The Cooperative Research Centre for
Water Quality and Treatment

Guidance Manual for the Design and Installation of Urban Roofwater Harvesting Systems in Australia (Edition 1)

Research Report 39

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FOREWORD

Research Report Title: Guidance Manual for the Design and Installation of Urban Roofwater Harvesting Systems in Australia (Edition 1)

Research Officers: Dr Neil Tripodi, (under contract to) Water Services Association of Australia

Project Leader: Tony Cartwright, Sydney Water

CRC for Water Quality and Treatment project No 2.0.2.6.0.4 'Assessment of Water Quality and Health Risk Analysis of Water from Urban Rainwater Tanks'. This Manual is one outcome of the project. The other output is 'Research Report 42: Water Quality and Health Risks from Urban Rainwater Tanks' (CRC for Water Quality and Treatment 2008).

Research Nodes:

CRC for Water Quality and Treatment members that were part of this project were:

- ACTEW Corporation
- Brisbane City Council
- Department of Human Services, Victoria
- Melbourne Water Corporation
- Monash University
- Natural Resources and Water, Queensland
- Queensland Health Scientific Services
- South Australian Water Corporation
- Sydney Water Corporation
- Water Services Association of Australia
- Yarra Valley Water

Non Member participant was:

- NSW Health

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Our special thanks to Ted Gardner of Natural Resources and Water, Queensland and Adam Lovell of Sydney Water.

USING THIS MANUAL

This Manual has been prepared in good faith exercising due care and attention. However, the Manual does not purport to be a comprehensive statement and analysis of its subject matter. No representation or warranty, expressed or implied, is made as to the relevance, accuracy, completeness or fitness for purpose of this Manual in respect of any particular users' circumstances.

Users of this Manual should satisfy themselves concerning its application and seek, if necessary, expert advice about their situation. The CRC for Water Quality and Treatment and its members shall not be liable to a user of this Manual or any other person or entity with respect to liability, loss or damage caused or alleged to have been caused directly or indirectly by this Manual.

In relation to roofwater harvesting systems, the CRC for Water Quality and Treatment endorses the recommendations and requirements of the appropriate Health Department and/or Regulatory Agency around Australia. If information is presented in this Manual that contradicts these recommendations and requirements, or any legal requirements, then the information in this Manual shall be disregarded.

PREFACE

There is an increasing trend to install a rainwater tank in the urban situation. This trend has been greatly assisted recently by the provision of rebates for the installation of rainwater tanks and the introduction of planning regulations mandating the use of rainwater tanks in new developments. There are many advantages in integrating a rainwater tank into the water supply system, including assisting with water conservation and reducing stormwater flows from properties. However, it is critical to the success of integrated roofwater harvesting systems that processes be established to ensure that systems are properly designed and installed.

This Guidance Manual for the Design and Installation of Urban Roofwater Harvesting Systems in Australia was commissioned by the Cooperative Research Centre (CRC) for Water Quality and Treatment to address the gap in availability of information relating to roofwater harvesting systems in the urban environment. The Manual is to provide guidance on the inter-related issues of site design, materials and system components, including treatment and plumbing configurations, with the focus on water quality.

The researchers and personnel at the CRC for Water Quality and Treatment have developed the information in the Manual from current general literature, knowledge at the CRC for Water Quality and Treatment and results of research.

GLOSSARY

Words used in this document aim to be consistent, where possible, with AS/NZS 3500.0 (2003). Common terms used in AS/NZS 3500.0 (2003) and some terms not covered in AS/NZS 3500.0 (2003) are shown below:

Term	Definition
drinking water*	Water that is suitable for human consumption, food preparation, utensil washing and oral hygiene (see AS/NZS 4020).
dual delivery	Specifically referring to delivering water to end uses – it is the plumbing arrangement where there are two sets of delivery pipes servicing the property, i.e. the rainwater tank delivers roofwater to some end uses and the mains drinking water independently delivers to other end uses.
end use(s)	Specifically referring to roofwater; the purpose(s) for which the roofwater is collected.
mains drinking water	The reticulated water supply provided by the local water agency.
multiple tanks	Where tanks are connected to one another in series to create a single water storage (*e.g.* when using smaller tanks to create a single larger-capacity water storage).
non-drinking water*	Any water other than drinking water.
rainwater	Water that falls as rain (it could be collected from a roof or the ground as surface run-off). See roofwater.
rainwater tank	A storage container for roofwater.
rainwater tank connection valve**	An automatic valve which enables a change of water supply between a pressurised rainwater tank supply and a water service to designated fixtures and outlets.
receiving tank	In multiple tank arrangements, where a number of tanks are arranged in series and connected to each other, the receiving tank is the tank that receives the roofwater (*i.e.* the first tank in series).
Regulatory Agency*	The Agency that is empowered by statute to exercise jurisdiction over the installation of water, plumbing, sewerage or stormwater works.
roofwater* (under stormwater)	Runoff due to rainfall from roofed areas.
single delivery	Specifically referring to delivering water to end uses – it is the plumbing arrangement where all end uses are directly serviced from the rainwater tank. The mains drinking water is only used as a back-up supply to the rainwater tank.
storage tank	See tank.
tank*	Tank - A fixed container for storing liquids. Storage tank – A container for storing water.
top-up system	A mechanism for partially replenishing a rainwater tank from the mains drinking water supply.
Water Agency*	An authority, board, business, corporation, council or local government body with the responsibility for planning or defining planning requirements, for defining and authorising design requirements, for defining and authorising construction requirements and for operating and maintaining or defining operation and maintenance requirements for a water supply and/or sewerage system or systems.
water heater*	An appliance, designed to provide heated water.

Glossary Sources

*	The Plumbing and Drainage Standard (AS/NZS 3500.0 2003).
**	Technical Specification for plumbing and drainage products - Rainwater tank connection valve (ATS 5200.467).

TABLE OF CONTENTS

FIGURES

TABLES

1 INTRODUCTION

1.1 Purpose

The main purpose of this Manual is to assist the water industry to integrate roofwater harvesting systems into the urban environment by providing guidance that may be utilised by practitioners to improve the design and installation of these systems. The focus of the Manual is on water quality.

1.2 Objectives

The main objectives of this Manual are to:

- improve the design and installation of roofwater harvesting systems
- ensure that the quality of roofwater is suitable for its intended end use
- minimise the health risks to owners and users
- maximise the water conservation benefits of rainwater tanks
- minimise the energy requirements of roofwater harvesting systems

1.3 Scope

The scope of this Manual mainly covers the design and installation of roofwater harvesting systems in the urban context. It also covers their operation and maintenance. Guidance is supplied on various topics including:

- site design
- types of rainwater tanks (round, slimline, bladder etc) and system components
- plumbing configurations
- roofwater treatment
- non-standard installations, including buried tank systems and tanks for multi-units
- supplying heated water systems
- maintenance

1.4 Sections

Sections 2 to 10 in this Guidance Manual systematically address issues regarding the design and installation of roofwater harvesting systems. These section headings are shown pictorially in Figure 1 and are:

- Section 2 - Roofwater End Uses
- Section 3 - Sizing of Storage
- Section 4 - Site Design
- Section 5 - Roofwater Collection
- Section 6 - Roofwater Conveyance from Roof to Tank
- Section 7 - Rainwater Tank
- Section 8 - Roofwater Delivery to Dwelling
- Section 9 - Roofwater Treatment
- Section 10 - Heated Water Systems

Sections 11 to 14 address other issues including maintenance.

Section 15 develops cases in the form of various practical configurations that reflect the information presented in the Manual.

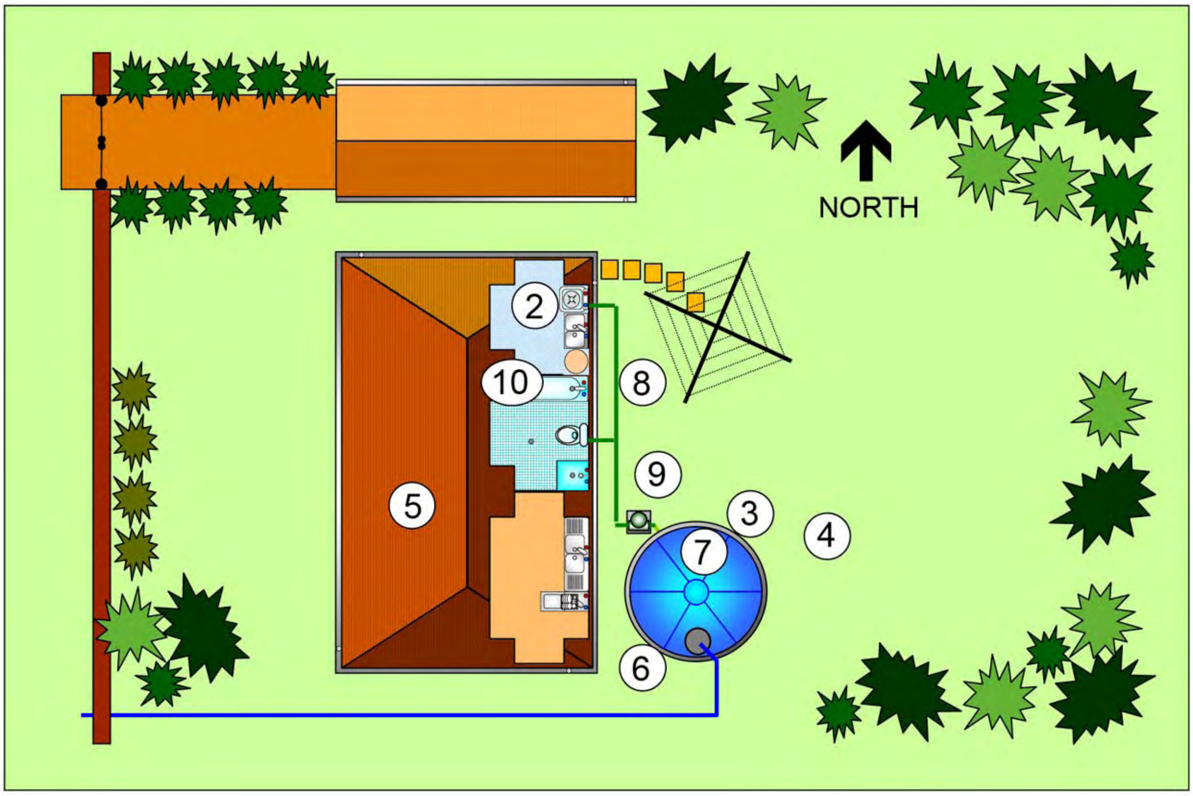

Figure 1 Pictorial Plan of Section Headings

1.5 Sources

Information used in preparing this Manual was sourced from a range of published and unpublished reports; the CRC for Water Quality and Treatment's research results and the accumulated experience of our members; and input from others with knowledge of issues associated with roofwater harvesting systems.

