WaterWise
Queensland

WaterWise Queensland

Queensland Water Recycling Guidelines

December 2005






Queensland Government
Environmental Protection Agency

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http://www.epa.qld.gov.au/waterrecyclingguidelines

Recycled paper saves energy and resources.

Contents

1. Introduction

1.1 PURPOSE OF THE GUIDELINES

The purpose of these guidelines is to encourage and support water recycling that is safe, environmentally sustainable and cost-effective. They are designed to provide guidance on water recycling that is appropriate to Queensland conditions and to provide a road map to other resources that can support water recycling*.

These guidelines are intended to cover issues common to all of the main uses of recycled water sourced from sewage treatment plants in Queensland. They are not intended to function as a manual, nor do they prescribe water quality standards or treatment for every possible final use. Instead, these guidelines provide a risk management framework combined with guidance on best practice to ensure that water recycling project planners and operators can match water quality to intended uses in the safest and most cost-effective manner.

These guidelines have been prepared in fulfilment of the commitments contained in Action Plan 2 of the *Queensland Water Recycling Strategy* (EPA 2001). The Queensland Water Recycling Strategy (QWRS) was published in December 2001 to provide a set of guiding principles, policy positions on appropriate uses and sources of recycled water, and action plans with objectives and targets to guide public and private sector initiatives.

Water recycling is a key component of integrated water cycle management. This approach aims to manage all of the components of the hydrological cycle (rainwater, stormwater, sewage, ground water, surface water and recycled water) to secure a range of social, economic and environmental benefits. The safe implementation of water recycling can help to reduce inputs of nutrients and other contaminants to surface waters, conserve drinking water and provide economic and social benefits to communities throughout Queensland.

The Queensland Government supports a consistent national approach to water recycling in Australia. To this end, these guidelines have been aligned with the Natural Resource Management Ministerial Council and Environment Protection and Heritage Council's draft *National Guidelines for Water Recycling – Managing Health and Environmental Risks* (NRMMC & EPHC 2005) (hereafter called "the national guidelines").

For more information see section 1.4.1 of this document.

* Web addresses for all electronic versions of documents cited in these guidelines are shown in Appendix C.

1.2 STRUCTURE OF THE GUIDELINES

Chapter 1 introduces the guidelines, their purpose, scope and relationship to other guidelines.

Chapter 2 describes the regulatory framework for water recycling in Queensland, including approval requirements and health and environment impact assessment.

Chapter 3 discusses planning issues and emphasises the importance of establishing partnerships for water recycling and engaging with communities on water recycling issues.

Chapter 4 introduces the Recycled Water Management Plan as a mechanism to manage the risks involved in treatment and use of recycled water.

Chapter 5 discusses sewage and recycled water quality.

Chapter 6 covers treatment technologies for production of recycled water from municipal sewage and puts forward water quality recommendations for recycled water.

Chapter 7 makes recommendations for distribution, storage and use of recycled water.

Chapter 8 summarises some typical hazards encountered during treatment, supply and use of recycled water and suggests possible control measures.

1.3 SCOPE OF THE GUIDELINES

1.3.1 Sources of recycled water

These guidelines cover water recycling using effluent from sewage treatment plants (STPs) that have the capacity to treat sewage from 21 or more equivalent persons (EP), or approximately 5250L/day. This includes water mining from sewers. Use of effluent from on-site wastewater treatment systems, treated and untreated greywater and other forms of wastewater is discussed in section 1.4 of these guidelines.

1.3.2 Uses of recycled water

These guidelines cover water recycling for the following purposes:

- domestic and commercial property use
- public open space irrigation
- irrigation of food crops
- irrigation of retail and wholesale nurseries
- irrigation of pasture, stock watering and stockyard washdown

- irrigation of non-human food chain crops, including trees, turf and cotton
- industrial and municipal purposes, including washdown and dust suppression
- fire fighting
- supplementing raw water sources, including ground water
- environmental purposes, including recreational water bodies not used for swimming or boating.

1.3.3 Acknowledging the importance of the community, the environment and the economy

Water recycling brings significant benefits to the people, the environment and the economy of Queensland.

1.3.3.1 Community

As well as providing technical guidance for those involved in water recycling, these guidelines also provide the following benefits to the Queensland community:

- They will promote an understanding of the types of water recycling that can be safely undertaken.
- They make it clear that local governing bodies have an obligation to involve the local community in planning for total water cycle management.
- They also make it clear that water service providers and other recycled water suppliers have an obligation to keep the local community informed of the performance of water recycling schemes.
- By providing a framework for the safe use of recycled water, they will help to develop community support for water recycling.

Community education is the key element in promoting the understanding and acceptance of water recycling as part of sustainable water management. Local communities must have a better understanding of water quality and treatment before they can make a meaningful contribution to decision-making over local water resources. The Queensland Government is responsible for facilitating statewide education on water recycling, while local government will provide more community-based water recycling education programs that will deal with the needs of particular target groups.

1.3.3.2 Environment

The environmental benefits of water recycling include conservation of water resources (surface and ground water), reduced discharge of pollutants to waterways and enhanced recycling of nutrients via irrigation with recycled water. These guidelines will help protect the environment by ensuring that recycled water schemes are considered in the context of the ecosystems in which they take place. Proper planning will ensure that all significant environmental values are protected, and the development and implementation of Recycled Water Management Plans (see Chapter 4 of these guidelines) will ensure that environmental risks are managed alongside health and other project risks. There is increasing recognition that environmental quality and human health cannot be considered in isolation so the joint consideration of environmental and human health factors in the one plan will assist with the effective integration of these related issues.

1.3.3.3 Economy

Water recycling can provide significant economic benefits, both to local communities as well as the national economy. In order to be sustainable, water recycling must be cost-effective. In other words, water recycling schemes must ensure that:

- recycled water is only applied for beneficial reuse
- recycled water is valued as a resource and an appropriate price is charged for its use
- recycled water is applied to uses producing the highest added value
- recycled water is only treated to such a level as to be fit for the intended purpose. Treating water to a level higher than is required wastes energy, chemicals, money and human resources.

1.4 RELATIONSHIP TO OTHER GUIDELINES

1.4.1 National guidelines for water recycling

As noted in section 1.1, national guidelines for water recycling are currently being developed by the Natural Resource Management Ministerial Council and the Environment Protection and Heritage Council. The national guidelines are expected to have the support of Commonwealth, state and territory governments. The draft national guidelines describe a generic process for development and implementation of preventive risk management systems for water recycling. The first phase of the national guidelines covers recycled water sourced from sewage treatment plants as well as domestic greywater. The second phase of the guidelines is expected to include reuse of urban stormwater, aquifer storage and recovery and indirect potable use of recycled water.

The draft national guidelines (NRMMC & EPHC 2005) note that the sustainable use of recycled water requires adherence to the following three principles:

- Protection of public and environmental health is paramount and should never be compromised.
- Ongoing protection of public and environmental health depends of the implementation of a preventive risk management approach.
- Application of control measures and water quality requirements should be commensurate with the source of recycled water and the intended uses.

The management framework put forward in the Queensland guidelines has been aligned with the draft national guidelines.

1.4.2 Guidance for fresh and marine water quality

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000a) are also referenced in a number of places in these guidelines. Even though they are not directly applicable to recycled water quality, they provide an authoritative guide for setting water quality objectives that may be relevant to users of recycled water. They also include recommendations for irrigation water quality that may be referenced during development of Recycled Water Management Plans for irrigation with recycled water.

1.4.3 Guidance for agricultural and industrial wastewater

The *National Water Quality Management Strategy* has produced a range of industry specific guidelines for effluent management, including guidelines on management of effluent from piggeries, dairy processing plants and wineries and distilleries. These include advice on land application of recycled water from these industries.

Effluent from intensive animal production facilities has a substantially different microbiological profile from municipal sewage, so it is not suitable for inclusion with these guidelines. For detailed guidance on the collection, storage and utilisation of effluent from piggeries, dairies and cattle feedlots the following publications should be consulted:

- *Environmental Code of Practice for Queensland Piggeries* (DPI 2000)
- *Queensland Dairy Farming Environmental Code of Practice* (DPI & QDO 2001)
- *National Beef Cattle Feedlot Environmental Code of Practice* (ALFA 2000).

It is difficult to provide generic guidance for reuse of industrial wastewater as the contaminants found will be highly variable, as will the uses to which the treated water could be put. While the risk management approach advocated in these guidelines can be readily applied to water recycling in an industrial context, companies or industries wishing to treat and recycle their effluent should obtain technical advice specific to their particular wastewater and reuse options.

1.4.4 Guidance for stormwater

The Commonwealth Department of the Environment and Heritage (DEH) has produced an *Introduction to Urban Stormwater Management in Australia* (DEH 2002). Another useful reference for urban stormwater management is the *Urban Stormwater – Best-Practice Environmental Management Guidelines* (CSIRO 1999). The Institute of Engineers Australia National Committee on Water Engineering has produced a draft document, *Australian Runoff Quality Guidelines* (Engineers Australia in draft), that contains a great deal of information on stormwater pollution, treatment and reuse.

As noted in section 1.4.1 the second phase of development of national guidelines for water recycling will include guidance for stormwater reuse.

1.4.5 Guidance for greywater reuse

There are existing Queensland *Guidelines for the Use and Disposal of Greywater in Unsewered Areas* (DNRM 2003), which provide an authoritative reference to greywater recycling in unsewered areas of Queensland. The Queensland Government is also currently preparing a code of practice for the limited use of greywater in sewered areas. When completed, this will be provided on the website of the *Department of Local Government, Planning, Sport and Recreation*. For more information see section 2.1.4 of these guidelines.

1.4.6 Guidance for aquifer storage and recovery of recycled water

The South Australian Environment Protection Authority has produced a *Code of Practice for Aquifer Storage and Recovery* (South Australian EPA 2004) that contains information on water source selection, aquifer selection, treatment and maintenance requirements for aquifer storage and recovery systems.

2. Regulatory and formal requirements

The starting point for all water recycling schemes must be compliance with all relevant regulatory provisions, including state, federal and local government laws. It is the responsibility of both the suppliers and users of recycled water to ensure that they maintain up to date knowledge of all relevant regulatory provisions.

While it should be noted that the Queensland Water Recycling Guidelines are not mandatory at this time, consideration is currently being given to the development of a state-based regulatory framework for the operation and management of recycled water infrastructure. This regulation will provide for the sustainable use of recycled water through the preservation of public health and environmental values.

2.1 STATE LAWS

2.1.1 Environmental Protection Act

The principal legislation governing the use of recycled water in Queensland is the *Environmental Protection Act 1994* (EP Act) and its subordinate legislation, the Environmental Protection Regulation 1998 (EP Reg) and the Environmental Protection (Water) Policy 1997 (EPP (Water)). Schedule 1 of the Environmental Protection Regulation lists all activities that are ERAs.

Water recycling is not an *environmentally relevant activity* (ERA) in its own right and no development approval is required from the Environmental Protection Agency (EPA) for water recycling as such. However, it may be an integral part of an activity that is an ERA, or otherwise requires a development approval. In this case, the EPP (Water) states the matters the EPA must consider when making a decision about approval of the recycling component. In the case where recycling is not a component of an ERA and no statutory approval is needed (for example, when the recycled water will be used by a third party on land that is not subject to a development approval), s. 319 (1) of the EP Act requires that a person must not carry out any activity that causes or is likely to cause environmental harm unless that person takes all reasonable and practical measures to prevent or minimise the harm. This is known as the *general environmental duty*.

For example, operating a sewage treatment works with a peak design capacity of 21 or more EP is defined as a Level 1 ERA. This would include treatment plants that produce recycled water from "water mining" from sewers. If recycled water is used within the property boundary of the holder of the development approval for the STP, this will be subject to regulation under the current approval.

If the operator of the STP commences the supply of recycled water to an external user or to a site separate from the STP, this may require an amendment to existing approval conditions. If the recycled water is supplied to a user (or "third party" not subject to the licence), the EPA will require the supplier to enter into a formal Recycled Water Agreement with the user. Among other things, this Recycled Water Agreement commits the third party to only use the recycled water in a certain way and for certain specified purposes. Often, it will also include a requirement to comply with the general environmental duty as described in the Environmental Protection Act, that is, to prevent environmental harm or public health impacts. Recycled Water Agreements are discussed further in section 3.9 of these guidelines.

Part 8 of the Environmental Protection Act contains provisions relating to contaminated land. Land is considered contaminated when it has been affected by a hazardous contaminant. A hazardous contaminant is anything that, if improperly treated, stored, disposed of or otherwise managed, is likely to cause "serious" or "material" environmental harm (as defined in ss. 16 and 17 of the Act). Its capacity to cause harm may be due to its quantity, concentration, acute or chronic toxic effects, carcinogenicity (capacity to cause cancer), teratogenicity (capacity to cause birth defects), mutagenicity (capacity to cause genetic mutations), corrosiveness, explosiveness, radioactivity or flammability or its physical, chemical or infectious characteristics.

When recycled water is used for irrigation of land and is managed according to a Recycled Water Management Plan (see Chapter 4 of these guidelines), the concentrations of hazardous contaminants in the recycled water would not be expected to reach levels that would cause "serious" or "material" environmental harm. In the event of a treatment plant failure, or prolonged use of low quality recycled water for irrigation resulting in the possibility of land contamination, the provisions of Part 8 of the Environmental Protection Act should be followed.

In Part 7, Division 2 (local government environmental plans) of the Environmental Protection (Water) Policy, local governments are required to produce environmental plans relating to water management. Each of the specific plans, covering sewage management, trade waste management, urban stormwater quality management and water conservation, may include options for recycling water.

As noted above, use of recycled water within the property boundary of the holder of the development approval for an STP is considered to be part of the ERA for the facility and is thus regulated directly by the EPA. While use of recycled water by an STP for washdown and irrigation of gardens and lawns is unlikely to lead to environmental or public health impacts, large-scale application to a limited land area is less likely to constitute beneficial reuse. As this may lead to adverse environmental impacts, the EPA may choose to apply conditions to this form of reuse.

These conditions may involve requirements for monitoring the quality and quantity of recycled water applied or otherwise used, impacts on soil and ground water and off-site impacts on any waterways that may drain the site. If the EPA is satisfied on reasonable grounds that the holder of the development approval is contravening the conditions of their approval, or contravening an environmental protection policy or environmental management program, the EPA can require the person conducting the activity to conduct or commission an environmental audit and submit a report to the EPA.

For water recycling schemes operating beyond the boundary of an STP, the Environmental Protection Act's provisions on Environmental Evaluations (Chapter 7, Part 2) may be invoked. These provide that, if the EPA is satisfied on reasonable grounds that an activity is causing environmental harm, the proponent of the activity can be required to conduct or commission an environmental investigation and submit a report on the investigation to the EPA.

The EPA Operational Policy *Approval of sewage treatment plants including options for use of reclaimed water* (EPA 2005a) describes the approach EPA takes to approve new, upgraded or augmented sewage treatment plants that have a peak design capacity to treat sewage from 1000 EP or more.

2.1.2 Integrated Planning Act 1997

The *Integrated Planning Act 1997* is the principal legislation in Queensland regulating development and the effects of development, and is administered by the Department of Local Government, Planning, Sport and Recreation (DLGPSR). Where it is proposed to commence water recycling as part of a development that requires approval under the Integrated Planning Act, all conditions of an environmental nature will be placed on the development approval granted under the Integrated Planning Act, including approval for any STP. The EPA can be either a concurrence agency or alternate assessment manager under the Integrated Development Assessment System IDAS for all ERAs and for contaminated land, and will provide a response that may recommend conditions related to the activity, including the reuse application.

For further advice on when a development requires assessment under IDAS, see the DLGPSR website and, in particular, the DLGPSR publication *IDAS Overview* (DLGP 2001).

If the peak design capacity or storage of an STP increases by more than 10%, this will be regarded as a "material change in the intensity or scale of an existing use" under the Integrated Planning Act, and thus the EPA should be approached to make a determination as to whether the proposed development will need to be assessed under IDAS.

Where a water recycling project is currently in operation and a development approval has already been issued, the publication of these guidelines does not create a retrospective requirement for compliance. However, in the interests of effective risk management and continuous improvement, current operators of water recycling projects are encouraged to implement the risk management framework described in these guidelines.

2.1.3 Water Act 2000

The *Water Act 2000* provides for the sustainable management and efficient use of water in Queensland by establishing a system for the planning, allocation and use of water. It also provides the regulatory framework for the provision of water and sewerage services, for the establishment and operation of water authorities in Queensland, and for the management of referable dams and flood mitigation.

Schedule 4 of the Act contains a series of definitions that are important to an understanding of the relevance of the Water Act to water recycling. In Schedule 4 of the Act, a *water service provider* is a person registered under the Act to provide a *water service,* which is defined as including the transmission of water, reticulation of water and water treatment or recycling. However, it does not include a water service supplied where the only user of the service is the owner of the infrastructure or the owner's guests or employees, including, for example, guests at a resort.

A *sewerage service provider* is a person registered under the Act to provide a *sewerage service,* which is defined as including the collection and transmission of sewage through infrastructure, sewage treatment, or the disposal of sewage or effluent. Again, it excludes a sewerage service supplied where the only user of the service is the owner of the infrastructure or the owner's guests or employees.

A *retail water service* means a reticulated water service in a service area for a water service but it does not include an irrigation service or a bulk water service in any area, or the supply of recycled water in any area.

The Act also contains exemptions from certain of its provisions for *small service providers* (see the Act for a definition of "small service provider").

An *irrigation service* means the supply of water or drainage services for irrigation of crops or pastures for commercial gain. A *bulk water service* means the supply of large quantities of water other than as an irrigation service.

Subartesian water means water that occurs naturally in, or is introduced artificially into, an aquifer, which if tapped by a bore, would not flow naturally to the surface. It can therefore include recycled water that has been injected or otherwise introduced into an aquifer.

In general terms, the Water Act, which is administered by the Department of Natural Resources and Mines (DNRM), deals with wastewater management in sewered areas up to the point of connection with the premises, and the Plumbing and Drainage Act, administered by the Department of Local Government, Planning, Sport and Recreation regulates wastewater management in unsewered areas and after the point of connection to a property in sewered areas (see section 2.1.4 below).

The responsibilities of local governing bodies under the Water Act depend on whether they are a water service provider or a sewerage service provider, although in most cases the same local governing body will be responsible for both services. Because the definition of water service includes water recycling (see above), any local government or water authority that owns infrastructure for providing a recycled water service, or any person who owns infrastructure for supplying a recycled water service for which a charge is intended to be made, must be registered as a water service provider under Chapter 3 of the Water Act, unless exempted. This imposes certain obligations on the service provider including preparation of Strategic Asset Management Plans, Annual Reports and Customer Service Standards (when the service provider does not have a contract for supply of services with all its customers).

Under s. 469 of the Act, a local government that is a sewerage service provider may give a person an approval to discharge trade waste (a trade waste approval) into the local government's sewerage infrastructure. Before giving the approval, the local government must consider the effect of the proposed discharge on any existing or potential reuse of wastewater or sludge. Section 824(4) prohibits the discharge of a prohibited substance into the sewer. A prohibited substance is one that, given its quantity, is capable alone, or by interaction with another substance discharged into the sewer, of:

- inhibiting or interfering with a sewage treatment process or
- causing damage or a hazard to sewerage or
- causing a hazard for humans or animals or
- creating a public nuisance or
- creating a hazard in waters into which it is discharged or
- contaminating the environment in places where effluent or sludge from a sewage treatment plant is discharged or reused.

Chapter 3, Part 3, Division 4 of the Act deals with water for fire fighting but applies only to a service provider who provides a retail water service. The provisions of this Division of the Act therefore do not apply to recycled water used for fire fighting.

2.1.4 Plumbing and Drainage Act 2002

The *Plumbing and Drainage Act 2002* is administered by the Department of Local Government, Planning, Sport and Recreation and deals with plumbing and drainage within the property boundary.

The Plumbing and Drainage Act and the subordinate Standard Plumbing and Drainage Regulation 2003 and On-site Sewerage Code (which will be replaced from 1 March 2006 by the Queensland Plumbing and Wastewater Code) regulate the design and operation of on-site sewerage facilities that consist of or include a sewage treatment works with a peak design capacity of less than 21 EP.

An on-site sewerage facility is defined in the Schedule to the Plumbing and Drainage Act as a facility for the treatment on-site of sewage generated on-site and either disposed of on-site, or disposed off-site by common effluent drainage or by collection from an on-site storage tank.

Section 96(2)(a) of the Plumbing and Drainage Act limits the installation of such on-site sewerage facilities to premises that cannot be served by a sewerage system or that are connected to a common effluent drainage scheme.

Local governments approve the installation of on-site sewerage facilities (treatment plant plus the land application area) and administer the provisions of the legislation governing the day-to-day management of on-site sewerage within their local government areas.

In unsewered areas, greywater is normally co-treated with blackwater by an on-site sewage treatment plant and disposed of by land application or, if treated acceptably, used for irrigation. Greywater may also be treated and disposed of, or recycled, separately from blackwater. Both options require approval from the local government, which assesses the adequacy of the treatment facility and the land application area in accordance with legislation requirements, including the On-site Sewerage Code. The local government may also set conditions for operational matters and for disposal or reuse, depending on effluent quality.

As noted in section 1.4.6 of this document, the existing *Guidelines for the Use and Disposal of Greywater in Unsewered Areas* (DNRM 2003) promote water conservation and acceptable greywater recycling practices in unsewered areas. The Queensland Government has approved changes to the Plumbing and Drainage Act to permit limited reuse of untreated greywater in sewered areas. These changes will come into force from 1 March 2006. For more information contact Building Codes Queensland (contact details in Appendix D).

The Plumbing and Drainage Act also covers regulation of plumbing and licensing of plumbers. Under the Act, *regulated work* requires both an approval process and performance by a licensed plumber. *Minor work* requires a licensed plumber, but no approval. *Unregulated work* requires neither approval nor a licensed plumber, but still requires work to be in accordance with the Plumbing and Drainage Act. The scope of unregulated work is very limited. The majority of plumbing work, both new work and maintenance, must be performed by a licensed plumber. Further discussion of plumbing issues relating to recycled water can be found in section 7.2 of these guidelines.

2.1.5 Health Act 1937

The *Health Act 1937* does not specifically regulate recycled water but there are a number of provisions in the Act and the *Health Regulation 1996* that may be relevant. These include:

- requirements for local government to act to prevent the occurrence of a notifiable disease within its area (s. 34A of the Act)
- prohibition of a business activity that is a nuisance or injurious to the health of any of the inhabitants of an area (s. 86 of the Act)
- provisions for mosquito and vermin control (ss. 69-74 of the Regulation)
- prohibition of the carrying off of sewage or stormwater drainage to particular places (s. 10 of the Act).

This Act is to be repealed in the near future. The current Public Health Bill provides the ability to regulate risks to public health, including recycled water. Under the proposed recycled water regulatory framework mentioned above, a public health regulation may establish the following for each class of recycled water:

- water quality standards
- system compliance
- investigation protocols
- incident notification protocols.

2.1.6 Food Act 1981

Under s. 13(2) of the Queensland *Food Act 1981* a person may not sell food that is “unsuitable”. Under s. 5E(1) food is defined as unsuitable “if it contains a biological or chemical agent, or other matter or substance, that is foreign to the nature of the food”. However, under s. 5E(2) food may contain certain contaminants specified in the Australia New Zealand Food Standards Code if they are below the maximum residue limit set for those contaminants in the Code. For further information see the website of *Safe Food Australia*. Section 7.3.6 of these guidelines also contains specific advice on the use of recycled water on food crops.

2.1.7 Workplace Health and Safety Act 1995

2.1.7.1 Employer obligations

Under the *Workplace Health and Safety Act 1995,* recycled water is considered to be a “substance” (i.e. “any natural or artificial substance, whether in solid or liquid form or in the form of a gas or vapour”). As such, a person in control of a workplace has an obligation under s. 15 of the Act to ensure that the substance is “used properly”. A substance is not used properly when it is used without regard to available appropriate information or advice about its use.

Also, in general terms, an employer has an obligation to ensure the workplace health and safety of their employees, themselves and other persons who may be exposed to risks arising out of the conduct of the employer’s business or undertaking. This obligation (ss. 28 & 29 of the Act) may include one or more of the following:

- conducting a hazard identification and risk assessment
- providing and maintaining a safe and healthy work environment
- ensuring safe use, handling, storage and transport of substances

- ensuring safe systems of work
- providing information, training and supervision to ensure health and safety.

2.1.7.2 Supplier obligations

Under s. 34 of the Act, a manufacturer or supplier of a substance for use at a workplace has an obligation to ensure that:

- the substance is safe and without risk to health when used properly
- the substance is tested and examined to ensure it is safe and without risk to health when used properly
- the substance, when supplied to another person, is accompanied by relevant information for the substance.

"Relevant information" means information that clearly identifies the substance, and that states the following:

- any precautions that must be taken for the safe use of the substance
- any health hazards associated with the substance
- the results of any tests carried out for the substance that are relevant to its safe use.

2.1.7.3 Implications for water recycling

The employer obligations contained in the Workplace Health and Safety Act are the same for workplaces where recycled water is used as they are for any other workplace. However, the supplier obligations in the Act mean that suppliers of recycled water (in most cases this would be municipal STPs, but may also include other facilities) should provide their customers with all relevant information about possible contaminants in recycled water that could cause harm to human health as a result of the use of the recycled water. This should include appropriate advice on how the recycled water can be safely used. This information could appropriately be provided during development of the Recycled Water Agreement or the Recycled Water Management Plan.

2.2 LOCAL LAWS

Under the Integrated Planning Act, all councils are required to prepare and implement a planning scheme to help guide growth and change in their local government area. The planning schemes are essential as they identify what level of assessment is applicable to different forms of development, and provide the policy information to guide planning decisions on development applications.

In addition to planning schemes, local governments have also adopted many local laws, the details of which will differ from the local laws adopted by other local governments. As some of these may affect water recycling projects, proponents of water recycling schemes should consult their local government to find out whether their proposal is consistent with the local planning scheme and local laws.

