MANAGING URBAN STORMWATER

Harvesting and Reuse

Department of **Environment and Conservation** NSW

stormwater TRUST

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Cover photo of stormwater harvesting and reuse at Sydney Olympic Park, courtesy J Dahlenburg, wsud.org

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Foreword

The recent drought and concerns about climate change have all highlighted the need to manage our water resources more sustainably. Expanding the use of stormwater runoff to add to our water supply and reduce water pollution are important objectives for the NSW Government. Stormwater is now recognised as a valuable resource, rather than a nuisance to be disposed of quickly, especially in large urban centres.

Over recent years, stormwater harvesting and reuse have emerged as a new field of sustainable water management. Harvesting and reusing stormwater offer both a potential alternative water supply for non-drinking uses and a means to further reduce stormwater pollution in our waterways. Stormwater harvesting complements other approaches to sustainable urban water management, including rainwater tanks, greywater systems, effluent reuse and demand management.

The NSW Government recognises the many benefits that can accrue from harvesting stormwater. Through the Government's Stormwater Trust, we have already provided over $4 million for ten pilot projects that together are saving up to 13 million litres of water annually. This has been Australia's most comprehensive stormwater harvesting funding program and many of these projects are profiled in this document.

Additional funding for stormwater harvesting will be made available from mid-2006 through the NSW Government's $80 million Urban Sustainability Fund, part of the Iemma Government's $439 million City and Country Environment Restoration Program.

The pilot projects that have already been funded have taught us much about what goes to make a stormwater harvesting scheme successful. In an Australian first, this document combines these lessons with ideas and principles from the fields of stormwater, wastewater and water supply management to provide specific guidance on developing successful stormwater harvesting schemes. It aims to encourage projects that will lead to more sustainable urban water management, while also managing the health and environmental risks associated with stormwater reuse.

Managing urban stormwater: harvesting and reuse provides a sound basis for implementing operational stormwater harvesting schemes more widely. It is also an invaluable part of the Government's Metropolitan Water Plan which aims to utilise all cost-effective means to help meet the demand for water resources as Sydney grows, while sustaining the health of our rivers.

I encourage all local councils, water managers, developers and planners to use this document and help realise the full potential of stormwater harvesting and reuse schemes.

Bob Debus
Minister for the Environment

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This document also incorporates the results of modelling carried out for the Department by WBM Pty Ltd.

Several people and organisations kindly supplied photographs for use in this report:

Cover: Stormwater treatment at Sydney Olympic Park (J Dahlenburg/wsud.org)

Contents: Kogarah Town Square (J Dahlenburg/wsud.org)

Section 1 opener: Taronga Zoo stormwater treatment plant and Sydney Harbour (H Pantenburg/Taronga Zoo)

Sections 2 & 3 openers: Water ponding at Sydney Olympic Park (J Dahlenburg/wsud.org)

Section 4 opener: Fenced constructed wetland at Camden (J Dahlenburg/wsud.org)

Section 5 opener: Stormwater planning at Hornsby Council (K Walters/DEC)

Section 7 opener: Weed control in stormwater reuse system at Archers Creek, Ryde (M Sharpin/DEC)

Section 8 opener: Hornsby stormwater harvesting and reuse scheme (J Dahlenburg/wsud.org)

References opener: Stormwater treatment at Victoria Park (J Dahlenburg/wsud.org)

Appendices opener: Water-sensitive urban design at Victoria Park (J Dahlenburg/wsud.org)

Contents

1. Introduction

1.1 Water in the urban environment

Water is an integral part of urban life. In our homes, we use water for drinking, washing and watering our gardens. Away from home, we swim and fish in water, and sail on water. At the beach or paddling a canoe on a river, we appreciate good quality water. We value water for its usefulness, its recreational benefits and its place in the landscape and environment.

Urbanisation changes the way water flows through a catchment, and this can have a range of adverse impacts on the water environment, including:

- poor water quality and degraded aquatic ecosystem health within rivers and creeks from the disposal of stormwater and wastewater
- changes to the pattern of flow in streams and rivers
- increased frequency and magnitude of flooding
- demand for potable water exceeding the sustainable supply, and impacting on the availability of water for users.

These are significant issues facing urban water managers and urban communities, although there are many potential solutions.

One option receiving increasing attention is water recycling and reuse. Water for reuse in urban areas can be sourced from rainwater, stormwater, greywater and effluent from sewage treatment plants (STPs).

Water reuse projects can achieve multiple benefits, including:

- reduced demand for mains drinking water
- reduced pollution loads to waterways
- reduced wastewater flows (where effluent and greywater are reused)
- reduced stormwater flows (where stormwater and rainwater are reused).

Recognising all of the potential benefits is a key to the economic and environmental viability of many reuse projects.

1.2 Harvesting stormwater for reuse

The capturing or harvesting of urban stormwater for reuse can contribute to water conservation, water quality and streamflow objectives. It complements other approaches to sustainable urban water management such as demand management, rainwater tanks, and the reuse of effluent and greywater.

Stormwater harvesting and reuse can be defined as the collection, treatment, storage and use of stormwater run-off from urban areas. It differs from rainwater harvesting as the run-off is collected from drains or creeks, rather than roofs. The characteristics of stormwater harvesting and reuse schemes vary considerably between projects, but most schemes would have the following elements in common:

- collection – stormwater is collected from a drain, creek or pond
- storage – stormwater is temporarily held in dams or tanks to balance supply and demand. Storages can be on-line (constructed on the creek or drain) or off-line (constructed some distance from the creek or drain)
- treatment – captured water is treated to reduce pathogen and pollution levels, and hence the risks to public health and the environment, or to meet any additional requirements of end-users
- distribution – the treated stormwater is distributed to the area of use.

Some components of a scheme may serve multiple purposes, such as a grass swale that collects and treats stormwater while forming a feature in the urban landscape.

Stormwater harvesting and reuse is a relatively new form of water reuse compared to rainwater tanks and the reuse of STP effluent. It is, however, increasingly recognised as a potential option for meeting the water demands and other objectives of many projects and sites. Harvested stormwater has commonly been used for irrigating public parks and golf courses, and other non-potable uses are possible.

1.3 The purpose and scope of this document

This document is part of a series of publications from the Department of Environment and Conservation NSW (DEC) under the *Managing urban stormwater* theme which provide guidance on different aspects of managing stormwater in the urban environment.

As noted above, urban stormwater harvesting and reuse is a relatively new field of water management and most of the projects constructed to date have been pilot projects. The main aim of this document is therefore to provide guidance on key considerations for future stormwater harvesting and reuse projects, based on experience gained from early stormwater harvesting projects. The most important considerations are:

- planning – assessing the context of a project within a broader strategy of integrated urban water cycle management and risk assessment
- project design – particularly treating stormwater to address risks to public health and the environment, and meeting any additional end-use requirements
- operations, maintenance and monitoring – ensuring that potential impacts to public health and the environment are managed appropriately and the project remains sustainable.

The elements typically used in stormwater harvesting and reuse projects are also found elsewhere in the water industry, such as in wastewater management. A successful harvesting and reuse project will select, design and adapt elements from these other contexts and integrate them into a sustainable system with multiple objectives and benefits.

Experience to date has shown that no two stormwater harvesting projects are exactly the same – there is no single approach to developing these projects, and any guidance needs to provide for this in its approach.

A successful stormwater harvesting and reuse scheme needs specialist input from a number of areas: stormwater management, water supply management, environmental management and public health. One of the secondary aims of this document is therefore to give specialists from these areas insights into key aspects of disciplines other than their own.

This guidance was prepared to help stormwater harvesting become a more 'mainstream' water management discipline. It also aims to encourage wider appreciation of the factors that can maximise the potential benefits of stormwater harvesting while minimising the associated risks.

Stormwater harvesting is closely related to rainwater reuse, as they are both sourced from rainfall. A discussion of rainwater and stormwater reuse is provided in section 2. Guidance on using rainwater tanks has not been included in this document, as existing comprehensive guidelines are available, including enHealth (2004), NSW Health (2004) and Melbourne Water (2005).

This document does not address urban stormwater harvesting as a raw water source for large-scale potable water supply schemes. Relevant information about these schemes can be obtained from the *Australian drinking water guidelines* (NHMRC & NRMMC 2004a).

1.4 Structure of this document

Section 2 provides a brief overview of stormwater harvesting and reuse, including potential applications, advantages and limitations

Section 3 summarises statutory requirements for a stormwater harvesting and reuse project in New South Wales

Section 4 discusses the key considerations for managing public health and environmental risks in stormwater harvesting and reuse projects

Section 5 presents an overview of planning a stormwater harvesting and reuse project, both in existing urban areas and new urban developments

Sections 6 and 7 outline key considerations for the design and operation of stormwater harvesting and reuse schemes

Section 8 contains case studies of stormwater harvesting and reuse projects.

Appendices provide detailed information to support the planning, design, operation and maintenance of stormwater reuse schemes. Appendix A contains the key considerations from sections 5 to 7 – these can be used as a project checklist.

2. Overview of stormwater harvesting

2.1 Stormwater harvesting, treatment and reuse

This section looks at some of the applications for treated and reused stormwater. Some of the potential benefits and limitations associated with non-potable applications are described and pointers provided on what makes a scheme successful.

This section also compares stormwater reuse, rainwater tanks and effluent reuse and looks at the willingness of communities to accept and support stormwater reuse.

2.2 Potential applications

Stormwater harvesting and reuse schemes can be developed for existing urban areas or new developments and are mainly suitable for non-potable purposes such as:

- residential uses
- irrigating public areas
- industrial uses
- ornamental ponds and water features
- aquifer storage and recovery.

This report does not cover potential uses for stormwater reuse in growing crops, such as in market gardens, many of which are located on the urban fringe, or in aquaculture.

2.2.1 Residential uses

Stormwater in residential areas could be harvested and used for several purposes that would significantly reduce household demand for mains water, such as:

- toilet flushing
- garden watering
- car washing.

Toilet flushing has a relatively constant demand throughout the year and typically accounts for around 15% of internal household water use. Garden watering consumes up to 30% of total household water, depending on the premises and season. Car washing is normally a relatively small component of residential water use compared to toilet flushing or garden watering.

In new urban areas, a scheme for harvesting, reticulating and reusing stormwater for non-potable residential uses could help a proposed development meet its BASIX (building sustainability index) water-savings targets. The water savings targets are required under the Building Sustainability Index, BASIX, a state environmental planning policy (NSW Government 2004).

Stormwater used for these purposes could expose the general public to potential health risks from pathogens, usually arising from animal wastes, and would therefore need to be treated to ensure a low risk to public health.

2.2.2 Irrigation

To date, harvested stormwater has been mainly used to irrigate public reserves and playing fields. It is used to grow and maintain grass surfaces on playing fields, golf courses and in other public open spaces, and to establish and grow ornamental plants in public gardens.

Typical annual irrigation demand for open areas ranges between 3 and 8 ML/ha, depending on the local climate, the type of vegetation being irrigated and the type of irrigation system used.

The type of irrigation system will also help determine the degree to which the stormwater needs to be treated before reuse in order to reduce health risks, and may also affect whether public access needs to be controlled or restricted during irrigation.

The irrigation methods commonly used in urban areas are:

- sprinkler or spray irrigation – the most widely used technique for irrigating large areas
- drip irrigation – often used for garden areas
- subsurface irrigation using perforated pipes – which can be used to irrigate small or large areas.

2.2.3 Industrial and commercial uses

Various processing and manufacturing industries have a regular and significant demand for water, making them well-suited for stormwater reuse. Typical uses would include washdown, cooling tower make-up or process water. Treated stormwater could also be used on construction and mining sites for applications such as dust suppression and vehicle washing. In commercial premises, stormwater could be reused for toilet flushing and vehicle washing.

The degree of treatment required depends on the proposed use, particularly the level of public exposure. Additional treatment may be required for specific industrial uses, with little or no extra treatment required for low-grade uses such as washdown and dust suppression.

Irrigation with stormwater at Greenway Park, Cherrybrook

2.2.4 Ornamental ponds and water features

Water is commonly used in the landscape design of residential and commercial developments. These features can consume a considerable volume of water through evaporation or seepage. Stormwater can be used as make-up water to maintain design levels where the public has no direct contact with the water. The stormwater would need to be low in pathogens to reduce public health risks and low in nutrients to prevent algal growth.

2.2.5 Aquifer storage and recovery

Aquifer storage and recovery (ASR) is the planned infiltration or injection of water into an aquifer during times when water is available, and the subsequent recovery of the water when it is needed. ASR can also increase the yield of the aquifer or protect it from seawater intrusion. Before recharge, the stormwater needs to be treated to prevent the aquifer from becoming clogged with particulate or organic material, or contaminated by other pollutants. ASR is not common in New South Wales, but is used elsewhere in Australia where geologic conditions near urban areas are more suitable, such as in Adelaide.

2.3 Potential benefits and limitations

2.3.1 Potential benefits

The main benefits that can be gained from a successful stormwater reuse scheme are reductions in:

- demand for mains water
- stormwater volumes, flows and the frequency of run-off
- stormwater pollution loads to downstream waterways.

The extent of the benefits from a particular stormwater harvesting and reuse scheme depends on a range of factors, including:

- the local climate – particularly rainfall
- catchment land uses – which influence run-off quality and quantity
- the condition of the sewerage system – which affects sewer overflows to stormwater
- the demand for reuse water – in particular the flow rates and any seasonal variations
- the design of the scheme – particularly the flow diverted to the scheme and the storage volume provided.

Reduced demand for mains water

Stormwater reuse can substitute in full or in part for existing mains water uses. The volume of stormwater run-off from Australian capital cities (including Sydney) is about equal to the amount of potable water used (Environment Australia 2002).

More than 50% of high quality water piped to urban areas is used for lower quality purposes, such as garden watering and toilet flushing. There is potential therefore for more stormwater to be collected, stored and reused for non-potable purposes. As an example, stormwater harvesting could meet 10–25% of Adelaide’s water needs (Kellogg, Brown & Root 2004). However, as stormwater is also needed to provide flows for urban creeks and rivers, total stormwater harvesting is not an appropriate goal.

Lower stormwater volumes

Urban development typically has major impacts on the volume, frequency and quality of run-off, and has associated ecosystem impacts. For example, it can:

- double annual run-off volumes
- reduce infiltration
- increase peak flows by up to ten-fold
- significantly increase the frequency of run-off.

Stormwater harvesting can reduce the volume of water flowing into the drainage system and so reduce stream erosion and minimise the impacts of urbanisation on aquatic ecosystems. In new urban developments, harvesting stormwater can reduce the need for, and capacity of, on-site detention measures.

Lower pollution loads

Urbanisation of a catchment commonly results in up to a four-fold increase in stormwater pollutant loads to local waterways. A stormwater harvesting and reuse scheme can reduce these loads by:

- abstracting a proportion of the polluted stormwater within a drain or waterway for reuse
- trapping pollutants in on-line storages, where the treated stormwater flows back to the waterway rather than being reused
- returning surplus treated stormwater to receiving waters, further reducing pollutant loadings.

Indicative outcomes

The actual outcomes from a stormwater harvesting and reuse scheme depend on the specifics of the scheme and its catchment. Table 2.1 indicates the potential outcomes that could be achieved from schemes in New South Wales, based on moderate and large on-line storages and an irrigation demand (WBM 2004, 2005).

The noted peak flow reductions for rare events, e.g. 100-year average recurrence interval (ARI), are low. This is because stormwater harvesting and reuse schemes focus on more frequent events (i.e. below the three-month ARI event). This is discussed further in section 6.