Many people also provided comments during the preparation of the Manual. The CRC for Water Quality and Treatment is grateful for the work of these people.

1.6 Documents

The main document used as background information for this project was:

- enHealth Council (2004). *Guidance on Use of Rainwater Tanks*. enHealth Council. Australian Government Department of Health and Ageing. Web: enhealth.nphp.gov.au/council/pubs/documents/rainwater_tanks.pdf

General documents reviewed for this project included:

- ACTG (2004) Rainwater Tanks: 'Guidelines for residential properties in Canberra', Australian Capital Territory Government, ActewAGL Environment ACT. (ACT Urban Services). ACTPLA (ACT Planning and Land Authority) pp. 1-31.
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- Ashworth J (2005) 'Rainwater Tank Supply Best Practice', Serving Communities of 25 People or Less. Auckland, New Zealand.

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- CRC CH (1999) 'The Reuse Potential of Urban Stormwater and Wastewater', Report 99/14, Cooperative Research Centre for Catchment Hydrology.
- CRC WQT (2005) 'Public Health Aspects of Rainwater Tanks in Urban Australia', Occasional Paper 10, The Cooperative Research Centre for Water Quality and Treatment.
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- Leggett D J, Brown R, Brewer D, Stanfield G and Holliday E. (2001) 'Rainwater and greywater use in buildings: Best practice guidance', CIRIA. C539. Department of Trade and Industry, Multiplex Medway, Walderslade, Kent.
- NWQMS (2004) 'Australian Drinking Water Guidelines **6,** National Water Quality Monitoring Strategy', National Health and Medical Research Council & the Natural Resource Management Ministerial Council.
- PIC (2004) 'Technical Solutions, 5: Cold Water Plumbing, Rainwater Tanks'. Plumbing Industry Commission, Victoria.
- Standards Australia (2006) 'HB 230 – 2006, Rainwater Tank Design and Installation Handbook, First Edition'.
- Wade R (1999) 'Sustainable Water from Rain Harvesting: How To Plan It & Where To Get It', Third Edition. Environmental Conservation Planning Pty Ltd.
- WA Health (2003) 'Urban Rainwater Collection', Environmental Health Directorate, Government of Western Australia, Department of Health. HP 8481
- WSAA (2001) 'Materials for Rainwater Collection and Storage', Materials Fact Sheet No. 4, Water Services Association of Australia pp. 1-5.

2 ROOFWATER END USES

Key Issue

- Recommendations for the use of roofwater for various end uses should be checked with the appropriate Health Department and/or Regulatory Agency

No.	Implementation
2.1	Recommendations for the use of roofwater for various end uses should be checked with the appropriate Health Department and/or Regulatory Agency.
2.2	Plumbing requirements for supplying end uses should be checked with the appropriate Regulatory Agency.

3 SIZING OF STORAGE

Key Issue

- Local information should be checked for information on the sizing of roofwater tank storages

No.	Implementation
3.1	Local information should be sought for sizing of roofwater tank storages. Local Councils, rainwater tank suppliers and some Government Departments or Authorities may have created a rainwater tank sizing model to suit the usage and rainfall patterns in your local area. The University of Newcastle has undertaken much research work on rainwater tanks, including sizing and capacity issues (Coombes *et al.* 2000, 2002 and 2003). The Plumbing Industry Commission, Victoria, has guidance on sizing issues for toilet flushing in Victoria (PIC 2004). The Department of Environment, Heritage and Aboriginal Affairs, South Australia, has guidance on sizing issues for rainwater tanks in South Australia (DEHAA 1999). The Cooperative Research Centre for Catchment Hydrology reviewed the effectiveness of a 10,000 litre rainwater tank supplying landscape and toilet flushing demands for a large residential block (980 square metre lot and 730 square metre garden – note this is much larger than a standard sized urban block) located in both Sydney and Canberra (CRC CH 1999). The Queensland Department of Natural Resources and Water has produced a model for determining tank yields. The model can be obtained free from the Department (see Vieritz *et al.* 2007).
3.2	Some information on minimum sizes for rainwater tanks in the urban situation follows: • Sydney Water Corporation has on its website www.sydneywater.com.au/SavingWater/RainwaterTanks/SizesAndTypes.cfm 'As a guide, we recommend: - a minimum size of 5,000 litres for non potable (non drinking) domestic water uses (e.g. flushing the toilet, washing machines, watering the garden, washing the car) and holding stormwater. - a minimum size of 2,000 litres for toilet flushing use only or when you have a small garden area to water.' • Brisbane City Council has a fact sheet (see BCC 2005) on its website that states 'Council would recommend you consider a minimum 3000 litre capacity rainwater tank …'
3.3	Generally, to maximise water savings, designers should: a) increase the size of the tank, where practicable b) increase the contributing roof area, where practicable c) increase the number of allowable water uses d) ensure at least some internal fixtures, such as toilets, are connected to the tank

4 SITE DESIGN

Key Issues

- Correct location of the tank on site can avoid many future problems
- Safety aspects should be incorporated into the design of roofwater harvesting systems
- End uses should be supplied by gravity, if possible
- Above-ground tanks should be used in preference to buried tanks, if possible

No.	Implementation – Non Water Quality Issues
4.1	Before installing a rainwater tank, check with the Local Council for their requirements. Council may have concerns if the rainwater tank is: a) to be situated in the front yard (above-ground) b) of large capacity c) located in a heritage listed area d) higher than 2.4m above natural ground level e) within proximity of a rear or side boundary f) made of reflective, white or off-white material
4.2	The rainwater tank's dimensions should be checked to ensure: a) the tank will fit in the place chosen (get the exact dimensions of the tank, including the platform and stand, or the base, as appropriate) b) the tank will fit, if required, under eaves (usually approximately 500mm is required from the bottom of the gutter outlet to the top of the water inlet on the tank) c) the tank can be delivered to the chosen site (the tank will fit down driveway and there is access for delivery vehicle)
4.3	The rainwater tank should be located where possible: a) in the backyard or side yards, if above-ground b) as close as possible to collection points (downpipes) and outlets
4.4	Consideration should be given to supplying end uses with a gravity-fed supply from a primary storage, rather than a pumped system, especially in the absence of end uses that require higher-pressure delivery. Generally, there are three types of tank configurations that provide a gravity-fed supply. These are where there is: a) an on-ground rainwater tank (can be used to supply low head requirements such as soaker hoses for irrigation, filling buckets, etc.) b) an elevated primary rainwater tank (on a tall stand or mound) that receives water directly from a downpipe; see Figure 2) c) a primary rainwater tank (either an above-ground tank or a buried tank) and also an elevated secondary rainwater tank (header-tank) (see Figure 3), with a pump being used to transfer roofwater from the primary tank to the secondary tank Note: mechanical inlet valves suitable for low pressure situations are available for toilet cisterns from at least one major manufacturer.
4.5	If installing an elevated tank, the stand should not be placed anywhere near large trees (or immature small trees) so that tree root growth does not unbalance the stand.
4.6	When selecting a site for the placement of a rainwater tank: a) prepare a site with flat, level and uniform compacted ground and follow the tank manufacture's instructions in relation to the base b) avoid areas where water naturally flows overland during rainy periods

4.7	The designer/installer should contact Dial Before You Dig on 1100 before starting any excavation work (DBYD 2005) to ascertain the location of underground pipes and cables. This is an Australia-wide service.
4.8	The location of the rainwater tank should not block a neighbour's: a) natural light b) ventilation c) outlook
4.9	The designer/installer should strive to reduce any visual impact of the rainwater tank. To that end: a) design the tank to integrate into the household form b) select materials, colour and finishes for tank/accessories that are compatible with your house, adjoining houses and the streetscape c) use rockeries, shrubs, climbing plants and screens d) avoid highly reflective metallic finishes or materials where glare will impact on the residents and neighbours
4.10	Safety aspects should be incorporated into the design of roofwater harvesting systems. Issues include: a) minimising maintenance requirements. Try to design the roofwater harvesting system, if possible, with minimal devices that need on-going maintenance b) providing safe access to maintenance points, including sufficient and flat space for the positioning of a step-ladder for maintenance purposes (where applicable) c) providing safe layout of above-ground piping and any electrical wiring d) securing tanks against toppling, especially tall, thin tanks.

No.	**Implementation – General Water Quality Issues**
4.11	The rainwater tank should be located where possible: a) in a shady area (*e.g.* under a patio or the eaves). Locating the tank in a shady position is beneficial to avoid the possibility of light entering the tank (to avoid algae) and also reducing the temperature of the roofwater in storage b) away from overhanging branches and sources of debris. Leaves etc. contribute carbon, which may provide a food source for nuisance organisms, as well as having the potential to cause staining for items such as toilet bowls  Photo courtesy of NSW Department of Education
4.12	Above-ground tanks should be used in preference to buried tanks, if possible. The main issues with buried tanks are: a) the potential for infiltration of contaminated sewage, groundwater or floodwater b) they are generally more expensive c) leaks and faults are generally concealed d) tank and pipework is susceptible to damage by tree roots Plumbing regulators usually address the increase in risk of contamination of roofwater in buried tanks compared to above-ground tanks by requiring different backflow prevention requirements. The level of risk associated with buried rainwater tanks would generally require a testable backflow prevention device, while above-ground tanks would generally require a non-testable device. If there is limited space to install a traditional round above-ground tank, consideration should be given to installing space-saving above-ground modular or slimline tanks. Note - the space-saving designs are generally more expensive than the traditional round tanks.