2.3 COMMONWEALTH LAWS

2.3.1 Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The principal Commonwealth environmental legislation that could affect water recycling projects in Queensland is the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act). This Act regulates actions that are likely to have a significant impact on a matter of national environmental significance. Thus a water recycling scheme that could significantly impact the following issues could require referral, assessment and approval under the EPBC Act:

- a World Heritage property (e.g. the Great Barrier Reef, Wet Tropics or Fraser Island)
- a Ramsar wetland (e.g. Moreton Bay, Great Sandy Strait, Bowling Green Bay)
- migratory species, threatened species or ecological communities listed under Commonwealth legislation
- Commonwealth land or marine environment.

For further information contact the Commonwealth Department of the Environment and Heritage (for contact details see Appendix D). A flowchart illustrating the process for referral, assessment and approval under the EPBC Act is shown on the DEH website (see Appendix C for link).

2.3.2 Commonwealth Trade Practices Act 1974

The Commonwealth *Trade Practices Act 1974* contains a number of provisions that could relate to the supply of recycled water where there is a commercial element to the arrangement. For example, s. 52(1) states that a corporation shall not engage in conduct that is misleading or deceptive or is likely to mislead or deceive. This may require the supplier of recycled water to disclose to the purchaser information on the reliability of the treatment process they are using that could influence the consistency of the quality of the recycled water. The *Queensland Fair Trading Act 1989* has provisions that mirror these provisions of the Commonwealth Act.

Section 74(1) of the Act provides that where there is a contract for the supply of services there is an implied warranty that "the services will be rendered with due care and skill and that any materials supplied in connexion with those services will be reasonably fit for the purpose for which they are supplied". In other words, suppliers of recycled water must ensure that the water is fit for the purpose for which it is supplied.

Part VA of the *Trade Practices Act 1974* contains provisions on product liability. Under these provisions, consumers can seek compensation through the courts for damages for personal injury or other loss caused by a defective product. Suppliers and users of recycled water should be aware of these provisions. For further advice on product liability see *Consumer Product Standards and Bans: A Compliance Guide for Suppliers* (ACCC 2003).

2.4 COMMON LAW

As well as their responsibilities under state and Commonwealth law, suppliers and users of recycled water could be liable for injuries or damages caused by their negligence in producing, storing, delivering or using recycled water. Suppliers and users of recycled water may be able to limit their risk in the event of negligence and product liability claims by:

- complying with any relevant laws and approval conditions (including the general environmental duty under the Environmental Protection Act)
- complying with any industry codes of practice or state government guidelines (such as these guidelines)
- having clear contractual arrangements between suppliers and users of recycled water (Recycled Water Agreement – see section 3.9 of these guidelines)
- having an effective management system in place that incorporates risk assessment and quality assurance (e.g. a Recycled Water Management Plan – see Chapter 4 of these guidelines)
- ensuring that the supplier is capable of reliably matching the quality of recycled water to all proposed uses
- ensuring any employees involved in managing recycled water are fully trained and properly equipped
- having an appropriate level of local community and stakeholder involvement in integrated water resource planning, including recycled water schemes
- maintaining openness with regulators and the local community about monitoring results.

2.5 ENVIRONMENTAL IMPACT ASSESSMENT

Figure 2.1 shows a generic process map for new water recycling proposals. As can be seen in the figure, not all water recycling proposals would trigger a statutory impact assessment process. Those proposals that would trigger a statutory assessment process include:

- significant projects declared under the *State Development and Public Works Organisation Act 1971* (SD&PWO Act)
- projects that include establishment of an ERA on the site (e.g. a new STP with a peak design capacity of 21 or more EP)
- projects in local government areas where environmental impact assessment measures are incorporated into the local government planning scheme. These may also include guidelines on impact assessment specific to industries and features in the local government area
- any other project that involves assessable or self-assessable development as specified in Schedule 8 of the Integrated Planning Act.

If a water recycling proposal is assessable development under the Integrated Planning Act, the application is processed through the Integrated Development Assessment System (IDAS). Under IDAS, the application may be code assessable or impact assessable. However, the application would only be impact assessable if the local planning scheme made it so.

If the Coordinator-General has declared the proposal to be a significant project under the SD&PWO Act, the EIS process under that Act replaces the Information and Referral Stage and the Notification Stage of IDAS. Further information on development assessment under IDAS can be obtained from the *Department of Local Government, Planning, Sport and Recreation website*, which allows project proponents to produce their own IDAS flow charts depending on the nature of their particular development.

The EPA has also published a number of information sheets describing the process for obtaining development approvals, including *Obtaining a development approval for an environmentally relevant activity* and *Integrated Development Assessment System (IDAS)*, both available on the EPA website.

The EPA provides a range of other resources for project proponents to help with their environmental impact assessment (see Appendix C for web addresses).

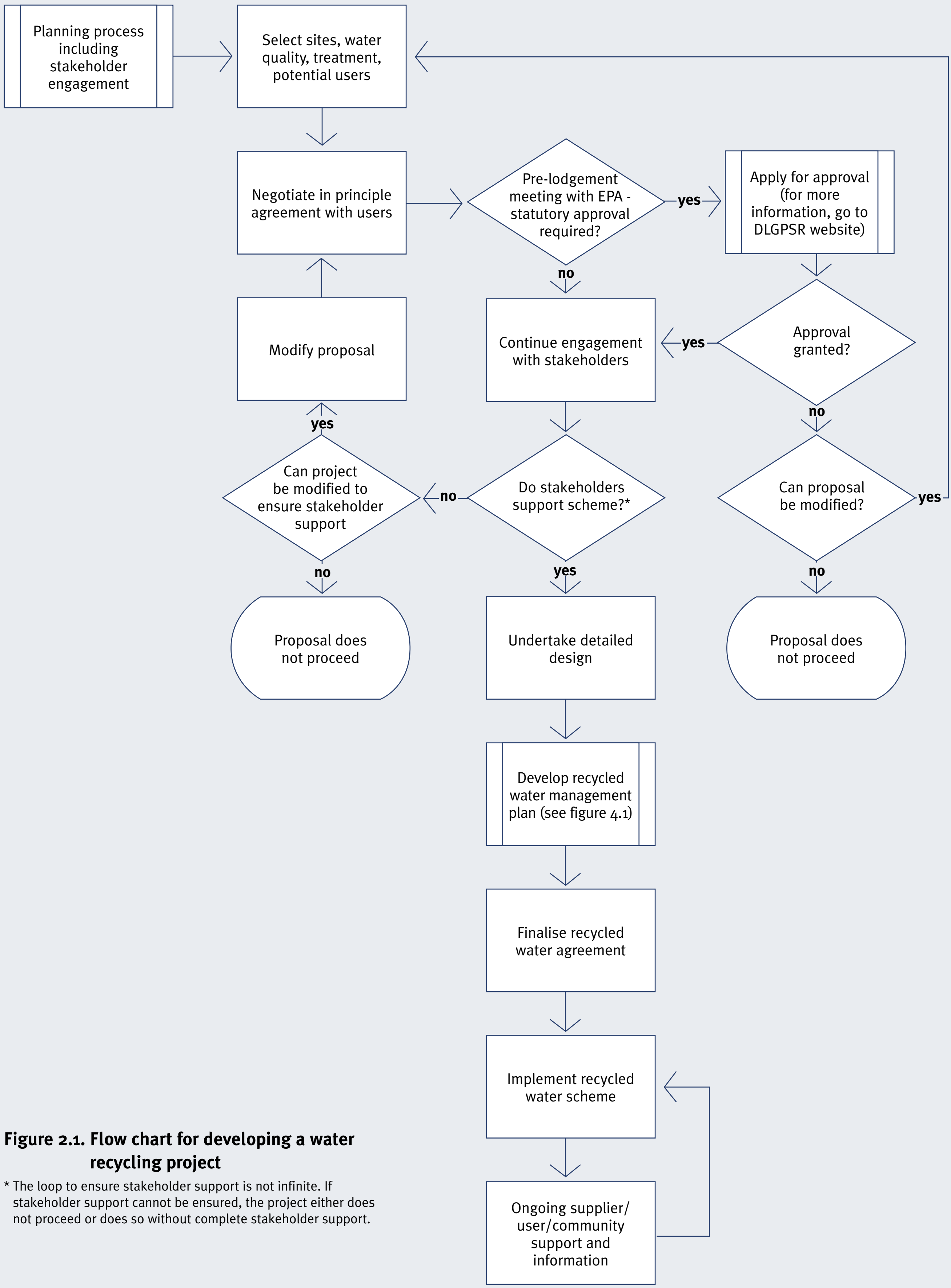

Figure 2.1. Flow chart for developing a water recycling project

* The loop to ensure stakeholder support is not infinite. If stakeholder support cannot be ensured, the project either does not proceed or does so without complete stakeholder support.

For example:

- The *Guide to Environmental Impact Assessment* (EPA 2003a) points the way to a variety of other resources that proponents of water recycling schemes in Queensland may wish to use in their planning.
- The *Generic Terms of Reference for Environmental Impact Statements* (EPA 2003b) shows all of the issues that typically need to be considered in formal environmental impact statements.
- The guideline *Preparing Environmental Management Plans* (EPA 2003c) provides guidance on when and how to prepare an environmental management plan (EMP). An EMP may need to be prepared to comply with environmental impact assessment requirements or information requests under IDAS, to meet other regulatory requirements, or simply as part of a proposal's application information or as part of a proponent's environmental management system for the proposal or the business as a whole.

The EPA also has a number of information sheets available to assist project proponents who wish to use economic valuation tools as part of impact assessment. *Introduction to environmental economic valuation and its relationship to environmental impact assessment* (EPA 2003d) and *Techniques for environmental economic valuation* (EPA 2003e) are both available on the EPA website.

For recycled water projects that do not come under IDAS, impact assessment may be limited to that which is necessary to ensure that the proponent's general environmental duty is maintained and their project risks will be adequately managed. Appendix E has a checklist of issues that water recycling proponents may wish to consider during the planning phase of their project.

2.5.1 Health and environmental risk assessment

Risk assessment is generally an intrinsic part of environmental impact assessment. Ideally, a risk assessment for water recycling should be undertaken during the planning phase of a project so that significant hazards can be either "designed out" of a project or effective control can be "designed in". If risk assessment and management is left to the operational phase of a project, the costs of mitigation may be considerably higher than if they are considered during the planning phase.

The key concepts to understand in risk assessment for water recycling are as follows:

- A **hazard** is a biological, chemical, physical or radiological agent that has the potential to cause harm to people, animals, crops/plants, aquatic life, soils or the general environment.
- A **hazardous event** is an incident or situation that can lead to the presence of a hazard (what can happen and how).
- **Likelihood** is the probability of a hazardous event occurring.
- **Severity** is the consequence or outcome of the hazardous event.
- **Exposure** is the extent to which people, organisms or ecosystems come into contact with the hazard.
- **Risk** can be calculated by considering the combined likelihood and severity of identified hazards causing harm in exposed populations or receiving environments in a specified timeframe.

During the planning phase of a recycled water project it may be useful to conduct a *screening level risk assessment*. A typical screening level risk assessment for the use of recycled water would involve the following steps:

- **hazard identification**: identify the contaminants that are known to be present in the recycled water at concentrations that could cause harm to people or the environment
- **exposure assessment**: which, and how many, people, organisms or ecosystems are exposed to the above hazards, what are the exposure routes and for how long? (this assessment should include inadvertent or accidental exposure)
- **dose-response assessment**: how do people, organisms and ecosystems respond to the hazards? (i.e. what is the consequence of the exposure to the doses anticipated?)
- **risk characterisation and prioritisation**: based on the information gained from the above steps, how significant are the risks?
- **risk communication**: development of strategies to communicate the issues to the wider community and the stakeholders involved.

Outputs from this initial assessment could influence the design of the water recycling project and then feed into the development of the Recycled Water Management Plan for the project, as described in Chapter 4 of these guidelines.

The complexity of the initial risk assessment process should be in proportion to the scale of the risks themselves. If no data are available on dose or exposure, the assessment can be qualitative or semi-quantitative using estimates of risk from the scientific literature or the advice of experts. The Commonwealth Department of Health and Ageing (2002) has published comprehensive *Guidelines for Assessing Human Health Risks from Environmental Hazards*. These national guidelines present a general environmental health risk assessment methodology, compatible with World Health Organization (WHO) models, that is applicable to a range of environmental health hazards, including recycled water.

If a water recycling project is already in operation, a full risk assessment should still be undertaken during development of the Recycled Water Management Plan for the project.

3. Planning considerations: establishing partnerships and engaging stakeholders

One of the most important elements in a successful planning process for recycled water is the establishment of partnerships and appropriate engagement with stakeholders.

3.1 INTEGRATED WATER RESOURCE PLANNING

Planning for the use of recycled water should take into account all relevant aspects of the total water cycle. Thus, consideration of the use of recycled water should take place on an equal basis with all alternative ways of providing water services and with the involvement of all relevant stakeholders as part of an integrated planning process.

Least cost planning is an integrated resource planning tool that can be used by local governments and suppliers of water services. Least cost water planning involves evaluating the costs and benefits of a range of means of meeting water customers' demand for water related services. In particular, it can involve reducing demand for water through demand management (encouraging the community to use less water), leakage reduction and water use efficiency, as well as exploitation of alternative sources for water (harvesting of rainwater and stormwater and use of recycled water). The least cost approach to provision of water services therefore entails the optimal combination of these options together with orthodox approaches (exploitation of existing water supplies) to produce the best water resource management outcome for the least cost.

In Queensland the Department of Natural Resources and Mines helps to promote integrated water planning by water and sewerage service providers through implementation of Total Management Planning. Total Management Planning is the means by which a service provider brings together all urban water-related strategic and operational matters into a single summary document. The document usually covers aspects of water supply, sewerage and storm water ingress to the sewerage system. The development and approval of a Total Management Plan is central to local government's ability to obtain subsidies from the Department of Local Government, Planning, Sport and Recreation for water and sewerage infrastructure. Total Management Planning can promote the sustainability of water supply if it effectively integrates economic, social and environmental dimensions of water planning as part of the one planning process.

Under the Water Act the Minister for Natural Resources and Mines must plan for the allocation and sustainable management of water to meet Queensland's future water requirements, including water for the protection of natural ecosystems and the security of supply to water users. The Minister may achieve this through the preparation of a Water Resource Plan. The Water Resource Planning Process, led by the Department of Natural Resources and Mines, seeks to encourage the least possible uptake of surface and ground water through water use efficiency and demand management techniques. The planning process does not take consideration of the discharge of effluent to waterways, as recycling may increase over time as opportunities arise. Hence, STP effluent is not considered in the water allocation and management system designed to provide secure water entitlements.

3.2 COMMUNITY/STAKEHOLDER INVOLVEMENT IN PLANNING

Engagement with local communities and other parties affected by, or with an interest in, a water recycling proposal can be decisive in determining the level of support the proposal gains. The Queensland Government has published a range of documents to assist government agencies in undertaking community engagement activities, including:

- *Engaging Queenslanders: An Introduction to Community Engagement* (DPC 2003a)
- *Engaging Communities: A Guide to Engagement Methods for Practitioners* (Department of Communities 2005)
- *Engaging Queenslanders: Community Engagement in the Business of Government* (DPC 2003b)

These documents can be accessed on the *Department of Communities website*. The document *Engaging Communities: A Guide to Engagement Methods for Practitioners (Department of Communities 2005)* in particular has a comprehensive description of community engagement methods that may be used by proponents of water recycling schemes.

Although designed for Queensland Government agencies, the general principles of community engagement described in these documents can also be applied by other organisations such as local government, developers or industry.

3.2.1 Forms of community engagement in water recycling

There is no ideal type model for community engagement in water recycling. Different situations will require different solutions. The challenge for the proponent of a water recycling scheme is to choose the model that best fits the needs of their local community, their stakeholders and the resources they are able to devote to the process.

The Queensland Government recognises a continuum of three levels of community engagement (see diagram below):

- Information provision involves dissemination of information from the project proponent to the affected community and stakeholders. It is a one-way process.
- Consultation is a two-way relationship in which the water recycling proponent seeks and receives the views of communities and stakeholders on their proposal.
- Active participation accepts that members of the community and other stakeholders should have a role in making decisions about water recycling in their community.

Information ⟷ **Consultation** ⟷ **Active participation**

⟶

Increasing level of engagement and community influence

These three levels of engagement are not mutually exclusive as each may be used at different stages of the one project.

3.2.2 Issues to consider for community engagement in water recycling

The project proponent should decide on the appropriate level of community engagement early in the planning process. This will ensure the maximum opportunity for feedback and participation by community members in the planning process, and ensure appropriate notice is given for the proposal. But it is also important to remain flexible about engagement. If the needs of the community change during the engagement process or there is a change in the external environment, the project proponent should respond to that change accordingly.

Once engagement commences there are many possible techniques that can be used. *Engaging Communities: A Guide to Engagement Methods for Practitioners* (Department of Communities 2005) recommends that when deciding on an approach, the project proponent should consider such factors as:

- The objectives of the engagement process: this will influence the scope of the engagement and assist in weighing up the possible benefits and costs.
- The nature of the target community: whether it is geographic or industry-based community, a community of interest or some other form.
- What is the political environment: is there political support for the project or is it contested?
- What is the capacity of the community to influence the project? In other words, what decisions have already been made? It can be very damaging to raise expectations within a local community about their capacity to influence a project when such decisions have already been made.
- What resources are available to support the engagement process? Skilled facilitators and communications experts may be required, as well as extended time periods to enable the community to absorb information and consider their interests.
- Is there high-level commitment among the project proponents to the proposed community engagement approach? This commitment is required to guarantee resources are available and any difficulties encountered are appropriately managed.

There are also aspects of the community itself that can significantly influence the engagement process. These factors may be discovered through techniques such as community profiling or stakeholder segmentation that are designed to ensure that the appropriate messages go to each part of the community and key sub-groups are identified for more focused engagement, where necessary. Some of the community features that should be considered are:

- Demographic features, such as age, socio-economic mix, literacy levels and any cultural issues.
- Community preferences for engagement. This will vary within sub-groups and may depend on the issue under consideration. Wherever possible community preferences should be addressed.
- Previous experience with engagement. If a community has had some previous experience with engagement that has been either positive or negative this could affect their level of trust in the engagement process.
- Communities and sub-groups will vary in their capacity to participate in engagement activities. Key elements of community capacity for engagement relate to their level of knowledge of the issues being discussed, the

resources available to them (in particular, time), the skills to make a positive contribution (e.g. literacy or public speaking) and the infrastructure to participate (e.g. transport to communication venues or availability of child care).

- Existing engagement structures and processes. Where possible, any existing networks, committees or other community structures should be utilised to support engagement within the community.
- The nature and extent of the possible impact on, or benefit to, the community. The benefits and costs of water recycling may not be evenly shared within communities so it is important to identify which parts of the community are affected and in what way.

3.2.3 The engagement process in water recycling

The Queensland Government has adopted six guiding principles for community engagement. These principles should be used when selecting techniques for community engagement:

- Inclusiveness: ensuring that everyone who may be affected by the proposed changes has the opportunity to be engaged, while also ensuring that dominant groups are not the only ones that get a hearing.
- Reaching out: making the effort to engage with those in the community who may not traditionally participate in engagement activities. This may involve taking action to overcome barriers to engagement.
- Mutual respect: this involves acknowledging the importance of the community's contribution to project development; in other words that the project proponent is truly listening to the views of the community, not just talking.
- Integrity: maintaining honest, open communication is essential to ensuring trust within the community. There must be a willingness to follow through on any commitments made to the community and an assurance that the proponent will follow up and explain any changes that take place in project planning over time.
- Affirming diversity: this is to ensure that engagement processes are appropriate to all sub-groups within the community and do not exclude anyone on the basis of age, gender, disability or cultural background.
- Adding value: ensure that the engagement process builds capacity for future engagement activities and supports sustainable community outcomes.

3.2.4 Tools for community engagement

Apart from the supplier and user of recycled water, there are other key stakeholders who should be involved in integrated water resource planning (including water recycling):

- relevant government agencies (e.g. EPA, Queensland Health, Department of Natural Resources and Mines, Department of Primary Industries and Fisheries and local government)
- downstream communities or farmers who may be affected, favourably or unfavourably, by upstream changes to effluent discharges
- local residents whose property values, health or peace of mind may be affected by proposed water recycling schemes
- key community groups (e.g. catchment management groups) or peak industry bodies that can provide specific knowledge and also assist in educating the public and encouraging support for water recycling
- local politicians (who are likely to have a crucial role in decision-making)
- customers who will purchase or use commodities or services produced using recycled water (e.g. supermarkets or golf course users)
- workers who may be exposed to health risks from contact with recycled water.

Wherever possible, integrated water resource planning should involve all of these stakeholders. In order for local communities to be in a position to select the right options to ensure their water service needs are met, they should be provided with appropriate levels of information about the range of choices open to them. This inclusive process for decision making ensures that all parties likely to be affected by a proposed water recycling project are satisfied not just with the decisions taken regarding the proposed use, but also with the process that has led to that decision. Consultation that is limited to presenting local communities with a final decision about implementation of recycling may fail to gain broad acceptance.

There are many tools available for community engagement. These are discussed in detail in *Engaging Communities: A Guide to Engagement Methods for Practitioners* (Department of Communities 2005).

3.2.5 Feedback, evaluation and ongoing engagement

Whichever engagement technique is chosen it is essential to provide opportunities for feedback and follow-up, once the planned engagement process is completed. Feedback allows participants to verify that their concerns have been accurately represented when decisions are being made. Follow-up is particularly important when there are delays between the engagement process (e.g. during planning) and the commencement of the actual water recycling project. The best time to establish the protocols for feedback and follow-up is during the planning stage for the community engagement process.

Evaluation is an important way to identify the successful and unsuccessful elements of an engagement process. It can identify whether the engagement process met everyone's needs, contributed to more effective decision-making and whether it was cost effective. The publication *Engaging Queenslanders: Evaluating Community Engagement* (Department of Communities 2004) has been developed by the Department of Communities to provide advice on evaluating community engagement activities. It provides advice on data collection tools, interpreting and analysing data and ensuring evaluation outcomes contribute to future planning and decision-making.

The significance of water recycling within a community does not end with the successful implementation of a scheme. It can be valuable for scheme proponents to establish an ongoing relationship with key stakeholders, including members of the local community, via a contact or liaison group, so that any emerging issues or concerns can be dealt with on a cooperative basis before any conflict develops. At a minimum this should include recycled water suppliers and users but could also involve neighbouring landholders, regulators and customers who use products or services that have recycled water as an input.

3.3 PARTICIPATION OF GOVERNMENT AGENCIES IN PLANNING

Regulators have an important role to play in planning by encouraging water recycling as a means for reducing discharges to waterways and by participating in Total Management Planning undertaken by water and sewerage service providers. Government agencies also have a statutory role to play in the Integrated Development Approval System (see section 2.1.2 of these guidelines).

Appendix D contains contact details for state government agencies that provide advice on water recycling in Queensland. Although the EPA is the lead agency for proponents of water recycling schemes, it is essential for EPA licensing officers to refer any proposals for water recycling that have the potential to impact on public health to the appropriate regional office of Queensland Health.

3.4 PLANNING CONSIDERATIONS FOR SUPPLIERS AND USERS OF RECYCLED WATER

While planning for recycled water schemes should take place within an integrated water resource planning framework, there are still specific planning issues that should be considered before particular recycled water applications are implemented.

3.5 ENSURING RELIABLE DEMAND FOR RECYCLED WATER

Multiple use of water can represent an important business opportunity both within existing enterprises that use significant amounts of water and for all other potential users of non-drinking water.

Notwithstanding this, recycled water suppliers should still ensure that they have confidence about potential markets for their recycled water before committing to development of water recycling schemes. There are a number of ways of achieving this. One way for local government to ensure reliable markets for recycled water is to encourage clustering of intensive users of recycled water (e.g. industrial developments, plant nurseries or turf farms) in close proximity to the sources of recycled water, such as STPs. This approach reduces the establishment and running costs of infrastructure and increases the reliability of markets for recycled water.

3.6 SUBSIDIES FOR RECYCLED WATER SCHEMES

Subsidies are available to local governing bodies that could assist with the cost of infrastructure to support water recycling. These are administered by the Department of Local Government, Planning, Sport and Recreation, which should be consulted for further information (see contact details in Appendix D).

3.7 PRICING OF RECYCLED WATER

To ensure financial viability of the recycled water project, a price for recycled water that reflects both the value of the resource and the capital and operating costs of the project should be considered. Further discussion of options for pricing of recycled water is contained in the EPA's *Manual for Recycled Water Agreements in Queensland* (EPA 2005b).

3.8 PLANNING CONSIDERATIONS FOR SMALLER SCHEMES

The scale of planning activities undertaken should be appropriate to the scale of the proposed development. For example, an STP that supplies recycled water to a neighbouring turf farmer located well away from urban development could be expected to require less detailed planning inputs than a major dual reticulation scheme serving many customers. Thus, for a small water recycling scheme, if the flow chart shown in Figure 2.1 is followed, no requirement for development approval exists and no stakeholder objections are encountered, then the process may be relatively short and simple.

Before committing to water recycling, potential users of recycled water should also consider what water savings could be achieved through discretionary measures such as water use efficiency or utilisation of alternative sources. For example, harvesting of roof water and storage in rainwater tanks may have advantages over water recycling from treated municipal effluent owing to simpler treatment and management issues.

3.9 RECYCLED WATER AGREEMENTS

With the exception of dual reticulation supplies (see below), whenever a recycled water producer supplies another person or organisation with recycled water, the two parties should negotiate a formal agreement regulating their relationship. In Queensland this Recycled Water Agreement is often referred to as a *Third Party Agreement* to indicate that it involves a party (the user) who is not bound by the existing development approval for the activity that produces the recycled water (the first and second parties being the EPA and the treatment plant operator). However, not all Recycled Water Agreements will be between "third parties" and the holder of a development approval.

A Recycled Water Agreement should be entered into freely by each party and should specify their respective obligations and responsibilities with respect to the supply and use of recycled water. Although the content of these agreements will be negotiated between the parties, they should have several key features:

- They should describe how and for what purposes the recycled water is to be used, and any uses that are specifically excluded.
- They should emphasise that water recycling is a partnership between the supplier and the user.
- In the event of dispute, they should facilitate joint problem solving rather than sanctions.