Table 2.1 Indicative outcomes from stormwater harvesting projects

Indicator	Indicative outcome	
	Moderate storage	Large storage
Mains water demand reduction	2–35%	5–50%
Annual stormwater run-off volume reduction	2–20%	2–40%
100-year ARI peak flow reduction	Negligible	Negligible
2-year ARI peak flow reduction	Negligible	1–2%
3-month ARI peak flow reduction	0–1%	1–2%
Suspended solids annual load reductions	15–35%	60–90%

Note: ARI – average recurrence interval

2.3.2 Potential limitations

The potential limitations and disadvantages to stormwater harvesting and reuse schemes depend largely on the nature of the scheme and the local environment. The major limitations are:

- variable rainfall patterns
- environmental impact of storages
- potential health risks
- high relative unit costs of treated stormwater.

Variable rainfall patterns

Variable rainfall is the main limitation for harvesting schemes, as this influences the reliability of stormwater flows from a catchment. The extent of this variability depends on local climatic conditions. For example, Sydney has an average of 130 rain days in a year, around half of which are likely to generate significant run-off for harvesting and reuse. Between-year variability also occurs, which is partly related to longer-term cycles such as the El Niño Southern Oscillation Index, and possible longer-term changes in rainfall due to climate change.

Variable rainfall patterns can affect the viability of stormwater reuse schemes by:

- increasing the required storage volume, resulting in larger land area requirements for above-ground storages – in the case studies in this report (see section 8), the average storage volume per unit of catchment area was 86 kL/ha, equivalent to one olympic-sized swimming pool per 23 hectares of catchment
- increasing the need for back-up water supplies and/or demand management when demand cannot be met from harvested stormwater
- causing considerable fluctuations in the water level in storages, due to the variability in streamflow and demand, particularly for irrigation schemes. This may reduce the aesthetic appearance of an above-ground storage – especially where it doubles as an urban lake or other landscape feature – with denuded banks and possible algal blooms and turbid water.

The required storage volume increases for a given reliability of supply as the demand becomes more variable (e.g. for irrigation) or when otherwise poorly matched to the availability of stormwater. The ideal system is therefore one where the stormwater supply closely matches the pattern of demand.

Environmental impact of storages and extraction

A storage constructed directly on a drain or creek normally consists of a dam wall or weir to retain streamflows. Planning for such storages would need to consider the potential impacts on the environment as well as on people, and would need to address various statutory requirements in New South Wales (discussed in section 3).

The environmental impacts of such storages can include:

- acting as a potential barrier to the passage of fish and other aquatic fauna (which often need to move freely upstream or downstream to grow, reproduce or feed)
- trapping coarse sediment, which not only reduces the capacity of the storage over time, but also results in downstream bank erosion where the sediment transport capacity of the stream exceeds the supply (a well-known phenomenon in fluvial geomorphology)
- increasing the potential for upstream flooding – this can also apply to diversion structures (e.g. weirs) constructed for off-line storage

- providing potential habitat for mosquitoes and associated mosquito-borne diseases
- posing a risk to human safety, especially to children.

Extracting stormwater from a watercourse may reduce streamflows to below pre-urbanisation levels. For on-line storage, this may occur during periods of low flow or where storage capacity and demand are large relative to inflows. Over-extraction of flows may impact on downstream aquatic ecosystems by reducing the available aquatic habitat, interfering with natural flow regimes to streams or wetlands.

This is normally only a problem where the storage is very large or where demand for water is high (Fletcher et al. 2006).

Potential health risks

Pathogens in stormwater for reuse can pose public health risks. These risks can be reduced by treating and disinfecting the harvested stormwater and/or limiting public access for some applications.

Higher unit costs of stormwater

Treated stormwater tends to have a higher unit or levelised cost (see glossary) than the retail cost of mains water (see section 8.2.3). However, this type of cost-effectiveness analysis does not take into account the multiple environmental benefits of stormwater harvesting schemes, including reduced downstream pollution loads and flows.

Figtree Place, Newcastle

Figtree Place, in inner suburban Newcastle, presents an innovative example of integrated stormwater management in a residential and commercial setting.

The site, consisting of 27 residential units, employs rainwater tanks, infiltration trenches and a central basin in which treated stormwater enters an unconfined aquifer.

During the planning phase of the development, it was determined that the stormwater harvested from the site should meet:

- 50% of in-house needs for hot water and toilet flushing
- 100% of domestic irrigation needs
- 100% of the bus-washing demand.

The main features of the development include:

- underground rainwater tanks, with capacities ranging from 9 to 15 kL, fitted with 'first flush' devices (i.e. to discard the first part of inflow carrying sediment, leaves, etc.). Each tank services between four and eight homes.
- recharge trenches on 19 of the home sites, each trench measuring 750 mm deep by 1000 mm wide, and containing gravel 'sausages' enclosed in geofabric. These trenches receive overflow from the rainwater tanks and help to recharge groundwater
- diversion of the run-off from impervious areas to the central detention basin for recharging of groundwater
- increasing the degree of flood protection for the site to the 50-year ARI level
- use of groundwater for garden watering and bus washing.

These measures achieved internal residential water savings of 45% by using treated water in hot water systems and flushing toilets, with total water savings anticipated to be 60%. For further details, see Coombes et al. (2000).

2.4 Characteristics of successful schemes

A successful stormwater harvesting and reuse scheme is one that:

- realises its full potential benefits
- addresses public health and environmental risks
- is both cost-effective and sustainable
- has the support of key stakeholders.

Some of the key characteristics of a successful stormwater harvesting and reuse scheme are:

- the project replaces an existing mains water use and is designed to reduce stormwater flows and pollution loads – that is, the project is designed to meet multiple objectives
- the project has clearly defined and quantitative objectives, consistent with those for the management of the catchment
- public health and safety risks are managed appropriately
- the end uses have relatively low water-quality requirements, minimising treatment costs
- the level of treatment is appropriate not just for meeting the needs of the end use, but also for addressing public health and environmental risks
- the storage capacity is designed to achieve 'reasonable' reliability of supply
- the scheme is located close to the end use, minimising distribution costs (e.g. a golf course located adjacent to a creek)
- procedures are in place for on-going operation, maintenance, monitoring and reporting.

While no two stormwater harvesting schemes are exactly the same, these points above can be used as a checklist for all schemes to varying degrees.

Another key consideration for a successful stormwater harvesting project is having all stakeholders in the planning, design and operation of a scheme recognise that a reuse scheme is a type of water supply scheme, not solely a form of stormwater management. This is important because the public health risks from reuse schemes are higher than in conventional stormwater management.

Consequently, stormwater reuse schemes need a more sophisticated management focus than other stormwater activities, especially in the operation, maintenance, monitoring and reporting. These issues are discussed further in section 7.

2.5 Stormwater harvesting and rainwater tanks

Stormwater harvesting schemes and the systematic installation of rainwater tanks across a catchment can have broadly similar benefits in reducing pollution loads, downstream stormwater flows and demand for mains water. However, there are distinct differences in costs, stakeholders, maintenance and health risks between these approaches – each has potential advantages and disadvantages.

Table 2.2 indicates the relative benefits and limitations of stormwater harvesting and wide-scale rainwater tank usage. The comparison demonstrates that neither alternative is clearly preferred – decisions about using rainwater tanks or stormwater harvesting should be made on a case-by-case basis, to meet specific project or catchment objectives, and should be based on the views of key stakeholders.

Combined rainwater and stormwater collection and reuse schemes have been implemented successfully for medium-density developments, in which reticulation costs are relatively low; see panels on Figtree Place, Newcastle (page 11) and Kogarah Town Square (page 15).

In a combined stormwater/rainwater scheme, and from a risk management perspective, the water treatment objectives for stormwater reuse should be adopted whether the source waters are combined or if the stormwater stream if managed separately to the rainwater. The references noted in section 1 can be used to guide development of the rainwater tank component of such schemes.

Treated stormwater from a stormwater harvesting and reuse scheme could provide an alternative non-potable water source to rainwater tanks to meet the requirements of BASIX for new developments in New South Wales (as noted in section 2.2.1). Conversely, where rainwater tanks are installed to meet BASIX requirements, less stormwater will be available for harvesting and reuse.

Table 2.2 Indicative potential benefits and limitations of stormwater

Aspect	Stormwater harvesting	Rainwater tanks
Application	Centralised community household or industrial uses	Domestic non-potable uses
Capital costs	Higher, but paid by central authority or industry owner	Lower, but paid by individual homeowner (rebates may be available)
Costs per kL of water used	Likely to be higher than rainwater tanks	Likely to be lower than stormwater harvesting
Distribution costs	Distribution costs may be significant, depending on the location of the storage relative to the use	Storage located near use, with negligible distribution costs
Flow attenuation benefits	Reuse schemes can reduce stormwater flows from a catchment	Rainwater tanks only reduce flows from roofs
Health risks – drowning	Potential public safety risks with open storages	No safety risks due to tanks
Health risks – pathogens	Higher pathogen levels in raw stormwater than rainwater	Pathogen levels in rainwater relatively low
Health risks – viruses	Potential for mosquito breeding in storages with associated diseases	Limited potential for mosquito breeding in tanks
Landtake	Above-ground storage can occupy a relatively large area of a catchment	Rainwater tanks can be readily incorporated on most residential blocks
Maintenance	Maintained by a single organisation (e.g. council), hence likely to be reasonable	Maintained by householder, likely to be highly variable
Statutory approvals	Approvals needed	Normally exempt from requiring approval (standard requirements need to be met)
Suitability for application in existing urban areas	Potentially suitable	Land availability on existing blocks likely to impair uptake
Water quality benefits	Potentially significant reduction in pollution loads as run-off from roads and other paved areas is collected	Limited reduction in pollution loads, as relatively clean roof run-off is collected

Kogarah Town Square

Kogarah Town Square was redeveloped in 2003 as part of Kogarah Council's shift towards sustainable development. The site contains 193 residential apartments, 4500 m^2 of retail and commercial space, a public building, an underground carpark and both public and private gardens.

Water-sensitive urban design concepts were incorporated into the original design, ensuring the capture, recycling and reuse of all stormwater from the site for irrigation, toilet flushing, car washing and the town square water feature.

The reuse system recognises the difference between 'clean' and 'dirty' stormwater.

The 'dirty' run-off from the square passes through a gross pollutant trap into a storage tank and is used for garden irrigation. The design uses the landscape to filter the water, so that excess nutrients and fine particles are retained by the soil. The 'clean' stormwater (predominantly from roof surfaces) is retained in a storage tank, and passes through a screen filter and disinfection unit prior to use for higher level needs.

The system saves up to 8 ML of mains water annually, representing a 50% reduction in water use for the site.

For further details, refer to Salan (2002) and Kogarah Council (2004).

2.6 Stormwater and effluent reuse

Some water reuse projects can use stormwater as well as effluent from STPs or leachate from waste disposal facilities. This document focuses on stormwater harvesting and reuse – DEC (2004) provides guidance on effluent reuse.

In general, the design criteria relating to effluent reuse will be more stringent than those for stormwater reuse and should be adopted for combined schemes in place of guidance in this document. The design needs to consider the different characteristics of stormwater and effluent. In particular, stormwater supply is more variable in quality, quantity and reliability, and pollution levels are usually lower than in treated effluent.

Some reuse schemes combine stormwater and effluent (by 'blending') to reduce effluent salinity levels. The panel about Sydney Olympic Park provides an example of a combined stormwater and effluent reuse project.

Sydney Olympic Park

The Water Reclamation and Management Scheme at Sydney Olympic Park represents a large-scale approach to recycling non-potable water. Established in 2000, the scheme aims to provide all water required for toilet flushing, irrigation and other residential uses in the park and the nearby suburb of Newington. The scheme conserves approximately 850 megalitres (ML) of mains water per year.

Stormwater is captured in two storages – the Brickpit Reservoir (located in the old quarry), having a 300 ML capacity, and a series of freshwater wetlands constructed as part of the Haslams Creek area remediation. Treatment through the wetlands reduces sediment and nutrient loads by up to 90%. Stormwater from both storages is combined with reclaimed water 'mined' from a trunk sewer, filtered via continuous microfiltration and disinfected prior to use. A dual reticulation system distributes the water to the park and to Newington homes.

In addition to conserving water, implementation of the scheme has allowed for the annual diversion of approximately 550 ML of sewage normally discharged through ocean outfalls.

The scheme, with a capital cost of $15 million, provides recycled water to consumers at a rate of $0.83 per kL. While this is lower than mains water charges, it does not reflect the true cost of recycled water supply.

For more information, see SOPA (2004a, 2004b).

2.7 Community acceptance of treated stormwater

Community acceptance and use of treated stormwater is a key factor in a successful scheme. Many of the existing schemes, particularly those referred to later in this document, have irrigation of public areas as the end use. However, research suggests that there is growing support for extending the use of treated stormwater for domestic purposes, including clothes washing, toilet flushing and garden irrigation.

In a study investigating social acceptability of treated stormwater in Perth, Melbourne and Sydney, Mitchell et al. (2006) found that:

- acceptance was highest among respondents for either household scale or large (centralised scale) systems, rather than neighbourhood/cluster schemes operated by a body corporate or similar entity
- respondents were more accepting of using rainwater than stormwater for garden watering
- the acceptance of treated stormwater was greater than that of treated wastewater.

More recently, stormwater harvesting and reuse has been successfully introduced as part of the water-sensitive urban design of several developments (see panels). The initial findings from these developments suggest a high degree of satisfaction and acceptance by residents of treated stormwater for use within a residential environment (Coombes et al. 2000).

3. Statutory requirements

3.1 Planning

> The statutory approvals required for stormwater harvesting and reuse projects vary between states. This section deals with the requirements that may apply in New South Wales. The information was current at the time of publication; however, statutory requirements and the roles of government agencies can change over time – proponents should check that this information is current during the planning stage of their project.

Stormwater harvesting schemes would normally be subject to the requirements of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The EP&A Act sets out the requirements for environmental impact assessment for development consent purposes.

Development consent is an approval for development issued by a 'consent authority', normally the local council but sometimes the Minister for Planning. Environmental planning instruments will determine if development consent is required for a development proposed for a certain zone. Therefore, depending on the provisions in the relevant environmental planning instruments, constructing a stormwater harvesting and reuse scheme may require development consent.

Development proposals that require development consent are subject to the requirements of Part 3A or 4 of the EP&A Act. Part 3A specifies the assessment and approval process for major infrastructure and other major projects while Part 4 specifies the process for other proposals requiring development consent. These Parts of the EP&A Act consider development applications to be 'integrated development' where certain licences or approvals are required from bodies other than a consent authority. Applicants must inform the consent authority of any licences, additional approvals or permits required from state agencies other than development consent before lodging their applications. Councils are then required to consult with the relevant state agency and obtain requirements in relation to the development.

Activities not covered by planning or development control processes, and thus not requiring development consent, fall under Part 5 of the EP&A Act. Such 'exempt' activities include installations of public utilities undertaken by local councils and government agencies. A review of environmental factors (REF) may be required in these circumstances.

3.2 Environmental and natural resource management

3.2.1 Environment protection licences

The *Protection of the Environment Operations Act 1997* is the principal legislation governing the protection, restoration and enhancement of the environment in New South Wales. Part 3.1 of the Act requires environment protection licences to be issued for scheduled activities that may cause pollution. Stormwater harvesting schemes do not require such licensing.

3.2.2 Water extraction

The *Water Management Act 2000* provides the statutory framework for water extraction from rivers, lakes and estuaries. The Act's definition of 'river' includes any watercourse, including an artificially improved channel, but not a piped drain. The definition of 'lake' includes any body of natural or artificial still water, including a wetland. In an urban context, the Act would apply to any river, creek, (open) drainage channel, lake or pond, but not to schemes that harvest stormwater from a drainage pipe.

Stormwater harvesting schemes proposed for construction on a 'river' normally require:

- a water access licence
- a water use approval
- a water supply work approval.

Applications for these licences and approvals should be made to the Department of Natural Resources and must be issued before water can be extracted from a river.