	When a buried tank is selected, the following design issues should be considered in order to reduce the risk of human/animal wastes or other contaminants entering the tank: a) separate buried rainwater tanks from septic tanks and pipe trenches, or any other wastewater treatment unit, as far as feasibly possible b) position the downpipes and rainwater tank pipework shallower than any wastewater pipework c) grade the surrounding ground level around the tank away from the tank d) excavate and place buried tanks well clear of soil treated with anti-termite chemicals (these are typically used along the house perimeter and/or around concrete slabs and stump footings)
4.13	Consideration should be given to using multiple tanks in series in lieu of a single water storage, especially where roofwater is being considered for drinking water end uses.  Multiple tanks connected in series may improve the biological quality of roofwater. As the water moves from one tank to the next, it is thought microbial activity decreases due to the reduced nutrient concentrations in the subsequent tank(s) (Ashworth 2002; Ashworth 2005; Leggett *et al.* 2001; Warner *et al.* 2003 and Abbott *et al.* 2006A). Photo depicts multiple tanks in series. Courtesy of www.irrigationwarehouse.com.au
4.14	To improve water quality, consideration should be given to using a secondary storage (see Figure 3) because: a) larger suspended particulates may already have settled in the primary water storage b) the organic carbon load may have already been reduced by microorganisms in the primary water storage In roofwater harvesting systems that include a secondary storage tank and a top-up system, the top-up should be installed to service the secondary storage rather than the primary storage (subject to the secondary storage being of adequate capacity) - see Figure 3.

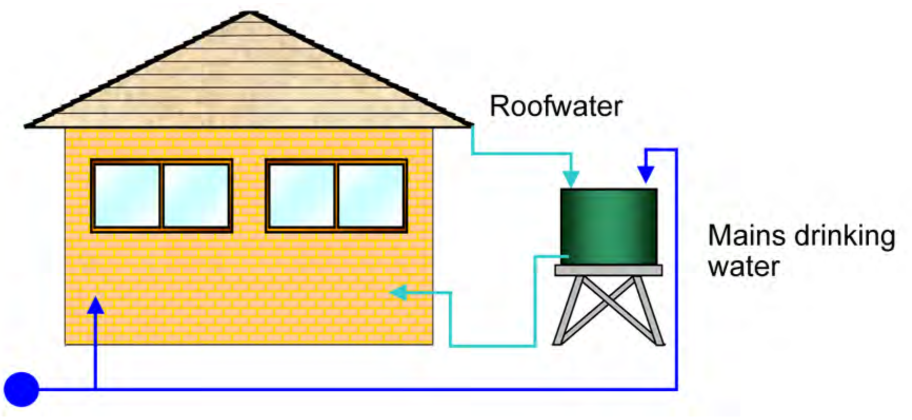

Figure 2 Direct Downpipe Conveyance, Elevated Primary Storage Delivery

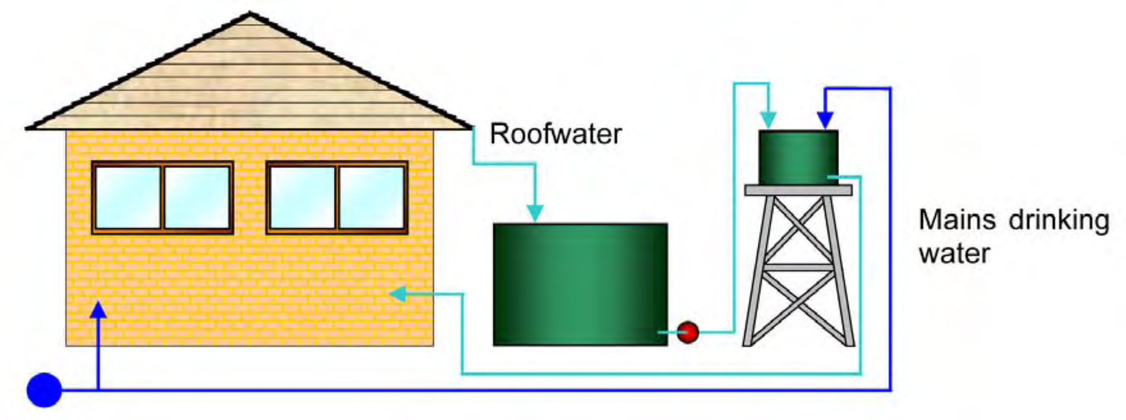

Figure 3 Direct Downpipe Conveyance, Primary Storage Tank, Pump and Secondary Storage (Header-tank) Delivery

5 ROOFWATER COLLECTION

Key Issues

- Care should be taken with the selection of materials for roofing products
- The use of lead products should be avoided

No.	Implementation – General Water Quality Issues
5.1	The roof manufacturer should be approached for information on appropriate materials to use for ancillary products. Further information on 'Do's and Don'ts' is contained in WSAA (2001). Information includes: a) avoid lead flashing b) avoid the use of galvanised gutters in conjunction with 'inert roofing materials', such as Zincalume® steel, Colorbond® steel or terracotta tiles, due to the possibility of electrolytic corrosion
5.2	Landscaping should be designed to avoid branches overhanging roof and gutters.
5.3	Problem plants and trees should be avoided – enHealth Council (2004) has a list under Dangerous Plants.

No.	Implementation – Water Quality Issues – If intended to use roofwater for drinking water purposes
5.4	enHealth Council (2004) provides considerable information in relation to roofing materials including: a) materials such as cement and terracotta tiles, Colorbond®, galvanised iron, Zincalume®, asbestos/fibro cement, polycarbonate or fibreglass sheeting and slate should be suitable for collecting rainwater b) where the asbestos roof surfaces have deteriorated badly, the roof should be replaced with asbestos-free substitutes c) bitumen based roofing materials are generally not recommended
5.5	The roof manufacturer should be approached for the following information when the roofwater is intended for drinking water end uses: a) a Certificate of Classification for the roofing material (to ensure suitability for drinking water purposes) b) advice on the type of pipes and fittings that should be used within the roofing system
5.6	Non-lead flashing should be used in new construction. Where lead flashing exists, it should be either removed or painted with a suitable coating. Care should be taken when connecting a roofwater harvesting system to an existing building. Older buildings may have copper and lead on their roofs, or they may have corroded steel roofing. It is possible that levels of metals (e.g. lead and copper) in the supply from any taps may be above safe limits in drinking water guidelines. A recent investigation in relation to a building in Canberra found that lead and copper levels in roofwater that was consumed were above guideline values (NWQMS 2004). The investigator found that the owner had breached safety regulations by not undertaking a risk assessment or implementing measures to control the risks. For further information, see Simmons *et al.* (2001) and Chapman *et al.* (2006).
5.7	Where roofwater is collected near industrial activity, information on the suitability of roofwater for drinking water purposes should be sought from local health or environmental agencies.

6 ROOFWATER CONVEYANCE FROM ROOF TO TANK

Key Issues

- Any improvement in roofwater quality due to first flush devices will generally not meet drinking quality guidelines
- The use of the wet inlet system configuration should be avoided
- A deflecting leaf diverter should be installed

No.	Implementation – Non Water Quality Issues
6.1	There are many types of devices that may be installed from the roof to the tank, such as first flush diverters, vortex filters and filter socks. Maintenance of these devices is a major issue, as some may easily block up during wet periods. One of the most maintenance-intensive devices appears to be the filter sock. While these devices may be good at capturing silt etc., they may not be suitable for those who are unable or do not want to undertake continual maintenance. Where a filter sock is used to intercept fine particulate matter from entering the tank, the filter sock should be inspected and, if necessary, rinsed after each significant rainfall event in order to prevent the sock from clogging.
6.2	Partial barriers can be used in guttering or downpipes to direct an increased proportion of roofwater toward one downpipe in preference to another. If using partial barriers, the impact of these should be assessed on gutter overflows, tank overflows and first flush diverters.

No.	Implementation – General Water Quality Issues
6.3	Builders should install gutters so drainage is effective. AS/NZ 3500.3 states that gutters must be installed with a fall of no less than: a) 1:500 for eaves gutters unless fixed to metal fascias b) 1:200 for box gutters Correct installation of guttering, especially ensuring the correct slope is maintained, is important for reducing ponding of water, which promotes mosquito breeding and bacterial habitats.
6.4	Open, uncluttered and easily maintainable gutters, e.g. half round guttering, should be used.
6.5	External gutter brackets should be fitted wherever possible.
6.6	Dry conveyance systems (see Figure 4) should be used rather than wet conveyance systems (see Figure 5). In wet conveyance systems, roofwater in partially filled downpipes can become stagnant and possibly discolour. Also, a habitat for mosquito breeding may be encouraged (if entrance not screened). If a wet conveyance system is installed, consideration should be given to installing a wet to dry conveyance system conversion device (see Figure 6). Another option is to install a drain hole to empty the pipe after rainfall events. Another solution is to have multiple rainwater tanks at different locations, e.g. at each end of the house, so that they can be placed closer to downpipes.

6.7	Deflecting leaf diverters should be installed in each roofwater harvesting system in an urban environment. For wet conveyance systems, a secondary mesh to prevent the entry of mosquitoes should be fitted behind the coarse screen of the leaf diverter. Currently most tanks have a horizontal inlet screen about 300 to 400 mm in diameter in the top of a rainwater tank. This inlet screen may occasionally be obstructed and cause overflows due to a build up of leaf litter. The horizontal inlet screen therefore may require periodic maintenance (removal of leaf litter). A deflecting leaf diverter, suitably placed on the downpipe, is designed to minimise leaf build-up on the horizontal inlet screen.  Photo depicts a deflecting leaf diverter (mesh size about 300 mm x 300 mm). Courtesy of Sydney Water.
6.8	For dwellings that are surrounded by tall trees that shed a high volume of leaf matter, gutter-guards should be used as well as a leaf diverter. Leaf matter sitting in gutters may build-up to: a) cause a blockage b) create tannins that cause staining c) create odours and poor tasting roofwater d) create a mosquito breeding habitat
6.9	Buried pipes should be installed away from, and shallower than, any sewer or septic system pipework that may be on-site or on a neighbour’s property (if known).
6.10	In theory, first flush diverters improve water quality in the tank by discarding the first portion of roof runoff. The effectiveness of container-type first flush diverters has been investigated and some recent research that has shown that first flush diverters produce variable results at best, as faecal coliforms and some metals (Gardner *et al.* 2004) and particulates (Yaziz *et al.* 1989) have been detected throughout the entire rainfall event(s). The results show that first flush diverters do not prevent all undesirable materials entering the storage tank and any improvement will not meet water quality guidelines for drinking. Roofwater losses through first flush diverters can be quite significant. For example, on a Gold Coast roofwater harvesting system over eight months, it was found that a first flush diverter with a 4mm outlet orifice accounted for greater than 30% of the rainwater losses (Millar *et al.* 2003). A smaller bore orifice could presumably solve a lot of the problem however there is an increased likelihood of blockage if not correctly maintained. Consideration should be given to installing a deflecting leaf diverter instead of a first flush diverter in a roofwater harvesting system supplying non-drinking water end uses. If a first flush device is to be installed: a) a nominal capacity (around 20 to 50 litres) first flush diverter should be sufficient in most residential applications supplying non-drinking water end uses b) a small-size drainage orifice should be used to avoid excessive roofwater losses (see Gardner *et al.* 2004) c) any drainage orifice should be frequently checked for blockages (preferably after each rainfall event) Roofwater that has been diverted from the tank by a first flush unit does not need to be wasted. It could be used for low risk uses such as watering garden beds. It is mandatory in some areas that a first flush diverter be fitted to roofwater harvesting systems.