The EPA has published a *Manual for Recycled Water Agreements* (EPA 2005b) and associated *Model Recycled Water Agreement* (EPA 2005c) containing a set of model clauses that may be used by recycled water suppliers and users to design their own Recycled Water Agreements that best suit their circumstances.

3.9.1 Terms and conditions of supply for users of dual reticulation

It would not generally be practical to negotiate Recycled Water Agreements for recycled water systems that have large numbers of customers, as would be the case with dual reticulation systems delivering recycled water from advanced water recycling plants. The best approach for this form of reuse is for the recycled water supplier to present each customer with a "Terms of Use" document containing the conditions under which the recycled water will be supplied. This will specify the obligations of the supplier and the responsibilities of the customer to ensure safe use of the product. The user accepts these terms and conditions by using the recycled water supplied and paying the appropriate tariff.

The supplier should also have a system to ensure that whenever a property changes ownership or a rental property is re-tenanted, the new owner or tenant is fully informed of the supplier's responsibilities and the user's obligations in using recycled water. Local government could ensure that new owners are alerted to the supply of recycled water to their property via an annotation to the local government rates database. For rental properties, the terms and conditions of supply of recycled water should be appended to the rental lease.

3.10 COMMITMENT TO RESPONSIBLE USE AND MANAGEMENT OF RECYCLED WATER QUALITY

The sustainable use of recycled water requires clear allocation of responsibilities for protection of public and environmental health. Acceptance of these responsibilities by all relevant parties can be formalised through development of a recycled water policy.

3.10.1 Responsible use of recycled water

During both planning for and operation of water recycling schemes, it is essential that appropriate responsibility is allocated and accepted by the relevant parties, for every element of the scheme that could lead to risks to public or environmental health.

3.10.2 Responsibilities of government agencies

Employees of government agencies, at both the state and local level, need to be familiar with the legal basis for water recycling (see Chapter 2 of these guidelines), and the Queensland Government's policies that support water recycling, largely contained in the *Queensland Water Recycling Strategy* (EPA 2001). They should also take account of the advice provided by these guidelines.

EPA officers involved in development approvals for persons undertaking the ERA of sewage treatment that supply water recycling schemes should also be familiar with any relevant EPA administrative guidelines that exist for water recycling. The EPP Water also contains a specific requirement for EPA officers making environmental management decisions about activities involving water recycling to consider the water quality objectives for waters affected by the recycling as well as the maintenance of acceptable health risks. EPA officers are also required by the EPP Water to take appropriate account of the *waste hierarchy* (outlined in the Environmental Protection (Waste Management) Policy) by encouraging, first of all, waste prevention (e.g. by reducing the contaminants in trade waste), then reuse and recycling, and only then disposal to land or water.

EPA officers involved in any application to modify an existing STP licence or development approval to permit water recycling, or a proposal for a new water recycling scheme, must have confidence in the capability of the existing or proposed treatment system to reliably and consistently deliver recycled water that is fit for the purpose for which it is intended. If the user applies additional treatment (e.g. extended lagoon storage to achieve additional virus reduction) this should also be taken into account when assessing the treatment capability of the system.

For existing STPs, evidence of consistent performance could include:

- monitoring results that indicate achievement of the water quality standards appropriate to the class of recycled water being supplied (see Tables 6.2a and 6.2b)
- evidence of management systems comprising quality assurance and quality control that are capable of ensuring the reliable production of quality recycled water (e.g. a Recycled Water Management Plan prepared in accordance with these guidelines)
- evidence that management systems are capable of dealing with non-conformances or system failures
- evidence that the personnel who will manage the production and use of the recycled water have the technical capability to run the system successfully.

EPA officers who assess new water recycling proposals will require the following information from proponents:

- evidence (e.g. in terms of hydraulic loading rates, substitution for current use of potable water or economic benefit from cropping or pasture production) that the proposal involves beneficial reuse and is not intended primarily to avoid discharge to a water body
- evidence that the proposed treatment process is capable of delivering the performance required to ensure delivery of recycled water to specification
- a draft Recycled Water Management Plan, or other equivalent plan, that includes risk assessment, quality assurance, and procedures for dealing with system management
- plans for training of personnel who will be involved in management of the system.

Regulators in EPA and local government must ensure that proposed water recycling schemes having the potential to affect public health are referred to the local office of Queensland Health for their advice.

As it is Queensland Government policy to encourage and support water recycling that is safe and cost-effective, all regulators have a duty to work with suppliers and users, and with one another, to facilitate this to the greatest extent practicable.

3.10.3 Responsibilities of suppliers of recycled water

In general terms, suppliers of recycled water have a responsibility to:

- supply recycled water that is fit for its intended purpose. To achieve this, they should have in place infrastructure, management systems and monitoring programs that will ensure effective management of trade waste discharges, operation of treatment facilities and delivery of water of a quality fit for its intended use
- provide each user with all "relevant information" about the recycled water, as required by the Workplace Health and Safety Act (see section 2.1.7 of these guidelines). This will include information about the quality of the recycled water
- negotiate a Recycled Water Agreement with each person using their recycled water, or provide terms and conditions of use for users of recycled water from dual reticulation schemes (see section 3.9 of these guidelines)
- keep to the terms of the Recycled Water Agreement
- ensure that the entire system for producing and using the recycled water, including each site where recycled water is used, is covered by a Recycled Water Management Plan, or equivalent site-based management plan or irrigation management plan, that incorporates risk assessment
- alert each user, as soon as practicable, of any problems relating to recycled water quality or supply
- respond appropriately to any misuse of recycled water by the user that they become aware of. This could include notification to the EPA or termination of the supply of recycled water to that user
- provide all relevant information to each user that is required for the user to develop their component of the Recycled Water Management Plan or equivalent management plan.

Water service providers registered under the Water Act (including providers of recycled water) also have certain responsibilities relating to asset management planning, reporting and customer service standards that are spelt out in the Water Act, unless exempted.

3.10.4 Responsibilities of commercial users of recycled water

Users of recycled water, other than domestic users connected to a dual reticulation scheme, have a responsibility to:

- protect the health and safety of employees, contractors and site visitors
- adhere to the terms of the Recycled Water Agreement entered into with the supplier
- produce and maintain management systems comprising well-documented work and emergency procedures (e.g. as part of a Recycled Water Management Plan)
- provide their employees with appropriate and up to date training (including personal hygiene when working with recycled water) so that employees can work safely and responsibly
- provide their employees with appropriate personal protective equipment as determined by their Recycled Water Management Plan
- maintain their equipment so that it operates safety
- provide appropriate signs to inform employees and visitors of the use of recycled water
- audit implementation of their Recycled Water Management Plan regularly
- notify the EPA if they become aware of any actual or potential serious or material environmental harm resulting from their use of recycled water (in accordance with the requirements of the Environmental Protection Act).

Queensland Workplace Health and Safety (a division within the Department of Industrial Relations) will produce a document on the safe workplace use of recycled water. Contact details for Queensland Workplace Health and Safety are shown in Appendix D. When this document is available a link will be placed on the EPA website.

3.10.5 Responsibilities of domestic users of recycled water

The responsibilities of domestic users of recycled water supplied by Council or other provider of recycled water services are to:

- only use recycled water in accordance with the terms and conditions or other guidance provided by their recycled water supplier

- ensure that visitors and family members are aware of the use of recycled water and all relevant measures for safe use
- ensure that they do not waste recycled water or use it inefficiently
- ensure that the recycled water applied to their garden does not leave their property as runoff or as spray drift.

3.11 RECYCLED WATER POLICY

A recycled water policy is essentially a way to document the commitment of an organisation and its members to the responsible management of recycled water and communicate this to others. The draft National Guidelines for Water Recycling (NRMMC & EPHC 2005) recommend that a recycled water policy should address the following issues:

- commitment to responsible use of recycled water
- commitment to application of a risk management approach
- recognition and compliance with relevant regulations and other requirements
- communication and partnership with agencies with relevant expertise including water suppliers, primary industry departments, health departments, environment protection authorities and other regulators
- communication and partnership arrangements with users of recycled water (e.g. farmers, local government, operators of sports facilities and recreational parks, industry, firefighters)
- communication and engagement with employees, contractors, stakeholders and the public
- intention to adopt best practice management, including the *multiple barrier approach* to water quality (see Chapter 4 of these guidelines).
- continual improvement in the management of recycled water treatment, use and application.

The recycled water policy must be communicated to, and accepted by, all parties with responsibilities under the recycled water management system, including contractors.

4. Recycled Water Management Plans

Risk management is playing an increasingly important role in the water industry. The 2004 *Australian Drinking Water Guidelines* (NHMRC & NRMMC 2004) apply a risk management approach to production of drinking water in Australia, as does the third edition of the World Health Organization's *Guidelines for Drinking Water Quality* (WHO 2004).

In these guidelines, the term Recycled Water Management Plan has been used to describe a documented system for the management and use of recycled water. While this plan is not a necessary condition for safe water recycling, the full implementation of a risk-based Recycled Water Management Plan is more likely to ensure safe water recycling than not. Alternative approaches to risk management may be used, as long as they comprehensively address all significant risks in the production and use of recycled water.

It is recommended that Recycled Water Management Plans should be completed for all water recycling projects in Queensland. If the proponent of a water recycling scheme is unsure of the need for, or potential scope of, a Recycled Water Management Plan, they should discuss their proposal with the appropriate regional office of the EPA or Queensland Health.

Many recycled water suppliers will already be operating under an existing management system, such as an ISO 9000-style quality management system or an ISO 14001-style environmental management system. Equally, many existing users of recycled water will already have in place a site-based environmental management plan or irrigation management plan. In these cases, suppliers and users of recycled water may choose to add those elements of the risk management process outlined in these guidelines to their existing plans. Where there is no existing management system or plan, the Recycled Water Management Plan, with its associated supporting programs, would provide the operating framework for the entire water recycling scheme.

It is better to prevent hazardous events from occurring than to mitigate their impacts after they have occurred. A key element in the prevention of hazards in water recycling is the *multiple barrier approach*. This approach is well established in Australia as a means of protecting drinking water quality (see *Australian Drinking Water Guidelines* (NHMRC & NRMMC 2004)) and is readily applied to recycled water.

The application of the multiple barrier approach through the Recycled Water Management Plan should embrace every stage in the production and use of recycled water. This will include:

- source control
- treatment
- disinfection
- transport
- storage
- use (including both on-site and off-site health and environmental impacts).

This is because hazardous events can occur during each of these stages. In those cases where the supplier and user of recycled water are different entities, it may be necessary to prepare separate Recycled Water Management Plans. However, care should be taken to ensure that the hazard analysis includes all relevant stages listed above.

The risk management approach contained in these guidelines is based on the draft National Guidelines for Water Recycling (NRMMC & EPHC 2005), *AS/NZS 4360:1999 Risk Management* and the HACCP (Hazard Analysis and Critical Control Point) system (CAC 1997).

Figure 4.1 shows each of the stages in developing a Recycled Water Management Plan. While these stages are not necessarily sequential, they should all be followed to guarantee the comprehensiveness of the plan. The following chapters contain information on sewage treatment and storage, distribution and use of recycled water that can provide an input into the risk assessment process described in this chapter.

4.1 ASSEMBLE THE RISK ASSESSMENT TEAM

Once all statutory and other planning requirements have been satisfied, the Recycled Water Management Plan team can be formed. Members of this team will have the job of developing, verifying and implementing the Recycled Water Management Plan. The size of the team and the skills required will depend on the complexity of the recycled water treatment and distribution system and the sensitivity of the planned uses.

The multi-disciplinary team could comprise personnel from the following areas: operations, maintenance, quality control, customer service, laboratory staff, as well as external consultants, regulators and users. At least one member of the team should have received training in risk management. Before the risk management process begins, all of the remaining members should receive at least an introduction to how the risk management process for water recycling works.

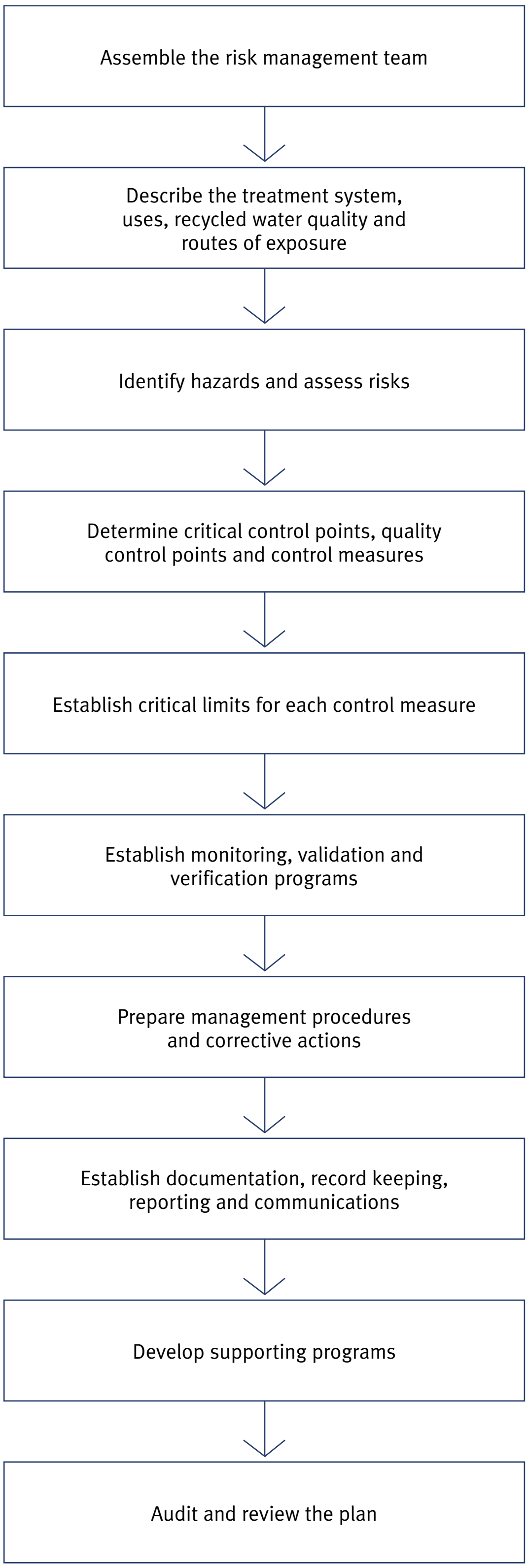

Figure 4.1. The steps in developing a Recycled Water Management Plan (adapted from WHO 2004 and NRMMC & EPHC 2005).

4.2 DOCUMENT AND CONFIRM THE SYSTEM

In order for all potential hazards from use of recycled water to be identified, and either removed or mitigated, it is essential for proponents of water recycling schemes to have a thorough documented knowledge of the entire water recycling system, from source to end use.

The risk assessment team must therefore construct a flow diagram that clearly indicates all of the steps in the production and use of the recycled water. The diagram must show when and where the supplier's responsibility starts and ends, and when and where the users' responsibility starts and ends. Steps prior to and after each organisation's direct responsibility should also be included.

This process of documenting the recycled water system should be carried out by persons who have an appropriately detailed knowledge of the system and of the current or proposed end uses. Elements mapped should include:

- all inputs to the source water (in the case of domestic customers, this can be generic, but for licensed trade waste discharges, specific locations should be identified)
- pipe networks and pumping stations for transport of sewage
- treatment systems for sewage and advanced treatment of recycled water
- storage and distribution systems for recycled water
- current and planned end use locations
- products (e.g. irrigated food crops or industrial products)
- receiving environments (including, for irrigation applications, soils, ground water or receiving waterways).

Once the flow diagram has been developed the risk assessment team should confirm that it is both complete and accurate, as it will be used later in the hazard analysis. The best validation is for team members to actually walk through and observe each process in the system, including reuse. If the final reuse system is not yet set up, those who will be running the system can validate the flow diagram at the desktop level. Once constructed, the entire system should be validated again to ensure the accuracy of the flow diagram.

This information should be stored in a format (e.g. a map, geographic information system, flow diagram) that is most useful to the water recycling scheme operators, and reviewed periodically to reflect any changes to the system.

Also, a full description of the recycled water product should be documented. While it is difficult to specify all chemical and biological contaminants that may be found in raw sewage or even well treated effluent, all existing information about the composition of both should be assembled and analysed for evidence of trends or specific hazards that may influence the final quality of the recycled water. This should include the potential effect on treatment systems of hazardous events such as storms, power outages or illegal dumping of contaminants into the sewer, all of which may affect the quality of the final product water. As water quality is inherently variable, comprehensive information about the variability of the final recycled water quality should also be provided, if it is available. This may include data not just on means and medians, but also maxima, minima and 95th percentile values. As noted in section 2.1.7 of these guidelines, to comply with the Workplace Health and Safety Act, suppliers of recycled water should provide their customers with all relevant information about possible chemical and biological contaminants in recycled water that could cause harm to human health as a result of the use of the recycled water.

The development of a Recycled Water Management Plan requires detailed knowledge of the intended uses for the recycled water. This will include who the expected users will be (e.g. farm workers, golf course superintendents, householders), who else may be exposed (e.g. neighbours, golf course users, consumers of produce irrigated with recycled water), and any likely contact between the recycled water and the natural environment (e.g. runoff to waterways, contact with aquatic life or water birds, percolation to ground water or through soils).

4.3 IDENTIFY HAZARDS AND ASSESS RISKS

Where a risk assessment has already been completed as part of the planning process for a water recycling scheme, the information assembled can be used in developing the Recycled Water Management Plan. However, risk assessments must be kept up to date and so any assessments undertaken during planning should be updated following final design or construction.

The method used to identify and assess hazards must be structured, consistent and comprehensive. During development of a Recycled Water Management Plan, hazard identification and risk assessment could involve the following steps:

- Identify hazardous contaminants: this information will mainly come from the previously completed assessment of recycled water quality, but additional contaminants may be added during treatment or produced as a result of disinfection. For example, where chlorine is added to recycled water to provide residual disinfection in a piped distribution system, this could present a hazard to certain sensitive crops.
- Identify sources for these contaminants: knowledge of the source may help in assessing the risk and suitable control strategies. For example, if hazardous levels of heavy metals only occur intermittently in the raw sewage, this may be from a single trade waste customer who may be able to take action on site to reduce or eliminate the discharge.
- Identify the hazardous events that could lead to exposure of humans or the environment to the identified hazards. The events considered should include inadvertent and unauthorised uses of recycled water, because this will assist in designing control measures to prevent these uses.
- Determine and rank the risks. There are a number of potential qualitative and semi-qualitative risk ranking methods that could be used for this, including simply using expert judgement. Tables 4.1 to 4.3 use qualitative measures of impact and likelihood adapted from *AS/NZS 4360:1999 Risk Management*. Table 4.1 can be used to consider the impact or severity of each hazardous event (both in terms of the nature of the impact and its extent or scale). Table 4.2 considers the likelihood of each hazardous event. Table 4.3 can be used to calculate the overall risk from each event. From this, a priority ranking of hazardous events can be developed. As the significance of a hazardous event can be influenced by the nature of the control measures applied, the risk assessment process should be run using both maximum risk (assuming no control measures) and residual risk (assuming control measures are in place).

A significant hazard must be removed or reduced to an acceptable level to ensure the safe production and use of recycled water.

Each risk management team should determine the cut-off threshold for significance. For example, risks that scored *low* may not require mitigation in the short term, but only a "watching brief" involving occasional monitoring or visual inspections. Risks that score v*ery high* or *high* would require regular monitoring and appropriate control measures to reduce the risks to acceptable levels. These risks are likely to occur at *critical control points* in the process of production or use of recycled water.

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

4.4 DETERMINE CRITICAL CONTROL POINTS, QUALITY CONTROL POINTS AND CONTROL MEASURES

A critical control point is a point, step or procedure at which control can be applied and is essential to prevent a hazard or reduce it to acceptable levels. A quality control point is a process step that, while important, is not critical to maintaining product quality, cannot usually be monitored online or in a timely fashion, or is not under the direct control of the treatment plant or user. A control measure (also known as a preventive measure) is any action or activity that can be used to prevent or eliminate a hazard or reduce it to an acceptable level. The flow chart shown in Figure 4.2 may be used to determine if a process step is a critical control point. However, the decision tree is only a guide. Other decision trees could be used, or the risk management team can rely solely on the expert judgement of the group. The essential requirement is to have a consistent, logical and transparent process in place.

During the hazard identification phase of the risk assessment process, all of the biological, chemical and physical hazards in the production and use of recycled water will have been identified and each of the process steps will have been documented. Examples of processes that may qualify as critical control points in an advanced water recycling plant would be:

- Where ultraviolet radiation (UV) is used to disinfect recycled water, turbidity levels after treatment could be a critical control point (CCP) as turbidity affects UV transmissivity.
- Disinfection residual could be a CCP to prevent regrowth of bacteria within a lengthy reticulation system.
- Cross-connection control is likely to be a CCP in dual reticulation systems so implementing backflow prevention to prevent accidental ingestion of recycled water would be an appropriate control measure.

Examples of quality control points would be trade waste agreements or runoff control from a recycled water irrigation site. In most cases there should be fewer critical control points than quality control points.

4.5 ESTABLISH CRITICAL LIMITS FOR EACH CONTROL MEASURE

A critical limit is the maximum or minimum value to which a physical, biological or chemical hazard must be controlled at a critical control point to prevent, or reduce to an acceptable level, the occurrence of a hazard. A critical limit defines the cut-off to ensure recycled water safety. If a critical limit is not met then the hazard is not controlled and corrective action must be taken.

A critical limit will usually be a physical reading such as turbidity or UV intensity; a time, e.g. for chlorine contact during disinfection; or a chemical property, such as available chlorine or salinity. Critical limits should be exact values: a range is not acceptable. Critical limits may be derived from regulatory requirements (e.g. an existing development approval), from the technical literature or expert advice (e.g. chlorine contact time) or specified in treatment plant documentation (e.g. UV dose). Critical limits must be established for each control measure applied at a critical control point.

It can be useful to establish a target level for each CCP slightly below the critical limit so that early warning can be given of potential exceedances of critical limits, and appropriate control measures implemented before the product water goes out of specification.

4.6 ESTABLISH MONITORING, VALIDATION AND VERIFICATION PROGRAMS

Monitoring programs are used to:

- establish baseline conditions before a water recycling project commences
- validate that technology works and management systems are capable of ensuring project safety
- check the day to day operation of a recycled water scheme to ensure critical limits are complied with
- verify ongoing achievement of required recycled water quality and environmental safeguards
- comply with any statuary obligations imposed on the water recycling scheme by a development approval.

4.6.1 Baseline monitoring

Baseline monitoring is mainly applied to environmental receptors such as soils, receiving water quality and vegetation health, but could also be applied to human health impacts if the planned use of recycled water poses significantly high risks to human health.

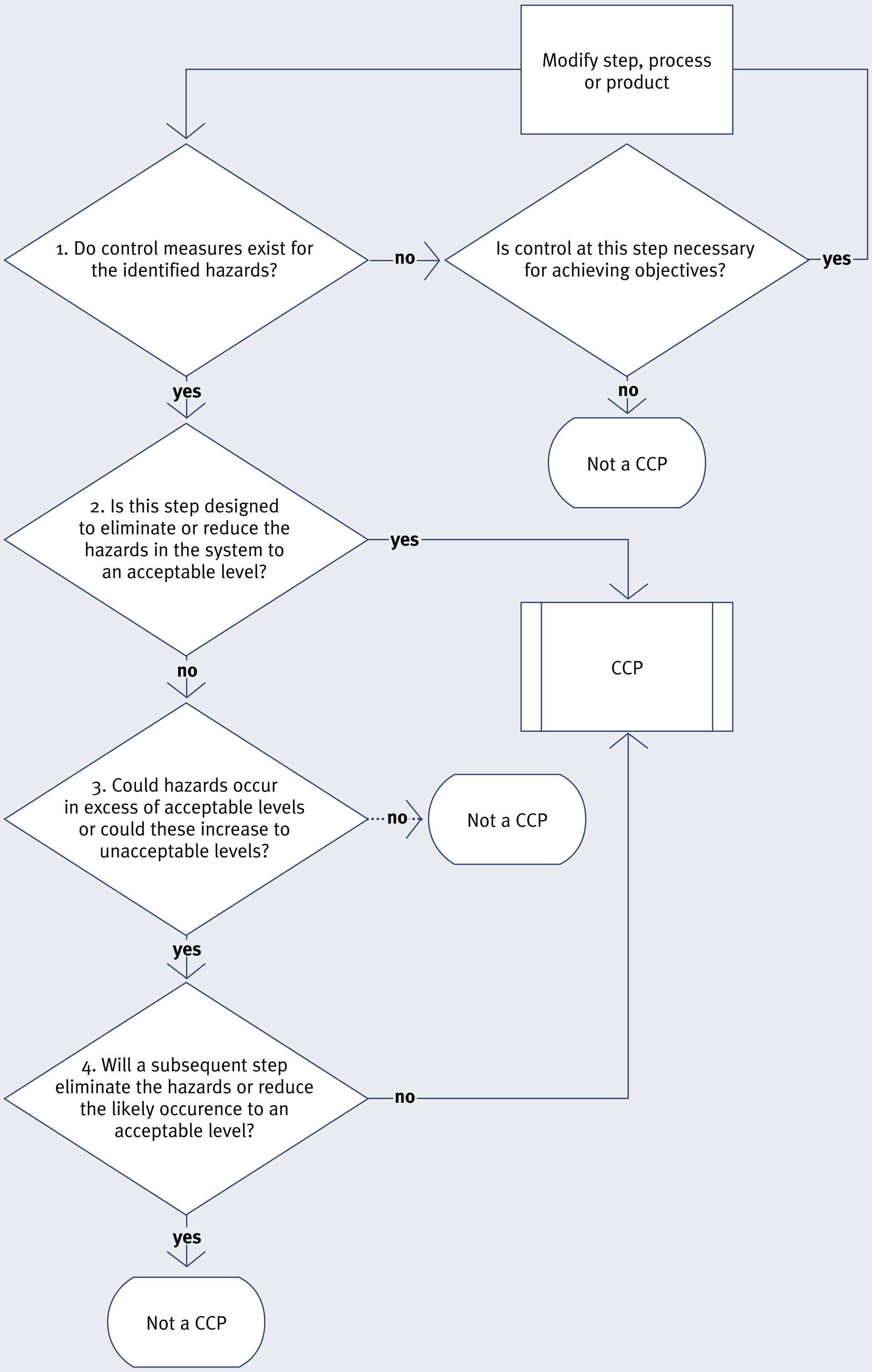

Figure 4.2. Determination of critical control points

Once the risk assessment has determined which risks need to be monitored and controlled, a baseline monitoring program should be established to check for any quantifiable changes in the environment or human health that could be linked to recycled water use. This is important as environmental or health indicators may already be elevated owing to pre-existing impacts and so critical limits for hazards may need to be set at a specified margin above the recorded baseline level (e.g. a 20% increase above the baseline).