New water access licences for commercial purposes are generally not being granted, to stop unsustainable over-allocation of water. In particular, this applies to areas covered by a gazetted water-sharing plan. An existing access licence can be purchased on the water market, subject to dealing (trading) rules. A water utility may apply for a special purpose licence, although the amount of water available may depend on the rules of the water-sharing plans.

An approval to use water is required before river water may be used at a particular location, such as for irrigation or town water supply. A stormwater harvesting scheme granted development consent under Part 4 of the EP&A Act does not require a water use approval.

A water supply work approval is required for water management works associated with water use, including to:

- extract water from a river or lake
- store water taken from a river or lake (in off-line storages)
- convey water extracted from a river or lake to another location
- retain water in a river (via a weir or in-river dam).

3.2.3 Impacts on fish habitats

Components of a stormwater harvesting project that involve works in a watercourse are likely to require a permit from the Department of Primary Industries under the *Fisheries Management Act 1994.* Further details can be obtained from *Policy and guidelines – aquatic habitat management and fish conservation* (NSW Fisheries, 1999).

3.2.4 Impacts on rivers and foreshores

A permit under the *Rivers and Foreshores Improvement Act 1948* may be required for projects undertaken in or adjacent to a stream, river, lake or lagoon. Depending on the location of the project, the permits are to be obtained from the Department of Natural Resources or the NSW Maritime Authority. The Act does not apply to works on piped stormwater drainage systems.

3.2.5 Impacts on threatened species

The *Threatened Species Conservation Act 1995* integrates the conservation of threatened species and communities into the processes for planning and development control under the EP&A Act. The Minister for the Environment can certify environmental planning instruments if satisfied that they will bring an overall improvement or maintenance in biodiversity values. A separate threatened species assessment may not be needed for development applications in areas that have certified environmental planning instruments.

Where a development is proposed in an area for which the environmental planning instrument has not been certified, the EP&A Act sets out factors to be considered in deciding whether there is likely to be a significant effect on threatened species, populations or ecological communities and if a species impact statement is required. Where there is likely to be a significant effect, the consent authority must seek the concurrence of DEC.

3.2.6 Clearing of native vegetation

The *Native Vegetation Act 2003* applies to the clearing of native vegetation and certain regrowth vegetation. The Act applies primarily to rural areas and not to the Sydney metropolitan area, Newcastle, areas with certain residential land use zonings, or national parks, conservation areas and state forests. Approvals are required from catchment management authorities for clearing native vegetation in areas subject to the Act.

3.2.7 Impacts on Aboriginal cultural heritage

The *National Parks and Wildlife Act 1974* protects all Aboriginal objects and Aboriginal places in NSW. A consent under the Act must be obtained from DEC for activities that are likely to destroy, damage or deface an Aboriginal object or Aboriginal place.

3.3 Other requirements

3.3.1 Dam safety

The requirements of the *Dams Safety Act 1978*, as administered by the Dam Safety Committee, may apply to storages for stormwater harvesting schemes depending on the height of the dam wall and the associated hazard rating (Dam Safety Committee 1998, 2002). The hazard rating (consequence categories) is related to the population at risk of a dam failure and the severity of the associated damage and loss.

3.3.2 Plumbing requirements

The plumbing requirements for distribution systems associated with stormwater harvesting and reuse schemes are discussed in section 6.

4. Risk management

4.1 Background

Risk management is playing an increasingly important role in the water industry. The Australian drinking water guidelines (NHMRC & NRMMC 2004a) apply a risk management approach to the production of drinking water in Australia. Another relevant example is the publication *Guidelines for managing risk in recreational water* (NHMRC 2005).

The draft national guidelines for water recycling (NRMMC & EPHC 2005) include a risk-based framework for managing the quality and use of recycled water. This is based on the framework in the Australian drinking water guidelines. The draft water recycling guidelines note that the sustainable use of recycled water should be based on the following three principles:

- the 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 panel below summarises the approach to risk management used in the Australian drinking water guidelines and adopted in this document. Further information on risk management can be obtained from AS/NZS 4360:2004 *Risk management* (Standards Australia 2004) and related documents.

Ideally, risks for a stormwater harvesting and reuse project should be assessed during the project's planning phase. This will enable many significant hazards to be managed during the project's design. If risk assessment and management are left to the operational phase of a project, the costs of effective mitigation may be considerably higher than if they were considered during the planning phase.

Further information on risk management is provided in appendix B.

Risk management

The current edition of the Australian drinking water guidelines emphasises the importance of taking a preventive management approach to drinking water quality, in which risks are identified and managed proactively, rather than simply reacting to when problems arise.

There are three basic steps in taking a preventive approach. The first step is to look systematically at all the potential hazards to the water supply from the catchment to the consumer's tap (i.e. what might happen and how).

Once the hazards are identified, the next step is to assess the risk from each hazard by estimating the likelihood that the event will happen and what the consequences would be if it did. The final stage is to ensure that existing preventive measures are sufficient to control the hazards, and to improve or replace such measures if necessary.

Source: NHMRC & NRMMC (2004a)

4.2 Potential hazards

There are a range of potential public health, public safety and environmental hazards from stormwater harvesting and reuse. Table 4.1 summarises the most common of these (see also appendix B). The public safety risks are primarily related to schemes where open storages are used.

Additional hazards relating to scheme operations and occupational health and safety are also likely – these are not considered in detail in this section (refer to section 7.3 for information on occupational health and safety).

4.3 Risk management framework

It is important that stormwater harvesting and reuse schemes are developed and operated within a risk management context.

The draft national guidelines for water recycling include a comprehensive risk-based framework for public health and environmental risks associated with wastewater recycling and greywater reuse. This framework can be used in the planning, development and operation of a stormwater harvesting and reuse scheme. A future version of these guidelines (due in 2008) will address stormwater harvesting specifically.

The framework incorporates a preventive risk management approach, including elements of hazard analysis and critical control point (HACCP) assessment, ISO 9001 (Quality management) and AS/NZS 4360 (Risk management), and it applies them in the context of recycled water supply.

A summary of the framework is provided in table 4.2, with further details provided in appendix B. The elements in this framework are similar to those adopted in the Australian

Table 4.1 Common potential hazards associated with stormwater harvesting and reuse

Area	Hazard
Public health	Microorganisms (pathogens) in water: • bacteria • viruses • protozoa • helminths Chemical toxicants in water: • inorganic chemicals (e.g. metals, nutrients) • organic chemicals (e.g. pesticides, hydrocarbons)
Public safety	Water storages (above ground): • drowning • embankment failure/overtopping
Environmental	Over-extraction of stormwater flows Storage constructed on natural watercourses Flooding above any diversion weir Surface water pollution by run-off (irrigation schemes) Groundwater pollution (irrigation schemes) Soil contamination (irrigation schemes)

drinking water guidelines. A related approach has been used in Queensland for water recycling (EPA Queensland 2005a).

The framework in table 4.2 recognises that successful risk management requires appropriate scheme planning, design and operations. As the monitoring of treated stormwater is not continuous and there is normally a period of time (hours or days) between sampling and the availability of monitoring results, monitoring should not be used as a primary risk management activity – the focus of monitoring should be primarily on validating the effectiveness of the preventive approaches to managing water quality.

The framework applies to schemes of all sizes and complexity, the main difference in application being the extent to which the elements are applied. The extent of risk management for a project should be appropriate to the project's risks. Hence a large stormwater harvesting and reuse scheme with significant public contact (exposure) to treated stormwater warrants a comprehensive risk assessment. Smaller schemes with controlled public access (i.e. lower exposure risk) warrant a less comprehensive risk assessment.

The approach taken in this document is to provide guidance on appropriate public health and environmental risk management activities for stormwater harvesting and reuse schemes that meet the nominated threshold criteria noted in table 4.3 and follow nominated design and operational practices. Management practices suitable for sub-threshold schemes are noted in tables 4.4 and 4.5 and described in sections 5 to 7. Public safety, occupational health and safety and operational risks should be assessed separately for each scheme. The basis for the thresholds in table 4.3 is provided in appendix B.

This default approach is intended to provide guidance on suitable risk management activities to achieve low public health and environmental risks from the scheme's operations. This approach is particularly suitable for small schemes, particularly where the application has relatively low public exposure such as irrigation. Most stormwater harvesting and reuse schemes to date are relatively small-scale compared with many effluent reuse schemes, and this is likely to continue for the foreseeable future.

Table 4.2 Risk management framework for recycled water quality and use

Element	Description
1	Commitment to the responsible use and management of recycled water quality
2	Assessment of the recycled water system
3	Preventive measures for recycled water management
4	Operational procedures and process control
5	Verification of recycled water quality and environmental sustainability
6	Management of incidents and emergencies
7	Employee awareness and training
8	Community involvement and awareness
9	Validation, research and development
10	Documentation and reporting
11	Evaluation and audit
12	Review and continual improvement

Source: NRMMC & EPHC (2005)

Environmental risks from a well-designed and oprerated stormwater reuse scheme are generally low. Further, the health risks from stormwater reuse are generally lower than for wastewater reuse for the same application. However, stormwater reuse does carry some health risks and these need to be managed appropriately. All recycled water schemes need to be appropriately designed and managed to minimise risks – for example, a poorly operated stormwater harvesting scheme may present greater health risks than a well-operated effluent reuse scheme.

These thresholds are not intended to represent a threshold between viable and non-viable schemes. The intention is to distinguish between schemes that can readily achieve low public health and environmental risks and those where further investigation is appropriate.

Table 4.3 Thresholds for use of default risk management approach

Parameter	Threshold criteria – all schemes
Catchment land use	Residential/commercial (i.e. no significant industrial areas)
Sewer overflows in the catchment	Low frequency and volumes
Stormwater reuse application	• Residential non-potable (small scale) • Irrigation of public open spaces • Industrial uses • Water feature • Irrigation of non-food crops • Aquifer storage and recovery
Storage	Constructed either off-line or on-line on a constructed drain
Extraction	Flow in watercourse after extraction is greater than the estimated pre-urbanisation flow. Stormwater is reused in the catchment from which it was extracted
Stormwater quality	Turbidity levels are low or moderate
	Threshold criteria – irrigation schemes
Salinity levels in stormwater	Low/medium
Groundwater	Not in an area where groundwater is vulnerable
Location of irrigation area	More than 1 km from a town water supply bore
Slope – sprinkler irrigation	< 6%
Slope – trickle or microspray irrigation	< 10%
Landform	crests, convex slopes and plains
Surface rock outcrop	Nil
Soil salinity (0–70 cm)	< 2 dS/m
Soil salinity (70–100 cm)	< 4 dS/m
Depth to top of seasonal high water table	> 3 m
Depth to bedrock or hardpan	> 1 m
Soil saturated hydraulic conductivity (0–100 cm)	20–80 mm/h
Available soil water capacity	> 100 mm/m
Emerson soil aggregate test (0–100 cm)	Class 4, 5, 6, 7

Where a scheme does not meet some or all of the threshold criteria or different management practices are proposed, a risk assessment should be carried out. It should focus on the area exceeding the threshold or the different management practice. This may result in additional management actions being developed.

The scheme's developer should check that the management measures are appropriate for the circumstances of the particular scheme, recognising that all schemes have some unique features.

Further information is provided in appendix B, including a generic risk assessment for sub-threshold schemes.

Table 4.4 General management measures for default risk management approach

Area	Management measures
Planning	• Identify any point sources of pollution and industrial land uses within the catchment • Identify sewer overflow characteristics within the catchment • Involve scheme's proposed operator in the scheme's planning
Design	• Involve scheme's proposed operator in the scheme's design • Limit stormwater extraction rates • Use plumbing controls and signage
Operations	• Ensure organisational commitment, including continuous improvement • Ensure appropriately qualified scheme operators • Manage upstream catchment • Follow appropriate scheme operations and maintenance • Implement workplace procedures • Establish and follow incident response procedures • Monitoring, reporting and record keeping • Prepare and implement scheme management plan

Table 4.5 Specific management measures for default risk management approach

Application	Access restrictions	Stormwater quality criteria	Specific operational practices
Residential (non-potable)	Nil	Level 1	Above-ground storage design and management Additional plumbing controls
Irrigation of open spaces	Nil	Level 2	Irrigation scheme design and operational controls
	Controlled public access or subsurface irrigation	Level 3	
Industrial	Nil	Level 2	
	Controlled public access	Level 3	
Ornamental waterbodies	Nil	Level 2	
	Controlled public access	Level 3	
Aquifer storage and recovery	Not applicable	Level 3	ASR scheme operational controls

5. Planning considerations

5.1 Planning process

Key considerations in the planning process

The planning process should aim to:

- identify all risks to public health, safety and the environment
- identify all of the upstream catchment characteristics likely to present public health or environmental risks to stormwater reuse
- involve the organisation(s) responsible for operating the scheme, and other key stakeholders
- identify all site constraints and regulatory requirements
- evaluate possible arrangements for a stormwater harvesting and reuse scheme, including evaluating costs and benefits.

Stormwater harvesting and reuse schemes can be implemented either in existing urban areas or as part of a new urban development. The project's context will therefore influence the nature of the planning process.

The process summarised below could be used in part for preparing a plan for integrated water cycle management in an existing urban area or as part of the master planning for a new urban development. The basic steps are common to both situations, but the details of each step may differ. The planning process is based on the assumption that a decision has been made to proceed with a stormwater harvesting and reuse scheme to at least the planning stage.

Also, the planning process is likely to be iterative, requiring several rounds of review in earlier stages as new information arises and negotiations progress with stakeholders (including end users) that may alter the objectives and/or available options.

The complexity of the planning process for stormwater harvesting schemes should match the size and nature of the project and the associated levels of public health and environmental risks. For example, a small scheme to harvest stormwater for irrigating a playing field would require less risk assessment than a major scheme to treat and reticulate harvested stormwater to a new development area.

During the project's planning stage, a risk management strategy should be developed. This should, in particular, identify public health and environmental hazards and an appropriate mix of controls to be implemented during the design and operational phases.

Key stakeholders should be consulted throughout the planning process, particularly during the setting of project objectives. Their engagement in the scheme from the planning stage will:

- provide opportunities for educating the community and the proponents
- allow for any concerns or misconceptions to be identified and addressed early in the scheme
- build user confidence in the scheme, resulting in greater use of treated stormwater as an alternative to mains water.

Additionally, providing feedback mechanisms to gain community opinions throughout the design, construction and operation phases may help to secure greater community acceptance for the project and any future schemes.

The five steps discussed below for stormwater harvesting and reuse schemes are broadly similar to other planning processes, but they differ in the specific details relevant to stormwater harvesting and reuse schemes:

1. identify the project objectives
2. assess the site and catchment
3. identify potential options
4. evaluate options
5. recommend an option.

5.1.1 Identify the project objectives

In developing reuse schemes for a site, broader catchment or regional objectives are important (see section 2.3). These could involve specified reductions in:

- mains (potable) water use
- stormwater flow rates and/or volumes
- stormwater pollution loads
- the effective (connected) impervious area of the catchment.

Organisational objectives, government policies and environmental planning instruments may also provide a strategic context for the project. The most common project objectives will relate to:

- managing public health and safety risks
- managing environmental risks
- meeting the requirements of the end user, primarily relating to water quality, quantity and reliability of supply
- protecting or enhancing visual amenity or aesthetics.

This step should determine the relative importance of reliability of supply and reductions in mains water use. A scheme aiming for a high reliability of supply will generate a relatively low yield (resulting in a smaller reduction in mains use). Put another way, less harvested water would be used than if the design sought to maximise reuse volumes by withdrawing stormwater to keep water levels in storage low, while keeping the capacity to store new inflows high.

5.1.2 Assess the site and catchment

This step identifies and assesses the potential constraints and opportunities of the proposed project site. Potential constraints may include:

- topography
- land use
- adjacent land uses (including potential land-use conflicts)
- watercourse characteristics (e.g. tidal watercourses are normally inappropriate for stormwater harvesting)
- vegetation and other sensitive ecosystems (potential biodiversity impacts)
- soil characteristics, such as salinity or acid sulfate – refer to DEC (2004) for further details


K Walters/DEC

- existing water management infrastructure
- statutory or regulatory constraints.