6.11	Care should be taken to avoid light penetration in inlet pipework. enHealth (2004) states that white pipes can allow light penetration and the corrective action is to paint pipework a dark colour.

No.	**Implementation – Water Quality Issues – If intended to use roofwater for drinking water purposes**
6.12	Where metal guttering is used, avoid the use of uncoated galvanised as this is more susceptible to corrosion than coated galvanised.
6.13	Plastic downpipes and pipework should comply with AS/NZS 4020. Products that comply with this standard are deemed to be suitable for contact with drinking water.
6.14	The Centre for Appropriate Technologies (2005) describes a system where a 545 litre settling tank is used before filling a much larger tank. The settling tank basically acts as a large first flush device. The results showed a 90% reduction of *E. coli* from the water in the settling tank compared to water after a screen. The roofwater is further treated and used to supply an indigenous outback community. See also section 4.14.

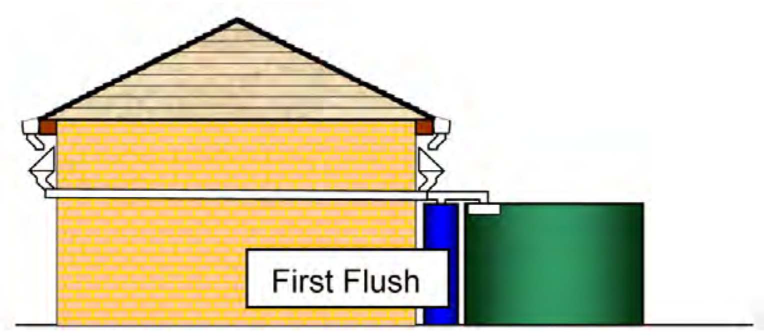

Figure 4 Typical Dry Inlet System Configuration

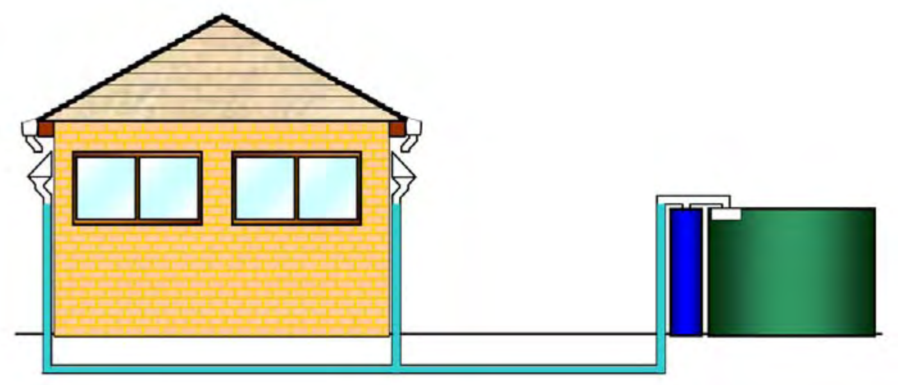

Figure 5 Typical Wet Inlet System Configuration

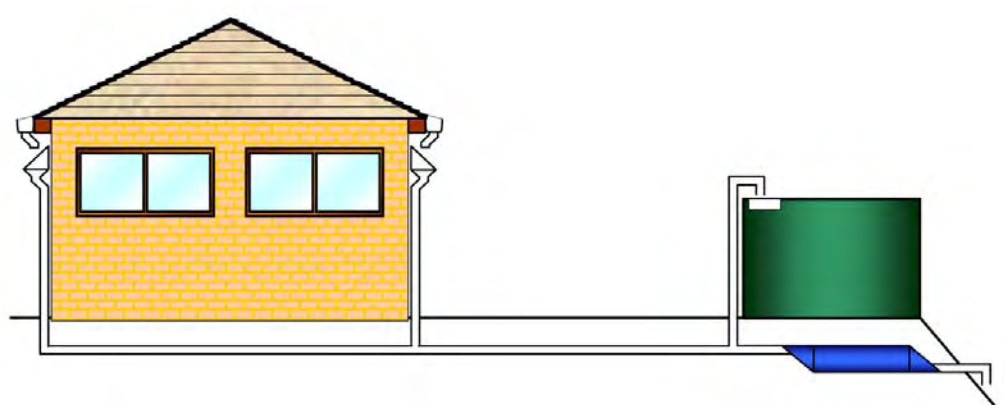

Figure 6 Typical Wet-to-Dry System Conversion using a Subsurface First Flush Diverter

7 RAINWATER TANK

The Local Council may set requirements for fire fighting and on-site detention. These requirements may affect the way each rainwater tank is configured. Some of the many different ways of configuring an above-ground rainwater tank to supply end uses are shown in Figure 7.

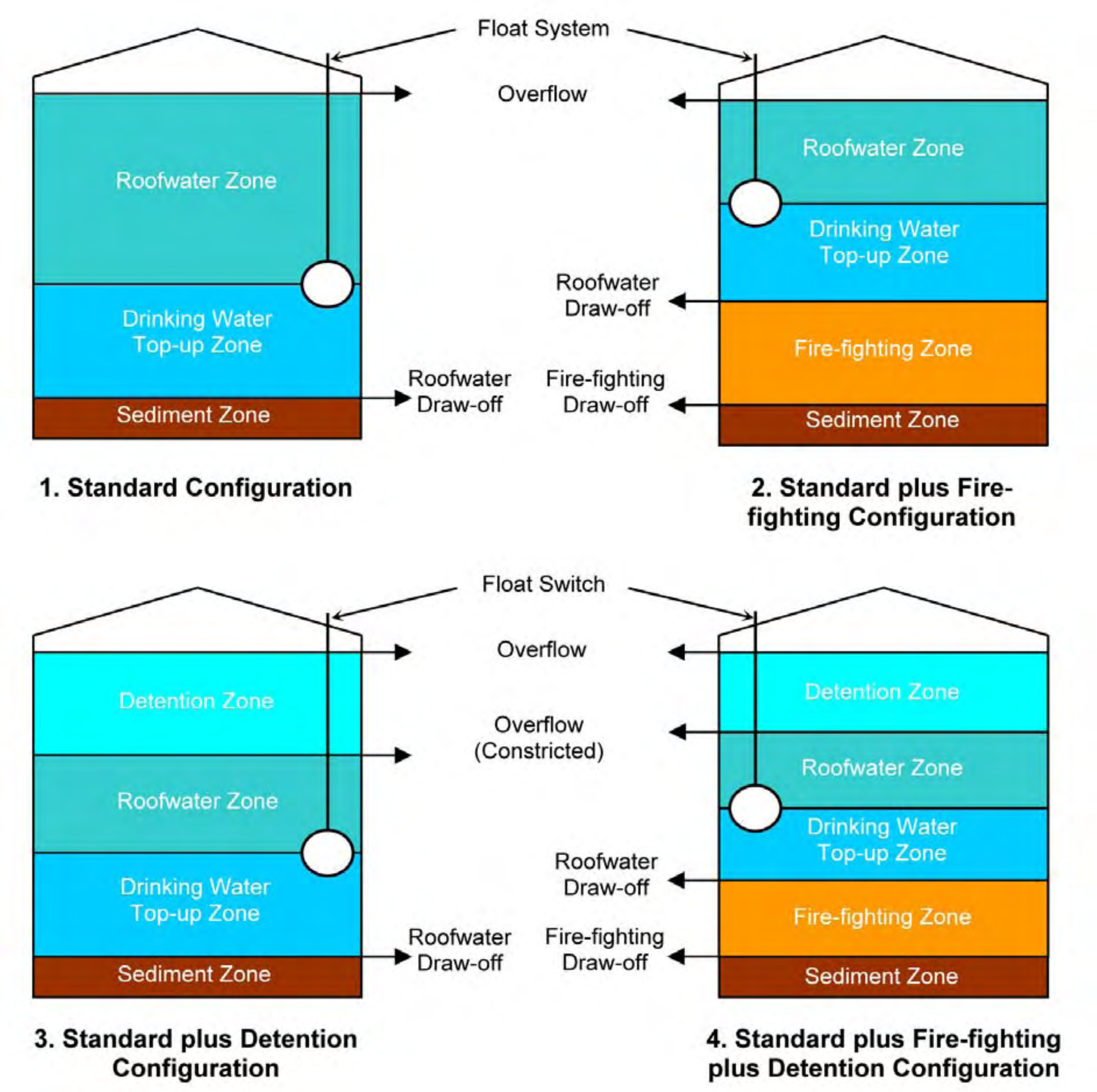

Figure 7 Rainwater Tank Water Draw-off Point Configurations (not to scale)

Key Issues

- Prevent light entering the tank where possible
- Ensure screens are in place to control mosquitoes
- Ensure the draw-off point is above accumulated sediment

No.	Implementation – Non Water Quality Issues
7.1	Fundamental requirements of a rainwater tank include: • size of overflow pipe(s) to match (as a minimum) the combined diameter of all inflow pipes • the ability to deal with excess roofwater by overflowing in a manner that doesn't damage the tank or its foundations • the drainage from the overflow pipe should be connected to the stormwater system, not the sewerage system • exclusion of mosquitoes and vermin • exclusion of light (so that algae do not grow and larval growth is inhibited) • adequate ventilation • easy access for maintenance • appropriate signage • sufficient structural strength to withstand wear and tear • drainage pipes from the overflow pipe should be laid away from the base of the tank and house foundations • no hazard to passers-by or small children • not imparting an unacceptable taste to the water (if used for drinking water purposes)
7.2	Openings should be screened to protect against mosquitoes. Mosquitoes are a major concern for Health Departments due to their ability to transmit diseases. For more information on mosquitoes, see Geary *et al.* (2005), QLD Health (Undated), CRC WQT (2005) and Whelan *et al.* (2003).