4.6.2 Validate processes, including research and development

Validation involves investigating the effectiveness of control measures in reducing the risk posed by hazards or hazardous events. This can be achieved by obtaining evidence on the performance of control measures and ensuring that the information supporting the Recycled Water Management Plan is correct.

Validation has an important role to play during establishment of a recycled water scheme. For example, during the commissioning phase for a new recycled water treatment plant, or an existing STP that is to commence supply to a new recycled water use, it will be necessary for the treatment plant operator to demonstrate the capability of the plant to consistently produce recycled water of the quality required for the planned uses. Validation requirements for production of Class A+ recycled water are discussed further in section 6.6.1.

If there is insufficient knowledge of the effectiveness or reliability of the treatment plant to maintain recycled water quality within critical limits, or if the impact of contaminants in irrigation water on the receiving environment are unknown, there may be a need to undertake formal investigations or research. For example, if there is concern about the possible input of harmful contaminants into the sewage collection system, sampling and analysis of trade waste discharges may need to be undertaken to identify the source of contaminants and possible non-conformances with trade waste agreements.

Validation is also required whenever new processes or equipment are introduced or when significant changes to recycled water uses take place.

4.6.3 Conduct operational monitoring

During the production and use of recycled water, operational monitoring is performed to check the performance or implementation of control measures. It is designed to identify both non-conformances with target criteria as well as trends that may indicate a decline in system performance.

All critical limits have associated process monitoring activities to ensure that the critical limit is complied with. If monitoring indicates that the critical limit has not been met, then corrective action must be taken.

The method and frequency of monitoring for each critical limit must be specified and recorded. For the purpose of operational monitoring, continuous or online monitoring is preferable to discrete or grab sampling. If non-continuous monitoring is used, the risk management team will have to ensure that sampling takes place often enough to be sure that the process is under control. A notable exception to this would be where disinfection of recycled water is achieved through extended lagooning. As the residence time in the lagoon may be days or weeks, this provides the opportunity for microbiological monitoring, with its inherent time delays, to still have a role in verifying disinfection effectiveness.

Passive samplers are devices that remain *in situ* at a water quality sampling point, concentrating ambient contaminants over a period of time. Passive samplers are able to concentrate the analyte so that water analysts can identify contaminants using mass spectrometry techniques. They are able to detect contaminants at the ultra trace level that cannot otherwise be readily identified. Passive sampling is unlikely to provide information that can be used to monitor a critical control point, but could be useful at a quality control point to assess whether the recycled water has trace contaminants at levels that could present long-term risks to the environment or human health.

When monitoring indicates that there has been a deviation from a critical limit, corrective action will need to be applied at some point in the production, distribution or delivery system for the recycled water. If monitoring is not continuous, this corrective action (e.g. re-treating or disposing of the water) will have to be applied to all of the non-complying recycled water produced since the last sample was taken.

The particular parameters that are selected for monitoring will be determined by the hazard analysis and from a detailed knowledge of each step in the production and use of recycled water. Some of these parameters will be critical to the safety of the system, and thus will need to be monitored at critical control points, while others (generally quality control points) will be more routine, and thus provide backup information on the operation of the system.

Operational monitoring does not just encompass treatment indicators; it should also include aspects of the reuse system that require regular checking to ensure control measures are being applied. This could include the water quality in any storages in the system or aspects of the user's site-based management plan, such as irrigation timing, control of access, or signage.

4.6.4 Verify recycled water quality

Verification is the use of methods, procedures, or tests to determine if the required recycled water quality is being delivered. It also confirms that the Recycled Water Management Plan is being followed and that identified hazards, control measures and critical limits are appropriate.

Recycled water quality monitoring verifies that the control measures implemented during treatment and use are working to protect public and environmental health. Where the hazard identification and risk assessment has identified contaminants that could pose a risk to the safe use of recycled water, the level of these contaminants in the recycled water should then be monitored as part of the monitoring program for the Recycled Water Management Plan.

Frequency of testing for contaminants will depend on the variability of the parameter itself. Sampling should be frequent enough to identify adverse trends in the data. If the data are to be analysed, the sampling frequency should be sufficient to ensure statistical validity.

Parameters that are important in ensuring the safety of the final use of the recycled water, for example, the chlorine residual, should be monitored as close as practicable to the point of supply to the user, particularly if they can change during residence time in the distribution system. Specific advice on monitoring for production of Class A+ recycled water is found in section 6.6 of these guidelines.

4.6.5 Site and environmental monitoring

As noted in section 4.6.1, baseline monitoring is important to establish existing environmental conditions at sites where recycled water is used for irrigation or introduced directly or indirectly into surface or ground water. Ongoing environmental monitoring would then be used to verify the effectiveness of control measures in preventing environmental impacts or to comply with development approval conditions.

Environmental receptors that may require monitoring include crop or other vegetation health, soil structure, ground water levels, ground and surface water quality and aquatic ecology. Selection of environmental parameters for monitoring should take place on the basis of an appropriate consideration of their risk ranking, as discussed in section 4.3.

In general terms, the monitoring program should be appropriate to the scale of the water recycling scheme, reflect the intended uses of the recycled water, be developed in consultation with key stakeholders (including regulators) and adjusted to reflect the environmental performance of the scheme. In other words, if critical limits are regularly exceeded, the frequency of sampling should be increased; if critical limits are never exceeded, frequency could be reduced.

4.6.6 Quality control and quality assurance

All monitoring for recycled water schemes should be undertaken within a quality assurance/quality control (QA/QC) framework.

QC is the implementation of procedures to maximise the integrity of monitoring data and includes procedures for proper collection, handling and storage of samples, replicate sampling, inspection and calibration of equipment, analysis of blank or spiked samples, and use of standards or reference materials. QA is the implementation of checks on the success of the QC and includes management activities, training, validation of data, and auditing of laboratory and data analysis and management (ANZECC & ARMCANZ 2000a).

All sampling protocols used, and monitoring programs undertaken, during the production and use of recycled water should take place in accordance with either of the following publications: *Australian Guidelines For Water Quality Monitoring And Reporting* (ANZECC & ARMCANZ 2000b) or *Water Quality Sampling Manual* (EPA 1999). Appropriately trained personnel should collect all samples. A laboratory accredited for the specified tests by an independent body acceptable to Queensland Health for human health parameters or EPA for environmental parameters (such as the National Association of Testing Authorities (NATA) or equivalent) should carry out all analyses. Test results should be made available to Queensland Health or EPA upon request. Further information on industry standard analytical methods can be found in *Standard Methods for the Examination of Water and Wastewater* (APHA 1998).

When measuring equipment is used to monitor a process to ensure valid results, the equipment should be calibrated or verified at specified intervals, or prior to use, against national or international measurement standards. If no standards exist, the basis used for calibration should be recorded.

4.6.7 Feedback on recycled water user satisfaction

Verification monitoring should also include formal processes for obtaining feedback on the satisfaction of the recycled water user with the quality and reliability of the final product. Any complaints about recycled water quality or reliability should be recorded and an appropriate response generated. If necessary, a corrective action should be initiated to ensure customer satisfaction in accordance with the appropriate clause in the Recycled Water Agreement or, in the case of a dual reticulation system, the terms of use document.

4.7 PREPARE MANAGEMENT PROCEDURES, INCLUDING CORRECTIVE ACTIONS

The ongoing safety of a water recycling scheme can only be assured if there are clear, documented operating procedures. Each written procedure should contain the following information:

- the purpose of the procedure (in terms of the risk controlled or eliminated)
- who is responsible for maintaining the procedure (i.e. who is responsible for updating the procedure and ensuring its ongoing relevance, including managers who are responsible for the regular review of procedures)
- what tasks must be performed under the procedure, when and by whom: this will include relevant operational employees and supervisors
- which parameters must be monitored including, where relevant, critical limits for each parameter
- record keeping requirements for each procedure
- corrective actions in the event of a non-conformance with the procedure or any critical limits identified in the procedure.

Procedures should be developed for each process step or significant risk; in other words, for every activity that is necessary for the safe operation of the system. This will include routine maintenance, corrective actions and emergency response.

4.7.1 Non-conformances and corrective actions

A non-conformance is a failure to meet a critical limit or any other situation (e.g. customer complaint) defined as a non-conformance within the Recycled Water Management Plan. Corrective actions are the procedures to be followed when a non-conformance occurs. An important purpose of corrective actions is to prevent recycled water that may contain hazards from reaching users or being used in a way that may harm the environment. Corrective actions should determine and correct the cause of non-conformance, determine the status of non-conforming water or non-conforming uses of the water, and record the corrective actions that have been taken. The corrective action procedure must identify what must be done, who is responsible, and what records must be completed in the event that a non-conformance occurs.

Examples of corrective actions could be to cease supply of recycled water to a customer, to retreat water to ensure appropriate disinfection, or to provide an alternative water supply while the recycled water is brought back into conformance. This form of corrective action should be covered by a *traceability and product recall* procedure within the Recycled Water Management Plan. The recall process for recycled water should also include provisions for flushing, and in the case of microbiological contamination, disinfection of mains that may have been affected by non-conforming water.

In discussing management response to non-conformances with critical limits, a distinction needs to be made between process indicators and indicators of final water quality. Data that are collected continuously are generally indicators of process effectiveness and it is appropriate to initiate an immediate response to any non-conformances in accordance with the Recycled Water Management Plan. For these parameters, e.g. turbidity, alarm systems should be activated when guideline values are exceeded. There should also be a mechanism to shut down the recycled water supply or divert the non-conforming recycled water to an appropriate disposal site (e.g. by returning it to the head of the treatment plant) or an alternative storage so as not to contaminate conforming recycled water already in the storage.

If a parameter can only be checked periodically by 'grab' sampling and is found to be outside its critical limits, further sampling or testing should be performed immediately. If a second non-conformance occurs, supply should be discontinued, the process should be investigated and rectified, and any below-specification recycled water disposed of or further treated in accordance with the traceability and product recall procedure discussed above. The recycled water supply should not be reconnected until the recommended water quality has been met.

A non-conformance with a quality control point does not necessarily have to be addressed immediately. The timing for implementation of corrective actions relating to quality control points should be specified in the relevant procedure for each quality control point.

4.7.2 Management of incidents and emergencies

Most water service providers will have existing emergency response procedures. These should be amended to include incidents that may arise during treatment and distribution of recycled water. Where a recycled water producer or user does not have emergency response procedures, these should be developed to encompass both identified potential emergency situations as well as unexpected events.

Emergency response procedures for recycled water should include response to:

- cross-connection incidents involving recycled and drinking water systems
- illegal dumping of trade waste into the sewage collection system
- disruption to treatment processes that result in non-conforming recycled water being produced
- disruption to power supplies affecting treatment or distribution
- spills resulting from a pipe rupture in the collection or distribution system
- protocols for communication between suppliers and users as well as other stakeholders such as regulators, neighbours and the news media
- any other incident that could affect the safe production or use of recycled water.

All employees should be trained in these emergency response procedures, which should be reviewed and updated regularly to reflect any changes in processes or knowledge about risks. Emergency response drills should be undertaken periodically to improve processes and validate the appropriateness of the planned response. In accordance with the following section, appropriate documentation and reporting of incidents should take place. Following any significant incident, a debrief should be held to assess the suitability of the emergency response and further improve the Recycled Water Management Plan.

4.8 ESTABLISH DOCUMENTATION, RECORD KEEPING, REPORTING AND COMMUNICATIONS

The Recycled Water Management Plan should be the place for most documentation relating to the supply and use of recycled water. Where procedures or records relating to recycled water are contained in other quality or environmental management systems, these documents should be cross-referenced within the Recycled Water Management Plan. As noted elsewhere in this section, a range of documentation is required as proof of compliance with the Recycled Water Management Plan and to provide evidence of maintenance of due diligence. Recycled Water Management Plan records should be dated and signed by the responsible person.

4.8.1 Record keeping

Among the records that should be maintained are:

- recycled water policy
- register of relevant regulatory requirements
- list of stakeholders with up to date contact details including, for key stakeholders like regulators, out of hours contact details
- flow diagram or map of the entire system for collection, treatment, distribution and use of recycled water
- standard operating and emergency procedures
- critical control points, quality control points, control measures and critical limits
- training programs, any training needs analysis undertaken and training records for employees and contractors
- monitoring data.

A number of factors can influence how long monitoring records should be retained. The minimum storage period would be whatever is required to meet any relevant regulatory requirements and to satisfy auditing needs. This assumes that once results have been reported to the relevant regulator or provided to the external auditor, any actions that may be required will have been closed out and so further storage would not be necessary. Data storage for longer periods should be determined by the managers of the system. Relevant considerations may be the need to track treatment system performance over time, monitor the performance of new technology such as membranes, or maintain data on microbiological or chemical contaminants that may be of value in epidemiological studies into the impacts of use of recycled water over extended periods.

Where a Recycled Water Management Plan is prepared for a sewage or advanced recycled water treatment facility, it is important to link this to plans prepared by users. These plans may be in the form of an irrigation management plan, environmental management plan or site-based management plan, depending on the scope of the final use. Whatever form these user-specific plans take, it is essential that the key elements of risk management are integrated into the site-based plan to ensure that all recognisable risks to human health and the environment from the current or proposed recycled water use have been identified, monitored and controlled.

The form that this linkage between supplier and user takes should be specified during negotiation of the Recycled Water Agreement. In many cases, the recycled water supplier will be able to provide assistance to the recycled water user during development of the user's plan, as the supplier will generally have greater resources and expertise in the handling of recycled water and in risk assessment. But by the same token, recycled water users must take responsibility for their own safe use of recycled water, so it is important that each user maintains ownership and control over those parts of the plan that have a critical role in their use of recycled water.

Recycled Water Management Plans developed by recycled water suppliers should maintain a register of users to ensure that their risk assessment accurately reflects the uses to which the recycled water is put.

4.8.2 Reporting

Internal reporting plays a crucial role in ensuring the reliable production and safe use of recycled water. Internal reporting processes should be designed to ensure that all incidents or non-conformances that are crucial to maintaining safe use of recycled water are communicated to all relevant employees, contractors and stakeholders. One way of achieving this during both production and use of recycled water is to have mandatory reporting to all relevant managers of all non-conformances with critical limits, within 24 hours of their occurrence, together with the outcome, suspected cause and actions taken.

Other reportable issues or occurrences could include microbiological monitoring that indicates the presence of indicators above specified levels, accidental ingestion of recycled water by a worker or member of the public, or a complaint from customers or neighbours about the odour or colour of recycled water. Routine reporting of operational monitoring data should be kept to the minimum required to identify adverse trends or declining operational performance. Results from management reviews and internal and external audits should also be reported to all persons responsible for safe operation of the recycled water system.

Routine external reporting requirements for regulators are generally specified in development approvals for recycled water schemes. Other forms of external reporting could include:

- any reporting specified in the Recycled Water Agreement between suppliers and users. This may include reporting by recycled water producers on system performance and planned changes or upgrades to performance, or reporting by users of planned changes in recycled water use (e.g. crops grown or volumes required)
- reporting on system performance to any external stakeholders identified during the planning or operational phases of the recycled water scheme
- reporting to health or environmental regulators of any incidents that may cause harm to human health or the environment.

4.8.3 Consultation, communication and recycled water awareness

As noted in Chapter 3 of these guidelines, appropriate levels of consultation with all relevant stakeholders is an essential element in the planning of recycled water schemes. This process of engagement with stakeholders should also continue into the development of the Recycled Water Management Plan and the implementation of water recycling schemes. However, the precise form of this engagement will vary with the nature of the reuse, the location, the scale of the scheme and the risks involved. Establishing the appropriate design of the stakeholder engagement process is an important step in the planning of the recycled water scheme.

4.9 DEVELOP SUPPORTING PROGRAMS

There are many actions that make a contribution to safe water recycling but which do not constitute control measures as such. These are sometimes referred to as supporting programs. Some of these may have to be in place before the Recycled Water Management Plan is developed (pre-requisite programs) while the need for others will be identified during development of the plan. These supporting programs may be integrated with the Recycled Water Management Plan or they may be a part of an existing quality system. Supporting programs for production and use of recycled water could include:

- training and awareness programs for employees, visitors and contractors, including personal hygiene for workers and site visitors

- implementation of source control via trade waste agreements and monitoring
- equipment and process flow design
- development of equipment maintenance schedules, including calibration
- control of hazardous chemicals
- pest control.

4.9.1 Training and awareness

All employees who work with recycled water must be given appropriate training in the safe use of recycled water. At all workplaces where employees may have contact with recycled water, employers must provide all necessary facilities so that employees can comply with appropriate hygiene requirements. For all classes of recycled water other than Class A+ this would include at a minimum wash basins and soap and, where a Recycled Water Management Plan has identified a high level of contact with recycled water, may include hot showers and personal disinfectants. All relevant provisions of the *Workplace Health and Safety Act 1995* must be adhered to in the use of recycled water (see section 2.1.7 of these guidelines). Owing to the very high level of treatment applied to Class A+ recycled water, no specific hygiene steps are required for users of this quality of water.

Training and awareness programs for recycled water should include induction programs for new employees, site visitors or contractors and training of employees in risk management principles. All employees should also be aware that it is part of their job to immediately report problems or impending problems to their supervisors rather than to wait until the equipment or process they are responsible for malfunctions or any harm is caused to human health or the environment.

4.9.2 Source control

One of the most important elements in producing high quality recycled water is effective source control. In simple terms, source control means that by reducing the inputs of pollutants to source water, the treatment required can be reduced and thus better quality recycled water can be produced, more reliably, for less cost. All sewerage service providers who are considering water recycling should have trade waste agreements with their industrial and commercial customers that contain provisions for continuous improvement in environmental performance over time. Where trade waste agreements do not exist, the sewerage service provider should ensure that they have adequate monitoring in place to detect contaminants that may affect the quality of their product water.

4.9.3 Equipment and process flow design

All equipment selected for recycled water systems should be carefully assessed to ensure its capability to perform the operations required. Among the factors that should be considered in process flow design for production and use of recycled water are:

- The treatment plant should be capable of dealing with all flow rates, and contaminant loading rates, without disruption to performance. This is particularly an issue with smaller systems and those with large seasonal changes in hydraulic load, such as resorts.
- Process control should be automated where possible so that responses to non-conformances can be immediate. This particularly applies to non-conformances at critical control points that require the supply to be shut off immediately. Online monitoring is an essential component of automated process control systems.
- As the production process for recycled water is generally continuous, this also requires 24-hour monitored alarm systems to indicate equipment breakdowns. This should include breakdowns in monitoring equipment and loss of power supply. These alarms should be independent of the normal power supply to the plant. The alarm devices should include operator call-out alarm systems that are online whenever the treatment plant is running unattended. Systems should be designed such that breakdowns do not compromise the quality of the recycled water that is supplied to customers or the safety of recycled water delivery systems.
- In the event of equipment breakdown or power loss, backup equipment should be available, including power generators. This is particularly important if a continuous supply of recycled water is critical to users or there is inadequate storage available to permit temporary storage of 'out of specification' water.
- When new equipment or processes are introduced, including monitoring equipment, their performance in dealing with the conditions under which they will operate should be subject to appropriate validation before the equipment is made fully operational.

Delivery systems for recycled water should also be designed and validated to ensure:

- leakage detection and prevention
- prevention of cross-connections to other pipe systems, and detection of non-conformances. For example, with dual reticulation systems, cross-connections can be detected with online conductivity sensors (that can

detect the higher salinity of recycled water) or through colouring or embitterment agents added to the recycled water supply

- early detection of pipe bursts or blockages. This is particularly important with irrigation systems that do not have constant operator attendance, such as during night time irrigation of parks or golf courses. For example, safety shut-off valves can close a line and stop the flow of recycled water when a pre-set condition occurs such as excess flow or a pressure pulse from a broken pipeline or blockage.

4.9.4 Development of equipment maintenance schedules, including calibration

A documented maintenance program should be established that includes operational procedures, schedules, responsibilities and record keeping for routine equipment maintenance and major repairs. This should include calibration of monitoring equipment.

4.9.5 Control of hazardous chemicals

A range of potentially hazardous chemicals may be used in the production of recycled water. For example chemicals are often used during sewage treatment for coagulation and flocculation, nutrient removal, oxidation, pH adjustment, disinfection, scale prevention, and water softening. If the hazard analysis finds that any of these chemicals could cause a risk to humans or the environment, they should be evaluated in terms of their potential for contamination, levels of impurities, concentration build-up and potential for affecting the infrastructure.

4.9.6 Pest control

The need for pest control arises during storage of recycled water. Most recycled water distribution systems have storage reservoirs. In an open storage, faeces from water birds can contaminate recycled water and add nutrients that encourage algal growth. In a closed reservoir, roosting birds or bats may contaminate the stored water. These potential sources of contamination should be evaluated and, if they have the potential to cause harm to human health or the environment, they should be controlled to maintain recycled water quality. Also, as noted in section 7.1.4, open water storages can provide habitat for disease vectors like mosquitoes, so these hazards should also be controlled appropriately.

4.10 AUDIT AND REVIEW THE SYSTEM

4.10.1 Management review of the Recycled Water Management Plan

Recycled Water Management Plans should be subject to internal review periodically to ensure that they continue to accurately reflect the uses to which recycled water is put, and current understanding of the risks and controls involved in using recycled water. This review should be overseen by senior personnel within the organisation responsible for the water recycling scheme. It should include all components of the water recycling scheme, including end use. All monitoring data and, in particular, any environmental parameter that is subject to long-term degradation, e.g. soil structure or heavy metal build-up in soil, should be included in the review.

The outcome of each review should be documented and improvements in operations or standards should be implemented within an appropriate timeframe.

4.10.2 Audit of the Recycled Water Management Plan

Where third party certification of a recycled water scheme has been achieved, this will involve regular third party audits for compliance with the requirements of the certificate. This process holds for ISO 9000 and ISO 14000 as well as for HACCP certification.

Where third party certification does not exist, the Recycled Water Management Plan should be audited regularly, preferably by an external party. This is essential to ensure the maintenance of standards and encourage continual improvement.

5. Recycled water quality: health and environmental issues

The *Wastewater Recycling Health Effects Scoping Study* (DNR 2000a) describes many of the biological and chemical contaminants that may be found in sewage. It is essential for proponents of recycled water schemes to have an understanding of the nature of these contaminants in order that they may be sure of the capability of their treatment processes and risk management systems to adequately manage the hazards that may be posed by these contaminants during treatment of sewage or use of recycled water.

Agents of concern in sewage can be divided into biological and chemical agents, with chemical agents (also called toxicants) further divided into organic and inorganic chemicals.

5.1 BIOLOGICAL CONTAMINANTS IN SEWAGE

Many pathogenic micro-organisms and parasites are commonly found in domestic sewage (DNR 2000a, Rynne & Dart 1998).

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.

5.1.2 Bacteria

Bacterial pathogens commonly found in sewage include *Salmonella spp*., *Shigella spp*., *Vibrio cholera*, *Clostridium spp*., *Campylobacter jejuni*, *Legionella spp*. and pathogenic strains of *Escherichia coli* (*E. coli*). Faecal matter contains up to 10^{12} bacteria per gram although most bacteria in faeces are not pathogenic. Bacteria range in size from 0.2 to 5 microns.

5.1.3 Protozoa

The two most common parasitic protozoa found in sewage are *Giardia spp.* (8-18 microns) and *Cryptosporidium spp.* (3-9 microns). Most protozoan parasites produce cysts that enable them to survive outside of their host for weeks or even months. Under appropriate conditions, a new trophozoite (the active motile feeding stage of its life cycle) is released from the cyst, although it is the cyst that constitutes the infective stage outside the host. *Giardia lamblia* trophozoites are 9-21 microns long and 6-8 microns wide, while cysts are 8-12 microns long and 7-10 microns wide. *Cryptosporidium parvum* trophozoites are 2-6 microns in diameter and produce a thick walled oocyst 5-6 microns in diameter. Cryptosporidium oocysts have been shown to pass through filtration membranes if the pore size is greater than 1 micron. Protozoan parasites have low infectious doses but are generally found in low numbers in secondary treated effluent in Queensland.

5.1.4 Helminths

Helminth parasites (worms) include: tapeworms or cestodes (e.g. *Taenia saginata* and *T. solium*); roundworms or nematodes (e.g. *Ascaris lumbricoides*) which also includes hookworms (e.g. *Ancylostoma sp*. and *Necator sp*.), whipworms (e.g. *Trichuris trichiura)* and pinworms (e.g. *Enterobius vermicularis*); and flukes or trematodes (e.g. *Schistosoma mansoni*). Helminths are generally large enough to be visible to the naked eye but their ova (eggs) can be microscopic. Ova are the infective stage in the life cycle of helminths. The ova are very resistant to environmental stresses including chlorination, but are removed by conventional sewage treatment practised in Queensland and are thus not expected to be found in appropriately treated recycled water in Queensland.

5.1.5 Algae and cyanobacteria

Blooms of algae and cyanobacteria (also known as blue-green algae) are relatively common in Australia, especially in still, warm, nutrient-rich waters. Excessive amounts of algae can block irrigation equipment and some cyanobacteria can produce toxins that may cause illness when ingested or inhaled. Although algal blooms can occur in many different kinds of water body, elevated nutrient levels in recycled water storages may make blooms more likely. For more information on managing algal blooms see section 7.1.2 of these guidelines.