This step should identify opportunities for reusing treated stormwater, as well as suitable locations for storages. Other aspects of the end-user's operations may also be important, such as future development plans or land-use changes that may affect longer-term water use patterns.

The quality of stormwater for a reuse project is affected by the characteristics of the scheme's catchment. For example:

- the risk of chemical pollution in a catchment increases with the extent and nature of industrial uses and paved roads, particularly those with high traffic volumes
- the risk of pathogen contamination increases where catchments have multiple sewer overflows or high loadings of animal wastes.

The impact of such diffuse pollution sources can be gauged by investigating water quality during wet and dry weather, or by referring to existing water quality databases.

Similarly, the scheme should investigate the impacts on water quality from any point sources of pollution, such as sewage treatment plants and landfills. The hazard assessment for the scheme (see section 5.1.4) may need to consider both diffuse and point sources of pollution – for example, significant sewer overflows may pose a significant hazard for a scheme involving residential use for garden watering.

The level of the site and catchment investigation required should match the size and scale of the development and its potential impacts (i.e. larger developments having a greater impact would require greater site investigation). As noted for effluent reuse schemes (DEC 2004), a staged approach to site investigations can be adopted to minimise costs. This involves an initial screening level assessment using readily available information to identify major constraints and opportunities, then focusing efforts on any identified constraints.

5.1.3 Identify potential options

This step identifies various possible layouts for a scheme to meet the project's objectives. As noted in section 2, different stormwater harvesting projects can have several elements in common. However, the arrangement and sizing of these elements tends to be specific to each project; for example, on-line and off-line storages could be considered, as well as different treatment techniques depending on end uses and catchment water quality.

This step should assess the influence of different sizes for key elements such as storages. This step is likely to involve modelling the outcomes from various options, identifying the degree to which each option meets the adopted project objectives. This could be iterative, modelling the influence of a number of key aspects of the project (such as different storage volumes against predicted outcomes), and may include modelling of:

- water balance
- stormwater pollution and environmental flows
- stormwater peak flows and flood levels.

Water balance modelling

The water balance will determine the relationship between storage capacity, reuse demand and reliability of supply or frequency of stormwater discharges for various scenarios. If the demand pattern is known, the required storage capacity can be estimated for varying levels of supply reliability and discharge frequency. Information from section 5.1.2 is used as an input to the modelling. The outputs are then compared to the water management objectives for the project. Water balance modelling can also be used to assess variations in water levels, a consideration where fluctuations in open storages may have aesthetic, environmental and operational impacts.

Stormwater pollution and environmental flow modelling

Modelling of stormwater pollution loads from the catchment, and the reduction achieved through the stormwater harvesting and reuse scheme, should be conducted for each option. The stormwater pollution load reductions to waterways that can be achieved by a scheme include:

- the ‘loss’ of pollution due to the reuse of the extracted stormwater
- pollutant retention in on-line storages
- reduced loads in any stormwater that is treated by a scheme, but which is returned to the stormwater system because it is not needed for reuse,

This modelling usually employs an extended timeframe (e.g. 10 years) with daily or shorter time steps. It can also be used to assess the impacts of the scheme on downstream streamflows – see Engineers Australia (2005) for further details of this form of modelling.

Stormwater peak flow and flood level modelling

The third form of modelling involves estimating peak flows in the system for a range of average recurrence intervals (ARI), commonly including the 100-year ARI flood. Flood levels in the vicinity of the scheme can then be estimated, using hydraulic modelling, to assess the impact of an option on upstream flood levels (Institution of Engineers Australia 1987). This modelling can also assess the benefits of the scheme in reducing downstream flood flows.

5.1.4 Evaluate options

The various options identified in section 5.1.3 should be evaluated, taking into account social, economic and environmental considerations. The evaluation is likely to consider the factors noted in table 5.1.

The evaluation of options should primarily assess how well each option meets the project’s objectives. It is likely that during this process trade-offs between objectives may need to be assessed as, for example, it may not be cost-effective to meet all objectives.

There is no widely used evaluation technique for water recycling schemes such as stormwater harvesting (Hatt et al. 2004, Kellogg Brown & Root 2004, McAlister 1999). This may be partially due to the difficulty in quantifying many of the costs and benefits of such schemes, and where some of the costs and benefits can be attributed to parties not directly involved in the proposed scheme.

Possible evaluation techniques include:

- economic evaluation:
  - cost-benefit analysis
  - cost-effectiveness analysis
- triple bottom-line analysis
- multiple criteria analysis.

Economic evaluation: cost-benefit analysis

Cost-benefit analysis quantifies in monetary terms all the major costs and benefits of project options. The outcomes for a range of options are therefore translated into comparable terms to facilitate evaluation and decision making. The technique can also makes explicit allowance for the many costs and benefits which cannot be valued. In both cost-benefit and cost-effectiveness analysis, all unquantifiable benefits and costs should be described.

Cost-benefit analysis is a more comprehensive technique than cost-effectiveness analysis and is normally the preferred technique wherever feasible (NSW Treasury 1999). An approach that can be adopted to cost-benefit analysis is described in NSW Treasury (1999). This approach involves quantifying the benefits and costs over the project life, with a 20-year analysis period recommended for consistency. The costs and benefits are expressed in net present value terms, using a 7 per cent discount rate.

A potential difficulty in using cost-benefit analysis for stormwater harvesting and reuse proposals is that some benefits can be difficult to quantify. Further, the analysis is often not warranted for small reuse projects.

While capital costs for projects are relatively easy to estimate, maintenance costs (which are important in the life-cycle cost of a project) are often more difficult.

Appendix D provides some guidance on estimating maintenance costs for stormwater treatment measures.

Table 5.1 Potential option evaluation considerations

Area	Evaluation consideration
Social	• risks to human health and safety • aesthetic benefits/impacts of storages • any improvements to the condition of community assets (i.e. sports fields) and other amenity improvements. • any flooding impacts caused by weirs (this may also be a social, economic and/or environmental factor)
Economic	• capital costs (e.g. project management, investigation, design, construction and any land acquisition) • recurrent costs (e.g. operating, power, maintenance, asset renewal and monitoring) • any savings in mains (potable) water costs • any income received from the sale of the treated stormwater • any income benefits for end users (e.g. golf course remains green and attractive to golfers) • any savings in fertiliser application
Environmental	• benefits of reduced stormwater pollution and downstream flows • benefits in reduced mains water consumption • potential impacts of on-line storages or diversions for off-line storages • environmental risks (e.g. potential impacts of irrigation on surface water quality, groundwater and soils) • potential impacts of the scheme on endangered ecological communities, populations and species • energy use and any associated greenhouse gas production

Economic evaluation: cost-effectiveness analysis

Where the main benefits of a project are not readily measurable in monetary terms (using either actual or proxy values), it may not always be possible to apply cost-benefit analysis. An alternative approach is to use cost-effectiveness analysis to compare the costs of each option, assuming the benefits of each option are broadly similar. Where the benefits of each option differ, cost-effectiveness analysis is less useful than cost-benefit analysis, where costs and benefits of different kinds of options are more readily comparable (NSW Treasury 1999).

The approach to cost-effectiveness analysis described by NSW Treasury (1999) quantifies the present value of project costs over the project life, using a 20-year analysis period and a 7 per cent discount rate.

An alternative approach to estimating project costs for cost-effectiveness analysis is life-cycle costing (Standards Australia 1999, NSW Treasury 2004), which is a process to determine the sum of all the costs associated with all or part of an asset, including acquisition, installation, operation, maintenance, refurbishment and disposal. Taylor (2003) provides further advice on life-cycle costing for stormwater projects.

A simplified approach to life cycle-costing is to calculate the net present value of a project's capital and operating costs, using the 20-year analysis period and 7 per cent discount rate noted above.

A related approach is levelised costing, defined as the net present value of the project's costs over the analysis period divided by total volume of water supplied or pollutant removed (IPART 1996). The 20-year analysis period and 7% discount rate noted above can be used for these calculations. Levelised costs are expressed in cost per kilolitre or cost per kilogram of pollutant removed.

A disadvantage of the levelised cost approach is that it associates the project's costs with a single objective (e.g. water supply volumes), whereas most stormwater harvesting schemes satisfy multiple objectives that cannot readily be accounted for using this approach. When the outcomes from different options are the same (e.g. the same volume of water reused), levelised cost calculations are not warranted, as the comparison does not need to be based on unit costs – life cycle costing can be used. Life cycle or levelised costs can also be used in triple-bottom-line and multi-criteria analysis.

Triple-bottom-line analysis

An alternative and often more comprehensive approach to assessing costs and benefits in a sustainability context is triple-bottom-line (TBL) assessment. This method provides for the equal consideration of environmental, social and economic elements associated with a given scheme proposal (see table 5.1).

While the obvious benefits of this approach lie with the potential to undertake a balanced assessment of project options, the considerable investment of time required for detailed investigations suggests that TBL assessment is best suited to large-scale proposals. Taylor (2005a) generated comprehensive guidelines on the application of this approach for stormwater management measures, and explains the preferred use of multi-criteria analysis in evaluating multiple objectives.

Multi-criteria analysis

Multi-criteria analysis or evaluation provides a decision-support framework that can be used to undertake a triple bottom-line assessment of project options. This technique requires that proposals be evaluated against predetermined criteria, with the most favourable option identified through comparing relative weightings or rankings arising from this evaluation. While complicated, this approach allows for an in-depth assessment of the multiple parameters and objectives normally associated with a stormwater harvesting and reuse scheme. Further information on undertaking a multi-criteria analysis can be found in Proctor & Qureshi (2005).

5.1.5 Recommend an option

This step identifies a recommended option, based on the evaluation of options. The options evaluation report should include a risk management strategy identifying actions to reduce risks (including to public health and the environment) during the design and operation of a scheme.

The selected option may then be subject to more-detailed conceptual design and analysis to confirm its feasibility and suitability. This may include preparing a conceptual layout that indicates the size and location of the proposed facilities for stormwater collection, treatment, storage and distribution.

Water-sensitive urban design at Kogarah Town Square

5.2 Considerations for schemes in existing urban areas

The decision to implement a stormwater harvesting and reuse system in an existing urban area should ideally be made in the context of a regional or catchment-based plan or strategy for integrated urban water cycle management.

Such a plan would seek to integrate all streams of the urban water cycle – not just stormwater, but also potable water and wastewater – towards multiple objectives such as water demand, pollution loads, environmental flows and flooding.

A stormwater harvesting scheme could be developed in the context of a water utility's integrated water cycle management plan (DEUS 2004) or water savings plan (DEUS 2005).

In existing urban areas, option evaluation of a scheme may be more straightforward than in new urban areas, as the scheme's proponent would also usually be the scheme's operator. The economic analysis can therefore be based on both the capital costs and the operating costs to the proponent, which can be integrated through an analysis such as life-cycle costing (Taylor 2005b).

5.3 Considerations for schemes in urban developments

For stormwater harvesting schemes in new urban developments, key project objectives are likely to be established by council, and possibly by the water supply authority and/or the Department of Planning. Such a scheme needs to be considered early in the processes of master planning and development approval. It should also be an integral part of a site's water cycle master planning, accounting for water supply, sewerage and stormwater objectives. This integrated approach should achieve the optimal water cycle balance for the development, for example by addressing competing demands for non-potable water uses between treated stormwater and effluent (e.g. dual reticulation). It can also allow for the scheme to take into account any flood mitigation benefits when assessing on-site detention requirements.

In new developments, it is important to consider the interests of the developer, the council and the scheme's operator (if this is not the council) by assessing the costs and benefits to these stakeholders separately. The assessment should consider the capital costs to the developer and the recurrent costs to the scheme's operator (e.g. council). This is a different emphasis to the life-cycle costing approach, which is useful when the proponent is also the operator.

Councils would probably refer a development application for a stormwater harvesting and reuse scheme to the Department of Health for comment. It would therefore be useful for the proponent to discuss the project with that department during the development phase.

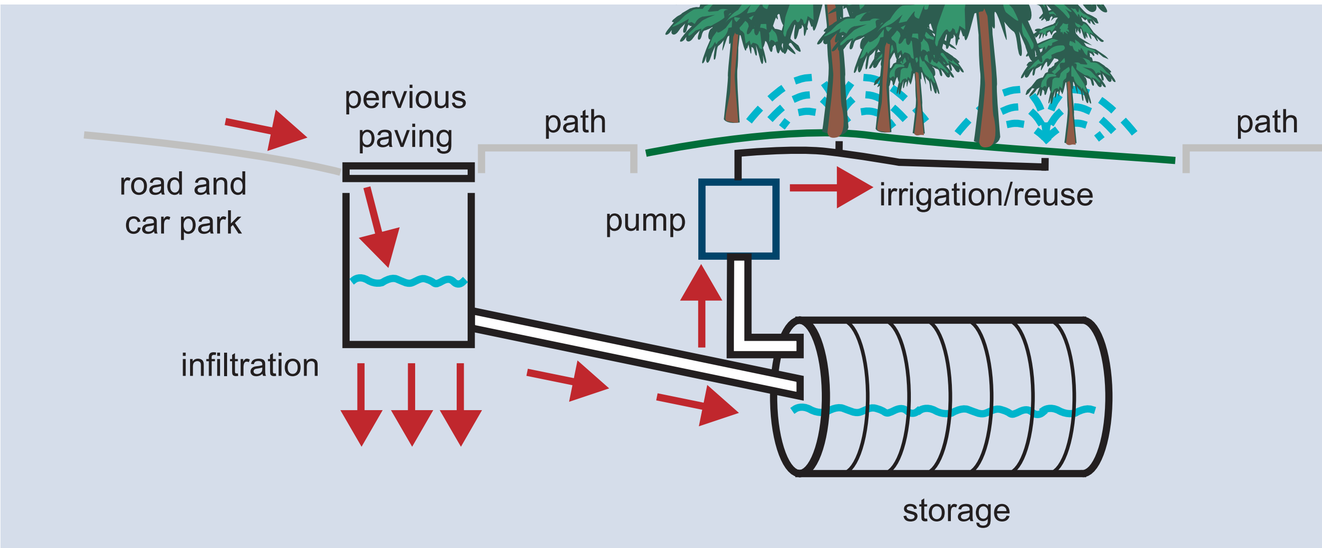
The likely issues that a council may want included in a development application involving a stormwater harvesting and reuse scheme include:

- anticipated benefits and impacts associated with scheme construction and operation (including social, environmental and economic aspects)
- consideration of environmental impacts during construction and operation phases through the preparation of an environmental management plan (EMP)
- compatibility of the proposed scheme with council's objectives, plans or strategies, including any relevant strategic water management plan or strategy
- how public health and safety risks are addressed

- management arrangements for the scheme
- what (if any) risks and/or financial obligations would be transferred to council if it operates the scheme (e.g. operations, maintenance, monitoring and reporting costs)
- compatibility of the proposed plan with surrounding land uses (compliance with zoning requirements)
- a 'scheme management plan', as described in section 7.

The development consent for a stormwater reuse scheme may include conditions requiring:

- appropriate management arrangements to be in place, if council is not the scheme's operator (e.g. a golf course operated by a club or private company)
- implementation of an EMP to manage construction impacts on the environment
- the scheme management plan to be implemented
- regular reviews and updating of the management plan as required
- reporting of monitoring results (including any exceedances) and implementing any corrective actions.



6. Design considerations

6.1 Design overview

Key considerations in the design process

The design process should aim to:

- design the reuse scheme for ease of operations and maintenance
- incorporate elements in the design intended to address public health and environmental risks, to complement operational risk management activities
- cost-effectively meet the project's objectives identified during project planning.