No.	Implementation – General Water Quality Issues
7.3	For any rainwater tanks and the associated pipework: a) prevent light penetrating any openings, including the tank inlet screen, to reduce the likelihood of algal growth. A specially designed under-guard for an inlet screen is available from at least one manufacturer. This under-guard lets water through but minimises light entering the tank. b) check with the manufacturer if a new tank needs to be flushed before use The University of Newcastle has undertaken much research work on rainwater tanks, including the water quality processes occurring inside the tank (see Spinks *et al.* 2003).
7.4	The draw-off point from the tank or the suction level (where a submersible pump or suction pipe is used) should be above the sediment zone, as significant concentrations of some metals have been found in sediments. Gardner *et al.* 2004 has suggested a distance from the household water intake to the bottom of the tank of 150mm to 200mm. Research at Monash University is currently investigating the issue (see Magyar *et al.* 2006 and 2006A). The tank manufacturer's minimum distance for the draw off point from the base of the tank should be heeded. Inappropriate positioning of the draw off point (if the outlet is placed too close to the bottom of the tank) may result in possible leakage and/or structural weakness in the tank.

7.5	There could be an association between tank water temperature and the level of bacterial contamination (lower temperatures are associated with lower activity). Very dark colours of tanks (above-ground) are thought to increase temperatures. Further research on this issue is currently underway by the CRC for Water Quality and Treatment and the Centre for Appropriate Technology at Mutitjulu (Northern Territory).
7.6	Care should be taken to avoid tanks that are not opaque. There may be certain types of materials that allow light to enter through the walls, thus possibly creating an algal problem.
7.7	With regards to controlling mosquitoes, the: a) tank overflow should be fitted with a mosquito and vermin proof screen or flap valve b) mosquito-proof screens should have openings less than $1mm^2$ (Queensland and Northern Territory have regulations – see Standards Australia (2006)) c) rainwater should not pool on the tank lid
7.8	Tanks should be adequately ventilated. Consideration should be given to having at least two vents and/or other openings (covered with mosquito-proof mesh and protected against light intrusion), preferably at opposite ends of the tank, in order to improve cross-ventilation. Anaerobic bacterial activity increases when high concentrations of organic debris and nutrients enter the tank. Cross-ventilation should facilitate the removal of gases produced with the breakdown of organic matter.
7.9	Appropriate devices should be installed in the overflows from buried rainwater tanks to prevent contaminated stormwater backflowing into the tank.

No.	Implementation – Water Quality Issues – If intended to use roofwater for drinking water purposes
7.10	The tank and its appurtenances should comply with AS/NZS 4020. Where roofwater is stored in a tank that does not comply with AS/NZS 4020, the roofwater should only be used for non-drinking water end uses.
7.11	Plasinska (2003) stated that tank capacity was the most important of the factors influencing the microbiological quality of tank water (tank capacity and the level of contamination have an inverse relationship), with tanks over 20,000 litres seeming to be most advantageous. However, tanks of this size are difficult to place in the urban environment.

8 ROOFWATER DELIVERY TO DWELLING

Key Issues

- A dual delivery plumbing arrangement should be used
- The use of alternative products to metallic pipes should be considered
- Consideration should be given for the installation of a rainwater tank connection valve rather than a top-up system

No.	Implementation – Non Water Quality Issues
8.1	 Labelling of pipework and signage should be as required by AS/NZS 3500 and the relevant Regulatory Agency.
8.2	The air-gap associated with a top-up system (see Fig. 8) should be a visible air-gap. The visible nature of the air-gap will hopefully assist in detecting a leaking inlet valve and therefore avoid water wastage.
8.3	If a top-up system is installed, consideration should be given to install a trickle top-up system. A trickle top-up system uses a flow regulator to restrict flow to a defined limit. One advantage of a trickle top up is that only minimal pressure fluctuations should occur in operating domestic fixtures (e.g. showers) when flow to the tank turns off/on.
8.4	When installing a tank the property-owner/installer should check with the Regulatory Agency as to the local requirements for backflow prevention. The level of backflow prevention is dependant on risk. Generally, above ground tanks would be classified as a “low” hazard (see AS/NZS 3500) and therefore require a non-testable device/s. Generally, buried rainwater tanks would be classified as a “medium” hazard and thus require a testable backflow prevention device/s. The cost of ongoing maintenance of any testable device is an issue as they require annual inspections by a plumber. Capital costs for the testable devices are also usually higher than non-testable devices. Note - some new water meters may contain an integral dual check valve. At least one Regulatory Agency (Sydney Water) will supply free of charge, upon request if installing an above-ground rainwater tank, a new standard sized domestic water meter containing an integral dual check valve.
8.5	If purchasing a pump, information should be sought from an experienced professional pump dealer on: a) the type of pump that is best suited for the particular purpose b) whether a solar or low voltage pump would be suitable Concerns are raised that many of the current pumps being installed are: a) very energy inefficient due to high starting losses (see Gardner *et al.* 2006) b) oversized for the intended applications e.g. when a pump sized to supply a household is used to only supply a toilet.

8.6	If a pump is installed, strategies should be employed to mitigate pump-generated noise, including: a) use of an acoustic enclosure b) locating any surface pump away from sensitive living areas (such as bedrooms and living rooms c) use of a submersible pump
8.7	In multi-unit development, consideration should be given to sharing of infrastructure, e.g. tanks and pumps, to save both capital and operating costs (see Figure 10).

No.	Implementation – General Water Quality Issues
8.8	Roofwater from tanks has generally been found to be soft and sometimes acidic (see Chapman *et al.* 2006). Low pH conditions are generally less prevalent in concrete tanks because the leaching of lime from the tank walls effectively neutralises the acid, or buffers against this pH change. Any low pH roofwater, used in the delivery system, may be responsible for the increased corrosion of metal pipes compared to neutral pH conditions. This can have implications for the longevity of metal pipework. One solution, if supplying low pH roofwater to metal pipework, is to neutralise the roofwater. However, it is difficult to find an easily prescribed method for neutralising. One possible solution is to submerge a masonry block in the tank, however the effect on pH is difficult to determine without continual monitoring. Further research is required on this issue. Where metal pipes are used, ensuring organic substances (leaves etc.) are kept out of the storage will be beneficial. Consideration should be given to the use of alternative products to metal pipes, as there are suitable non-metal pipes available.
8.9	There are two ways to automatically provide mains drinking water back-up to roofwater, and these are: a) a top-up system with air-gap, via an indirect connection to the tank (similar to a tap over the tank) (see Figure 8); and b) a rainwater tank connection valve (Standards Australia 2004), via a direct connection from the tank delivery pipework to fixtures (see Figure 9) when roofwater is not available. Consideration should be given to installing a rainwater tank connection valve (see Figure 9) rather than a top-up system. Advantages of a rainwater tank connection valve over a top-up system include: a) the water quality of the mains drinking water is preserved at the outlets, when rainwater is not available, as the mains drinking water by-passes the rainwater tank b) the valve reverts to the mains drinking water supply (if feature is built into the design) if power failure occurs c) there is usually an increase in yield from the rainwater tank as a mains drinking water top up zone (see fig. 7) is not required (hence more usable storage within the tank) d) there are energy savings and noise avoidance, when rainwater is not available, as the pump is not in use.

	However, disadvantages of a rainwater tank connection valve over a top-up system do exist and include: a) the remaining water quality inside the tank may deteriorate if a long period of time elapses when by-passing the rainwater tank (during dry periods) b) some rainwater tank connection valve designs deliver reduced pressure from the mains drinking water system due to a pressure reducing valve c) rainwater tank connection valves are usually more expensive to purchase compared with a top-up system.
8.10	The local Regulatory Agency should be checked as to whether certain supply sources (e.g. dam, bore water etc) are allowed as top-up to a rainwater tank. The local Regulatory Agency should also be checked as to the appropriate marking and signage that should be used if topped-up with an alternative supply source.

No.	**Implementation – Water Quality Issues – If intended to use roofwater for drinking water purposes**
8.11	A single delivery system can cause a problem for Water Agencies as there could be situations where the mains drinking water may become stagnant in the reticulation pipework during wet periods when the roofwater supply would be continually used. One regional Water Agency in Queensland (Beaudesert Shire Council) requires a mandatory connection of the mains drinking water supply to the kitchen sink (see BSC 2004). This is to ensure that there is at least some turnover of the mains drinking water supply while there is adequate roofwater available. A dual delivery system should be used (see Figs. 8, 9 and 10), rather than a single delivery system. Consideration should be given to supplying several end uses with mains drinking water supply, especially end uses such as the kitchen sink and basins. Having the mains drinking water supplying several end uses should at least minimise the stagnation problem for Water Agencies.
8.12	Where roofwater is used for drinking and metal pipes are in place with low pH roofwater, pipework should be flushed each morning to remove roofwater that has been standing in the pipe overnight. This roofwater often has increased concentrations of dissolved metals. Generally, for an average sized home, flushing consists of running the relevant taps for about one to two minutes. The flushed water could be used for non drinking water uses.