5.1.6 Possible health impacts of pathogens

Pathogens found in sewage can give rise to a range of health impacts in humans including gastroenteritis involving vomiting and diarrhoea, fever, respiratory illness, anaemia, hepatitis, meningitis, paralysis and eye and skin infections. However, the occurrence, concentration and type of pathogen can vary substantially in accordance with the source of the sewage (e.g. domestic, municipal or industrial), the health of the population contributing to the sewage and the ability of the infectious agents to survive outside their hosts. Following treatment, the ability of infectious agents to then cause disease, in humans or animals, will depend on the remaining concentration of pathogens in the treated recycled water, their infectivity and pathogenicity, the susceptibility of the potential host and the degree of contact that potential hosts have with the recycled water. The human sub-populations with the highest risks are the very young, the aged, pregnant women and those with weakened immune systems.

The ability of a pathogen to cause disease will depend on its reaching a minimum infective dose. This will depend on the form of contact between the pathogen and its host. The principal transmission pathways for pathogens in recycled water to humans include:

- direct ingestion of contaminated water, droplets or airborne particles
- direct ingestion of food that has been contaminated by pathogens from recycled water
- indirect ingestion of pathogens via licking of fingers or objects that have touched contaminated surfaces
- direct inhalation of contaminated water droplets and aerosols
- direct contact with skin, eyes or ears.

Direct ingestion of recycled water has the greatest risk of causing disease, as it is capable of delivering the largest dose of pathogens and causing the greatest incidence and severity of sickness in the community.

Bacterial endotoxins are toxins found in the outer membrane of the cell wall of certain bacteria. These toxins are released upon destruction of the bacterial cell, such as during sewage treatment or disinfection. Similar toxins are found in some cyanobacteria. Endotoxins have given rise to health concerns in occupational settings where workers are exposed to high levels of airborne endotoxins on a daily basis, such as at sewage treatment plants. While the levels of endotoxin remaining in highly treated recycled water are unlikely to give rise to health impacts during use of recycled water, research into this issue is continuing.

5.1.7 Epidemiological evidence of disease caused by recycled water

Internationally, most disease outbreaks caused by use of recycled water have occurred in developing countries using untreated or poorly treated sewage on uncooked food crops. In the USA, where large quantities of highly treated water are recycled for many different uses, including all of the uses contemplated by these guidelines, the only recorded disease outbreaks have been from inadvertent cross-connections between potable water and recycled water systems carrying secondary treated recycled water.

However, as gastroenteric disease is relatively common in Australia (estimated in 2002 to be around 0.9 cases per person per year or 17.2 million cases in total (OzFoodNet Working Group 2003)) there are often difficulties in linking the low risks from recycled water usage with the low-level disease that may result from typical infections (many of which go unreported). This has encouraged the use of quantitative microbial risk assessment as a means of discerning these low-level health risks from water recycling.

Quantitative microbial risk assessment (QMRA) uses the same basic approach as a screening level risk assessment described in section 2.5.1 of these guidelines, but with a greater degree of quantification of hazards and risks. QMRA generally starts with a quantitative assessment of the dose of a certain pathogen that an individual may be exposed to, then uses this dose in a dose-response model to calculate the probability of infection. Risks are then calculated by considering the frequency of exposure events for the range of pathogens examined to estimate total risk, expressed as number of infections per year or overall disease burden in the community.

A number of QMRAs have been completed for particular applications of water recycling around the world. These assessments are very sensitive to the assumptions used for dose and infectivity, and have produced a range of outcomes depending on the assumptions used. Studies that examined the risk from tertiary treated, disinfected effluents have generally found a low risk to human health from reuse (Asano et al. 1992, Rose and Gerba 1991, Shuval et al. 1997).

5.2 INORGANIC CHEMICALS IN SEWAGE

Untreated sewage can contain a high concentration of dissolved solids. These solids mostly consist of salts, e.g. sodium chloride, metal salts and nutrients.

5.2.1 Salts in sewage

The total dissolved salts (TDS) content of water, measured in milligrams per litre, can be determined accurately by ion analysis or be estimated approximately from electrical conductivity (EC). EC is measured in microSiemens per centimetre (µS/cm) or deciSiemens per metre (dS/m)

(ANZECC & ARMCANZ 2000a) and can be converted to TDS using a factor appropriate to the type of water. Domestic sewage usually has moderate to high levels of dissolved salts (>500 mg/L) while industrial sewage has variable levels that may be very high.

Many uses of water have the effect of adding more dissolved solids, including salts, to the wastewater stream. For example, many laundry detergents contain significant loads of salts. As conventional sewage treatment has a very limited capacity to remove salts, this means that the more water is recycled within a closed system, the saltier it will become, and thus the less beneficial it will be for many uses. This underlines the importance of undertaking a thorough mass balance (quantification of inputs and outputs) for salts during the planning phase for any water recycling scheme (Haworth 1997) and, for irrigation applications, undertaking periodic leaching of water through the soil to remove any build up of salts. See section 7.3.5 of these guidelines for more information.

As noted above, conventional sewage treatment processes typically remove only a small amount of TDS, with some form of specific treatment needed to reduce this to low levels. Specific treatments include reverse osmosis, distillation, electrodialysis or dilution with less salty water. Elevated TDS levels in recycled water do not, of themselves, constitute a health hazard for humans, but may cause the water to become corrosive or result in scale formation within pipes.

Elevated salinity in recycled water used for irrigation can increase soil salt levels and have detrimental effects on soil structure and plant growth. The sodium adsorption ratio (SAR) is the ratio of sodium ions to magnesium and calcium ions in the soil solution or irrigation water. SAR is used to predict the potential for sodium to accumulate in the soil, causing soil structure breakdown which, in turn, can lead to erosion and soil clogging. This is particularly a problem in low rainfall areas where most of the irrigation water applied is transpired by growing plants, leaving a concentration of salts in the soil and ground water much higher than in the recycled water itself.

Trigger values for TDS in waters used for a range of different purposes are contained in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000a). These provide a useful guide for recycled water quality for environmental protection (Chapter 3) and irrigation (Chapter 4). More advice, and further references, on managing salinity in irrigation applications is provided in section 7.3 of these guidelines.

5.2.2 Nutrients in sewage

Although they are only a minor fraction of the total dissolved solids in sewage, nutrients such as nitrates and phosphates can trigger significant water quality degradation of receiving water bodies. Nutrients and dissolved organic matter in recycled water can also encourage growth of biofilms (slimes) inside water pipes, storage tanks or irrigation infrastructure. These biofilms can shield pathogens from disinfectants, become odorous during storage, discolour the water and can accelerate corrosion of metallic and concrete water distribution pipes. Nutrients can also promote the growth of algae and cyanobacteria (blue-green algae) in open storages.

While nutrients in recycled water can also make a positive contribution to crop growth in irrigation applications, the relative proportions of these nutrients found in recycled water are not always optimal for plant growth. Also, plant demands for water use will not always match demands for the nutrients supplied in recycled water. It will therefore usually be necessary to carefully manage the nutrient and water balance in recycled water used for irrigation to prevent impacts on crop growth or, for pasture applications, animal health.

This is particularly important when an irrigator switches from use of a low nutrient water source (e.g. river water or ground water) to a higher nutrient source such as recycled water. In other words, any addition of nutrients from recycled water should be balanced by reductions or other adjustments in nutrient additions from agricultural fertilisers.

Nitrogen

Nitrogen can occur in recycled water as organic nitrogen, ammonia, ammonium, nitrate or nitrite. Secondary treated effluent, without nutrient reduction, will generally have a total nitrogen concentration of 25-50 mg/L. With the use of nutrient reduction technology this can be reduced to less than 5 mg/L. The fate of added nitrogen in the soil is complex and depends on the soil type, soil moisture, climate, soil-plant interactions, fire frequency, gaseous loss, leaching losses, particulate transport and offtakes (harvested plant or animal product). In most Australian soils relatively little nitrogen is stored within the soil profile, although if tree crops are grown there is some storage of nitrogen in the standing biomass and leaf litter.

When recycled water is used for irrigation, nitrogen loads must be carefully managed so that inputs from all sources do not exceed the buffering capacity of the soil-plant system.

Phosphorus

Phosphorus concentrations in secondary treated effluent usually range from 8 to 12 mg/L. Further nutrient reduction can reduce this to less than 1 mg/L. Phosphorus in sewage originates as organic phosphates from animal or human waste, and from ortho- and polyphosphates in detergents and industrial waste. Phosphorus that is added to the soil system in recycled water is either taken up by plant growth, stored within the soil (if the soil contains a significant amount of cation exchange sites, as with clay soils), or it may be lost through leaching.

For more information on managing nutrients during irrigation of recycled water see section 7.3 of these guidelines.

5.2.3 Metals in sewage

The main heavy metal pollutants of concern are arsenic, cadmium, chromium, copper, nickel, lead, mercury and zinc, while other metals such as aluminium are also commonly found in sewage. Metals are of concern due to their propensity for accumulation along the food chain and their acute toxicity to some plants and animals (including humans) at particular concentrations. There are no risks to human health from boron in recycled water but some plants are sensitive to boron in soil water.

Industrial wastewater may have significant amounts of heavy metals. These largely derive from industries that extract or refine metals or those that use them in manufacturing.

Although conventional sewage treatment can remove significant amounts of heavy metals, through concentrating them in the biosolids produced during primary sedimentation and secondary treatment, specific treatment processes are required if heavy metal concentrations are elevated. The best approach for operators of municipal STPs is to ensure the discharge of heavy metals from industrial customers is minimised through appropriate trade waste controls.

Trigger values for heavy metals in waters used for a range of different purposes are contained in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000a). Where recycled water is taken from a source that may contain elevated levels of heavy metals, and the recycled water will be used for irrigation or released to the environment, the relevant trigger values contained in Chapters 3 and 4 of the ANZECC & ARMCANZ guidelines should be considered.

5.3 ORGANIC CHEMICALS IN SEWAGE

Many organic chemicals are discharged to sewer, including pesticides, pharmaceuticals, personal care products (perfumes, deodorants, moisturisers) as well thousands of other chemicals used in industry and the home. Some of these (or their breakdown products) are known or potential endocrine disrupters, some are toxic or carcinogenic and some can have interactive or synergistic effects that magnify their impact on organisms.

While many of these compounds are removed during sewage treatment or broken down to less harmful components, some studies have detected these chemicals in secondary treated effluent. Also, certain disinfection methods can give rise to disinfection by-products (see section 6.3 of these guidelines), some of which are known to be harmful at certain doses.

There is growing concern in Australia, and overseas, that the presence of these chemicals in effluent discharged to waterways may be causing environmental harm to aquatic ecosystems. Concern has also been expressed at the potential for some of these chemicals to disrupt the endocrine system of humans when exposed to recycled water. However, the significance of these chemicals in the context of water recycling has not yet been fully explored.

A recent study (Leusch et al. 2005) examined the levels of certain endocrine disrupting chemicals (EDCs) in sewage and effluent from 13 STPs in south-east Queensland. The study found that while raw sewage contained high levels of both estrogenic (feminising) and androgenic (masculinising) activity, the final effluent contained very low levels, especially compared with overseas studies. Another study at an Australian STP (Khan & Ongerth 2005) found that conventional sewage treatment removed 80-90% of most of the eight pharmaceutically active compounds studied. The remaining concentrations ranged from less than 0.25 to 0.59 nanograms per litre.

Other research suggests that hydraulic retention time (HRT) and sludge retention time (SRT) are particularly important factors in the removal of endocrine disrupting chemicals during sewage treatment. Longer HRT and SRT promote enhanced biodegradation and biosorption (sorption to biological solids) by allowing a more specialised microbial population adapted to EDC removal to develop (Scruggs et al. 2005, Clara et al. 2005, Johnson et al. 2005).

An Australian review of the epidemiological data on the adverse effects of EDCs suggested that, in general, low level environmental exposure to EDCs has not yet been shown to cause harm to humans (Falconer et al. 2003).

There is increasing evidence that when applied after effective secondary sewage treatment, advanced treatment processes such as tertiary filtration, ozonation, UV, biologically activated carbon filtration and reverse osmosis can remove most of these contaminants from recycled water (Chapman 2003, Khan et al. 2004). Ying et al. (2004) reviewed the international literature on the presence of EDCs and pharmaceuticals and personal care products in recycled water. They concluded that due to the low concentrations of these chemicals in recycled water the risks to human and ecosystem health are expected to be low, especially when the recycled water is used for irrigation on agricultural land.

Research is continuing into the health risks of using recycled water. As this research produces substantive results, these guidelines will be appropriately updated. Chapter 3 of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000a) contains trigger values for a wide range of toxicants that may be found in water. These values should be considered during the process of developing a Recycled Water Management Plan.

Another useful resource for assessing the significance of potential chemical hazards is the *National Chemical Reference Guide* provided on the website of the Commonwealth Department of the Environment and Heritage. This database links to guideline values for many chemicals that may be found in recycled water, providing reference levels for drinking water, recreational water, ecosystem protection, livestock drinking, aquaculture, soils, irrigation water and ground water.

5.4 OTHER WATER QUALITY ISSUES

There are other water quality parameters that may be significant to particular uses of recycled water.

5.4.1 Suspended solids and turbidity

Suspended solids is a measure of suspended material in water. It is an indicator of treatment effectiveness as suspended solids contribute to poor water quality by providing a carrier for pollutants such as heavy metals and pathogens. Suspended solids are generally measured by 'grab' samples rather than continuously.

Turbidity is a measure of the cloudiness of water that is generally expressed in nephelometric turbidity units (NTU). Its measurement quantifies the degree to which light travelling through a water column is scattered by the suspended particles. The scattering of light increases with increasing loads of silt, clay, algae, micro algae, other plankton, organic matter and fine insoluble particles. These suspended particles reduce the effectiveness of disinfection processes that use chlorine or ultraviolet light. Turbidity is readily monitored continuously using online equipment.

5.4.2 Biochemical oxygen demand

Biochemical oxygen demand (BOD) is a measure of the oxygen in water required by micro-organisms for the biochemical breakdown of organic matter, and the oxidation of inorganic matter, over a given time at a given temperature. It is usually measured during a five day period in a reaction vessel at a temperature of 20 C and expressed as BOD5. When BOD is elevated in a water body, it can reduce dissolved oxygen to levels that are inadequate to support aquatic organisms, thus causing their death. BOD is often used as an indicator of sewage treatment plant effectiveness (the usual target value is <20mg/L) as it can indicate how successfully the treatment process has removed organic matter from the wastewater. Other measures of the effectiveness of sewage treatment to remove bulk organic matter include total organic carbon and chemical oxygen demand.

5.4.3 pH, corrosion and fouling potential

The pH of water is a measure of the concentration of hydrogen ions, and indicates the extent to which it is acidic or alkaline. 'Acidity' and 'alkalinity' are different parameters that provide a quantitative measure of the water's neutralising capacity, in terms of calcium carbonate equivalent. High or low pH can give rise to potential for deterioration of water quality in pipe systems as a result of corrosion or fouling of pipes. The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000a) recommend that pH should be maintained between 6 and 8.5 to limit corrosion and fouling of piping, pumping and irrigation equipment. Other trigger values for minimising scaling and fouling potential in pipe systems are also given in Chapter 4 of the ANZECC and ARMCANZ guidelines. The ideal pH for most plant production is 5.5-6.0 as this provides a balance of availability of essential inorganic nutrients. The relationship between pH and disinfection is discussed in section 6.3.4 of these guidelines.

5.4.4 Radioactive substances

Radioactive substances may originate from medical or extractive industry sources as well as from natural sources. All recycled water should conform to the trigger values for radionuclides contained in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000a). If recycled water is derived from a source suspected to be contaminated with radioactive material, specific investigation should be undertaken to ensure trigger values are not exceeded.

6. Treatment options and water quality specifications for recycled water

6.1 CONVENTIONAL SEWAGE TREATMENT

The treatment method used to produce recycled water should be suitable to reliably produce water of a standard that is fit for the purpose for which it is being provided, at a reasonable cost. Decisions about the best approach need to balance the environmental, social and economic advantages and disadvantages.

There are many treatment processes that can remove contaminants from sewage to varying degrees, depending on the intended final use of the recycled water. Conventionally, sewage treatment has been categorised as primary, secondary or tertiary, to reflect the sequential nature of sewage treatment. In recent years, other treatment options have also become available that can achieve high levels of removal of pathogens and other contaminants (see section 6.2 of these guidelines).

In simple terms, primary treatment can be said to involve screening out of gross pollutants and sedimentation of coarse particles; secondary treatment removes organic matter and lighter solids by biological and mechanical treatment; and tertiary treatment removes suspended solids and nutrients via biological and/or chemical processes and/or filtration. Disinfection may be applied to either secondary or tertiary treated effluent. However, advances in wastewater treatment technology have meant that a simple distinction between these processes is not always useful.

Generally speaking, the greater the level of treatment applied to wastewater, the greater the reduction in levels of pollutants. Virtually any quality of source water can be treated to any final standard given the right level of treatment. However, recycled water should only be treated to a level that matches its intended use, to avoid unnecessary treatment costs. For example, a high degree of disinfection is not essential for irrigation of crops like sugar cane where there is substantial processing of the crop after harvesting.

6.2 ADVANCED RECYCLED WATER TREATMENT

There are a number of advanced treatment technologies that can improve the quality of recycled water. These start from conventional filtration technologies such as deep bed gravity filters with upstream coagulation/flocculation through to modern membrane technologies, electrostatic treatment, distillation, ultrasound and hybrid technologies.

6.2.1 Conventional media filtration

Conventional filtration generally involves adding a coagulant/flocculant to secondary treated effluent to aggregate suspended solids and colloidal particles into flocs so that they can be removed via filtration through a deep bed filter using sand or other media. When followed by heavy dosing with chlorine, this form of treatment can achieve significant reduction in pathogens. However, as it does not rely on a physical barrier to filter out pathogens, as membrane technology does, it cannot be guaranteed to consistently achieve the same level of pathogen reduction as membranes. The effectiveness of particle removal during media filtration greatly depends on the skill on the operator and requires continuous monitoring to detect when breakthrough of particles will occur so that backwashing of the media can be initiated.

6.2.2 Microfiltration

Microfiltration is the most commonly used type of membrane filtration, either alone or as a pre-treatment for reverse osmosis. Most microfiltration membranes have a pore size of 0.1 microns. Particles in this size range, such as bacteria, are retained and concentrated by the membrane. Microfiltration can be used to remove bacteria, protozoa and small suspended solids or to clarify liquids. When combined with post-filtration disinfection by UV, this is a very effective technology for virus removal, as it removes the particles that can shield viruses from UV radiation.

6.2.3 Ultrafiltration and nanofiltration

Ultrafiltration membranes have a pore size of 0.01 microns while nanofiltration membranes have a pore size of 0.001 microns. Molecules such as proteins and sugars are in this size range. Ultrafiltration or nanofiltration can be used to reduce the BOD of wastewater, separate oil from wastewater and remove natural and synthetic organics, disinfection by-products and multivalent inorganic substances (e.g. water softening by removing calcium and magnesium). They are also very effective at reducing pathogens.

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.

6.2.5 Membrane bioreactors

Membrane bioreactors combine conventional biological treatment with membrane separation to produce very high quality recycled water. Treatment plants are very compact and have low requirements for operator attention compared with conventional sewage treatment plants.

6.2.6 Electrodialysis

Electrodialysis is a process that applies an electrical current to semipermeable membranes to remove impurities (e.g. metals or salts) from water.

6.2.7 Biologically activated carbon (BAC) filtration

Activated carbon is made by heating a carbon-based material such as wood, charcoal or coal to a high temperature in the presence of steam. This process removes non-carbon elements from the source material and creates a porous internal structure that provides a very large surface area. The surface of activated carbon is positively charged so any negatively charged particles in the water are attracted to it (that is they become adsorbed). Some carbon filters are designed so that bacteria are encouraged to grow on the surface of the carbon (biologically activated carbon or BAC). The bacteria growing on the carbon media will consume organic fractions adsorbed onto the carbon.

Filtration of recycled water through biologically activated carbon can remove many contaminants, including pesticides and herbicides, pharmaceuticals, disinfection by-products and cyanobacterial toxins. The effectiveness of activated carbon filters to adsorb organic chemicals can be enhanced by treating the water with ozonation to breakdown large organic compounds to smaller organic particles. Activated carbon filters are thermally regenerated by burning off the contaminants, after which they can be reused.

6.2.8 Ultrasound

When applied to wastewater treatment, ultrasound is generated by a transducer that converts electrical energy into high frequency vibration. This vibration then induces cavitation, in which air or vapour bubbles form due to a rapid reduction in pressure. At low ultrasound doses, bacterial flocs can be disaggregated by mechanical shear stresses. When the dose is increased, ultrasound cavitation breaks down the cell walls of micro-organisms, thereby achieving a measure of disinfection. Further disinfection by other methods like UV or chlorine dioxide is also facilitated.

6.2.9 Dissolved air flotation

Dissolved air flotation (DAF) involves injecting air into water, forming very small bubbles that attach to floc particles formed by addition of a chemical flocculant. Solids then float to the surface to be skimmed off. When combined with appropriate disinfection, DAF can produce high quality recycled water.

6.2.10 Ion exchange

Ion exchange is often used in industry to condition input water for industrial processes. It can also be used for treated effluent. It involves the replacement or exchange of specific ions in water for complementary ions to produce high purity industrial water. Ion exchange is not a typical sewage treatment process but rather it produces water of a specific quality suitable for a specific use. For example, sodium is exchanged with calcium so that calcium does not form scaling in heat exchangers.

6.2.11 Distillation

Distillation is the process of heating water to its boiling point, capturing and then condensing the steam to form pure distilled water. If the heat used for distillation is waste heat from some other process, this can be an efficient water purification process. Multi-effect and multistage flash distillation are thermally efficient processes that can produce pure water with very low salinity from recycled water or from salt water.

Reverse osmosis, thermal techniques (such as distillation) and electrodialysis are the most popular current technologies that can significantly reduce the salinity of water; however, they all produce significant saline waste streams.

6.2.12 Biofiltration through lagoons and wetlands

Wastewater has been treated through wetlands and lagoons for centuries. Wetlands remove pollutants through a combination of biological, chemical and physical processes. Wetlands can also be useful at the end of a secondary treatment process where they can reduce nutrients and other contaminants and also achieve some disinfection.

However, wetlands do need careful design and management to ensure their long-term effectiveness. Conventional biofiltration systems involve surface flow with visible water, while subsurface wetlands generally use emergent macrophytes growing in a saturated soil matrix. One of the key design features of biofiltration through lagoons or wetlands is the prevention of short-circuiting. The Queensland Government has published *Guidelines for Using Free Water Surface Constructed Wetlands to Treat Municipal Sewage* (DNR 2000b) that contain detailed advice on use of constructed wetlands for wastewater treatment.

6.3 DISINFECTION OF RECYCLED WATER

While most steps in sewage treatment can lead to some reduction in pathogenic organisms, specific disinfection steps are generally required to ensure that recycled water is fit for use. Among the disinfection options available for recycled water are chlorine (delivered as gaseous chlorine, liquid sodium hypochlorite or via anodic oxidation), chlorine dioxide, UV radiation, membrane filtration, pasteurisation (thermal disinfection) and advanced oxidation processes involving use of ozone, hydrogen peroxide or titanium dioxide in combination with UV. Each of these has advantages in different circumstances, and in many cases a combination of these approaches is best for recycled water.

All disinfection systems should be automated with alarms and automatic shut-off of the recycled water supply in case of failure. Effective maintenance and a quality assurance system would minimise the risk of treatment failure.

6.3.1 Chlorination

Chlorine is routinely added to drinking water supplies worldwide due to its disinfection capability and residual activity in water pipes. However, its use for disinfection of STP effluent gives rise to a number of problems.

The chlorine dose and contact time required to ensure adequate disinfection of STP effluent will depend on the characteristics of the effluent (e.g. pH, BOD and TSS), the chlorine demand (determined by the presence of organic matter, ammonia, iron and manganese) and the final uses of the recycled water (e.g. whether a residual is required). Also, there can be problems in measuring free versus available chlorine in STP effluent due to the formation of chloramines following the reaction of chlorine with ammonia in the effluent. This means that no single figure for free or total chlorine can be specified for chlorine disinfection of recycled water.

As with some other disinfectants, chlorine produces disinfection by-products in reaction with organic and inorganic substances usually present in STP effluent. The level of these by-products varies with the chlorine dose and the level of free chlorine in the water.

Also, chlorine is relatively ineffective at inactivating some pathogens, such as *Cryptosporidium* oocysts, and the residual chlorine can be toxic to sensitive organisms if it is released into the environment during final use of recycled water. When this potential for toxicity must be reduced, dechlorination may be required.

6.3.2 Ultraviolet radiation

Ultraviolet radiation is an effective disinfection process that does not produce by-products that may be toxic to humans or the receiving environment. UV dose is a product of UV intensity and exposure time and is expressed as milliwatt seconds per square centimetre ($mW.s/cm^2$). UV achieves disinfection by initiating a photochemical reaction that damages the DNA molecule within micro-organisms, so that cell division and consequently multiplication can no longer occur. The amount of cell damage depends on the dose of UV energy absorbed by the micro-organisms and their resistance to UV.

UV disinfection is only effective with recycled water that has low suspended solids, turbidity and colour. A chemical residual, such as chlorine, may be required after UV disinfection to limit bacterial regrowth within the distribution system.

6.3.3 Oxidation processes

There are many oxidation processes that can be used for treatment and disinfection of recycled water, the more common of which use ozone, chlorine dioxide or hydrogen peroxide. The most commonly used is ozonation. In a typical arrangement, ozone gas is generated on-site by passing an electric current through oxygen. This ozone is then passed through the recycled water where it oxidises organic matter, including micro-organisms, and achieves high removal of both pathogens and organic matter. A disadvantage of ozonation is that it produces small quantities of disinfection by-products that may be hazardous to human health when ingested or inhaled in sufficient quantities. In addition ozone gas is extremely toxic so ozone generating facilities must be managed in accordance with appropriate workplace health and safety provisions.

If ozone-treated recycled water has a significant amount of residence time in pipes, it is also likely to require a chlorine residual to prevent microbial regrowth.