6.1.1 Arrangement of project elements

Various combinations of elements can be used in a stormwater harvesting and reuse scheme, depending on the nature of the site and the end uses. The design process needs to consider the following components:

- collection
- storage
- treatment
- distribution.

The design process should also consider construction, operations and maintenance issues.

As noted in section 2, there is no fixed arrangement for project elements. For example, a storage may be located before, after or between treatment facilities. Depending on the design of the scheme, water may be transferred between these elements by gravity flow or pumping. The elements should be arranged to suit the characteristics of the site and of the specific application. Examples of two possible arrangements are shown in figure 6.1.

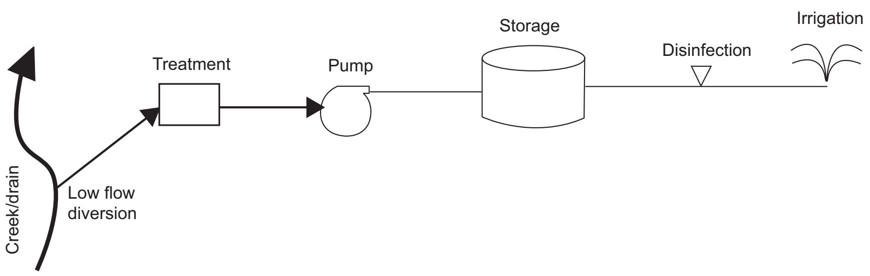


Figure 6.1 (a) **Schematic of an example harvesting scheme with off-line storage**

Figure 6.1 (b) **Schematic of an example harvesting scheme with on-line storage**

6.1.2 Approach to design

As with the planning process discussed in the last chapter, the design of a stormwater harvesting and reuse scheme is likely to be iterative, particularly to optimise the project's costs. As the end-use requirements essentially dictate the collection, storage and treatment elements of a scheme, the initial design is likely to follow the opposite direction of water flow:

- identify the end-use requirements relating to water quality and quantity, including reliability of supply
- for an irrigation scheme, prepare a preliminary design of the irrigation system to estimate the irrigation demand and the peak flow
- assess the water balance for sizing the storage to meet the end-use demand
- design the collection system for off-line storage so that it collects sufficient stormwater to meet the storage volume requirements – this can be estimated through a relationship between average annual volume and diversion flow rates
- design the treatment system based on the diversion flow rate if treatment is provided before the storage, or to the distribution flow rate if treatment occurs after the storage.

It is also important that the scheme is designed to consider the ease of operation and maintenance (see section 7). It is therefore useful for maintenance personnel to be involved in the design process. The project should also be designed to cost-effectively address the project's objectives determined during the planing phase (section 5).

As noted in section 5, a risk management strategy should be prepared during the planning stage to identify risk issues for the project design to address.

Stormwater pump at Greenway Park stormwater reuse scheme, Cherrybrook

6.2 Collection

Key considerations in the collection of stormwater for reuse

The design of the collection system should ensure that:

- sufficient stormwater is collected for transfer to storage to meet the end-use volume requirements
- the extraction does not compromise downstream aquatic ecosystems
- collection can be stopped if stormwater is contaminated by an incident within the catchment
- the risk of upstream flooding impacts is minimised.

This component of a scheme collects or diverts stormwater into the harvesting scheme from an urban creek, stormwater drain or overland flow. The nature of the collection arrangements depends on whether the storage is constructed on a drainage system (on-line) or away from the drainage system (off-line). These arrangements are discussed further in section 6.3.

Where on-line storage is used, there is no collection system, as stormwater flows directly into the storage. Stormwater can be directed to the storage by drains or swales.

For schemes with off-line storages, water is usually collected by a diversion weir constructed on a stormwater drain or urban creek. The weir diverts low flows into the scheme while enabling high flows to bypass the system. These schemes should also include a bypass facility to return stormwater to the drain when the storage is full. Where a scheme draws stormwater from larger watercourses, lakes or ponds, stormwater can be collected by installing a well with a submersible pump and associated rising main.

In new urban developments, stormwater can be collected through water-sensitive design elements such as swales and biofilters. These elements also provide a degree of stormwater treatment.

The design of the diversion weir should ensure that an adequate volume of stormwater would be diverted to meet the planned water demand and reliability of supply. The weirs are usually designed to divert flows below a specific average recurrence interval (ARI) peak flow into the scheme, with higher flows overtopping the weir. Usually it is the low ARI storm events that are diverted (e.g. 3-month ARI), as such low flows provide the bulk of the annual yield and account for the greater proportion of the pollution load.

The relationship between annual run-off volume and peak flow is site-specific and distinctly non-linear. Figure 6.2 from Wong et al. (2000) illustrates that 90–97% of the mean annual run-off from Australian urban catchments occurs at flows lower than the 3-month ARI peak flow. This relationship is indicative only, and a site-specific relationship should be developed for particular projects.

Figure 6.2 also highlights a distinct 'point of diminishing returns' in the relationship between diversion flow rate and the percentage of average annual run-off volume diverted. Diversion flows of 6-month to 1-year ARI are likely to divert nearly all (over 98%) of the annual run-off volume. The implication for the design of diversion structures is that the diversion of infrequent, high-ARI flows is unlikely to be cost-effective.

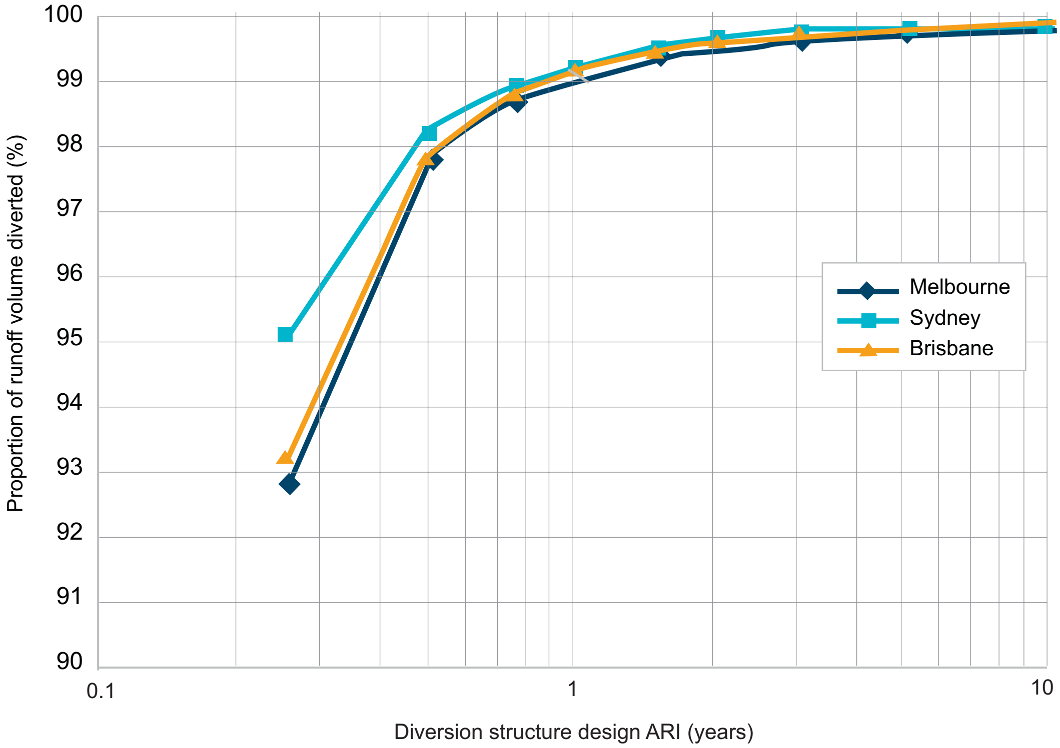


Figure 6.2 Relationship between diversion structure flow and run-off volume

Source: after Wong et al. 2000

Similarly, where water is pumped from a creek, the benefits of selecting a pump with a rate greater than the 3-month ARI flow would only be marginal.

The project design should assess the extraction volume compared to the needs of the downstream receiving environment and any downstream users to prevent over-extraction. For example, a 90% reduction in annual runoff volume may result in over-extraction relative to environmental flows, and a design diversion flow of 1-month ARI or less may be more appropriate. This needs to be assessed on a case-by-case basis as, for example, a high extraction could be compensated for by significant stormwater inflows downstream of a harvesting scheme.

6.3 Storage

Key considerations in the storage of stormwater

The design should aim to:

- store sufficient water to balance supply and demand, and meet reliability of supply objectives
- design above-ground storages to minimise mosquito habitat (virus control), risks to public safety and risks to water quality (e.g. eutrophication), and address dam safety issues.

6.3.1 Storage volume

Storage in stormwater harvesting and reuse schemes needs to balance the variability between stormwater inflow and demand. Demand variability can be significant, especially in the case of irrigation, and may be the inverse of stormwater availability because demand would decrease during periods of rainfall.

The primary function of a storage is to balance inflows and demand to achieve a desired reliability of supply. There is a complex relationship between storage volume, annual run-off volume, the demand for treated stormwater and the yield from a scheme. For example:

- if the storage size is increased for a given demand, the yield increases, as does the reliability of supply – there is less likelihood of the storage being empty
- if the demand increases for a given storage size, the yield increases although the reliability of supply decreases – the storage is empty or nearly empty more often, increasing the capture of inflows
- where the demand represents a high proportion of the mean annual run-off and a high degree of reliability is required, a significant storage volume will be needed.

These interactions highlight the importance of water balance modelling for sizing storages (discussed further in appendix C). The size of storages can be optimised when the pattern of demand is similar to that of stormwater supply. To keep storages to a reasonable size, the design could include a top-up facility, usually from mains water (if appropriate or permissible), or altered operating rules to ration or restrict demand in certain periods.

Storages may be constructed specifically for stormwater reuse or a scheme could utilise an existing storage, such as an urban lake. Alternatively, a harvesting scheme could use a storage created as part of a broader stormwater management scheme, such as a constructed wetland or pond for stormwater treatment. This would involve adding volume for reuse at the design stage of the wetland or pond.

While most storages for stormwater harvesting projects are above ground, alternatives include underground storages in tanks or injection into aquifers (known as aquifer storage and recovery or ASR). ASR is used widely in South Australia (Kellogg Brown & Root 2004) and is very space and cost-efficient. Dillon & Pavelic (1996), EPA SA (2005) and Dillon & Molloy (2006) provide further information on ASR.

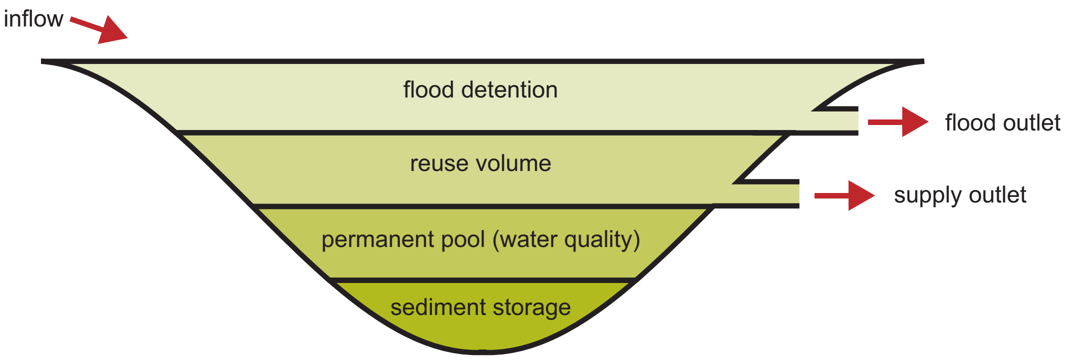
There are three main issues associated with the design of stormwater storages:

- function – single or multi-purpose
- capacity – meeting a specific reliability of supply
- location – on-line or off-line, surface or aquifer, centralised or distributed.

Storages, particularly those above ground, may also have other functions, including:

- flood mitigation
- visual amenity
- pollution load reduction
- habitat
- fire-fighting supplies.

Figure 6.3 Schematic diagram of a multi-purpose above-ground storage



While multiple objectives may be desirable, the scheme may not be able to satisfy all objectives all of the time, requiring some compromises to be made. For example, significant fluctuations in the water levels of open storages may hinder the growth of fringing macrophytes needed for effective water quality control, habitat, visual appeal and access control, requiring some trade-off between these objectives.

The various storage volumes for a multi-purpose project can be derived through water balance, water quality and flood modelling, as described in section 5.

6.3.2 Design of storages

The design of a storage should take the following constraints into account:

- location
- storage type
- water quality in storage
- human health and safety risks
- operations and maintenance
- spillway design and dam safety.

Location

Storage in stormwater harvesting and reuse schemes can be on-line and off-line. There are both advantages and disadvantages with each type (see table 6.1). Some of the potential disadvantages can be addressed through good design. Off-line systems are likely to be the most appropriate for schemes on natural watercourses.

Storage types

Open storages and above-ground or underground tanks are normally used in stormwater harvesting and reuse schemes. Each has particular advantages and disadvantages that should be considered during the planning and design phases (see table 6.2).

Table 6.1 Comparison of on-line and off-line storages		
Consideration	**On-line storage**	**Off-line storage**
Barrier to fish passage and connectivity of aquatic ecosystems	Potential barrier if constructed on natural channel	No or little impact
Downstream water quality benefits (additional to reuse benefits)	Relatively high	Relatively low
Potential for scouring of natural channels downstream of storage	Relatively high	Negligible
Relative yield for a given storage volume	Slightly higher	Slightly lower
Spillway costs	Relatively high	Negligible
Maintenance costs (e.g. sediment removal)	Relatively high	Relatively low

Water quality in storages

Water quality considerations apply to varying degrees to both on-line and off-line storages, as well as to open and covered (e.g. underground) storages. These considerations are most critical when treatment levels other than disinfection are low and when the demand is small relative to the storage volume.

Elevated nutrient loadings, particularly of phosphorus, can result in eutrophication of an open storage in which cyanobacteria (also called blue-green algae) can bloom and anaerobic conditions develop. The risk of eutrophication is higher if the water is stored for long periods and nutrients are not removed or reduced by the treatment process.

Table 6.2 Potential advantages and disadvantages of storage types		
Storage type	**Potential advantages**	**Potential disadvantages**
Open storages	Low capital and maintenance cost	Public safety Mosquito-breeding potential Higher potential for eutrophication Aesthetic issues with fluctuating water levels
Above-ground tanks	Moderate capital and maintenance costs No public safety issues	Aesthetic issues
Underground tanks	No visual issues No public safety issues	Higher capital cost Higher maintenance costs
Aquifer	Little space required Cost-effective Prevents saltwater intrusions to aquifer	Requires suitable geology Potential to pollute groundwater unless pre-treated

Stormwater storage at Pennant Hills Park stormwater reuse scheme

To minimise the risk of cyanobacterial blooms in open storages, Melbourne Water (2005) recommends that detention times should not exceed those noted in table 6.3 at the summer water temperatures indicated. This is based on the assumption that sufficient nutrients are available for algal growth and there is no light limitation due to elevated turbidity levels.

During the water balance modelling for the project, the residence time of water in the storages should be checked against these guidelines. If the residence times will exceed those indicated, consider options for minimising the likelihood of blue-green algal blooms, such as nutrient removal before storage or altering the diversion/demand operating rules.

Anaerobic conditions can develop in all storages, especially where elevated loads of organic matter occur with inadequate aeration. This is because the bacteria that break down organic matter consume the available dissolved oxygen faster than it can be replenished from the atmosphere. This may be a greater problem in underground tanks than in open storages. Management options include reducing the loads of organic matter before storage by installing a gross pollutant trap and not operating the scheme during periods of limited demand and long retention times (e.g. winter).