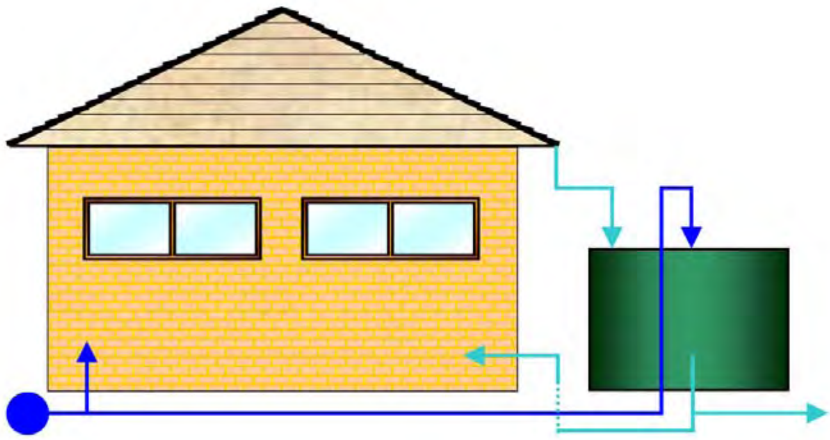

Figure 8 Dual Delivery System with Top-up

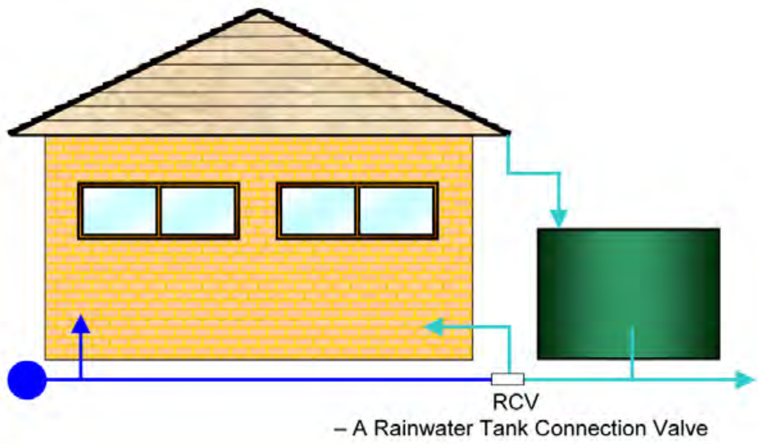

Figure 9 Dual Delivery System with Rainwater Tank Connection Valve

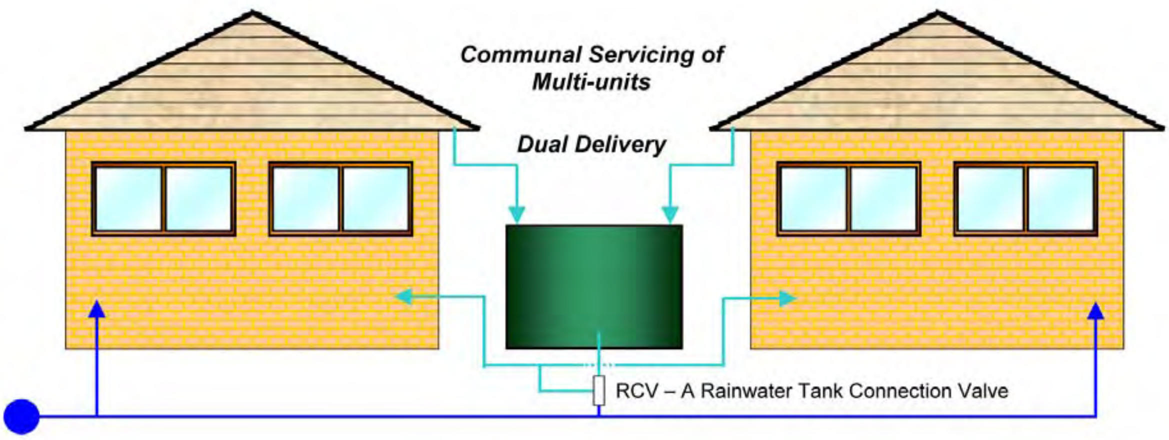

Figure 10 Plumbing Configurations: Communal Servicing of Multi-units with a Rainwater Tank Connection Valve

9 ROOFWATER TREATMENT

Key Issues

- A post tank treatment device should not be generally needed for roofwater supplying non-drinking water end uses
- A health risk assessment should be undertaken if roofwater supplies drinking water end uses

No.	Implementation – General Water Quality Issues
9.1	From a national survey, ABS (2004) stated that 11.3% of Australians use rainwater as their primary source of drinking water and that 17.2% of households had a rainwater tank.
9.2	In choosing a water filter or treatment system: a) buy a unit that is appropriate to the needs b) check that the flow rate is adequate to meet demands. Generally, as filter pore space sizes become smaller to provide better protection, flow rates tend to decrease c) consider maintenance/replacement costs and running costs (e.g. UV-lamps can be expensive to replace).
9.3	Further information, including the correct replacement cycle (where stated by the manufacturer) and flow-rate requirements for a water filter cartridge and/or media, can be found by visiting the NSF website: http://www.nsf.org/Certified/DWTU/ Note that all drinking water treatment units must bear a WaterMark – see http://www.watermark.standards.org.au/search.asp
9.4	In general, a post tank treatment device should not be needed for roofwater supplying non-drinking water purposes, subject to adequate maintenance of the roofwater harvesting system. enHealth Council (2004) states: 'Irrespective of how rainwater is used, water quality is dependent on implementing a sensible maintenance program'. A 100-150 micron coarse filter could be considered (post-tank), subject to the requirement that the device be regularly maintained. If the coarse filters are not properly maintained and blockages occur, the filter may cause major damage to pumping systems, if installed, and may even adversely affect water quality. Sometimes filters are recommended by irrigation companies to protect irrigation components (these may be required to ensure warranty compliance). These devices should be regularly maintained. Any filters in the open that have a clear viewing chamber should be avoided. The entry of light may assist algae growth.
9.5	Where roofwater is used for topping up swimming pools and spas, care should be taken to ensure that operating advice from the appropriate Health Department is always followed. The operating advice, including the addition of sanitiser chemicals and chemicals for controlling the pH level, is especially important for heated spas. Roofwater generally tends to have a more variable and lower pH on average than mains drinking water and therefore increased vigilance to ensure correct pH level may be required.
9.6	For information on microbial issues, see Albrechtsen (2002), CRC WQT (2005), O'Toole *et al.* (2006) and Abbott *et al.* (2006).

No.	Implementation – Water Quality Issues – If intended to use roofwater for drinking water purposes
9.7	Two epidemiological studies of gastrointestinal illness rates have been undertaken in South Australia. The CRC for Water Quality and Treatment (2005) states that the studies gave somewhat contradictory results, with the first study suggesting a possible increase in illness rates from rainwater consumption compared to conventional tap supplies, while the second study indicated slightly reduced risks from rainwater consumption. The second study is considered methodologically stronger due to its prospective design.
9.8	enHealth Council (2004) states that: 'The decision about how to use rainwater is a matter of personal choice. In making this decision, it should be recognised that, although the risk of contracting illness from rainwater supplied from well-maintained roof catchments and tanks is low, the quality of water from household tanks is not as consistently high as that provided by well-managed urban water supplies. Microbiological quality is not as reliable as mains water, particularly after rain events. In addition, there are a few areas where impacts from major industrial emissions (for example, Port Pirie, South Australia) mean tank rainwater is not suitable for drinking and food preparation. Further investigations are required to determine impacts of very large densities of traffic, and other emissions in Sydney and Melbourne.' Most Health Departments generally recommend that roofwater not be used for drinking water purposes when a mains drinking water supply is available. However, there appear to be many individuals who choose to drink roofwater from a rainwater tank in the urban situation. Lukin *et al*. (2005) states that out of 160 Maroochy (Queensland) respondents who completed the section of their questionnaire detailing water tank usage, 112 advised that they used roofwater for drinking purposes. However, there is little information on whether any treatment is applied to the roofwater before drinking. Also, a relatively new phenomenon in urban situations is that some individuals choose to plumb their household (in those jurisdictions where it is allowed) such that many end uses, including the kitchen sink (which could supply water for drinking), are supplied by roofwater. There are now some niche developments in urban areas around Australia where roofwater is used for drinking water purposes, including drinking. For these, developers are installing treatment devices with the intent of improving the quality of the roofwater to drinking water standards (see NWQMS 2004). Examples of some niche developments are: • Mosman Green, Mosman, New South Wales – www.archicentre.com.au/mosmangreen/index.htm • Payne Road, The Gap, Queensland - www.payneroad.com.au (see Gardner *et al.* 2006) • Currumbin Ecovillage - www.theecovillage.com.au/index2.htm For individuals or developers who choose to plumb their households such that end uses, including drinking water, are supplied by roofwater, a health risk assessment should be undertaken. The assessment should include issues such as: a) whether any nearby polluting industry is a problem. Near major industrial emissions, the owner/installer should contact the local Health Department to determine if roofwater is not advised for drinking purposes b) the suitability of roofing and ancillary materials, especially if retrofitting a roofwater harvesting system in an existing property. Lead has been detected in levels above drinking water guideline health limits (NWQMS 2004) in supplies from some rainwater tanks – see Chapman *et al.* (2006) and Simmons *et al.* (2001)

	c) the likelihood of very young, very old or immuno-compromised persons drinking the roofwater d) how visitors, renters and future owners are advised e) the increased risks with having an underground rainwater tank. Buried tanks have additional hazards in the urban situation, as there is potential for contaminated sewage, stormwater or groundwater to enter the tank f) how ongoing maintenance is assured.
9.9	Where roofwater is used for drinking water end uses and a water treatment device is not used, the owner should consider: a) the use of multiple tanks connected in series, as this may assist in improving the quality of roofwater b) allowing several days retention time after rainfall before use of the roofwater (this may not be practical if the rainwater tank is the sole source of supply) as turbidity of roofwater is expected to increase after a rainfall event. Water retained for a time is expected to improve in clarity and microbiological quality (Ashworth 2002).
9.10	Where treatment devices have been installed on the roofwater supply in urban situations, they tend to be either fine particulate filters or UV irradiation devices, or both. Most treatment devices require maintenance to be effective in the long term. If choosing a UV-lamp, scale build-up on the lamp over time may reduce the effectiveness. Hence a sensor/alarm should be used.

