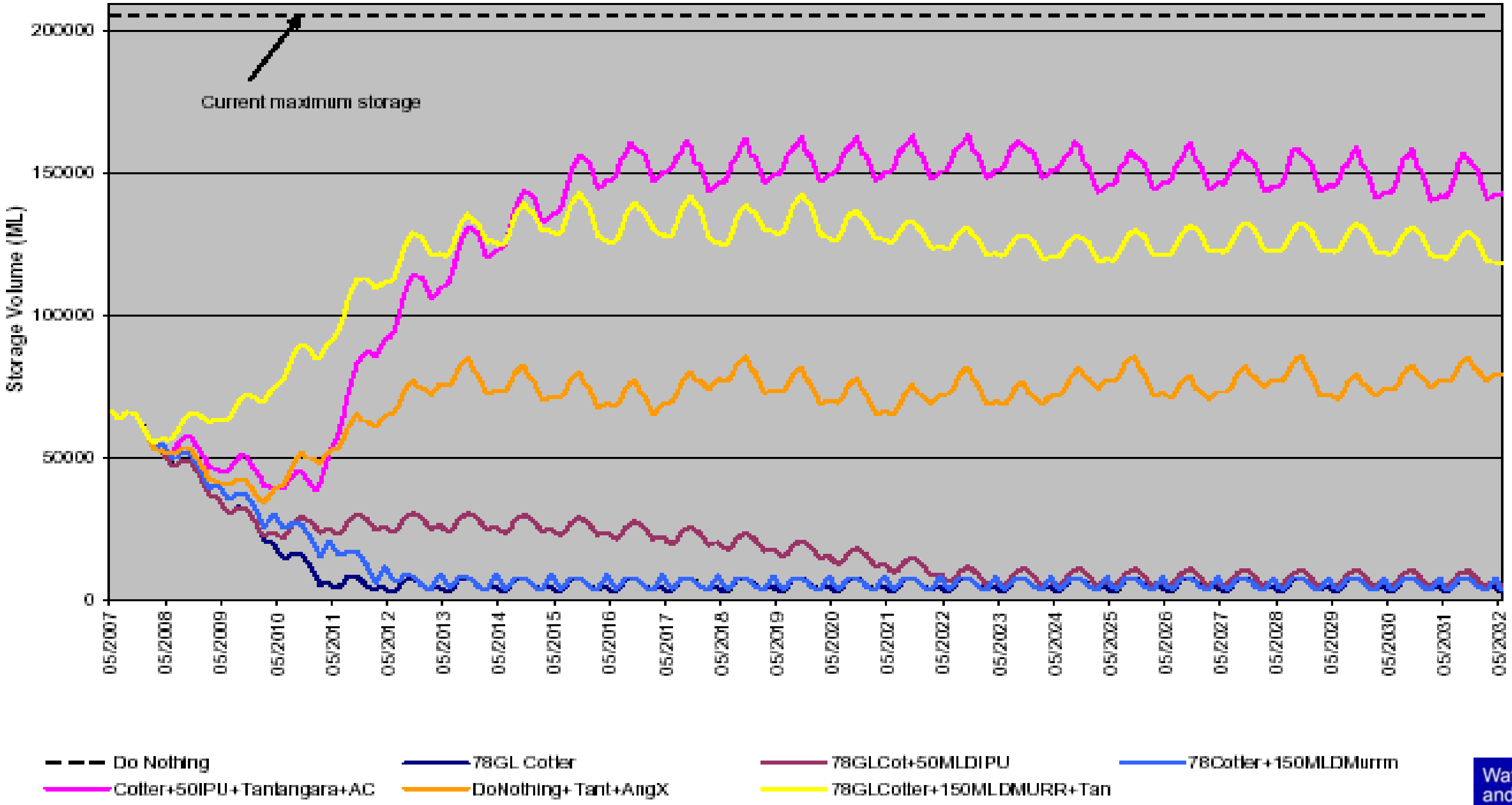

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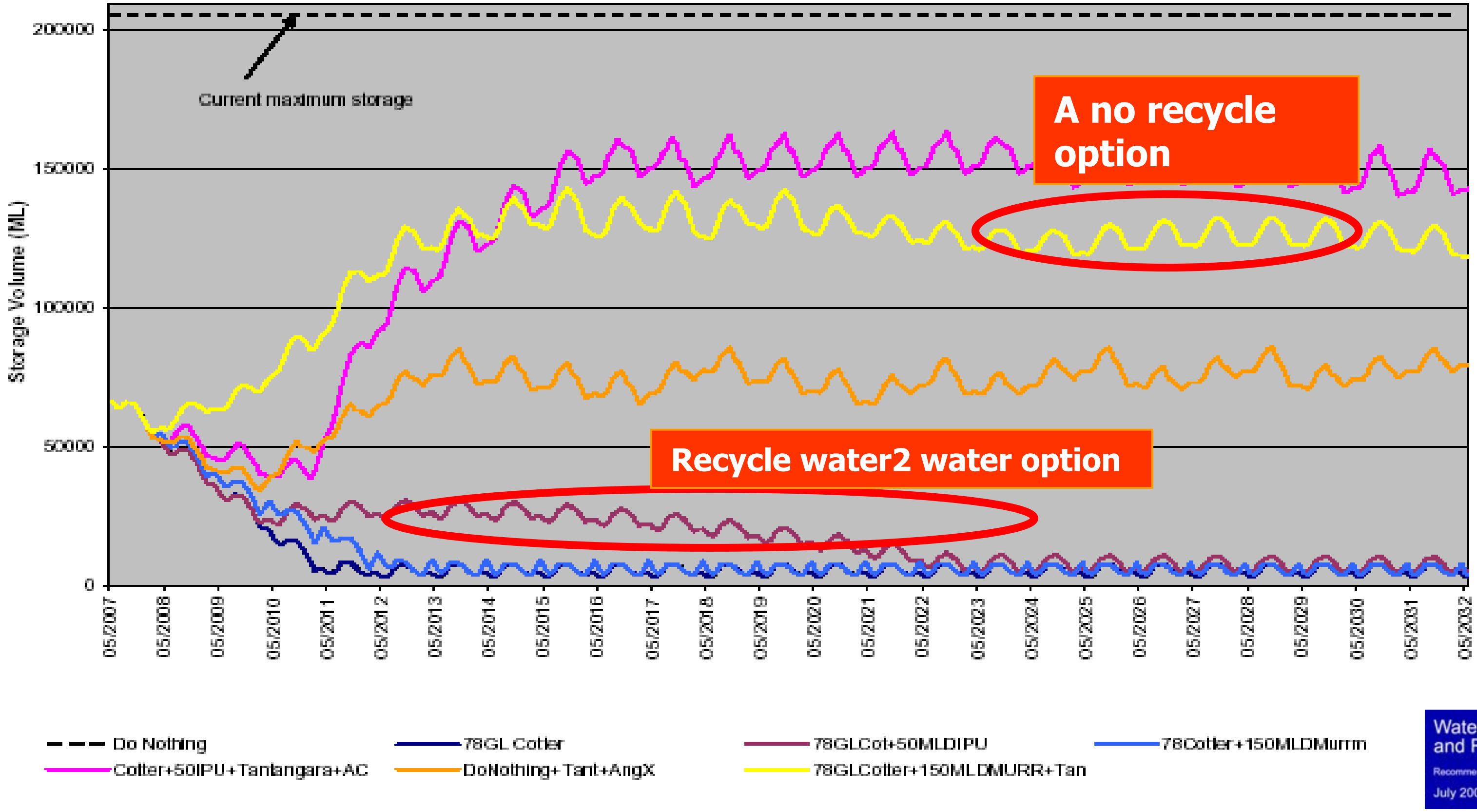
Figure 8.6: Predicted storage levels if the last 12-months of drought continues

Even if 90% reduction in water inflows, adequate water security can be obtained without having to recycle water from sewage into drinking water makes minimal difference to short or long term storage levels

(compare yellow to crimson lines)



A no recycle option

Recycle water2 water option

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Figure 8.6: Predicted storage levels if the last 12-months of drought continues

Need to explore many other water saving options

- so less water taken from our Dams

Risk management is inadequate if plan proceeds

- inadequate natural safety barriers in place if something goes wrong
- Exclusion of industry sewage etc
- What about disposal waste-water from process itself

Conclusion

- “High risk” option to recycle water from sewage into drinking water
- We have lots of other better options to give us water security
- We don’t need to take this “high” risk