Table 6.3 Detention times to reduce the risk of algal blooms

Detention time[1] (days)	Average daily temperature (ºC)
50	15
30	20
20	25

Note: 1 20th percentile

Open storages can be attractive to waterbirds, which contribute faecal matter containing pathogens, thus increasing public health risks. This is of particular concern where the treated stormwater is intended for residential uses, as low pathogen levels are required due to the high public exposure. To minimise attractiveness to waterbirds, the storage should be designed with relatively steep side slopes and no fringing macrophytes planted. The storage should also be fenced for public safety and to minimise faecal inputs from animals. This arrangement should be considered as an additional barrier for addressing health risks for schemes with residential uses of treated stormwater.

Turkey's-nest dam, Bexley golf course

Human health and safety risks

The layout of above-ground storages and associated stormwater treatment measures should consider public health and safety issues. These relate principally to side slopes and storage depths. The side slope affects the ease with which somebody can clamber out should they fall in, and from this viewpoint the slope should be shallow when adjacent to areas of deep water.

However, shallow side slopes may encourage disease-carrying mosquitoes to breed and so from this perspective steep slopes or vertical sides with handrails should be used. Ultimately, the design of the edge treatments needs to balance public safety and public health risks against environmental and aesthetic values.

Prominent warning signs should be considered for storages containing stormwater for reuse where public access is available. Warnings could read 'Recycled water storage – do not drink. No swimming, wading or boating'. Signs should be designed to AS 1319 and could also use supplementary symbols.

The design also needs to consider the extent of fluctuations in water levels within the storage, as this will influence the edge design.

The design of open storages is discussed further in *Managing urban stormwater: treatment techniques* (DEC 2006) and Melbourne Water (2005).

Warning sign at Bexley golf course

Sedimentation

Sediment levels in raw and treated urban stormwater are higher than those in mains water. It is important that the design allows for accumulated sediment to be removed, which is likely to involve dewatering of the storage. This also applies to storage tanks where sedimentation of fine particles will occur.

Spillway design

Above-ground storages should be provided with a spillway to safely convey a design flood flow. This design flow is commonly the 100-year average recurrence interval (ARI) event or higher. Further advice can be sought from the Dam Safety Committee (NSW) (2004).

6.4 Treatment

Key considerations in the treatment of stormwater

The stormwater treatment system should be based on:

- adopting stormwater quality criteria that:
  - minimise public health risks for the adopted public access arrangements
  - minimise environmental risks
  - meet any additional end-use requirements
- designing appropriate stormwater treatment techniques to meet the adopted objectives.

6.4.1 Treatment overview

The treatment arrangements for a stormwater harvesting and reuse scheme should relate closely to the project's objectives, in particular by:

- addressing public health and environmental risks
- meeting any additional end-use requirements.

Stormwater quality can affect the performance of a reuse scheme in several ways, and these need to be considered at the design stage. For example, a scheme may need to include disinfection, but disinfection may be affected by turbidity. Associated with this is the need to reduce sediment so that it does not block the distribution system, including the sprays for any irrigation component. These aspects are discussed later in this section.

Where stormwater reuse is part of a larger stormwater project that, for example, includes protecting receiving water quality, only the reuse component of the treatable volume needs to be subject to these water quality considerations.

Thus, the design of a treatment system for a stormwater harvesting and reuse scheme needs to consider both:

- stormwater quality criteria, and
- treatment techniques to meet these objectives.

6.4.2 Stormwater quality criteria

Stormwater quality criteria for public health risk management

National guidelines for water recycling that include stormwater reuse are due in 2008. As an interim measure, table 6.4 presents default stormwater quality criteria for managing public health risks for various applications. Different criteria apply depending on the access arrangements for some applications (refer to table 4.4), with more stringent criteria applying (i.e. lower levels of pathogens) where the potential for human contact and ingestion of water is higher.

These criteria are suitable for schemes below the thresholds noted in table 4.3. A health risk assessment should be prepared for larger schemes with high public exposure, such as medium to large dual reticulation schemes for residential purposes (refer to Department of Health and Aging & enHealth Council 2002, and EPA Queensland 2005a for guidance). This risk assessment may find that the stormwater quality criteria in table 6.4 are appropriate for the scheme.

The stormwater quality criteria in table 6.4 have an associated statistical descriptor; for example *E. coli* objective is the median value. These values should be based on the analysis of monitoring data conducted over a 12-month period. Section 7 provides monitoring guidance.

Other aspects of water quality relevant to public health considerations noted in table 6.4 are turbidity and pH. High turbidity levels can shield pathogens from disinfection, which may result in less-efficient disinfection or higher disinfection requirements (Health Canada 2003). When pH levels are lower than 6.5, plumbing features can be corroded. At higher levels (e.g. above 8), the efficiency of chlorine disinfection is impaired.

Stormwater quality criteria for environmental risk management

Stormwater harvesting and reuse projects that are below the threshold criteria noted in table 4.3 and are operated in accordance with the guidance in section 7 are expected to have low environmental risks related to water quality. Specific stormwater quality criteria for environmental risk management are therefore not required for these schemes. Specific investigations and possible additional treatment may be required for schemes where the raw stormwater quality is likely to be poorer than from sub-threshold schemes – this may apply in catchments with industrial land uses or significant sewer overflows.

Table 6.4 Stormwater quality criteria for public health risk management

Level	Criteria[1]	Applications
Level 1	*E. coli* <1 cfu/100 mL Turbidity ≤ 2 NTU[2] pH 6.5–8.5 1 mg/L Cl_2 residual after 30 minutes or equivalent level of pathogen reduction	Reticulated non-potable residential uses (e.g. garden watering, toilet flushing, car washing)
Level 2	*E. coli* <10 cfu/100 mL Turbidity ≤ 2 NTU[2] pH 6.5–8.5 1 mg/L Cl_2 residual after 30 minutes or equivalent level of pathogen reduction	Spray or drip irrigation of open spaces, parks and sportsgrounds (no access controls) Industrial uses – dust suppression, construction site use (human exposure possible) Ornamental waterbodies (no access controls) Fire-fighting
Level 3	*E. coli* <1000 cfu/100 mL pH 6.5–8.5	Spray or drip irrigation (controlled access) or subsurface irrigation of open spaces, parks and sportsgrounds Industrial uses – dust suppression, construction site use, process water (no human exposure) Ornamental waterbodies (access controls)

[1] values are median for *E. coli,* 24-hour median for turbidity and 90th percentile for pH

[2] maximum is 5 NTU

Source: derived from NSW RWCC (1993), DEC (2004), ANZECC & ARMCANZ (2000)

Operational stormwater quality criteria

Urban stormwater contains elevated levels of gross pollutants, including litter and coarse sediment (Engineers Australia 2005). These are likely to present a hazard to most stormwater harvesting and reuse schemes through their potential impacts on pump operations, the efficiency of treatment measures and the operations of the distribution system. A high degree of gross pollutant removal should be achieved for flows up to the scheme's collection flow.

Additional stormwater quality criteria for specific applications

Residential uses

The *NSW Guidelines for urban and residential use of reclaimed water* (NSW RWCC 1993) note the need to consider a number of characteristics in non-potable reticulated water, such as:

- salt
- nutrients
- heavy metals
- pesticides.

These apply equally to stormwater reuse, because garden watering is a key use of non-potable water and it is important to prevent impacts on soils or groundwater.

Irrigation

Irrigation with stormwater has different water quality requirements to irrigation with treated effluent. The levels of pollutants in stormwater are normally much lower than in effluent (see appendix C). Further, effluent reuse schemes typically have higher application rates (higher hydraulic loadings) because they aim primarily to dispose of effluent, whereas stormwater schemes may have multiple objectives. For these reasons, the environmental consequences of poor design or operation are likely to be more severe in an effluent irrigation scheme than in a stormwater irrigation scheme.

As noted above, urban stormwater is characterised by high loads of suspended solids, sand and grit. This can cause excessive wear and clogging of pumps and control equipment, and may block irrigation sprays. The specific treatment level required would depend on the design of the irrigation systems. For irrigating playing fields and golf courses, suspended solids levels below 50 mg/L are unlikely to result in operational problems. Limiting particle sizes to smaller than approximately 0.5–1.0 mm may avoid operational problems in conventional spray irrigation schemes. Specific information should be obtained from the irrigation scheme designer and/or equipment supplier.

High nutrient levels can cause operational problems for irrigation schemes through biofilms clogging irrigation equipment. ANZECC & ARMCANZ (2000) provides trigger values for agricultural irrigation that could be used for stormwater irrigation. These are presented in table 6.5.

Table 6.5 Trigger values for nutrients in irrigation water

Element	Long term (up to 100 years)	Short term (up to 20 years)
Total phosphorus (mg/L)	0.05	0.8–12[1]
Total nitrogen (mg/L)	5.00	25.0–125[1]

1 Requires site-specific assessment (refer to ANZECC & ARMCANZ 2000)

The phosphorus levels noted in appendix C are higher than the long-term trigger values in table 6.5 but are lower than the short-term values. Hence there is potential for long-term operational impacts where stormwater is irrigated without actions to reduce phosphorus concentrations. The nitrogen levels are lower than the long-term trigger levels.

Industrial uses

Additional stormwater quality objectives for industrial uses will depend on the nature of the use. Advice should be sought from the operator of particular industrial premises. Potential water quality concerns for industrial uses are noted in table 6.6.

Aquifer storage and recovery

Guidance on treatment objectives for aquifer storage and recovery can be obtained from Dillon & Pavelic (1996), and information about design and operations from EPA SA (2005) and Dillon & Molloy (2006).

6.4.3 Treatment techniques

The treatment arrangements for a stormwater reuse project should relate to the adopted stormwater quality criteria for the project.

Where a project has a single objective of stormwater harvesting and reuse, the treatment processes need to address the relevant public health and environmental risks, and any additional end-use requirements. For example, a small scheme irrigating a golf course with controlled public access may only need sediment removal by an efficient gross pollutant trap and disinfection.

Where reuse is only one of several project objectives, more conventional stormwater treatment measures (such as constructed wetlands for nutrient removal) may also be required in order to reduce pollution loads to design levels.

Water quality should be monitored during the planning and design phase for harvesting schemes where the upstream catchment has:

- point sources of pollution
- significant sewer overflows
- non-residential land uses, such as industrial areas
- roads with high traffic volumes.

The monitoring results will provide input into the project's risk assessment and design. A degree of redundancy or 'over design' is likely to be appropriate for these schemes, particularly for pathogen removal, due to the higher public health risks.

Table 6.6 Potential stormwater quality concerns for industrial uses

Quality	Potential problem
Pathogen levels	Health risks to public and workers
Chemical quality (e.g. ammonia, calcium, magnesium, silica, iron)	Corrosion of pipes and machinery, scale formation, foaming etc.
Physical quality (e.g. suspended solids)	Solids deposition, fouling, blockages
Nutrients (e.g. phosphorus, nitrogen)	Slime formation, microbial growth

Source: EPA Victoria (2003)

Stormwater treatment – contaminants

Stormwater for harvesting and reuse is likely to need pre-treatment to remove gross pollutants, including litter, organic matter and coarse sediment before it enters a storage or downstream treatment measures. Several types of proprietary and non-proprietary gross pollutant traps are available which could be used for this purpose.

As the level of gross pollutants in stormwater and the efficiency of gross pollutant traps are variable, the scheme should be designed on a contingency basis such that the scheme's operation is not compromised by the presence of gross pollutants. Pumps should be capable of pumping sand and grit, and subsequent stormwater treatment measures and storages should be able to accommodate some sediment inputs.

Table 6.7 shows indicative concentrations for pollutant retention and outflow from a range of stormwater treatment measures. The outflow concentrations have been based on the average stormwater concentrations contained in tables C.1 and C.3 (appendix C) for a residential catchment. Outflow concentrations will depend on inflow concentrations, with higher outflow levels expected in industrial catchments or those with high sewer overflows. The relationships also assume that there is no significant loss of volume through the treatment measure that might affect the concentration of a parameter.

Table 6.7 Indicative levels of pollution retention and outflow concentrations for different stormwater treatment measures

Stormwater treatment measure	Suspended solids	Total phosphorus	Total nitrogen	Turbidity	*E. coli*
Retention					
GPT	0–70%	0–30%	0–15%	0–70%	Negligible
Swale	55–75%	25–35%	5–10%	44–77%	Negligible
Sand filter	60–90%	40–70%	30–50%	55–90%	–25–95% (up to 1.5 log)
Bioretention system	70–90%	50–80%	30–50%	55–90%	–58–90% (up to 1 log)
Pond	50–75%	25–45%	10–20%	35–88%	40–98% (0.5–2 log)
Wetland	50–90%	35–65%	15–30%	10–70%	–5–99% (up to 2 log)
Outflow*					
GPT	42–140	0.18–0.25	1.7–2.0	18–60	9,000
Swale	35–63	0.16–0.18	1.8–1.9	14–34	9,000
Sand filter	14–56	0.08–0.15	1.0–1.4	6–93	500–11,000
Bioretention system	14–42	0.05–0.13	1.0–1.4	6–93	900–15,000
Pond	35–70	0.14–0.19	1.6–1.8	7–81	200–5,000
Wetland	11–67	0.09–0.16	1.4–1.7	19–53	100–9,000

* concentrations in mg/L except for turbidity (NTU) and *E. coli* (cfu/100 mL)

Source of retention data: DEC (2006), Fletcher et al. (2004), Victorian Stormwater Committee (1999).

The actual reduction in concentration achieved by a particular stormwater treatment measure will depend on its design and the inflow characteristics, both for flow and water quality. Information on the design of non-proprietary stormwater treatment measures can be obtained from DEC (2006) and Melbourne Water (2005).

The indicative results presented in table 6.7 highlight that stormwater treatment using conventional treatment measures can achieve the following levels of treatment:

- suspended solids concentrations of less than 50 mg/L – this is important for the design of irrigation systems
- reduced turbidity levels, but not to the levels of 2–5 NTU required for maximising disinfection
- reduced total phosphorus levels, although rarely to the long-term trigger value for irrigation systems shown in table 6.5 (no reduction is needed to meet the short-term trigger level or for the average total nitrogen level).

Stormwater treatment – pathogens

Treatment techniques for reducing pathogen levels suitable for use in a stormwater harvesting and reuse scheme fall into two broad categories:

- stormwater treatment measures – constructed wetlands, ponds, sand filters etc.
- water treatment techniques – disinfection using chlorine, iodine, UV radiation and ozone; membrane filtration etc.

Treatment to reduce the concentration of pathogens in stormwater should be undertaken at or close to where treated stormwater is used, normally downstream of the storage and at the start of any stormwater distribution system. Disinfection upstream of a storage is normally not effective as pathogen levels may increase in storage (e.g. waterbirds may add faecal matter to above-ground storages).

Stormwater treatment measures

Conventional stormwater treatment measures can achieve some degree of disinfection, as noted in table 6.7. However, the reductions are highly variable and at best can achieve the level 3 *E. coli* criteria noted in table 6.4. Overall, there will be difficulties in consistently achieving target pathogen levels for urban applications of treated stormwater using only conventional stormwater treatment measures.

The variability in pathogen removal efficiency of conventional stormwater measures is compounded by variability in the quality of stormwater inflows. The expected variation in pathogen levels in treated stormwater is a significant issue for public health risk management, as many of the health impacts are acute and related to a single exposure.

The use of stormwater treatment measures alone for reducing pathogen levels should be considered only when:

- a low level of treatment is required (e.g. level 3 criteria from table 6.4)
- site-specific monitoring has indicated that pathogen levels (as measured by indicator bacteria) are relatively low
- the treatment measures are conservatively designed.

The land area required for conventional treatment measures such as wetlands should also be considered. The scheme should also provide for the installation of disinfection equipment should monitoring indicate that the system is not meeting the stormwater quality criteria reliably.

Further information on the relative effectiveness of stormwater treatment measures and treatment technologies for reducing pathogen levels in stormwater can be found in Perdeck et al. (2003).