10 HEATED WATER SYSTEMS

Key Issues

- The requirement in AS/NZS 3500 which states that: ‘Heated water shall be stored at a minimum temperature of 60°C, to inhibit the growth of *Legionella* bacteria’ should be followed
- The appropriate Health Department and/or Regulatory Agency should be consulted for the position on supplying heated water systems with roofwater

No.	Implementation – General Issues
10.1	AS/NZS 3500 states that: ‘Heated water shall be stored at a minimum temperature of 60°C, to inhibit the growth of *Legionella* bacteria.’ AS/NZS 3500 prescribes information on sanitary fixture delivery temperatures: ‘All new heated water installations shall, at the outlet of all sanitary fixtures used primarily for personal hygiene purposes, deliver heated water not exceeding: - 45°C for early childhood centres, primary and secondary schools and nursing homes or similar facilities for young, aged, sick or people with disabilities, and - 50°C in all other buildings.’ Some areas have further amended the temperatures at outlets - check with the local Regulatory Agency.
10.2	When using a different supply source to supply the tempering device compared to the water heater, the installer should check with the local Regulatory Agency on the appropriate backflow prevention requirements, as a direct connection is formed (see Figure 11).
10.3	NEHF (1996 - 1) and NEHF (1996 – 2) state important design and maintenance control measures for heated water systems and spa pools. These include: a) minimising dead legs in pipework b) ensuring fixtures such as showers be operated each week, if not in use, to remove stagnant water from the system c) cleaning spa pools regularly
10.4	The Regulatory Agency should be approached regarding the required location, or any limitations on, the thermosiphon solar water heater overflow. Limitations may include avoiding the placement of the overflow into guttering that supplies rainwater tanks.
10.5	Advice should be obtained from the water heater manufacturer on the most appropriate sacrificial anode for use when a water heater is supplied with different sources of water (roofwater and mains drinking water) at different times. When installing a roofwater harvesting system to supply an existing storage water heater with cathodic protection, the existing anode type should be checked with the manufacturer to ensure it is appropriate. Using an inappropriate anode in certain situations may result in serious consequences.

No.	**Implementation – Water Quality Issues – If intended to use roofwater for drinking water purposes**
10.6	There are situations, that should be avoided, where a water heater may not heat water to greater than or equal to 60°C, including: a) storage depletion is continually occurring (insufficient time is available for in-coming roofwater to be heated) b) the booster is turned off in a solar heated water system c) the thermostat of any storage water heater is turned down to less than 60°C
10.7	Issues associated with the supply of roofwater to heated water systems include: • risk from microbial contamination if storage temperatures are less than 60°C • whether to use water treatment (where used, it is generally UV irradiation) • providing adequate information to risk groups e.g. the immuno-compromised • developing and promoting better education on design and maintenance issues. Supplying roofwater to heated water systems can conserve significant quantities of mains drinking water, as heated water can account for about 40% of household water demands. The current situation on recommendations and requirements relating to supplying heated water systems with roofwater should be sought from the appropriate Health Department and/or Regulatory Agency. For further information see CRC for Water Quality and Treatment (2005) as well as Broadhead *et al.* (1988), Sanden *et al.* (1989), Straus *et al.* (1996), Bentham (2000), Wolferen (2001), Broadbent (2003), Spinks *et al.* (2003A), Borella *et al.* (2004) and Jayaratne *et al.* (2006).

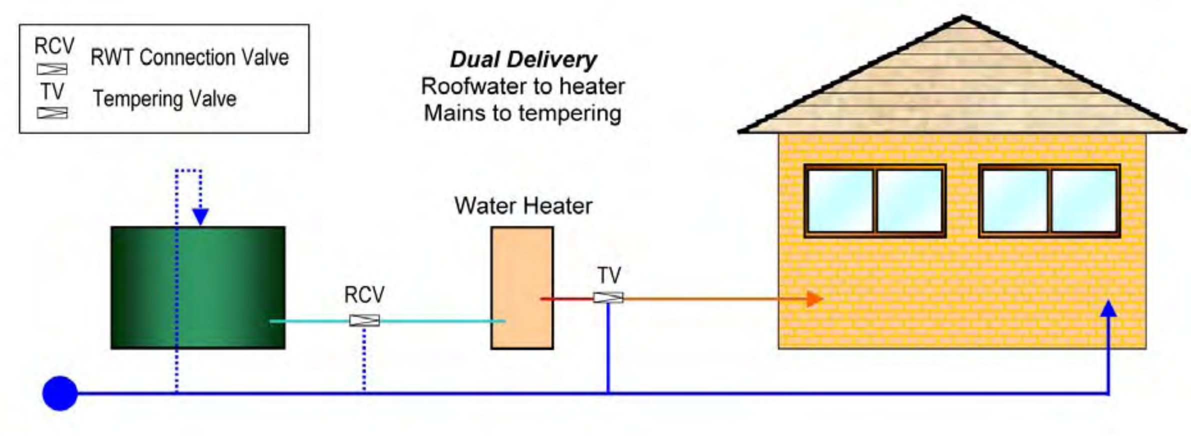

Figure 11 Cross Connection at Tempering Valve

11 OTHER ISSUES

Key Issues

- Immuno-suppressed people should consider boiling the roofwater before consumption
- Water efficient fixtures, fittings, appliances and products should be used

No.	Implementation – Non Water Quality Issues
11.1	Electrical equipment should be checked by a qualified electrician according to the relevant maintenance and inspection schedule requirements.
11.2	Plastic gutter-guards, guttering and downpipes should be avoided in bushfire prone areas.
11.3	Water level devices should be considered, especially if a back-up supply to the tank is not available.
11.4	Water efficient fixtures, fittings, appliances and products should always be used with any roofwater harvesting system. A mandatory labelling system (WELS) has now been introduced for some fittings and appliances based on a ‘star’ system. For further information, see: www.waterrating.gov.au

No.	Implementation – General Water Quality Issues
11.5	enHealth Council (2004), under a section labelled “Boiling” advises that immuno-suppressed people should consider boiling the roofwater before consumption. Extended boiling is not necessary – kettles with automatic shut-offs are suitable for this purpose.
11.6	enHealth Council (2004) provides information on water quality testing and suggests that advice on testing should be sought from a local health or water authority.

No.	Implementation – Water Quality Issues – If intended to use roofwater for drinking water purposes
11.7	WSAA Materials Fact Sheet No. 4 (2001) contains guidelines that should be adopted for material selection to minimise the risk of contamination from metal leaching, including: a) avoid lead flashing, which can cause accelerated corrosion of Zincalume® steel roofing and may also contribute to lead in the collected roofwater. Use zinc, aluminium, or bitumen coated aluminium flashing suitable for the roof type b) avoid bimetallic couples, e.g. do not use stainless steel screws on Zincalume® steel or on pre-painted roofing materials of either steel or aluminium c) copper roofing and guttering materials should never be used upstream of any aluminium, galvanised or Zincalume® steel products d) avoid the use of galvanised gutters in conjunction with “inert roofing materials” such as Zincalume® steel, Colorbond® steel or terracotta tiles. This combination can result in accelerated corrosion of the galvanised guttering, particularly in high rainfall areas.
11.8	enHealth Council (2004) provides information on the issue of lack of fluoride in rainwater in relation to dental health care.

12 POST INSTALLATION

Key Issues

- The roofwater harvesting system components and devices should be checked in the initial operating phase
- Many post installation problems can be prevented by good design

No.	Implementation – General Quality Issues
12.1	All the roofwater harvesting system components and devices should be checked in the initial operating phase, including (if present): a) the roofwater storage tank (for unexpected bulges or leaks) b) the tank overflow and vent flap(s) c) the roofwater delivery pump and acoustic cover d) the stored roofwater surface for mosquito larvae (to determine whether the mosquito-proof mesh has been effective) e) on-line filtration devices f) irrigation lines (if included) for leakage g) correctly working sensors or alarms (e.g. those with UV systems)
12.2	Information on preventative measures is available from: a) enHealth Council (2004) b) Table 1 Table 1 indicates possible solutions (i.e. devices and practices at the pre-tank, in-tank and post-tank stages and/or maintenance requirements) that would be used for various problems (biological or microbial contamination etc.). Some of the solutions may not be relevant in all situations; for example, the occurrence of lead contamination in roofwater is only an issue if the roofwater is intended for drinking – hence, the use of a (lead specific) ion-exchange resin filter (as shown in Table 1) would only apply if lead was found to be a problem and the roofwater was intended for drinking. It is likely that many problems shown in Table 1 may only be recognised after installation. However, by examining the number of 'X's or 'XX's in the columns in Table 1, it becomes apparent that many problems can be initially prevented or minimised by such items as 'removing overhanging branches' and installing a 'deflecting leaf diverter'.

No.	Implementation – Water Quality Issues – If intended to use roofwater for drinking water purposes
12.3	enHealth Council (2004) states that the corrective action for poor taste from new tanks or newly painted roofs is to use the first fill from the tank for non-drinking water purposes.

Table 1 Roofwater Harvesting Device, Preventative Practice, or Remedial Action for Resolving a Specific Water Quality Issue

Device for Problem	Outside	Roofwater Conveyance		In-tank						Post-tank					Routine Maintenance		
	Shade-screening	Deflecting Leaf Diverter	First Flush Diverter	Inlet Screen	Safety Hatch	Filter Sock	Turbulence Diffuser	pH Control	Overflow Screen	Coarse Filter	Fines Filter	Activated Carbon Filter	Ion-exchange Resin Filter	Disinfection Device	Removing Over-hanging Branches	Cleaning/ De-sludging	Chemical Disinfection
Biological or Microbial Contamination																	
Microbes	X	X	X	X		X		X			XX			XX	XX	XX	XX
Mosquitoes		X		XX					XX						XX		
Algae	X	XX	X	X		X									XX		
Organic Contamination																	
Colour		XX	X	X		X						XX			XX	X	
Odour		XX	X	X		X						XX			XX	X	X
Hydrocarbons & Pesticides		X	X	X				X				XX	X		XX	X	
Inorganic Contamination																	
Heavy Metals (Lead)		X	X	X		X		XX					XX		XX	X	
Corrosion		XX	X	X		X		XX				X			XX	X	
Turbidity			X	X			XX			X	X					X	
Particulates		X	X	X		X				X	XX				XX	X	
Other																	
Drowning					XX												
Noise							X										

X - [the device(s)/practice may assist in controlling the problem]   XX - [the device(s)/practice may be one of the best options for controlling the problem]