6.3.4 Disinfection and pH

Where disinfection relies on some form of chemical treatment, as with chlorine or ozonation, attention should be paid to the pH of the recycled water. The ideal pH range varies for different forms of chemical disinfection. Further information on pH and disinfection can be found in the Information Sheets published in Part IV of the *Australian Drinking Water Guidelines* (NHMRC & NRMMC 2004).

6.4 RECOMMENDED WATER QUALITY CHARACTERISTICS FOR RECYCLED WATER

As noted above, these guidelines do not recommend particular treatment processes for recycled water. But in order to protect public health and the environment, and to satisfy regulators, proponents of recycled water schemes should be able to produce evidence that the treatment technology and management system they propose to use has been shown to reliably achieve water quality appropriate for the intended use. This will need to be demonstrated not just for the treatment process but right through to subsequent storage, distribution and use.

In order to demonstrate this level of safety, it is necessary for everyone involved in water recycling, from treatment plant operators to users and regulators, to focus equally on indicators of treatment effectiveness and reliability as well as traditional microbiological, physical or chemical indicators at the end of the pipe. In practice, this means that once the Recycled Water Management Plan (see Chapter 4 of these guidelines) has identified the critical control points for the production, delivery and use of recycled water, these must be monitored and controlled to ensure the safety of the final use of recycled water.

The appropriate quality of water used for recycling will depend on the proposed end use, site characteristics and risk factors. The basic requirement is that recycled water should be fit for the given use. Table 6.3 details the class of water recommended for different purposes. However, it is important to note that the actual water quality used in any particular application will depend on the outcome of the risk assessment done as part of the Recycled Water Management Plan.

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.

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).

The use of bacterial and viral indicators, as discussed above, in combination with physical criteria to indicate treatment effectiveness, can provide a high degree of assurance of the safety of recycled water (NRMMC & EPHC 2005). As noted above, to guarantee protection of human and environmental health, it is essential to undertake a properly designed risk assessment process so that the monitoring effort can focus both on critical control points identified during that process, as well as recycled water quality at the end of the pipe.

6.5 REDUCTION OF PATHOGENS DURING SEWAGE TREATMENT

The ability of a treatment process to reduce pathogens in sewage is generally described in terms of $\log_{10}$ reduction (usually expressed as "log reduction"). One log reduction of a pathogen represents the removal of 90% of that pathogen from a sewage source, 2 log reduction represents 99% removal and 3 log reduction represents 99.9% removal. Table 6.1 shows the performance of typical sewage treatment process steps.

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.

6.6 RECYCLED WATER CLASSES

The classes of recycled water described in Tables 6.2a and 6.2b are based on recommendations contained in the draft national guidelines (NRMMC & EPHC 2005), supplemented by a quantitative health risk assessment for Class A+ recycled water completed for these guidelines (unpublished EPA report). If a risk assessment undertaken as part of a Recycled Water Management Plan, using accurate and relevant data, is able to demonstrate that human health risks can be properly managed, then alternative classes of recycled water may be used from those recommended in Table 6.3. In these guidelines a recommendation for use of any particular class of recycled water includes higher classes as well. In other words, if Class C is recommended, Classes A and B could also be used, but Class C is the minimum recommended quality.

Because of the potential health risks from use of recycled water, validation and verification of achievement of a particular class of recycled water is focussed on microbiological indicators.

6.6.1 Validation and verification of achievement of Class A+ recycled water quality

Where a supplier of recycled water intends to supply recycled water of Class A+ quality to customers, there are two related and important procedures to undertake. These involve validation or examination of the treatment technology and verification of the operating treatment system to ensure the system operates in practice as predicted by the validation.

6.6.1.1 Validation

Where a recycled water producer proposes to supply Class A+ quality water they should demonstrate that the proposed treatment technology is capable of achieving the Class A+ standard. Table 6.1 may be used in the planning of treatment processes but independent validation will be required that demonstrates the capability of the actual treatment processes used to achieve the required log reductions of viruses, bacteria and parasites. Validation of a treatment process is more readily achieved through laboratory or pilot scale testing but can also be performed at full scale.

Validation can be achieved either through:

- monitoring of the indigenous organisms present in both typical sewage influent fed to the treatment process and final treated effluent from the process or
- challenge testing the proposed treatment process through spiking sewage with cultured organisms and monitoring the organisms in both the influent fed to the treatment technology and final treated effluent from the treatment technology.

While monitoring of indigenous organisms can, in some cases, be sufficient to demonstrate the capability of a treatment process or processes to achieve a certain target log reduction of pathogens, often the levels of indigenous indicator organisms are not consistently high enough to demonstrate a 6 log reduction of pathogens (unpublished EPA data).

Where challenge testing is undertaken to validate achievement of the Class A+ recycled water standard, the collection and analysis of samples should be done by laboratories with NATA accreditation, which have the relevant tests in their scope of accreditation. Due to the highly variable content of sewage, triplicate sampling or better will greatly improve the statistical analysis of the data. Unpublished EPA research has indicated that 20 replicate samples taken over a range of operating conditions (e.g. different loading rates and times of day and week) are required.

It should be borne in mind that challenge testing treatment processes with cultured organisms at laboratory or pilot scale may overestimate the performance of the treatment process because cultured organisms may not be acclimatised to environmental conditions as well as indigenous organisms. This would be important if the log removal of cultured organisms during pilot testing only just meets the criteria in Table 6.2a.

6.6.1.2 Verification monitoring

Verification monitoring of Class A+ recycled water quality can be done through weekly sampling (with three replicates) during the first year of operation and monthly sampling thereafter.

6.6.2 Validation and verification of achievement of Class A-D recycled water quality

Validation and verification of achievement of Class A to D recycled water quality can be achieved through monitoring of final water quality using the levels of microbiological indicators shown in Table 6.2b. As with Class A+ recycled water, 20 replicate samples taken over a range of operating conditions (e.g. different loading rates and times of day and week) should be undertaken for validation of Class A to D recycled water.

The operation of the disinfection system should be validated separately using recycled water with a range of different concentrations of bacterial indicators to reflect the variability that would be found during STP operation.

Verification monitoring can be done through weekly sampling (with replication) during the first year of operation and monthly sampling thereafter.

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.

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 determined as part of the risk assessment. • pH 6-8.5 (if disinfection relies predominantly on chlorine, but not chlorine dioxide) or 6-9.2 if other disinfection systems are used • For sustainable irrigation, salinity should be kept as low as possible, e.g. if TDS >1000 mg/L or EC>1600 µS/cm, a salinity reduction program should be implemented • Any other physical or chemical criteria that the risk assessment phase of the RWMP has identified as representing a risk to soil, crop or human health
Validation requirement	20 sampling events (with three replicate samples) that demonstrate compliance with this standard before delivery of product to customers
Verification testing	Weekly sampling (with three replicates) during first year of operation Monthly sampling (with three replicates) thereafter
Other requirements	All non-conformances with this specification to be reported to Queensland Health and addressed in accordance with RWMP All sampling and analysis to be in conformance with relevant standards (e.g. *Method 1602: Male-specific (F+) and Somatic Coliphage in Water by Single Agar Layer (SAL) Procedure* April 2001 (US EPA 2001)).

[1] cfu = colony forming units

[2] pfu = plaque forming units

Table 6.2b. Recommended water quality specifications for Class A-D recycled water[1]

Class	*E. coli* (median) cfu/100mL[2]	BOD5 mg/L median	Turbidity NTU 95% ile (max.)	SS, mg/L median	TDS, mg/L or EC, µS/cm medians TDS / EC[3]	pH
A	< 10	20	2 (5)[4]	5	1000/1600	6-8.5
B	< 100	20	—	30	1000/1600	6-8.5
C	< 1000	20	—	30	1000/1600	6-8.5
D	< 10,000	—	—	—	1000/1600	6-8.5

[1] Use of any of these classes of recycled water should involve development and implementation of a Recycled Water Management Plan incorporating risk management. The location of the sampling point for these parameters will depend on the outcome of the Recycled Water Management Plan (see Chapter 4 of these guidelines).

[2] As these values are medians, for each of these guideline values a response value should be set (e.g. 50% above the guideline value). If the response value is exceeded, another sample should be immediately taken. If this exceeds the response value again, the supply of recycled water should be suspended, and the non-conformance and corrective action process implemented, with supply not being re-established until conforming product can be guaranteed.

[3] For sustainable irrigation, salinity should be kept as low as possible. For example, if TDS >1000 mg/L or EC >1600 µS/cm, a salinity reduction program should be implemented. However, there may be some uses where salinity reduction is not required, or where other salinity management options are more practical. This should be determined during the risk assessment.

[4] Turbidity would generally be measured before the disinfection point at the treatment plant as this is the point at which low turbidity is essential. Monitoring at the treatment plant should be continuous with an alarm activated at an NTU of 2, and automatic shut-off of supply at an NTU of 5. If disinfection of Class A recycled water is achieved partly through processes that are less dependent on turbidity, an indicator other than turbidity should be used. For example, extended lagooning would use detention time in the storage as the critical limit (typically 40 days), rather than turbidity. Ozonation may use an oxidation-reduction potential (ORP) sensor, with the critical limit (in millivolts) determined by the quality of the feed water.

6.6.3 Other water quality criteria

As has been noted, the presence of suspended material in recycled water is crucial to the effectiveness of most forms of disinfection. For this reason, a critical limit for turbidity should be set as part of the Recycled Water Management Plan, particularly during production of Class A or A+ recycled water.

As noted in section 6.3.1 of these guidelines, there are complex issues involved in determining the appropriate chlorine dose, contact time and residual when disinfecting STP effluent. As a result, no single number is specified in these guidelines. Instead, each producer of recycled water sourced from STP effluent must validate their disinfection system to ensure that it is capable of achieving the microbiological criteria in Tables 6.2a&b under a range of operating conditions. Once this has been determined, appropriate critical limits should be set as part of the Recycled Water Management Plan.

Maintenance of a chlorine residual can be important to ensuring recycled water quality in pipe networks, especially when there is long residence time within pipes. However, if recycled water goes to a storage lagoon immediately after disinfection, or is used with minimal residence time in pipes, there is no need to ensure a chlorine residual. Also, there are some applications and locations (such as irrigation of crops or some grasses, irrigation of sensitive environments or internal reuse where used recycled water is returned to small treatment plants) where a chlorine residual may be detrimental to crops, the environment or treatment processes. In these cases risks associated with use of chlorine should be assessed and addressed through the Recycled Water Management Plan, and appropriate levels of disinfection should be maintained in other ways or some form of dechlorination could be used.

If a disinfection system is used that does not rely on chlorine, an alternative indicator of disinfection effectiveness should be used that ensures the equivalent disinfection reliability.

The classes of recycled water described in Table 6.2 are focused on human health risk. They do not necessarily reflect suitability for uses where human health is not the principal consideration, e.g. agricultural irrigation of non-food crops. In these circumstances other water quality criteria, such as salinity or sodicity, are likely to be more important. However, the relevant criteria for factors such as salinity will vary depending on the existing soil type and salinity, hydraulic loading rate applied, crop susceptibility and other factors. Therefore, in order to demonstrate sustainability, the user will have to undertake an appropriate site assessment (see section 7.3.1 of these guidelines) to ascertain the safe levels of these environmental water quality parameters. The best reference for assessing salinity management for irrigation purposes is the Department of Natural Resources' *Salinity Management Handbook* (DNR 1997a). Chapter 4 (section 4.2.4) of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* also contains a flow chart for evaluating salinity and sodicity impacts of irrigation water on crops and pasture.

Table 6.3 summarises the recommended recycled water class and monitoring regime for the range of recycled water uses covered by these guidelines. These suggestions may be taken into account in developing a Recycled Water Management Plan that will identify all critical control points and associated trigger values that specifically relate to the particular recycled water sources and uses actually undertaken. With parameters that do not affect human or environmental safety, such as pH, once the treatment system has demonstrated its ability to reliably operate within an acceptable range, monitoring frequency can be reduced.

Wherever data are collected continuously, for example for process monitoring data like turbidity, 100 percentile values should be used for maxima while 95 percentile values can be used as response or action levels. In other words, as soon as the value reaches a predetermined critical limit or action level (in this case NTU=2), an alarm or other response should be activated, and appropriate action taken to ensure that the value of NTU=5 is never exceeded.

Data that are collected by grab sampling should be collected often enough to reveal, in a timely fashion, any violation of critical limits or action levels.

Chapter 7 of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000a) provides a very useful guideline for the design of monitoring and assessment programs for environmental water quality. *Information Sheets 3.1 to 3.4* from the *Australian Drinking Water Guidelines* (NHMRC & NRMMC 2004) also contain useful advice on analysing data from water sampling programs.

Table 6.3. Recycled water uses, recommended class and recommended monitoring

Recycled water use	Class[1]	Recommended monitoring
Domestic and commercial property use		
• toilet *flushing*, outdoor hosing and washdown, above ground garden watering	A+	See Table 6.2a
Irrigating public open space and golf courses		
• above ground open space irrigation, uncontrolled access	A	*E. coli* weekly, turbidity[2] continuous, disinfection[3] continuous, pH weekly
• controlled access or subsurface irrigation	C	*E. coli* weekly, SS monthly, disinfection[3], pH monthly
Irrigating food crops and retail nurseries		
• food crops consumed raw or minimally processed	A+	See Table 6.2a
• sugar cane and grapes for wine production	C	*E. coli* weekly, SS weekly, pH weekly
• other above ground food crops with above ground irrigation	A+ [4]	See Table 6.2a
• other above ground food crops with below ground irrigation	C	*E. coli* weekly, disinfection[3] weekly, SS weekly, pH weekly
• root crops	A+ [4]	See Table 6.2a
• retail nurseries irrigating ready to eat crops	A+	See Table 6.2a
Irrigating pasture/fodder and agricultural washdown		
• pasture/fodder for dairy animals without withholding period	B	*E. coli* weekly, disinfection[3] weekly, SS weekly, pH weekly
• pasture/fodder for dairy animals with withholding period of five days	C	*E. coli* weekly, disinfection[3] weekly, SS weekly, pH weekly
• pasture/fodder for other grazing animals except pigs with withholding period of four hours	C	*E. coli* weekly, disinfection[3] weekly, SS weekly, pH weekly
• washdown of hard surfaces in agricultural industries	B	*E. coli* weekly, disinfection[3] weekly, SS weekly, pH weekly
Irrigating non-food crops		
• retail nurseries not irrigating ready to eat products	A	*E. coli* weekly, turbidity[2] continuous, disinfection[3] continuous, pH weekly
• silviculture, turf, cotton, wholesale nurseries with controlled access and other safeguards to protect the health of workers or neighbours	D	*E. coli* monthly, pH monthly
Industrial purposes		
• open system (potential for high human contact) e.g. car wash or quarry where aerosol generation is constant	A+	See Table 6.2a
• open system (potential for occasional human contact, but with safeguards in place)	A	*E. coli* weekly, turbidity[2] continuous, disinfection[3] continuous, pH weekly
• closed system (low human contact) • irrigation of "no public access" areas	C	*E. coli* weekly, disinfection[3] weekly, pH weekly
• fire fighting	A+	See Table 6.2a
Supplementing drinking water supplies		
• surface water or direct injection to aquifer	N/A[5]	See section 7.6 of these guidelines
Recreational purposes		
• fountains and water features (no primary or secondary contact recreation)	A[6]	*E. coli* weekly, turbidity[2] continuous, disinfection[3] continuous, pH weekly
• water features for amenity purposes only (controlled access) • natural or artificial wetlands	C	*E. coli* weekly, disinfection[3] weekly, pH weekly Site specific, depending on the environmental values and water quality objectives of the receiving waterway

[1] In this table a recommendation for use of any particular class of recycled water includes higher classes as well. In other words, if Class C is recommended, Classes A and B could also be used, but Class C is the minimum recommended standard.
[2] See footnote 4 to Table 6.2b. Turbidity should be monitored at the stage in the production process for recycled water that is most relevant. In other words, if turbidity levels are important to the disinfection process, turbidity should be measured immediately before disinfection.
[3] See comments on chlorine disinfection in section 6.6.3 of these guidelines.
[4] See section 7.3.6 of these guidelines for exceptions to this recommendation.
[5] Not applicable, as no specific recycled water quality has yet been determined for this use. See section 7.6 of these guidelines.
[6] An alternative class of recycled water may be used depending on the outcome of the Recycled Water Management Plan (see section 7.7 of these guidelines).

7. Supply and use of recycled water

7.1 PROTECTION AND MAINTENANCE OF DISTRIBUTION SYSTEMS AND STORAGES

Most recycled water delivery systems require some form of storage to provide a buffer during periods of lower demand or for temporary detention in the event of system malfunction. The two principal issues that arise with regard to storage of recycled water are storage capacity and microbial and algal growth.

7.1.1 Sizing of recycled water storages

Recycled water that is supplied for irrigation, whether for crops, landscape irrigation or garden watering, is subject to large fluctuations in demand owing to seasonal variation in plant growth and precipitation.
As irrigation of recycled water should not take place during rain events or when the soil is saturated, either the supplier or the user will sometimes need to have the capability to store the excess supply of recycled water or to discharge it to the environment.

Where the water recycling project receives water from an STP operating under an existing development approval, the sizing of the storage and any consequent requirement for discharge to the environment resulting from overtopping or bypassing of the storage should be discussed with the relevant local office of the EPA. The sizing of storage should also be addressed in the project's Recycled Water Management Plan.

The Model for Effluent Disposal using Land Irrigation (MEDLI, see section 7.3.5 of these guidelines) can be used to compare the effect of different capacities of recycled water storage on the performance of a scheme using a given size of irrigation area. The size of the storage will influence the likelihood of releases of recycled water from the storage during wet weather. From this, a combination of storage size and irrigation area can be selected so that the magnitude and frequency of overtopping is such as not to cause environmental harm or adversely affect the environmental values of any receiving water body. For large scale recycled water irrigation schemes, any relevant provisions of Chapter 3 (Part 6, Referable Dams and Flood Mitigation) of the Water Act should be followed. These include the need for licensing of what are called 'referable' dams (classified by height and storage).

7.1.2 Maintenance of water quality during storage of recycled water

Whenever recycled water is stored, as well as during its residence time within the recycled water pipe system, there will be potential for microbial or algal growth that could lead to a reduction in water quality. Also, open storages are susceptible to contamination with animal and bird faecal matter and re-suspension of sediments. Where there is potential for degradation of water quality during storage or distribution, appropriate disinfection, further treatment or other preventive measures may need to be applied, depending on the planned final use of the recycled water.

Storage of recycled water in open storages at any stage of treatment or distribution has the potential to promote the growth of cyanobacteria and algae, which can significantly reduce water quality for many applications. The risk of algal blooms is increased when nutrient levels are elevated (particularly phosphorus) and when water temperature is high.

If an algal bloom occurs in a recycled water storage, supply of recycled water for stock watering, irrigation or other purposes that could involve inhalation of aerosols should be discontinued. As the identification of the specific cyanobacteria that may contain toxins can only be done by specialists, supply should not be reconnected until a laboratory (with accreditation by NATA for the appropriate testing method) has confirmed the absence of toxins.

If the risk of algal blooms in stored recycled water has been determined as being high or very high, control measures should be considered. These could include increased nutrient removal during treatment, establishment of aquatic plants within the storage so that excess nutrients can be taken up or some form of chemical or physical treatment to reduce algal growth in the storage. Destratification of water storages has been found to reduce the tendency for algal blooms, especially some toxic forms of cyanobacteria. Further advice on prevention of algal blooms in water storages can be obtained from the Department of Natural Resources and Mines (see Appendix D for contact details) or see the DNRM fact sheets: *Blue-green algae: General information* and *Managing blue-green algae blooms in farm dams*.

7.1.3 Disposal of below specification recycled water

When recycled water has been produced that does not meet specifications, or beneficial use is not possible, the recycled water supplier and/or user should ensure that alternative methods of either storage or disposal are available to avoid contamination of already treated water. If the supplier needs to dispose of below specification recycled water, this should be done in accordance with their existing development approval. If there is no development approval covering the use of recycled water, advice should be sought from the local EPA office before disposal to the natural environment is undertaken as any such release may cause environmental harm or adversely affect the environmental values of the receiving water body.

7.1.4 Mosquito control in storages

In Queensland, mosquitoes are vectors of Ross River virus disease, Barmah Forest virus disease, dengue, malaria, Japanese encephalitis virus disease and Murray Valley encephalitis virus disease. Breeding sites include fresh, brackish and polluted water in natural and constructed ground sites as well as artificial containers such as water storage tanks, constructed drains, tyres and discarded tins and bottles.

It is essential that the implementation of water recycling does not enhance mosquito breeding and the transmission of disease. The Local Government Association of Queensland has produced a *Mosquito Management Code of Practice* (LGAQ 2002) that contains detailed advice on mosquito control in Queensland. Some key preventative measures are discussed below:

- Consideration should be given to potential mosquito breeding in the design stage of recycling projects. Queensland Health (2002) has published *Guidelines to minimise mosquito and biting midge problems in new development areas*. This document provides advice on how to prevent or minimise the impact of mosquitoes and other biting insects in new development areas.
- Constructed wetlands, water impoundments, grass swales and open earth drains can all be designed so as to minimise mosquito breeding. The *Australian Mosquito Control Manual* (Mosquito Control Association of Australia 2002) has helpful advice on mosquito control. This manual can be purchased through the Association's website.
- Regular maintenance of all structures associated with storage or treatment of recycled water is necessary to minimise mosquito breeding. For example, if mosquitoes are present in an open water storage, water plants should be cleared away from the edge of the storage to reduce habitat for larvae. In particular, recent research suggests that dense mats of surface vegetation or fallen decaying material can encourage mosquito breeding (Dale et al. 2001).
- When recycled water is used for irrigation, surface ponding should be prevented by appropriate irrigation scheduling.
- Construction and installation of water storages should be carried out in accordance with Part 8, Mosquito Prevention and Destruction of the Health Regulation 1996. Where a risk assessment process has identified that there is a significant risk of mosquito borne disease, holding tanks for recycled water should be designed so as to prevent entry of mosquitoes.
- Open recycled water storages should be monitored regularly to identify presence of mosquito larvae.
- Where recycled water is used or treated in a constructed wetland, the cells of the wetland and the inlets/outlets should be designed so that there is no stagnant water. Also, aligning the cells parallel to the dominant wind direction so that wind ripples disturb the surface of the water appears to inhibit mosquito larval survival (Dale et al. 2001).
- If a potential health risk from mosquito breeding has been identified, biological control using natural predators, such as aquatic invertebrates or native fish known to prey upon mosquito larvae, may be considered.
- Chemical controls range from relatively benign "natural" larvicides such as those based on *Bacillus thuringiensis israelensis* (Bti) through to more toxic chemicals. Only chemicals registered for mosquito control should be used. If chemicals are used, this must not contaminate the recycled water so that it is no longer fit for its intended purpose.

Further information on mosquito control may be obtained from Queensland Health. Information on use of fish in mosquito control maybe obtained from the Department of Primary Industries and Fisheries (see Appendix D).

7.2 DUAL WATER SUPPLY SYSTEMS

Class A+ recycled water supplied through a dual water supply system to residences and industry can take the place of a broad range of current uses of drinking water. These uses include garden watering, washing of cars, boats and external surfaces of buildings, toilet flushing, and fountains and water features (not used for bathing).

Water supply systems in Queensland are generally owned and controlled by the water service provider up to the point of connection to the premises' supply pipe and after that by the property owner. Responsibility for ensuring the integrity of the recycled water system up to the point of supply therefore lies with the water service provider and thus works can only be undertaken by employees or contractors employed by the water service provider.

In some cases, for example, community title developments or resort islands, the water supply infrastructure is provided largely or entirely by the body corporate or leaseholder. In this case the responsibility for infrastructure lies with the owner of the infrastructure.

Work done on pipes or fittings located within the property boundary of the owner of the property is the responsibility of the property owner and must only be done by a licensed plumber in accordance with the Plumbing and Drainage Act.

7.2.1 Systems under the control of the water service provider

The Department of Natural Resources and Mines has published *Planning Guidelines for Water Supply and Sewerage* (NRM 2005). In these Planning Guidelines, the Queensland Government has adopted the following Water Services Association of Australia (WSAA) codes as suitable standards for the collection/reticulation component of sewerage and water supply schemes, including recycled water:
WSA 02 – 2002 Sewerage Code of Australia
WSA 03 – 2002 Water Supply Code of Australia
WSA 04 – 2001 Sewage Pumping Station Code of Australia

The Water Services Association of Australia Supplement to its *Water Supply Code 2002 (Version 2.3)* entitled *Dual Water Supply Systems (Version 1.1),* covers the design and construction of dual supply systems for servicing new developments that provide both drinking water and non-drinking water via reticulation. The supplement contains advice relating to:

- differentiation of drinking water and non-drinking water pipe systems via colour coding and other markings
- design considerations for dual supply systems, including system configuration, sizing of mains, pressure, main depths, fittings and flushing points
- construction and installation of property services
- standard drawings for prevention of cross-connections between drinking and non-drinking water supply systems.

While the WSAA codes are not mandated, they are suggested as suitable for installation and maintenance of dual pipe systems in Queensland.

7.2.2 Integrity testing for dual reticulation systems

The provider of dual reticulation water services should set up and undertake a systematic inspection procedure for all properties connected with the recycled water system. Integrity testing should be done in accordance with the AS/NZS 3500.1:2003, section 9: *Non-drinking water services*. The inspection should test operation of the non-return valves by pressure testing and check for cross-connections between potable and recycled water supplies.

Each provider of recycled water services should determine the frequency of inspection necessary to detect any cross-connections. The minimum inspection frequency should be:

- all new services at installation
- all services on change of ownership
- all services following completion of property extensions or plumbing modifications.

The provider should periodically audit recycled water services. If the audit indicates any cross-connections are occurring in the system, inspection frequency and practices should be reviewed and appropriate measures taken.

7.2.3 Cross-connection control and backflow prevention

It is fundamental to the design of recycled water distribution systems to maintain separation of the recycled water and potable water systems to avoid potential health risks from inadvertent cross-connection and possible direct ingestion of the recycled water. It is therefore essential that no direct connection of the recycled water system into any potable supply system take place.