Water treatment techniques

The most commonly used disinfection technology for urban stormwater is UV radiation – see the case studies in section 8, and Hatt et al. (2004). In these cases, the relatively small flows and ease of using UV at small facilities made this option feasible. As these schemes did not reticulate treated water for residential uses, there was no need for residual disinfection. Disinfection by ozone has also been used at some stormwater treatment facilities.

Chlorination is the most common disinfection technique for water supply schemes (NHMRC & NRMMC 2004a) which tend to be larger than typical stormwater schemes and where residual disinfection is important. Chlorination would be appropriate for residual disinfection where a scheme reticulates stormwater for residential uses. However, the chemical reactions in chlorine disinfection create by-products which may present other public health or environmental risks. This is discussed further in Department of Health and Aging & enHealth Council (2002) and NHMRC & NRMMC (2004a).

Table 6.8 presents typical reductions in *E. coli* levels that could be expected using common disinfection techniques. The actual disinfection efficiency however would depend on factors like the design of the process, the operating rules (e.g. the dosing rates) and the inflow characteristics. The resulting indicative outflow *E. coli* levels for all technologies are <1 to 90 cfu/100 mL based on the average levels in stormwater from residential areas noted in table C.1 (appendix C).

A further discussion on disinfection technologies is provided in the Australian drinking water guidelines (NHMRC & NRMMC) 2004a and EPA Victoria (2002). Guidance on the design of disinfection systems can be obtained from Water Environment Federation (1996) and American Water Works Association (1999).

As noted earlier, turbidity levels influence the effectiveness of treatment technologies. The EPA Victoria (2002) recommend that pre-disinfection median turbidity levels should be:

- < 10 NTU for chlorination and microfiltration
- < 5 NTU for ozone and UV
- < 2 NTU for any disinfection method where the reuse application demands a significant reduction in pathogens (e.g. *E. coli* to less than 10 cfu/100 mL).

This approach is based on the need to ensure high disinfection efficiency when low pathogen levels are required, and relaxing this requirement when pathogen requirements are less stringent. This guidance is based on effluent disinfection; however, it could also be used conservatively for stormwater disinfection.

Table 6.8 Indicative effectiveness of disinfection technologies

Technology	*E. coli* reductions – log	*E. coli* reductions (%)
UV light	2 to > 4	99 to >99.99
Chlorination	2 to 6	99 to 99.9999
Ozonation	2 to 6	99 to 99.9999

Source: NRMMC & EPHC (2005)

From table 6.7, turbidity levels less than 10 NTU can be achieved by appropriate, well-designed measures. However, achieving turbidity levels less than 2 NTU through stormwater treatment alone is likely to be difficult. Some additional turbidity reduction is likely to occur in storages having relatively long retention times, particularly tanks or underground storages.

A suggested approach to optimise disinfection efficiency is to pre-treat according to the stormwater quality criteria for the indicator pathogen *(E. coli)*. This approach involves:

- for *E. coli* levels below 10 cfu/100 ml (level 1 or 2) – provide pre-treatment using a conventional water or wastewater technology (e.g. filtration) or extended storage in tanks to achieve median turbidity levels of less than 2 NTU
- for *E. coli* levels above 10 cfu/100 mL (level 3) – provide well-designed conventional stormwater treatment as disinfection pre-treatment. *E. coli* levels should be monitored intensively during commissioning to ensure that turbidity is not reducing disinfection. If disinfection is affected, alter the disinfection process (e.g. incrementally increase the dose of chlorine for chlorine disinfection) or provide additional pre-treatment to reduce turbidity.

Overall, disinfection technologies can be expected to achieve the target pathogen levels for urban applications of treated stormwater with a relatively high degree of reliability. While wastewater and potable water disinfection is well known, stormwater disinfection is a relatively new field.

Although turbidity may affect disinfection, the concentration of viable pathogens associated with particulate matter in stormwater may be relatively small when compared to wastewater (Water Environment Federation 1996). Thus wastewater needs to be pre-treated (e.g. by filtration) to achieve high disinfection efficiencies. Consequently high turbidity levels may be less of a concern for stormwater disinfection relative to wastewater disinfection.

UV disinfection unit at Greenway Park stormwater reuse scheme, Cherrybrook

This uncertainty highlights the importance of monitoring water quality during the commissioning and operational phases of a scheme to ensure that adequate disinfection is achieved or modifications made to the disinfection arrangements.

It is also important to acknowledge that the reduction in the level of one type of pathogen (e.g. *E. coli*) achieved by a specific disinfection technique may not apply to other types of pathogens (e.g. other bacteria, viruses and protozoa). This is discussed further in NHMRC & NRMMC (2004a).

6.5 Distribution

Key considerations in the distribution of treated stormwater

The system for distributing treated stormwater should be designed to:

- minimise the potential for contaminant inputs downstream of the final treatment facilities
- minimise the potential for public exposure to treated stormwater and ensure there is no potential for cross-connection with mains water distribution networks or confusion with mains water supplies.

It is important that distribution schemes minimise the potential for contaminant inputs between the final treatment facility (e.g. disinfection) and the end use. This is usually achieved by using a piped distribution system.

There is a risk that treated stormwater contained in a piped distribution system could be mistaken for mains water, with the potential for accidental cross-connection. This is particularly important for schemes that use mains water as a supplementary water supply or for dual reticulation schemes for residential uses. To minimise these risks, the distribution system should be designed on the basis of:

- no cross-connection of the stormwater distribution system into the mains water system
- where mains water is used as make-up water, a backflow prevention device (e.g. an air gap) should be installed in the mains water supply before it enters the stormwater reuse scheme. The stormwater distribution scheme should also be operated at lower pressure than the mains water system, if practical
- underground and above-ground pipes in a stormwater distribution system should be colour-coded (e.g. purple) for schemes where there is public access, mains water back-up or dual reticulation. Identification tape should be installed on top of the underground pipes warning that the pipe contains recycled/reclaimed water and that it is not suitable for drinking
- hose taps for dual reticulation schemes should be have a removable handle and have a connection different to that used for mains water supply. Signs should be provided reading, for example, ‘Recycled water – not for drinking’. The sign could also include relevant symbols indicating that the supply is not for drinking purposes. For sign design, refer to AS 1319 (Standards Australia 1994).

If a harvesting and reuse scheme is operated on private property and there is no regular public access, appropriate signage for site workers and any infrequent visitors should be provided. Other special signage requirements may be needed in some circumstances.

Detailed information on the design of the distribution system’s plumbing is contained in the following documents (or more recent versions):

- for reticulated systems for residential uses:
  - *NSW Guidelines for urban and residential use of reclaimed water* (NSW Recycled Water Coordination Committee, 1993)
  - *NSW Code of practice for plumbing and drainage* (CUPDR, 1999)
  - *AS/NZS 3500: 2003 Plumbing and drainage* (Standards Australia 2003)
- for other uses:
  - *National Water Quality Management Strategy – Guidelines for sewerage systems: use of reclaimed water* (ARMCANZ et al. 2000).

6.6 Irrigation systems

Key considerations in the irrigation of treated stormwater

A system for irrigating with treated stormwater should be designed to:

- minimise run-off, groundwater pollution and soil contamination
- minimise spray to areas outside the control zone where access control is adopted to reduce public health risks.

6.6.1 Background

Irrigation with stormwater is a relatively new activity compared to irrigation using treated effluent. However there is a significant overlap between these applications. This section provides an overview of the issues to be considered in stormwater irrigation and highlights the differences in irrigating with stormwater or effluent. General information on the design of effluent irrigation schemes can be found in DEC (2004).

The main differences arise from the different pollutant levels in stormwater and effluent (as noted in appendix C). In general, contaminant levels in stormwater are lower than those in secondary treated municipal effluent, with the exception of some metals. DEC (2004) can be adapted to account for these differences.

6.6.2 Application rates

Designing the irrigation scheme's application rate is important for minimising surface run-off, groundwater impacts and impacts on soils. The application rates should consider the site's characteristics (particularly soils) and the irrigated vegetation. DEC (2004) provides guidance on water balance calculations for effluent irrigation schemes, which can also be used for stormwater irrigation. This provides input into the scheme's water balance described in section 5. The loading rate calculations for nutrients, organic matter and salinity in DEC (2004) are normally not required for stormwater irrigation.

The soil infiltration rate is an important consideration in the type of irrigation method used and in the way it is operated. Stormwater should be applied uniformly and at a rate less than the nominal infiltration rate to avoid surface run-off.

6.6.3 Buffer zones and irrigation scheme design

Spraying with stormwater may transmit pathogens through aerosols and mists from the spray water. Where stormwater has been treated to a relatively high level (e.g. level 2 in table 6.4), public health risks associated with irrigation sprays are low. However all spray irrigation systems should be designed to minimise off-site spray drift, as this may present a nuisance to neighbours.

Where a lower level of treatment is provided (e.g. level 3), greater management of irrigation water to reduce public exposure is required. This can be achieved either by using subsurface irrigation or by having buffer zones between the irrigation scheme's wetted perimeter and the nearest point of public access (e.g. road or private property).

DEC (2004) notes that the width of a buffer zone would depend on a range of factors, including the type of irrigation equipment used, slope, wind direction and vegetation present. The preferred approach is to carry out a site-specific study to determine a suitable width. Alternatively, the design could use an indicative buffer zone of 30 metres for drip or trickle irrigation schemes and 50 metres for spray irrigation (excluding high-pressure sprays). To help define buffer zones, low-flow sprinklers or 180° inward throw sprinklers can be used. Irrigation control systems can also include anemometers, which monitor wind direction and speed, to trigger an irrigation system cut-off under high wind conditions where excessive spray drift is likely.

In public access areas, facilities such as drinking water fountains, swimming pools and picnic tables should be placed outside the area irrigated by treated stormwater or be protected from drift and direct spraying.

Signage should be provided at all public access points to stormwater irrigation areas, warning not to drink the water. Additional signage will be needed to warn the public where access controls apply.

6.7 Construction

Key considerations in the construction of a stormwater reuse scheme

In constructing a system for using treated stormwater:

- construct the scheme to minimise water, air and noise pollution and waste generation
- protect any valuable vegetation during construction.

The design of a stormwater reuse project needs to consider the potential environmental impacts from both the operation and construction of the scheme. Construction may cause water, air or noise pollution, and generate waste, and may also damage soils and vegetation. These impacts maybe minimised by preparing an environmental management plan, the implementation of which should be monitored during construction. This will enable practices to be modified or the plan to be updated to address any observed implementation issues.

The construction of a scheme should be in accordance with:

- relevant legislation and guidelines
- relevant development consent conditions
- any environmental management plan that may have been submitted with the development application.

Jute matting prevents bank erosion – wetland reconstruction, Strathfield

Guidance of particular relevance includes Landcom (2004) for water quality management, and any council guidelines or requirements for preserving trees or other vegetation during construction. Particular attention needs to be paid to the construction of on-line storages, where flows within the drain or stream on which the storage is being built need to be diverted around the construction site (refer to Landcom 2004).

7. Operational considerations

7.1 Background

The planning and design phases of a stormwater harvesting and reuse scheme play a key role in managing risk, cost-effectiveness and sustainability. However, the operational phase is equally important in achieving the scheme's anticipated outcomes, particularly from a risk management perspective.

The operation and maintenance of stormwater harvesting and reuse schemes are similar to those of other recycled water reuse schemes and, to varying degrees, to other areas of water supply and stormwater management. Consequently, guidance on the operation and maintenance of stormwater reuse systems can draw on the available information from these other types of recycled water schemes (see DEC 2004, ARMCANZ et al. 2000, EPA Queensland 2005a, EPA Victoria 2003).

This section provides an overview of the issues to be considered in stormwater irrigation, highlighting the differences relative to effluent irrigation, and it provides references to additional relevant information.

7.2 Organisational responsibilities

Key considerations for an organisation operating a stormwater harvesting and reuse scheme

A stormwater harvesting and reuse scheme's operator should ensure that:

- the organisation is committed to the appropriate management of the scheme
- appropriately qualified staff operate the scheme
- the scheme's management is committed to refining the scheme's operations.

7.2.1 Organisational commitment

It is important that the organisation responsible for managing a stormwater harvesting and reuse scheme is committed to the appropriate operation of the scheme. This forms the foundation for all operational activities, as the organisation should be willing to commit appropriate funds and other resources to the scheme's operations.

The degree of management effort and commitment for a stormwater harvesting and reuse scheme should be commensurate with the scale of the scheme and the risks associated with the scheme's operation. For example, a large scheme with significant public exposure to treated stormwater should attract considerable management effort.

In many stormwater harvesting and reuse schemes, the scheme's operator is also the scheme's developer. This makes achieving organisational commitment relatively easy. However, different parts of the organisation may have been involved – a design department may have developed the scheme and the maintenance department may have responsibility for the scheme's day-to-day operation. Often these departments have separate management and budgets. The group responsible for operational management should become involved in the design phase to ensure that the scheme is cost-effective to operate and that a budget is provided for operations. Senior management should resolve any disagreements about responsibility and resourcing before committing to the scheme.

As stormwater harvesting schemes are often not cost-effective when compared solely with potable water costs, many schemes are funded by grants from external bodies (e.g. state and federal governments). In these circumstances, the organisation or department that would be responsible for management should also be involved in the decision to apply for the grant and the development of the project. As for internally funded schemes, agreement with the scheme's managers should be reached during the planning phase.

Stormwater harvesting and reuse schemes can also be constructed as part of a new urban or commercial development project. In these circumstances, the developer is responsible for the design and construction of the scheme, which is then transferred to a separate organisation for operation. This operator may be a council, water utility, golf course, body corporate or other organisation with the ability to resource the scheme's operations. The scheme's proposed operator should be involved in the project's development and agree to the scheme's design.

To provide a framework for the sustainable management of a scheme, the developer and operator should develop a written agreement during the project's development phase. This agreement should focus on the roles and responsibilities of both parties and ensure that all elements of the risk management framework are clearly attributed to one or both parties. Under these circumstances, the developer should prepare a scheme management plan for the scheme's operator. The preparation of such an agreement should be a condition of the development consent for the scheme – there are significant potential risks if the scheme's operator is not aware of their roles and responsibilities.

A similar arrangement on agreed roles and responsibilities should be developed in circumstances where one organisation collects, treats or distributes the stormwater for reuse by another organisation. Guidance on the content of such agreements can be obtained from EPA Queensland (2005b), EPA Victoria (2003) and ARMCANZ et al. (2000).

7.2.2 Qualified staff

This document has emphasised that there can be significant public health and environmental risks from the operation of stormwater harvesting and reuse schemes. Accordingly, it is important that only appropriately qualified staff manage and operate the scheme. Depending on the scheme, plumbers, electricians and specialist technicians may all be involved in operations. These staff should be suitably qualified and appropriately trained in relevant aspects of the scheme's operations and should follow the scheme's operational procedures.

If an organisation does not have the capacity to operate part or the entire scheme, it is important that any contractors used for scheme operations are suitably qualified and knowledgeable about the scheme's operational procedures and protocols.

The operator should also maintain details of training programs delivered, any training needs analysis undertaken and training records for employees and contractors.

7.2.3 Continuous improvement

The management team responsible for a stormwater harvesting and reuse scheme should be committed to the continuous improvement of the scheme's operations. This is likely to involve:

- reviewing monitoring results and assessing what, if any, corrective actions are required
- preparing and implementing a plan to address identified problems
- auditing the operation of the scheme to identify any areas where procedures are not being followed
- based on the audit results, reviewing procedures and/or retraining staff
- regularly reviewing the operations of the scheme to assess whether there have been any changes to public health or environmental hazards
- revising the risk assessment and altering the operations as required.

7.3 Operations

Key considerations for scheme operations

In operating a stormwater harvesting and reuse scheme:

- scheme commissioning should be carried out before starting routine operations
- catchment managers should identify and respond to incidents affecting the quality of stormwater entering a scheme
- appropriate incident response procedures should be in place
- appropriate equipment and materials should be used
- occupational health and safety procedures should be followed, including procedures related to working with recycled water
- appropriate records should be maintained.