13 MAINTENANCE

Key Issues

- Controlling mosquitoes and keeping leaves from entering tanks are two of the main issues
- Hydrocarbon treatment (paraffin or kerosene) should not be used to control mosquitoes

No.	Implementation – Non Water Quality Issues
13.1	enHealth Council (2004) should be consulted regarding general maintenance information. Controlling mosquitoes, due to concerns about mosquito borne diseases, and keeping leaves from entering tanks are two of the main issues. Further issues in relation to maintaining a roofwater harvesting system in an urban situation include: • owners who do not want to, or are unable to, maintain their roofwater harvesting system • renters of properties may not understand the maintenance requirements • water agencies would like the systems to be operational for as long as the dwelling exists, as the water savings gained by the systems assist their water conservation programs • some of the work involved in maintaining systems can be dangerous for untrained people without professional equipment • any water treatment device usually requires maintenance, with some devices actually causing water quality problems if they are not maintained • in multi-unit developments, there are advantages in the body corporate undertaking much of the maintenance (to ensure programmed maintenance takes place) • some equipment is expensive to replace when eventually required, e.g. pumps, UV lamps and some filters • regular maintenance of devices such as inlet screens is important, especially in reducing blockages
13.2	Information on preventative measures is available from: a) enHealth Council (2004) b) the leaflet 'What to do if you have too much lead in your tank water' (Gibson 2002) c) Table 1

No.	Implementation – General Water Quality Issues
13.3	The various options for water agencies, or other authorities with relevant powers, to promote maintenance include: a) conduct random or periodic audits and publish the general results b) have a certification system in place that assures any prospective property/home buyers that any roofwater harvesting system installed on that property has been inspected and is in good working order c) promote maintenance in education material (including website material) d) require multi-unit developments to have the body corporate undertake much of the maintenance work

13.4	Generally, in the case where a breach in the mosquito-proof mesh has been located, a non-chemical approach to controlling the emerging adults should be taken. This approach is to discover how the adult mosquitoes gained entry into the tank and then seal off the access. If the mosquito mesh is repaired and there are no other points of entry or exit, the larvae will emerge from the water as adult mosquitoes, but will not be able to escape the tank and will therefore eventually die. A Queensland Government brochure states that if the screen is missing or damaged, treat the tank with an insect growth regulator (IGR) containing *s*-methoprene (see QLD Health undated). The brochure notes that rainwater tanks have the potential to become breeding sites for the mosquito that spreads Dengue Fever and states that screens should be replaced as soon as possible. Hydrocarbon treatment (paraffin or kerosene) should not be used. Use of a hydrocarbon treatment for mosquito control may cause problems. One undesirable side-effect of kerosene or liquid paraffin treatment is that by impeding oxygen exchange across the air-water interface, the water may become anaerobic. Another potential problem with this method of treatment is that any food-grade polymer lining or liner in the tank may be damaged (the hydrocarbon treatment may void any product warranty that may be in place).
13.5	Maintenance of water treatment devices should be undertaken as recommended by the manufacturer. Where UV irradiation systems are used, maintenance is important. The effectiveness of the system may diminish over time for various reasons, e.g. scaling on the UV lamps. The disposal of UV-lamps should not be through the Local Council general waste collection service as they contain mercury. The manufacturer may provide a disposal service.

14 FURTHER WORK

Current known PhD studies relating to roofwater harvesting systems in Australia are:

Name	University	Topic/Area
Craig Evans	Newcastle University	Microbial and biochemical diversity
Rob Huston	Griffith University	An assessment of organic contamination of rainwater tanks in urban/industrial areas of Australia
Mirela Magyar	Monash University	Determining how the design of residential rainwater tanks affects water quality
Anthony Martin	Newcastle University	Mosquitoes and rainwater harvesting
Jo O'Toole	Monash University	Alternative water sources and health risks
Shelly Rodrigo	Monash University	A randomised double-blinded intervention study to assess health effects of drinking water from rainwater tanks.
Anthony Spinks	Newcastle University	Water quality, incidental treatment train mechanisms and health risks associated with the use of urban rainwater harvesting systems
Ian White	Griffith University	Social interactions with rainwater tank technology

15 CASES

Introduction

For roofwater harvesting systems, the CRC for Water Quality and Treatment endorses the recommendations and requirements of the appropriate Health Department in relation to the supply of roofwater to end uses.

However, even though the local Health Department may not recommend the use of roofwater for drinking where a reticulated drinking water supply is available, the local plumbing regulator may allow plumbing configurations that have drinking water uses connected to the roofwater supply.

There are therefore literally hundreds of plumbing and component configurations possible in a roofwater harvesting system. This section develops four cases, in order to simplify the situation, in the form of various practical configurations and provides a series of tables in order to present the major outcomes previously developed. The four cases are:

- CASE 1 - NON-DRINKING WATER EXTERNAL
- CASE 2 - NON-DRINKING WATER (INTERNAL AND EXTERNAL)
- CASE 3 - NON-DRINKING WATER PLUS HEATED WATER
- CASE 4 - DRINKING AND NON-DRINKING WATER

Table 2 shows the end uses for each of the cases.

Table 2 End Uses for the Four Cases

	Title	**End Uses**
Case 1	Non-drinking water external	Irrigation and car washing
Case 2	Non-drinking water (internal and external)	Irrigation, car washing, toilets and washing machine (cold water tap)
Case 3	Non-drinking water plus heated water	Irrigation, car washing, toilets and washing machine (cold water tap); plus heated water for: shower, bath, basin, laundry trough, kitchen sink and washing machine
Case 4	Drinking and non-drinking water	All end uses

The assumptions used in developing the four end use Cases are that:

- the roof is free from overhanging branches or other plants;
- the roof is not situated in or near an area where exposure to heavy loads of faecal matter is likely (e.g. from bat colony, seagull or pigeon roosts, etc.);
- the roofwater harvesting system is of good design and in a good state of repair. Specifically, there are no:
  - rusting or oxidised metal components;
  - flaking paint, deteriorating fibre-glass or fibre-board surfaces;
  - areas of the guttering or downpiping subject to water pooling;
  - exposed lead surfaces and no lead-containing components in the roofwater harvesting system;
- there is no heavy mining or industrial activity in the vicinity;
- there is no farm scale pesticide application taking place in the vicinity;
- the system is regularly monitored and maintained by the user and/or other(s), and
- people in poor health or potentially susceptible to health problems, e.g. immuno-suppressed groups and the aged, are not living in the dwelling.

For post-commissioning developments that arise beyond those covered in the assumptions above, the designer is advised to refer to enHealth (2004) and Table 1 for trouble-shooting recommendations.

Devices

There are several devices that should be included in a roofwater harvesting system. Table 3 is provided as a guide to determine the appropriate devices to suit the relevant cases.

Table 3 Components for a Roofwater Harvesting System

Devices	Case 1 Non-drinking - External	Case 2 Non-drinking - Internal and External	Case 3 Non-drinking Plus Heated Water	Case 4 Drinking and Non-drinking	Reference Section
Leaf Diverter	✓	✓	✓	✓	6.7
Gutter Guards	(1)	(1)	(1)	(1)	6.8
Mosquito-proof Mesh (2)	✓	✓	✓	✓	7.7
Water Treatment	GNR	GNR	(3)	(3)	9.8
Storage Water Heating Unit >60°C	NA	NA	✓	✓	10.6

Shading note – The light shading on Case 3 and 4 columns show where roofwater could be used for drinking water purposes.

Notes:

1. Should be used when a high volume of leaf matter occurs.
2. Mandatory in most areas in Australia.
3. A health risk assessment should be undertaken.

Legend:

✓ Indicates that components should be used.

GNR – generally not required
NA – not applicable

Plumbing

Table 4 is provided as a guide to determine the appropriate plumbing materials and configurations to suit the relevant cases.

Table 4 Water Quality Related Comments on Plumbing Materials and Configurations

Plumbing Issues - Water Quality Related	Case 1 Non-drinking - External	Case 2 Non-drinking - Internal and External	Case 3 Non-drinking Plus Heated Water	Case 4 Drinking and Non-drinking	Reference Section
Above-ground Storage	✓	✓	✓	✓	4.12
Multiple Tanks in Series and/or Secondary Storages	Consider	Consider	Consider	Consider	4.13, 4.14
System Materials - Lead Free	✓	✓	✓	✓	5.6
Dry Conveyance System	✓	✓	✓	✓	6.6
Rainwater Tank Connection Valve - Mains Back-up	Consider	Consider	Consider	Consider	8.9
Plumbing - Dual Delivery	✓	✓	✓	(1)	8.11

Notes:

1. Dual delivery systems should be used instead of a single delivery system. This is because a dual delivery system helps avoid situations when stagnation of the main drinking water supply could occur during wet periods.

Legend:

✓

Indicates that the plumbing material or configuration should be used. In reference to 'Plumbing – Dual Delivery', it indicates that a dual delivery system is required to supply the two sources of water (roofwater and mains drinking) to the end uses.

There are plumbing features that would be beneficial, but would not be necessarily associated with improving the quality of the roofwater. Table 5 is provided to guide the designer to incorporate these plumbing features.

Table 5 Non-water Quality Related Comments On Plumbing Materials and Configurations

Plumbing Issues Non-water Quality Related	Case 1	Case 2	Case 3	Case 4	Reference Section
	Non-drinking - External	Non-drinking - Internal and External	Non-drinking Plus Heated Water	Drinking and Non-drinking	
Gravity-fed Delivery Mechanism	Consider	(1)	(1)	(1)	4.4, 8.5
Non Metallic Delivery Pipework	Consider	Consider	Consider	Consider	8.8

Notes:

1. It is unlikely that adequate pressure requirements for the end uses can be supplied from a gravity header tank in an urban situation (however a low pressure toilet cistern inlet valve is available). If using a pump, review the type of pump with a professional pump dealer (check whether a solar or low voltage pump is available).

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CRC for Water Quality and Treatment

CRC AUSTRALIA

The Cooperative Research Centre (CRC) for Water Quality and Treatment is Australia's national drinking water research centre. An unincorporated joint venture between 29 different organisations from the Australian water industry, major universities, CSIRO, and local and state governments, the CRC combines expertise in water quality and public health.

The CRC for Water Quality and Treatment is established and supported under the Federal Government's Cooperative Research Centres Program.

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