All recycled water pipes should be installed in accordance with the Standard Plumbing and Drainage Regulation. If potable water is supplied into the recycled water system as make-up water, an approved air gap or other backflow prevention device must be installed at the point of delivery of the potable water supply in accordance with the Standard Plumbing and Drainage Regulation. If this device is a critical control point in any risk assessment process for a dual reticulation scheme, it should be regularly inspected and tested, with records kept of such inspections and tests, as part of the Recycled Water Management Plan.

Where the recycled water system does not have to provide the high flows or pressure required for fire fighting, the potable supply can be protected from the risk of backflow by operating the recycled water system at a lower pressure than the potable water system.

7.2.4 Differentiation of pipe systems

Recycled water distribution systems should be clearly and uniquely identified so they cannot be mistaken for any system used to convey potable water. All above ground and buried pipes for domestic and residential buildings should be distinctively and permanently colour-coded (deep purple or lilac) in accordance with AS/NZS 3500.1:2003, section 9: *Non-drinking water services*. Where practical, they should be laid below the depth of the potable water supply. For above ground installations, recycled water pipes should not be installed within 100 mm of potable water pipes and for below ground installations they should not be laid closer than 300 mm from potable water pipes.

In buildings other than dwellings or apartment buildings, all pipes installed in ducts, accessible ceilings or exposed in basements or plant rooms should be clearly identified in accordance with AS 1345-1995 *Identification of the Contents of Pipes, Conduits and Ducts*.

Recycled water pipes installed as part of an irrigation system should comply with AS 2698.2-2000 *Plastics Pipes and Fittings for Irrigation and Rural Applications*.

7.2.5 Skills and competencies of plumbers

In order for the additional requirements of dual reticulation systems discussed above to be implemented safely and consistently, it is essential for all plumbing work done on recycled water systems to be completed by a plumber holding an appropriate licence under the Plumbing and Drainage Act.

7.2.6 Domestic use of recycled water

Hazard control at the point of use of Class A+ recycled water in residential situations must be limited to those actions that can be readily communicated to the community and easily complied with. The specific requirements for hazard control should be developed as part of the Recycled Water Management Plan and specified in the terms of use document supplied to customers. Hazard controls for this form of use may include:

- prohibition of the performance of any regulated plumbing works by anyone other than a licensed plumber
- maintenance of appropriate signs over any recycled water taps
- provision of advisory information to customers recommending approved and non-approved uses of recycled water.

7.2.7 Validation and verification for dual reticulation schemes

All of the above control measures, as well as any others identified during the risk assessment phase during development of the Recycled Water Management Plan, must be checked during both validation and verification of Class A+ schemes supplying recycled water for dual reticulation.

7.3 IRRIGATION WITH RECYCLED WATER

Appropriately treated recycled water may be used for irrigation of public open spaces such as parks, road verges, sports grounds, schoolyards, golf courses, racecourses and cemeteries as well as pasture, agricultural, horticultural and silvicultural crops. Appropriate classes of recycled water for all of these applications are shown in Table 6.3 of these guidelines.

Many of the management controls that should be developed for general irrigation purposes (i.e. regardless of source water used) also apply to irrigation with recycled water. This would include, for example, calculation of hydraulic loading rates, erosion control, prevention of runoff and nutrient monitoring. Therefore, an existing irrigation management plan could be readily adapted to apply to recycled water following completion of a properly conducted risk assessment.

Recommended hazard controls for irrigation with recycled water are discussed further below.

7.3.1 Site assessment

One of the first steps in developing an irrigation scheme using recycled water is to conduct a comprehensive site assessment. Appendix E shows some of the key factors that should be considered. The site assessment may be undertaken during the planning phase of project development, or later during development of the Recycled Water Management Plan, but any findings from the assessment, in terms of monitoring requirements or control measures, should become part of the Recycled Water Management Plan.

7.3.2 Signs

Wherever recycled water is used, erect prominent warning signs indicating, in English and any other appropriate community language:

"RECYCLED WATER BEING USED — DO NOT DRINK"

Alternative wording may be required, depending on the possible exposure route for humans. For example, a recycled water storage on a golf course may need a sign warning golfers not to enter the water to retrieve golf balls. Location, sizing and wording of signs should be determined after consideration of factors such as public accessibility, visibility from likely points of access and the nature of the sub-community targetted (e.g. children or non-English speakers). All recycled water signs should comply with AS 1319-1994 *Safety Signs for the Occupational Environment*.

7.3.3 Controlled access

Controlled access means that the recycled water user can maintain effective control over public access to an area being irrigated or being affected by spray drift from irrigation. This can be achieved by fences and lockable gates or clear demarcation of land that may be affected by irrigation, combined with prominent warning signs. Controlled access in public areas is not guaranteed simply by night-time irrigation. Additional mechanisms, such as those mentioned above or even temporary fencing erected for the duration of irrigation, should be used.

No restriction of public access is required when Class A or A+ recycled water is used, but the recycled water user should ensure the risk of inadvertent consumption or inhalation of aerosols is minimised via appropriate controls. Spray irrigation of Class B, C or D recycled water always requires controlled access. The precise nature of the controls used should be determined according to the risk assessment conducted during formulation of the Recycled Water Management Plan. Where subsurface drip irrigation is used, Class B or C recycled water may be used with uncontrolled access. However, it is essential that the drip irrigation does not lead to surface ponding of water. Subsurface irrigation should be installed below the soil surface and not just below surface mulch.

Class B or C recycled water may be used for spray irrigation in areas where public access can be prevented during irrigation and for long enough after irrigation that wetted surfaces have dried. No simple time limit can be placed on drying of surfaces, as this will depend on the season and atmospheric conditions. Use of this quality of recycled water may also necessitate measures to reduce spray drift from the reuse site (see below). All of these issues should be addressed during the scheme risk assessment and in the Recycled Water Management Plan.

Recycled water storages in areas open to public access should be either fenced off or clearly signposted to warn against swimming, wading, boating or misuse.

7.3.4 Irrigation buffer zones

Whenever using recycled water in areas where public access is uncontrolled, it is advisable to use irrigation delivery systems that minimise aerosols. This is important in both minimising contact with recycled water as well as the possibility of creating an adverse public reaction to recycled water use in public spaces.

No specific buffer zone is required for spraying of Class A recycled water. If no other information on risk factors dictates a need for a specific width of buffer zone, the following could be used as a starting point for the other classes of recycled water:

- 30 metres for Class B recycled water
- 50 metres for Class C recycled water
- 100 metres for Class D recycled water.

However, if a risk assessment completed as part of a Recycled Water Management Plan shows that these buffer zones do not accurately reflect the risks, alternative buffer zone distances can be used that more accurately reflect the risks of the particular site and usage proposed. When using Class B or C recycled water, spray-drift into residential areas and areas of public access can be reduced by use of screening trees (especially those with small leaf area such as casuarinas), which reduce wind speed and thus reduce transmission of water droplets. Other methods to reduce the impact of spray drift include use of anemometer switching systems, which shut off irrigation when wind speed is above a certain level, low rise sprinklers, which have a limited 'throw', and sprinklers with a large droplet size to reduce production of water vapour. Recycled water should not come into contact with picnic tables, barbecue facilities and drinking fountains.

Buffer distances should be measured from the edge of the spray zone to the point at which contact with recycled water could present a risk. For example, for irrigation of recycled water at a golf course, neighbouring residents could be expected to use every part of their yard so the buffer distance should be measured to the property boundary, not the house.

7.3.5 Use of mass balance approach for recycled water irrigation

The theory behind the mass balance approach in irrigation is that the application rate of any component of recycled water, whether it be hydraulic loading, salts, nitrogen or phosphorus, should not exceed:

- the rate at which it is taken up by the plants and removed from the site
- the safe storage of the element in the soil
- allowable losses into the environment.

Recycled water users who wish to irrigate crops, pasture or public open space should therefore undertake a comprehensive water, nutrient and salt budget for their proposed reuse. There are a variety of tools available for this purpose. One that is particularly suitable for Queensland conditions is MEDLI. This is a computer-based mathematical model that was developed jointly by the Queensland Department of Primary Industries and the Co-operative Research Centre for Waste Management and Pollution Control. It is designed to simulate the operation of a recycled water irrigation scheme over a long period, typically many decades.

MEDLI simulates the natural processes that take place from day to day, by performing material balance calculations using the volume of incoming water, its constituents (nitrogen, phosphorus, dissolved salts), data about the physical system itself, plus climatic data for the particular site covering a prescribed period. Either historical or synthesised climatic data can be used. The model is suitable for a range of different sources of recycled water, including municipal effluent and wastewater from intensive livestock industries. For further information, contact the Department of Natural Resources and Mines or the *Department of Primary Industries and Fisheries* (see Appendix D).

Salt management is a critical issue when using recycled water for irrigation. While a certain amount of salt build-up in soil irrigated with recycled water may be unavoidable, the salt must be prevented from damaging the productive capacity of the land, or significantly degrading ground water.

The accumulation of sodium in the soil can cause a decline in soil physical properties, especially in porosity and permeability to water. If salt builds up in the soil root zone, the growth rate of plants and their capacity to take up water and nutrients will be reduced. Some species cope better than others, and highly salt-sensitive crops should be avoided. Unless the accumulated salt is washed out of the root zone regularly damage will occur.

The amount of leaching required to achieve this 'washing' of the root zone can be estimated from the salt content of the recycled water, the presence of other contaminants and the crop's water-use rate. In many locations, rainfall will provide enough leaching in most years to protect the root zone. When this is not the case, and extra irrigation is needed to achieve the required leaching, provision may have to be made to use water with a lower salt content for this purpose.

Another point to remember is that the long- term sustainability of irrigation with recycled water is determined not so much by the concentration of salts in the recycled water as the actual loads applied to the soil. Thus, if implementation of water use efficiency measures can reduce the amount of water applied, this will bring about a commensurate reduction in the loads of salt and other contaminants. For example, if a golf course is using 1 ML of recycled water per day with a TDS concentration of 1200 mg/L, they could reduce their TDS load from 12 tonnes per day to 8 tonnes by reducing their water use by one-third.

Where an irrigator is concerned that salt levels in the recycled water they are using may affect the salinity or sodicity of their soil, they may wish to use the SALF (Salt and Leaching Fraction) computer program (DNR 2000c). SALF may be used to determine the long-term steady state effect of irrigation with recycled water on the salt leaching fraction from the soil, soil salinity level and effect on crop yield.

While hydrological, nutrient and salt modelling can provide a valuable input into the planning of recycled water irrigation schemes, ongoing monitoring of scheme performance will also be necessary to ensure scheme sustainability. A monitoring program should be designed as part of the Recycled Water Management Plan (see Chapter 4 of these guidelines). The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000a) contain trigger values for a wide range of potential contaminants and water quality characteristics in irrigation water used for primary production.

If the risk assessment shows that the quality of the recycled water is not appropriate to ensure the long-term sustainability of the project, further treatment of the recycled water or appropriate risk management strategies will have to be implemented to ensure sustainability.

The Queensland Government's *Planning Guidelines: Separating Agricultural and Residential Land Uses* (DNR 1997b) provide useful information on planning issues affecting agricultural land uses that may involve water recycling, including conflict assessment, buffer area design, control of odours and sediment and stormwater runoff.

7.3.6 Irrigating food crops

Regardless of the standard of recycled water used, irrigation of food crops using recycled water should only take place after a Recycled Water Management Plan has been completed that includes a HACCP or equivalent food industry risk assessment. HACCP assessments for irrigation of food crops must also take account of risks associated with post-harvest handling. For example, while an irrigated vegetable crop may have post-harvest processing or cooking, or a thick removable rind, irrigation with lower classes of recycled water could expose other harvested crops to cross-contamination risks during post-harvest handling (particularly during washing of produce), especially if the other crops are consumed raw.

The risks associated with food crops irrigated with recycled water vary with quality of the recycled water used, the irrigation delivery system, the type of crop, the nature of post-harvest handling and the extent of post-harvest processing.

As noted in section 2.1.6, food sold in Queensland must comply with the requirements of the *Queensland Food Act 1981,* the Food Standards Regulation 1994 and the *Australia New Zealand Food Standards Code*. In particular, Standard 1.4.2 of Part 1.4 (Contaminants and Residues) of the code sets out maximum residue limits (MRLs) for a wide range of contaminants that can enter the food chain during food production. If a chemical is detected in food that is above the MRL for that chemical, or is detected *at any level* for a chemical for which there is no MRL, then that food would be considered 'unsuitable' under the Queensland Food Act.

This has clear implications for the recycled water producer's trade waste management. If the risk assessment for the Recycled Water Management Plan identifies potentially hazardous chemicals in raw sewage, there may be a need for specific monitoring to ensure that treatment processes are consistently removing these contaminants.

Although uptake of chemical contaminants by food crops is not well understood, contaminant levels in food are unlikely to be affected by the generally low levels of chemical residues typically found in those classes of recycled water that are suitable for irrigation of food crops.

Any food crops that are likely to be consumed raw should only be irrigated with Class A+ recycled water. Crops that receive intensive, obligatory post-harvest processing, such as sugarcane or wine grapes, can be irrigated with Class C recycled water. Above ground food crops with subsurface irrigation delivery systems can also use Class C recycled water. Above ground food crops watered via spray irrigation and all root crops should use Class A+ recycled water but if a Recycled Water Management Plan has been completed and risk management strategies adopted that can guarantee the safety of the crop being irrigated, an alternative class of recycled water could be used.

The Commonwealth Department of Agriculture, Fisheries and Forestry has produced *Guidelines for On-farm Food Safety for Fresh Produce* (AFFA 2001) that provide a single consolidated source of information relating to on-farm food safety for fresh produce crops. They are designed to help assess the risks to food safety during on-farm production of fresh crops and provide information on good practices to prevent, reduce or eliminate the hazards, including the risk of contaminating produce when using water.

Many retail nurseries supply food plants that may be eaten shortly after sale (e.g. herbs and some vegetables). These should only be irrigated with Class A+ recycled water. Retail nurseries may also have a very high level of contact between customers (or workers) and wetted surfaces including plants. Therefore Class A recycled water should be used for irrigation in retail nurseries. If a Recycled Water Management Plan incorporating HACCP is prepared that can demonstrate that health risks can be managed, a lower class of recycled water could be used. For wholesale nurseries see section 7.3.8 of these guidelines.

7.3.7 Pasture irrigation, stock watering, and agricultural washdown

Recycled water can be used for irrigation of pasture and fodder for grazing animals, for stock water and for washdown of facilities:

- Class B recycled water can be used for irrigation of pasture and fodder for dairy animals where there is no withholding period between irrigation and feeding.
- Class C recycled water can be used for pasture and fodder for dairy animals if there is a withholding period of five days and for other grazing animals (except pigs) with a withholding period of four hours.

- Recycled water supplied for stock drinking water should meet the requirements of Class B, with the exceptions noted below. Stock should not drink recycled water sourced from the same or similar species of animals as this increases the hazard from pathogens.
- Stock should not be exposed to recycled water that may contain helminth (tapeworm) eggs. If the source water may contain helminth eggs, it should not be used for stock, or further treatment must be undertaken to achieve helminth removal. Helminth removal can be achieved by a minimum of 25 days pondage detention or filtration via sand or membranes. Where cattle may come into contact with recycled water, the Recycled Water Management Plan should include appropriate assessment of risks as well as specific control measures to prevent infection.
- Class B water can be used for washdown of facilities in dairies, stockyards and feedlots but should not come into contact with milking machinery.

Owing to the need to prevent the pig tapeworm, *Taenia solium*, from establishing a life cycle in Australia, pigs should not come into contact with recycled water sourced from municipal STPs.

Additional advice regarding water quality for stock animals can be found in Chapter 4 of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000a).

7.3.8 Irrigating non-food crops, including trees, turf and plant nurseries

Typical uses include irrigation of non-food crops such as cotton, trees, woodlots, turf farms and wholesale plant nurseries (for retail nurseries see section 7.3.6 of these guidelines). Production of these crops will generally take place in areas where public access can be excluded, and thus a lower quality of recycled water may be used. Where the risk assessment undertaken as part of the Recycled Water Management Plan has indicated that public access can be controlled, and off-site impacts prevented, Class D recycled water can be used to irrigate these crops. If a wholesale nursery is supplying fresh herbs or vegetables to a retail outlet, the Recycled Water Management Plan should ensure that any health risks are appropriately managed.

Parties wishing to supply or use recycled water to irrigate hardwood plantations in Queensland should refer to *Using Recycled Water to Irrigate Hardwood Plantations in Queensland* (DPI 2003).

7.4 USING RECYCLED WATER FOR INDUSTRIAL PURPOSES

Industrial use includes washdown, dust control on construction sites and quarries, boiler feed, process water, industrial cooling and mining as well as a broad range of other uses. Generally, the water quality requirements for industrial purposes will be determined by the needs of the process being supplied. Where the recycled water is used within an open system, for example for dust suppression on construction sites where workers or passing cars may be subject to intermittent spray drift, Class A recycled water, or better, should be used. For industrial uses of recycled water within closed systems, for example for industrial cooling or boiler feed, Class C recycled water could be used, subject to the need for additional treatment to prevent fouling, scaling, corrosion, foaming or biological growth within recycled water pipes. Where recycled water is used for above ground irrigation of landscaping where there is no public access, Class C recycled water may be used.

Where an industrial facility has a development approval from the EPA or other approval body, any discharge of recycled water from the site to stormwater or the natural environment (including ground water) should be covered by the conditions attaching to the development approval. If the facility or site is not covered by an existing development approval, discharges of recycled water will be subject to the user's general environmental duty not to cause environmental harm. In this case, further advice should be sought from the local office of the EPA.

7.5 USING RECYCLED WATER FOR FIRE FIGHTING AND FIRE PROTECTION

7.5.1 Fire fighting

Where possible, fire fighters need to have access to high quality water because the water they use to fight fires often saturates them, they ingest aerosols fighting a fire and water from fire hoses is sometimes used in first aid treatment of burns victims at the scene of the fire. In urban areas the highest quality water is supplied through the reticulated potable water system.

However, the need to provide fire flows via the potable water system can have some undesirable effects on this system. Fire fighting requires water pressure and volumes above those required for most domestic and commercial situations. This means that potable water mains that have a dual role as fire fighting mains often have to be of larger diameter than they would otherwise be. This leads to water spending more time in the mains, thus increasing the opportunity for microbial biofilms to grow within the pipe system. This can reduce water quality for customers, shield pathogens from disinfection and give rise to more frequent mains flushing. In turn this can lead to wastage of potable water, increased use of chorine and possibly increased levels of disinfection by-products in the potable water system.

For this reason, when dual reticulation systems are being planned, it may be found that it is not practical to provide fire flows through both the potable and recycled water mains. It can be therefore be advantageous to move the requirement for fire flows out of the potable water mains and into the recycled water mains.

Use of Class A+ recycled water for fire fighting represents a negligible health risk for fire fighters (WSAA 2004). This is because the high level of treatment of Class A+ recycled water removes pathogens to such an extent that the likelihood of any health impact on fire fighters, given their infrequent exposure, would be negligible. Also, although there can be trace chemical residues in Class A+ recycled water (unpublished EPA data), the levels are so low that occasional exposure from fire fighting would not be expected to present a health hazard to fire fighters.

Where fire fighters have to treat burns at the scene of a fire that is being fought with Class A+ recycled water, it is essential that immediate measures be taken to rapidly cool the burn with copious amounts of cool water. The need to cool the affected tissue and alleviate pain is of far greater importance than the small differences in the quality of Class A+ recycled water compared with drinking water. First aid treatment for burns victims always involves infection control regardless of the quality of the water used to cool the burn.

However, in providing first aid to persons with burns or scalds in areas where there is a readily accessible reticulated drinking water supply, preference would normally be given to the drinking water supply, provided this does not delay the immediate treatment of the burn.

In accordance with the requirements of the Workplace Health and Safety Act, described in section 2.1.7 of these guidelines, whenever recycled water is proposed to be used for fire fighting, the employer of the fire fighters has an obligation to ensure the workplace health and safety of their employees. The employer's responsibilities under this Act are summarised in section 2.1.7.1 of these guidelines. A recommendation in these guidelines does not take the place of the employer's responsibilities under the Workplace Health and Safety Act.

7.5.2 Fire protection through automatic fire sprinkler systems

Water used in automatic fire sprinkler systems needs to be high quality because it may sit in the pipe system for extended periods, leading to the possibility of microbial regrowth within the system. As long as it complies with the requirements of Australian Standard AS2118.1-1999 *Automatic Fire Sprinkler Systems*, recycled water that has been treated to the Class A+ standard may be suitable for this purpose. However, if it has higher nutrient levels than potable water, there may be a need for additional management (e.g. regular flushing or disinfection) to reduce growth of biofilms. As the use of recycled water in automatic sprinkler systems is not likely to generate significant potable water savings, and may involve higher management overheads, this use may not be practical in most cases.

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.

Recycled water may be added to a river, aquifer, dam or other water body where it mixes with the existing source for drinking water. When this is done in a planned way, the recycled water will usually be treated to a standard that is even higher than potable water, before being blended with raw water, re-treated, and supplied to customers.

The treatment required to ensure safe indirect potable reuse of effluent would have to be determined on a case by case basis. This is because there are many man-made chemicals that potentially may be found in sewage and it is not possible at this time to set safe concentrations for all of these chemicals. Also, it is not feasible to monitor for all known chemicals that could occur in recycled water sourced from STPs, as most chemical contaminants require specific analytical tests that, if undertaken on a regular basis, would not be economically feasible.

For these reasons, the best method of ensuring the safety of planned, indirect potable reuse is to undertake a comprehensive HACCP-based risk assessment of the entire system for collection, treatment and use of recycled water for indirect potable purposes. This should involve the following steps:

- a human health risk assessment of the extent of contaminant removal required to guarantee that drinking water quality can be consistently achieved
- a systematic characterisation of the catchment of the sewerage system supplying the raw sewage
- identification of the sources for all contaminants of concern in the source sewage
- negotiation of strict trade waste controls specifying the concentration and loads of all contaminants of concern discharged to sewer (this may need to include domestic discharges if these are suspected to be the source of identified contaminants)
- specification of monitoring requirements for all high risk contaminants of concern at their source (for commercial customers only). Consideration should be given to automated systems (e.g. telemetered alarms back to the treatment plant) to alert operators about any out of specification wastewater that enters the sewerage system
- design of a treatment process that specifically removes all contaminants of concern that have been identified in the risk assessment. The treatment process will also have to guarantee a sufficiently high log removal of pathogens to ensure that none enters the drinking water system. This is likely to exceed the five to six-log removal discussed for dual reticulation quality recycled water, but will depend on the outcome of the health risk assessment
- where possible, online monitoring of treated water for all contaminants or indicators that the Recycled Water Management Plan has identified as representing a hazard to human health. Currently, online monitoring is limited to a small range of contaminants, but this field of science is rapidly advancing and so treatment plant operators must ensure that they make use of new online monitoring technologies as soon as they become sufficiently reliable and affordable. Over time this will include DNA-based biosensors that are capable of detecting specified pathogens
- a final recycled water quality monitoring program targeting all known contaminants of concern in the final treated water.

It should be borne in mind that, as noted in section 3.1 of these guidelines, the Queensland Government will not recognise STP effluent in water allocation and management frameworks established under a Water Resource Plan.

7.6.1 Aquifer storage and recovery

Aquifer storage and recovery involves recharge of aquifers with water for storage and later use. This aquifer recharge can be achieved either by surface spreading of water with percolation to ground water or direct injection of water into aquifers. Recycled water can be used for this purpose to achieve augmentation of potable or non-potable water supplies, to renew depleted aquifers or to prevent seawater intrusion into aquifers in coastal areas.

The overriding consideration when investigating the introduction of recycled water into aquifers is that there should be no resulting deterioration of ground water quality. Where recycled water sourced from STPs is introduced into an aquifer that may be used for extraction of potable water, the same site-specific assessment and management processes should be used as discussed above. Where recycled water is introduced into an aquifer that has no drinking water extraction, Class A+ recycled water should be used. Further information on aquifer storage and recovery using stormwater can be found in the South Australian EPA *Code of Practice for Aquifer Storage and Recovery*.

7.7 USING RECYCLED WATER FOR WATER FEATURES AND HABITAT PURPOSES

Determination of the appropriate class of recycled water for fountains and ornamental water bodies should only take place after an appropriate assessment of the risks of human contact has been undertaken. Amongst the factors that should be considered are the likelihood and frequency of human exposure to recycled water, the effectiveness of disinfection, the extent of aerosol generation and the prominence and wording of signage. For example, if the person responsible for the water quality in the fountain or water feature is aware that there is a likelihood of human contact with the water (e.g. wading on hot days or occasional accidental ingestion of water) it may be appropriate to use only class A+ recycled water. If human contact can be appropriately controlled, class A recycled water could be used. If there is certainty about no human contact (e.g. no physical access or no aerosol generation) class B or C recycled water could be used. Use of any class of recycled water other than Class A+ must involve appropriate consideration of control measures during development of the Recycled Water Management Plan.

Highly treated recycled water may be used to create artificial wetlands or to restore natural wetlands degraded by drought or over-extraction of water. However, the continuous discharge of treated effluent should not be used to create environmental flows within rivers, as this will not replicate the highly variable nature of natural flows. As noted in section 3.1 of these guidelines, the Department of Natural Resources and Mines will not include releases of recycled water to a waterway as comprising part of the allocatable flow from that waterway.

Where recycled water is used for environmental purposes, it is essential that the environmental qualities and water quality objectives of the receiving waterway are considered before this takes place. The EPA is currently working with stakeholders to establish these values in accordance with the Environmental Protection (Water) Policy. For more information see the *EPA website*.

Where recycled water is being supplied by a facility that is subject to a development approval from the EPA, such as an STP, the holder of the approval will have to demonstrate to the EPA both the need for environmental releases of recycled water as well as a clear net benefit to the environment from the release.

8. Sample hazard control tables

In keeping with the multiple barrier approach to water recycling there are many actions that can be taken to reduce or eliminate hazards, and the likelihood of their occurrence, during production, supply and use of recycled water.

Table 8.1 contains examples of some typical hazards that can be controlled by suppliers and users of recycled water, as well as typical hazardous events and suggested control measures. However, these are by no means comprehensive and must be critically assessed and supplemented during development of the Recycled Water Management Plan. In other words, all risks specific to the particular sewage collection system, treatment plant, distribution system and reuse application must be assessed and controlled.

Further detailed information on hazards and controls for use of recycled water can be found in the National Guidelines for Water Recycling (NRMMC & EPHC 2005).

Table 8.1. Sample hazard control tables for recycled water collection, treatment, storage and use

Collection of sewage and production of recycled water (hazards and controls are dependent on type of treatment used)

Hazard	Hazardous event	Possible controls	Responsibility
Chemical contaminants in domestic sewage	Excessive use of household cleaning products containing contaminants like boron, phosphates and other salts	Awareness campaign to encourage residential water users to use cleaning products with lower levels of chemicals	Sewerage service provider
Chemical contaminants in industrial sewage (trade waste)	Discharge of trade waste beyond the capacity of STP to safely treat	Trade waste agreements with all industrial and commercial customers Strict compliance auditing of trade waste agreements Pollution reduction programs to reduce strength of trade waste to level of domestic discharges Undertake trade waste investigation to discover the source of contaminants	Sewerage service provider
	Biomass inhibition or die off at STP due to toxic chemicals in influent	Temporary storage of poorly treated effluent to allow re-treatment to reduce level of contaminants	Treatment plant operator
BOD and ammonia	Inadequate BOD and ammonia removal in aeration tanks due to mechanical failure of blowers	Online monitoring of blower operation Shutdown of supply to recycled water system Preventive maintenance program	Treatment plant operator
Toxic chemicals or hydrocarbons used at STP	Spill of toxic chemical or hydrocarbon used on site	Standard operating procedures for use of all chemicals and hydrocarbons on site Appropriate bunding of all chemical and fuel storage tanks on site Emergency response procedures for chemical spills	Treatment plant operator
All contaminants in recycled water	Heavy rain causing high flow rate through STP	Temporary storage of poorly treated effluent to allow re-treatment to reduce level of contaminants	Treatment plant operator

Table 8.1. (continued)

Collection of sewage and production of recycled water (hazards and controls are dependent on type of treatment used) (continued)

Hazard	Hazardous event	Possible controls	Responsibility
Heavy metals	Supply of recycled water with high levels of heavy metals	Additional physical/chemical treatment process to remove heavy metals during treatment Membrane treatment to remove heavy metals in final effluent Undertake trade waste investigation to identify source of heavy metals	Treatment plant operator
High levels of suspended solids in final effluent (and odour and nutrients)	Excessive sludge age due to increased bacterial activity during warm weather	Increase the wasting rate from activated sludge plant	Treatment plant operator
Human pathogens in recycled water	Pathogens shielded from disinfection by suspended solids	Online particle counter and/or turbidity meter to monitor levels of suspended solids If UV disinfection used, UV transmissivity sensor must be used to detect drops in transmissivity Automatic shut-off of supply in the event of critical limit being reached	Treatment plant operator
	UV lamps fail or dose inadequately	Online monitoring of UV lamp performance	Treatment plant operator
	High pH in treatment plant effluent prevents chlorine from achieving adequate disinfection	Adjust pH Use alternative disinfection step	Treatment plant operator
Organic chemicals in recycled water (e.g. surfactants, pesticides, endocrine disrupting chemicals)	High level contact by humans with recycled water resulting in daily ingestion of significant amounts of recycled water	Remove organic chemicals during treatment through reverse osmosis or biologically and/or activated carbon filtration	Treatment plant operator
Chemical contaminants in the membrane filtration concentrate (waste stream)	Disposal of concentrate and cleaning solutions containing high levels of chemical contaminants	Specialised treatment or disposal of spent cleaning solution and concentrate	Treatment plant operator

Table 8.1. (continued)

Storage of recycled water

Hazard	Hazardous event	Possible controls	Responsibility
Vector borne disease (e.g. Ross River virus, Barmah Forest virus)	Outbreak of disease resulting from mosquito breeding in recycled water storage	Regular monitoring, cover storages, mosquito control (see section 7.1.4 of these guidelines)	Manager of storage
Toxic cyanobacteria (blue-green algae) in recycled water storage	Inhalation of toxins from irrigation with recycled water	Destratification via mixing or aeration, or chemical treatment. Care should be taken that the treatment process does not rupture the algal cells, thus releasing toxins into the water Restrict light by covering the storage	Manager of storage
		Prevent growth of cyanobacteria by reducing nutrient concentration during treatment	Treatment plant operator
		Filter recycled water before entry to delivery system No irrigation during algal blooms	User
Human pathogens in recycled water storage	Presence of water birds or other potential carriers of Campylobacter and Salmonella in open storage	Cover storage Test for contamination and, if necessary, disinfect before final use	Manager of storage
All contaminants in recycled water	Entry of contaminated stormwater runoff	Prevent entry of stormwater runoff to recycled water storage	Manager of storage
	Human contact with open storage (e.g. retrieval of golf balls)	Advisory signs	Manager of storage
	Unauthorised swimming in recycled water storage (e.g. local children)	Warning signs at likely access points Fencing to prevent access to storage Direct notification to local schools and residences	Manager of storage
	Leakage of recycled water to ground water	Line recycled water storages to minimise seepage to ground water	Manager of storage
	Contact with employees during maintenance	Safe work procedures, including personal protective equipment and disinfection facilities	Employer, employees
	Overflow of recycled water storage resulting in pollution of receiving waters	Size storage adequately taking account of rainfall intensity, irrigation demands and flows to storage from STP Redirect overland flow around storage	Manager of storage
		Comply with relevant conditions on development approval for discharge to waterways	Holder of development approval

Table 8.1. (continued)

Domestic use of recycled water from a dual reticulation system

Hazard	Hazardous event	Possible controls	Responsibility
Human pathogens or chemical contaminants	Ingestion of water containing contaminants by customers due to a cross-connection between the drinking water and recycled water pipe systems	All plumbing work on premises must be done by a registered plumber	During construction: builder After construction: resident
		Regular checks of salinity of potable water as the salinity of recycled water and potable water are usually significantly different	Water service provider
		Comply with the Standard Plumbing and Drainage Regulation	Plumber
	Ingestion of recycled water while swimming	Do not fill swimming pools with recycled water	Resident
	People drinking from recycled water hoses or taps	Sign on all recycled water taps saying "do not drink"	During construction: supplier After construction: resident
	Inhalation or ingestion of spray drift	If spray irrigation is permitted (e.g. when using Class A+ recycled water), contact between people and recycled water spray drift should be minimised	Resident
	Contamination of domestic vegetable gardens with pathogens	Wash all home grown fruit and vegetables with drinking water before consumption	Resident
Nutrients or other contaminants in recycled water	Runoff of recycled water from the property	Don't irrigate immediately before, during or after wet weather	Resident
	Nutrient imbalance due to use of recycled water	Ensure soils and slopes are suitable for irrigation Monitor the health of plants receiving significant amounts of recycled water for signs of ill health such as yellowing of leaves and leaf drop Only irrigate to meet plants' water needs (e.g. deep soaking once per week rather than daily hosing)	Resident

Table 8.1. (continued)

Irrigation with recycled water

Hazard	Hazardous event	Possible controls	Responsibility
Human pathogens in recycled water (nature of the hazard depends on the class of recycled water used)	All events involving contact between people and recycled water	Supply agreed class of recycled water	Supplier
		Use appropriate class of recycled water	User
	Exposure of people to spray drift	Use low rise or low throw sprinklers Plant screen trees to intercept spray drift Irrigate at night Use of anemometers to detect wind speed above a safe threshold Maintain appropriate buffer zone between irrigation area and areas used by people Prevent public access Use a higher class of water Ensure appropriate drying time before permitting public access to irrigated areas Provide appropriate personal protective equipment to workers exposed to recycled water	User
	Irrigation of fruit and vegetables with recycled water	Use only Class A+ recycled water if produce eaten uncooked For lower classes of recycled water, consider subsurface delivery system Cook or otherwise process fruit and vegetables Employ harvesting methods that minimise soil contact with produce during harvest Ensure no cross-contamination of machinery used to harvest or process crops irrigated with lower classes of recycled water	User
Salinity of recycled water	Irrigation water salinity causing toxic effects on plants	Reduce inputs of salt from customers via trade waste agreements and customer education In sewered areas with saline ground water, reduce inputs of salt resulting from infiltration to sewer via rehabilitation of sewers	Sewerage service provider
		Hydraulic, nutrient and salt loadings should be calculated, assessed and appropriate loading rates determined before irrigation commences Dilute recycled water with less saline source water (e.g. stormwater or raw water) or partially desalinate the water Increase leaching fraction to move salts beyond root zone of plants (but see below) Use salinity tolerant plant species Monitor soil salinity yearly Monitor plant and/or stock health	User
	Excess leaching of saline water to ground water	Use soil tensiometer or other soil water measurement device to monitor percolation of recycled water below the root zone of plants, subject to the need to facilitate leaching of salts to prevent salt accumulation in the soil	User

Table 8.1. (continued)

Irrigation with recycled water (continued)

Hazard	Hazardous event	Possible controls	Responsibility
Salinity of recycled water plus cadmium levels in soil, recycled water or fertiliser	If salinity exceeds 1100 mg/L TDS, cadmium in soil may be taken up in crops eaten by humans	Do not use phosphate fertilisers with elevated cadmium levels	User
		Maintain TDS of recycled water below 1100 mg/L	Supplier
SAR (relative concentration of sodium, calcium and magnesium ions) of recycled water	SAR of recycled water excessive relative to ESP in soils (depends on soil type – see NRMMC & EPHC (2005))	Avoid irrigation of soils with moderate to high ESP Apply gypsum ($CaSO_4$) or lime ($CaCO_3$)	User
		Shandy recycled water with less saline water, assuming Ca and Mg levels are sufficiently high Reduce sodium levels in recycled water during treatment	Supplier
Nutrients in recycled water	Nutrients not in correct balance for soils or crops grown	Calculate nutrient balance for the target crop/soil/recycled water quality and apply appropriate fertilizer regime Periodically monitor soil nutrient concentrations and adjust fertiliser regime accordingly Monitor the health/productivity of plants receiving significant amounts of recycled water for signs of ill health such as yellowing of leaves and leaf drop	User
Heavy metals in recycled water	Heavy metal build-up in soil	If recycled water contains heavy metal contamination, monitor build-up in soil and if necessary reduce application rates	User
Chemicals in recycled water	Detection of chemical residues in produce irrigated with recycled water	Identify point source dischargers of chemicals of concern into the sewer and develop effective trade waste controls, including monitoring of 'sentinel' or indicator chemicals, if necessary	Sewerage service provider
		Modify or improve treatment to reduce chemical residues	Treatment plant operator
Carbonate and bicarbonate at excessive levels in recycled water, e.g. >1.25 meq/L (milliequivalents per litre)	Change in soil chemistry leading to nutritional deficiencies in turf grasses	Acid injection to irrigation pipeline	User
Boron in recycled water	Boron levels in recycled water above threshold for target crop	Increase leaching fraction through use of other water sources or by mixing recycled water with other water	User
Residual chlorine in recycled water	Damage to sensitive plant species during irrigation	Dechlorination before irrigation Storage to allow chlorine to dissipate	Treatment plant operator or user

Table 8.1. (continued)

Irrigation with recycled water (continued)

Hazard	Hazardous event	Possible controls	Responsibility
		Accurate chlorine dosing to balance disinfection needs with plant susceptibility to chlorine	Treatment plant operator
Organic chemicals in recycled water (e.g. surfactants, endocrine disrupting chemicals)	High level contact between biota and recycled water (e.g. discharge to waterway)	Minimise runoff or other discharge of recycled water to waterways Prevent contact between birds, animals and recycled water e.g. via covered storages	User
Odours	Odour impacts on neighbours	Controls as for exposure to spray drift, above	User
Loss of public amenity	Any events that affect public perception of the recycled water scheme	Establish and maintain good stakeholder communications	User
All pollutants in recycled water runoff	Uncontrolled runoff of recycled water during irrigation	Runoff control (e.g. prevent over-irrigation; plant out buffer zone; catch drains that return tail water to storage, no irrigation during or after rain, no irrigation of slopes >10%)	User
	Unattended pipe rupture resulting in uncontrolled runoff of recycled water	Pressure sensor in irrigation system to automatically shut off supply when pressure drops suddenly Regular inspections of infrastructure	User
	Pipe leakage causing gradual infiltration of recycled water to soil or ground water	Flow gauges to calibrate water delivered against water supplied; visual checks for wet soil along irrigation lines Use of leak detection system	User
	Pollution of ground water or receiving waterways due to overuse or excess leaching of recycled water	If there is a specific pollutant in the recycled water that has been identified during the hazard identification phase of RWMP, monitor the ground water and/or receiving waterway for this pollutant	User
Hydraulic loading	Recycled water applied in excess of crop requirements or capacity of soil	Calculate water budget Monitor crop health and irrigate only up to crop requirements Sized buffer storage appropriately Irrigation scheduling to prevent irrigation during rainfall events Monitor depth to ground water Site selection and/or preparation to ensure good drainage and adequate depth to water table Increase wet weather storage Use catch drains	User
		Flexible agreement between supplier and user so that user is not forced to take recycled water regardless of crop requirements (i.e. not disposal)	Supplier & user
Greenhouse gas emissions	Use of inefficient pumping equipment	Ensure equipment is maintained to manufacturers specifications and replaced as necessary to ensure efficient use of energy	User

Appendices

APPENDIX A. GLOSSARY

aquifer	Rock formation containing water in recoverable quantities
aquifer recharge	The infiltration or injection of natural waters or recycled waters into an aquifer, providing replenishment of the ground water resource
aquifer storage and recovery	Injection of recycled water into aquifers for storage, which may be recovered later to meet water demands
biosolids	The treated and stabilised solids from sewage
beneficial use	The use of any element or segment of the environment that contributes to public benefit, welfare, safety, health or aesthetic enjoyment
blackwater	Toilet wastewater that contains organic matter from urine, faecal matter and toilet paper
control measure	Any action or activity that can be used to prevent or eliminate a hazard or reduce it to an acceptable level
critical control point	A point, step or procedure in a recycled water process at which control can be applied, and a safety hazard can as a result be prevented, eliminated or reduced to acceptable levels
critical limit	The maximum or minimum value to which a physical, biological or chemical parameter must be controlled at a critical control point to prevent, eliminate or reduce to an acceptable level the occurrence of the identified safety hazard
direct potable recycling	The immediate addition of recycled water to the drinking water distribution system (without an intermediate stage of storage or mixing with surface or ground water)
disinfection by-products	Chemical compounds (e.g. chloroform and other trihalomethanes) produced during disinfection of water that have been shown to be detrimental to health in laboratory animal studies
dual reticulation	The simultaneous supply of water from two separate sources, requiring two sets of pipes: one to provide potable water (for drinking, cooking and bathing purposes); the other to provide recycled water for non-potable purposes
effluent	Treated or untreated liquid waste flowing from agricultural and industrial processes, or treated wastewater discharged from sewage treatment plants
enHealth Council	The Environmental Health Council established by the National Environmental Health Strategy
endocrine disrupting chemical (EDC)	A substance or mixture of substances exogenous to an organism that alters function(s) of the endocrine system and consequently causes adverse health effects in an intact organism, or its progeny, or (sub)populations

environmental flow	The release of water from storage to a stream to maintain the healthy state of that stream
equivalent persons (EP)	The number of persons who would contribute the same quantity and/or quality of domestic sewage as the establishment or industry being considered
floc	A clump formed when suspended particles combine with a flocculating agent
greywater	A combination of wastewater from the laundry, bathroom and kitchen. Kitchen wastewater is usually not suitable for reuse
ground water	Subsurface water from which wells, springs or bores are fed
helminths	Parasitic worms including roundworms, tapeworms, hookworms and pinworms
indirect potable recycling	The withdrawal, treatment and distribution of potable (drinking) water from surface or ground water that contains some proportion of recycled water. Compare with "direct potable recycling", above.
industrial effluent	Liquid waste produced by industry and its processes
industrial purposes	Use of recycled water by industry for purposes including cooling processes, operation of boilers, manufacturing and processing activities, washdown and cleaning, window washing, toilet and urinal flushing and other uses (e.g. dust suppression and irrigation of grounds)
influent	Liquid waste flowing into a treatment facility
internal recycling	The use of recycled water by the entity that produced the wastewater
irrigation	The watering of crops, pasture, golf courses, parks, gardens and open spaces, which may involve using different applications (e.g. drip, trickle, spray and flood)
micron	The millionth part of a metre
municipal effluent	Used water from community and industry that enters the sewerage system
nanogram	The billionth part of a gram
nanometre	The billionth part of a metre
non-potable purposes	The use of water for purposes other than drinking, cooking, bathing and laundry: for example, irrigation of gardens, lawns and toilet flushing
pasteurisation	The application of heat to matter for a specified time to destroy harmful micro-organisms or other undesirable species
potable	(Water) of a quality suitable for drinking, cooking and personal bathing
rainwater tanks	Tanks used to collect and store rainfall from household roofs for beneficial use
Ramsar wetland	A wetland listed under the Convention on Wetlands of International Importance (Ramsar Convention 1971)
raw water	Water that forms the source supply for potable water, before it has been treated
recycled water	Appropriately treated effluent and urban stormwater suitable for further use
sewage	The used water of community or industry, conveyed through sewers to be treated at a sewage treatment plant

sewerage	The sewerage system comprises the pipes and plant needed to transport and treat sewage
sodicity	The presence of a high proportion of sodium ions relative to other cations in a soil
sodium adsorption ration	The concentration of sodium relative to calcium and magnesium in the soil solution
sorption	The action by which molecules are attracted to or attach to solid particles, including soil or biosolids
stormwater	All surface water runoff from rainfall, predominantly in urban catchments; such areas may include rural residential zones
subsidy	Non-repayable grant of money
trophozoite	The active motile feeding stage of a protozoan
wastewater	The used water of community, industry or agriculture
water quality	The chemical, physical and biological condition of water
water recycling	Use of appropriately treated wastewater and urban stormwater for beneficial purposes
water mining	Withdrawal of wastewater from a sewer before it reaches the STP. The wastewater is then treated to whatever standard is required for the desired use
water resource	The sources of supply of ground and surface water in a given area

APPENDIX B. ABBREVIATIONS

AFFA	Agriculture Fisheries and Forestry Australia
ALFA	Australian Lot Feeders' Association
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AS/NZS	Australian Standard/New Zealand Standard
BNR	biological nutrient reduction
BOD	biochemical oxygen demand
CCP	critical control point
cfu	colony-forming unit (used to count cultured bacteria)
DHS	Department of Human Services (South Australia)
DLGPSR	Department of Local Government, Planning, Sport and Recreation
DNA	deoxyribose nucleic acid
DNR	(former) Department of Natural Resources
DNRM	Department of Natural Resources and Mines
DPIF	Department of Primary Industries and Fisheries
EDC	endocrine disrupting chemical
EMP	environmental management plan
EP	equivalent persons
EPA	Environmental Protection Agency
EPBC Act	Environment Protection and Biodiversity Conversation Act 1999
EPP (Water)	Environmental Protection (Water) Policy 1997
ERA	environmentally relevant activity (under the Environmental Protection Act 1994)
HACCP	Hazard Analysis and Critical Control Point
ISO	International Standards Organisation
L	litre
MEDLI	Model for Effluent Disposal using Land Irrigation
mL	millilitre
mm	millimetre
NATA	National Association of Testing Authorities
NEHF	National Environmental Health Forum
NHMRC	National Health and Medical Research Council
NTU	Nephelometric Turbidity Unit
NWQMS	National Water Quality Management Strategy
pfu	plaque forming unit (used to count cultured viruses)
QDO	Queensland Dairyfarmers' Organisation
QMRA	Quantitative Microbial Risk Assessment
QWRS	Queensland Water Recycling Strategy
SAR	sodium adsorption ratio
SD&PWO Act	State Development and Public Works Organisation Act 1971
SS	suspended solids
STP	sewage treatment plant
TDS	total dissolved salts
ThC	thermotolerant coliforms
UV	ultraviolet

APPENDIX C. REFERENCES AND WEB LINKS TO OTHER RESOURCES

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APPENDIX D. STATE GOVERNMENT AGENCIES THAT CAN PROVIDE ADVICE ON WATER RECYCLING

Environmental Protection Agency

EPA Southern Region

REGIONAL OFFICE (Brisbane)
288 Edward St
Brisbane
(07) 3224 5641

BUNDABERG
Govt Offices Bldg
Quay St
(07) 4131 1600
Fax (07) 4153 1620

GOLD COAST
Kabool Rd
West Burleigh
(07) 5520 9603

MARYBOROUGH
Lennox St (cnr Alice St)
(07) 4121 1800
Fax (07) 4121 1650
After hours
(Quote pager 72722)
1300 555 555

SUNSHINE COAST
29 Esplanade
Cotton Tree
(07) 5443 8940
Fax (07) 5443 8942

TOOWOOMBA
158 Hume St
(07) 4639 4599
Fax (07) 4639 4524

EPA Central Region

REGIONAL OFFICE
(Rockhampton)
61 Yeppoon Rd
North Rockhampton
General enquiries
(07) 4936 0511
Fax (07) 4936 2212
Environmental Operations
(Rockhampton District)
(07) 4936 0509

GLADSTONE
Centrepoint Bldg
Goondoon St
(07) 4971 6502
Fax (07) 4971 6500

EMERALD
Hospital Rd
(07) 4982 4555

MACKAY
Wood St (cnr River St)
(07) 4944 7800
Fax (07) 4944 7811

EPA Northern Region

REGIONAL OFFICE (Townsville)
Old Quarantine Station
Cape Pallarenda
Townsville
(07) 4722 5211
Fax (07) 4722 5222

Environmental Operations
(Townsville)
General enquiries
(07) 4722 5353
Fax (07) 4722 5351
A/hours (***Emergencies only***)
1300 130 372

Environmental Planning
(Townsville)
General enquiries
Cultural Heritage
Coasts, Wetlands &
Waterways
Planning & Assessment
Biodiversity
(07) 4722 5211
Fax (07) 4722 5222

CAIRNS
5b Sheridan St
(07) 4046 6600
Fax (07) 4046 6606

Contaminated Land (Cairns)
(07) 3227 7370

Environmental Planning
(Cairns)
Cultural Heritage
(07) 4046 6605
Planning & Development
Assessment
(07) 4046 6701

MT ISA
Level 1, Suite 30, Mt Isa House,
cnr Camooweal and Mary
Streets
(07) 4744 7888
Fax (07) 4744 7800
A/hours (***Emergencies only***)
1300 130 372

Queensland Health

Department of Health
Health issues (07) 3234 0938

Public Health Unit Office	Telephone	Public Health Unit Office	Telephone
Brisbane Northside	3250 8509	Hervey Bay	4197 7277
Brisbane Southside	3000 9148	Longreach	4658 0859
Redcliffe	3897 6300	Mackay	4968 6611
Bundaberg	4150 2780	Mt Isa	4743 9374
Cairns	4050 3601	Rockhampton	4920 6989
Charleville	4656 8100	Sunshine Coast	5409 6600
Darling Downs	4631 9888	Townsville	4750 4003
Gold Coast	5509 7222	West Moreton	3810 1500

Other Queensland Government agencies

Department of Natural Resources and Mines
Irrigation in agriculture 1800 803 788

Department of Primary Industries and Fisheries
Food safety
Irrigation in agriculture and horticulture
Aquaculture
Mosquito control 13 25 23

Department of Local Government, Planning, Sport and Recreation
Subsidies for water infrastructure
On-site reuse in unsewered areas
Greywater reuse (07) 3234 1870
Building Codes Queensland

Department of Industrial Relations

Workplace Health and Safety 1300 369 915

Commonwealth government agencies

Department of the Environment and Heritage

EPBC Act (02) 6274 1111

APPENDIX E. ISSUES TO CONSIDER DURING THE PLANNING STAGE OF A WATER RECYCLING PROJECT

Consideration of possible impacts (risks) should include construction impacts and impacts from ancillary works like provision for storages. Not all of the impacts/risks listed below will be relevant, particularly for projects involving closed water recycling, as occurs with many industrial applications.

Site assessment

Social

- consultation requirements for all relevant government agencies, local communities and other stakeholders
- current and proposed changes in land zonings, land use, or tenure that may affect the future viability of the project (e.g. if urban development is planned for the future this may influence viability of irrigation with lower quality recycled water)
- compatibility of surrounding land uses and possible impacts on public amenity (e.g. visual impacts, access, odours, noise) or neighbouring properties (e.g. impact on property values or future development potential)
- possible health or other impacts on local communities, particularly subgroups of concern like children, the elderly and people with weakened immune systems
- possible health impacts on employees, site visitors or customers who buy products produced with recycled water, including inadvertent or unauthorised use
- location of utilities and infrastructure (e.g. supply of electricity, road access, requirement for easements)
- impacts on cultural heritage from construction or operation
- economic costs and benefits

Environmental

- topography (e.g. slope and runoff potential)
- local climate (e.g. rainfall patterns and intensity, evaporation, prevailing winds)
- soils (e.g. permeability and drainage, salinity and sodicity, pH, cation exchange capacity, soil structure, acid sulphate soil status, cadmium and boron levels) and potential impacts from nutrients, salts and heavy metals in recycled water
- ground water depth and quality and impacts from hydraulic loadings and recycled water quality
- interaction between recycled water and crops (e.g. evapotranspiration rates, salinity tolerance, nutrient requirements, hydraulic requirements)
- site hydrology and flooding potential
- quality of surface water draining the site and possible impacts on water quality and aquatic flora and fauna from recycled water runoff
- terrestrial and aquatic flora and fauna that could be affected by the development
- construction impacts (e.g. for pipelines and storage)
- baseline monitoring requirements to satisfy regulators and the requirements of the Recycled Water Management Plan

For more information

- **visit** www.epa.qld.gov.au/waterrecyclingguidelines
- **email** sustainable.industries@epa.qld.gov.au
- **call** (07) 3225 1999

Queensland Government
Environmental Protection Agency