7.3.1 Commissioning

The operation of all equipment and the scheme as a whole should be tested during the commissioning phase. After equipment testing, the scheme should operate normally for a certain period for quality assurance purposes – NSW RWCC (1993) recommends one month. During this time, the scheme would operate normally, although all treated stormwater would be diverted and not applied to its end use. More frequent monitoring should be carried out during this commissioning phase (see section 7.5) and action taken to address any identified problems.

The commissioning phase is particularly important for stormwater harvesting and reuse schemes, as this is a relatively new approach to water management and there is a degree of uncertainty associated with the performance of aspects of scheme design (e.g. disinfection).

7.3.2 Catchment management

Managing stormwater quality from a harvesting scheme's catchment is an important preventive measure for addressing health and environmental risks. Appropriate catchment management activities for a stormwater harvesting and reuse scheme include:

- auditing and educating staff in any commercial and industrial premises within the catchment, focusing on those presenting the most risk of stormwater pollution
- abating sewer overflows.

These activities should be carried out by or on behalf of the scheme's operator.

Information on catchment management for potable source water quality protection can be found in the Australian drinking water guidelines (NHMRC & NRMMC 2004a) – while this guidance is specifically for potable water supplies, aspects are relevant for stormwater harvesting and reuse, particularly for a scheme with residential uses.

7.3.3 Chemicals

Some chemicals used in stormwater harvesting and reuse schemes may adversely affect the quality of treated stormwater or the receiving environment (e.g. chlorine for disinfection). These chemicals should be evaluated for potential contamination and impact on the integrity of the scheme (e.g. their corrosion potential). All chemicals used in treatment processes should be securely stored and bunded (as appropriate) to avoid spills or leakage to waters.

7.3.4 Incident response

Incidents or emergencies that may compromise the operation of a scheme and hence present public health or environmental risks should be responded to in a considered way. By their nature, most incidents and emergencies are difficult to predict, in terms of their nature and timing, and a contingency planning approach to management is therefore required.

Types of incidents that could influence a stormwater harvesting and reuse scheme include:

- a chemical spill or sewer overflow in the catchment upstream of the scheme
- power failure
- failure of part of the treatment system (e.g. disinfection)
- electrical or mechanical equipment failure (e.g. pumps)
- vandalism or operator error
- algal blooms in storages
- flooding.

The incident response should follow established procedures and communicate the details to relevant stakeholders.

The project's risk analysis should assess the likelihood of foreseeable incidents or emergencies and their consequences. For serious incidents, it should identify responses in an incident and emergency response plan. Operational staff should receive training in following the plan and the plan should be tested regularly.

The scheme's operator should develop a communications procedure as part of such a plan. Depending on the nature of the scheme and the incident, the procedure should nominate a person to communicate information to any end-users of the treated stormwater, as well as the relevant council and health authorities. The notification would summarise the nature of the incident and the actions to be taken. Following the incident, when the scheme's operations have returned to normal, all parties initially notified should be advised.

As part of the incident response arrangements, the scheme's operator should arrange with the council and DEC to be notified of any major chemical spills within the catchment, and with the water supply authority to be notified of any sewer overflows.

In the case of spills or sewer overflows within the catchment or algal blooms in the storage, the operator should consider suspending operations of the scheme.

7.3.5 Occupational health and safety

Employers are responsible for the health and safety of employees, and the operator of a stormwater harvesting and reuse scheme must provide a safe working environment, including:

- ensuring that employees are not placed at risk through exposure to stormwater
- providing adequate training so that employees can work safely and responsibly
- providing well-documented work and emergency procedures, and ensuring that employees are trained in using them
- conducting regular educational and training programs to ensure up-to-date knowledge for employees
- providing employees with appropriate protective equipment, such as impervious gloves and footwear, protective masks, hats and clothing that will reduce their risk of exposure to the stormwater
- ensuring the effective and safe operation of all equipment
- ensuring maintenance of all equipment
- ensuring that employees develop and maintain good personal hygiene
- providing, where appropriate, medical assessments of employees.

It may also be useful for owners/operators of these systems to prepare safe work method statements to identify potential hazards, risk levels and controls to be implemented.

There are potential health risks to workers on stormwater harvesting and reuse schemes, which should be managed during operations. Appropriate actions may include:

- training for workers (staff and any contractors) on the public health risks and appropriate risk management activities
- immunisation for workers
- no consumption of treated stormwater – mains water should be provided for drinking
- installation of a washbasin using mains water at worker amenities
- no eating, drinking or smoking while working with treated stormwater until after hand washing with soap and mains water
- prompt cleaning with antiseptic and dressing of any wounds
- using appropriate personal protective equipment
- avoiding high exposure to treated stormwater – for example, minimising access to irrigation areas during irrigation.

7.3.6 Controlling access

As noted in sections 4 and 6, controlling access is an effective risk management strategy commonly adopted for recycled water schemes. For irrigation schemes, this normally involves restricting public access during irrigation and for a withholding period after irrigation until the application area is dry. The length of this period depends on the application rate, soil conditions and climate, and is commonly 1–4 hours in temperate areas. These access restrictions do not apply to operations staff (refer to previous section on occupational health and safety). Access control is usually achieved by fencing and may be complemented by scheduling irrigation to occur at night.

7.3.7 Operating irrigation schemes

The application of the correct amount of treated stormwater can be controlled through manual or automated techniques. For example, the soil moisture deficit can be simply computed using monthly average evapotranspiration and actual rainfall events. Irrigation is then applied according to the size of the deficit (see section 6). The irrigator will need to know how much water is being delivered by their irrigation system over a given area. At a more sophisticated level, soil moisture monitors can be used to determine when irrigation is needed. These can be linked to a computer system.

Both methods are likely to give false results under certain circumstances and other controls must be put in place to mitigate these. For example, regular checks of soil moisture in the topsoil should be made before an irrigation event to ensure that the soil is dry and needs irrigating, and after the event to check that watering has been adequate but not excessive.

Anemometers, used to determine wind speed and direction, may be used to predict the direction and extent of spray drift and can also trigger the irrigation system to cut out under high wind conditions. Wind-activated systems may also be used to start the irrigation when conditions become suitable. The wind speed at which the system cuts out can be determined by considering the proximity to public or sensitive areas, the wind direction, the height of sprayers and droplet size, and the type of irrigation system used.

Irrigation controller at Greenway Park stormwater reuse scheme, Cherrybrook

7.4 Maintenance

Key considerations for scheme maintenance

In maintaining a stormwater harvesting and reuse scheme:

- the scheme should be inspected and maintained regularly
- asset management practices should be followed.

7.4.1 Inspections

Regular inspections of a scheme are needed to identify any defects or additional maintenance required. The inspections may need to include:

- storages for the presence of cyanobacteria, particularly during warmer months

- spillways and creeks downstream of any on-line storage after a major storm for any erosion
- stormwater treatment systems
- distributions systems for faults (e.g. broken pipes)
- irrigation areas for signs of erosion, under-watering, waterlogging or surface run-off.

7.4.2 Scheme maintenance

Appropriate maintenance of stormwater harvesting and reuse schemes is important to ensure that the scheme continues to meet its design objectives in the long term and does not present public health or environmental risks.

The actual maintenance requirements will depend on the nature of the scheme. Maintenance may include measures relating to each element of a scheme, as shown in table 7.1. To help ensure that the scheme is operated and maintained appropriately, a management plan (which includes operations and maintenance) should be prepared for all schemes (see section 7.5).

Guidance on maintenance can be obtained from:

- *Managing urban stormwater: treatment techniques* (DEC 2006)
- *Operations and maintenance manual for water pumping stations* (Water Directorate, 2004a)
- *Operations and maintenance manual for water supply service reservoirs* (Water Directorate, 2004b)
- *Operations and maintenance manual for water reticulation* (Water Directorate 2003a)
- *Operations and maintenance manual for chlorination installations* (Water Directorate 2003b).

Given that sediments removed from storages are likely to be highly contaminated, it is important to ensure that they are disposed of to an appropriate waste management facility.

Table 7.1 Indicative maintenance activities

Element	Actions required
Collection	• cleaning any blockages of or damage to diversion structures (e.g. weirs) • maintenance of any pumps and rising mains
Treatment	• removal of sediment and other pollutants from stormwater treatment measures • mowing and weed control for vegetated treatment systems (e.g. swales) • regular inspection and maintenance of disinfection equipment in accordance with manufacturer's instructions, including removal of any sludge
Storage	• removal of accumulated sediment • ensuring the integrity of any fences around open storages • ensuring the structural integrity of on-line storages (e.g. downstream erosion) – an inspection of storages may be appropriate after major storm events
Distribution systems	• cleaning of any screens and filters in irrigation systems • maintenance of pumps and rising mains • fixing any pipe leaks or breakages

7.4.3 Asset management

All elements of a stormwater harvesting and reuse scheme have a nominal design or replacement life. Some elements such as concrete pipes may have a 100–150 year life, while pumps may only have a 10-year life. Appropriate asset management should be carried out for the scheme to ensure programmed replacement of elements under an associated financial plan.

Guidance on asset management can be obtained from the *International infrastructure management manual* (IPWEA, 2006).

7.5 Monitoring and reporting

Key considerations for monitoring and reporting

In monitoring and reporting on a stormwater harvesting and reuse scheme:

- water quality should be monitored during the scheme's commissioning and operational phases
- monitoring results should be reported to internal and external stakeholders
- monitoring records should be maintained for an appropriate period.

7.5.1 Monitoring

Monitoring program

Monitoring programs should be developed to ensure that public health and environmental hazards are monitored to provide sufficient data to manage the relative risk each poses. Those components that play a critical role in the scheme's risk management will require more intensive monitoring than low-risk components.

Monitoring is costly and it is therefore important to design a monitoring program that gives sound information at an affordable cost. Several guidelines and standards are available on sampling techniques (e.g. ANZECC & ARMCANZ 2000, Standards Australia 1998).

The following monitoring recommendations are a guide only and provide a basis for tailoring a monitoring program to an individual scheme. It is important that any monitoring program is site-specific and takes account of the above considerations. In particular, the frequency (how often) and intensity (number of samples) of monitoring will depend on the type and scale of the scheme, sensitivity of the site and trends identified in any previous monitoring.

In an irrigation scheme using stormwater, the key component to be monitored is the quality of the treated stormwater. Monitoring of soil characteristics is less important in such a scheme than it is in effluent irrigation because of the generally lower contaminant levels of stormwater. Where stormwater salinity levels are high, DEC (2004) provides guidance on appropriate soil monitoring.

Environmental monitoring is also not usually important for a stormwater irrigation scheme. This form of monitoring commonly assesses water quality or aquatic ecosystem health upstream and downstream of a scheme to identify any impacts the scheme may be having on water quality. As harvesting schemes commonly draw stormwater from drains or creeks any runoff from the irrigation scheme is likely to have similar or lower contaminant levels than the receiving waterway, and downstream impacts are therefore unlikely.

Monitoring of the volume of treated stormwater and any mains water used can provide useful information for optimising the operation of a scheme. This would use metering or a combination of power usage records and pump characteristics where treated stormwater is pumped within the scheme.

Commissioning stage monitoring

During the commissioning of a stormwater harvesting and reuse scheme, treated water quality should be monitored frequently and regularly. Monitoring should aim to assess the degree to which the treatment system meets the scheme's stormwater quality criteria, as part of a validation process. EPA Queensland (2005a) suggests that 20 samples be taken for validation, with sampling occurring on different days and at different times during the day. During commissioning, the treated stormwater would not normally be reused.

Operational monitoring for public health

There are currently no specific national or NSW monitoring guidelines for verifying stormwater reuse schemes to protect public health under operational conditions. National guidelines for water recycling including stormwater reuse are due in 2008, and these will include guidance on monitoring.

Until then, the most appropriate monitoring guidance available relates to the reuse of reclaimed wastewater (effluent) from sewage treatment plants, where the public health risks are probably greater than they are for treated stormwater (and are therefore conservative). Table 7.2 provides interim guidance on the frequency of stormwater quality monitoring for assessing the effectiveness of a scheme against criteria to manage public health risks in the urban environment (see table 6.4).

Stormwater quality monitoring near Wagga Wagga

The required frequency of monitoring for treated water quality should be assessed when preparing the monitoring plan. This should be a risk-based assessment, considering the likelihood of significant variability in water quality and the consequences of poor water quality. For example, a risk assessment for a small scheme irrigating a playing field with controlled public access where UV disinfection is used may result in a sampling frequency similar to that shown in table 7.1 for the scheme's first year of operation. If the scheme's performance was found to be satisfactory, a reduced monitoring frequency could be adopted. If the scheme's performance deteriorates, corrective actions should be taken and the monitoring frequency reduced until the system has re-stabilised.

As noted in section 6, the stormwater quality criteria against which monitoring results are to be compared are the median values from annual monitoring, thus half of all results could be expected to exceed this value. It is important to determine, however, whether action is needed, rather than simply waiting to see if the next results are any better. It is useful to set trigger levels above which another sample should be taken immediately. Should this sample also exceed the trigger level, operations of the scheme could be suspended until corrective action occurs and monitoring results are below trigger levels. A trigger value 50% above the adopted *E. coli* stormwater quality criteria could be adopted (EPA Queensland 2005a).

Operational monitoring for irrigation schemes

Table 7.3 suggests a basic monitoring regime for treated stormwater used for irrigation purposes, based on values for low-strength effluent (DEC 2004), in addition to monitoring for public health (above). More-frequent and/or targeted analysis should be undertaken if any of these parameters exceed recommended trigger levels. A risk-based assessment of monitoring frequency could also be carried out for irrigation water quality monitoring, as noted above.

Table 7.2 Interim guidance on treated stormwater quality monitoring for public health

Stormwater quality criteria	Monitoring frequency
Level 1[1]	*E. coli* – five days in every week turbidity – continuous pH – weekly Cl_2 – daily (for chlorine disinfection systems)
Level 2[2]	*E. coli* – weekly pH – weekly turbidity – continuous Cl_2 – daily (for chlorine disinfection systems)
Level 3[2]	*E. coli* – weekly pH – monthly Cl_2 – daily (for chlorine disinfection systems)

Notes:
1 derived from NSW RWCC (1993) and ANZECC & ARMCANZ (2000) 2 derived from DEC (2004),

7.5.2 Reporting

Monitoring results and other scheme performance information should be routinely reported to key internal and external stakeholders (e.g. the consent authority), and this would normally be annually. This would enable the operator and the consent authority to assess the ongoing performance of the scheme, in particular by comparing monitoring results to the scheme's stormwater quality criteria. The report should identify appropriate follow-up actions needed where systems are not performing adequately.

7.5.3 Record keeping

It is recommended that all monitoring results be retained for a suitable period. 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 or development consent 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 completed and further storage would not be necessary. The managers of the system should determine data storage for longer periods.

Other relevant considerations may be the need to track treatment system performance over time, monitor the performance of new technology, or maintain data on microbiological or chemical contaminants that may be of value for future projects.

Table 7.3 Interim guidance on treated stormwater quality monitoring for irrigation

Constituent	Monitoring frequency
Suspended solids	Quarterly
Total phosphorus	Biannually
Total nitrogen	Biannually
Conductivity/total dissolved solids	Quarterly

7.6 Scheme management plan

Key considerations for a scheme management plan

A management plan should be prepared for all stormwater harvesting and reuse projects, outlining:

- roles
- responsibilities
- procedures for the scheme's operations.

The scheme management plan should be reviewed regularly and after any major incident.

The proponent of a stormwater reuse scheme should prepare a management plan for the scheme and the site during the planning phase. The plan should highlight the roles and responsibilities of relevant parties and provide a framework for the appropriate operation of the scheme. The plan should be made available to all staff involved in the scheme's operations.

The content and extent of the management plan will vary depending on the nature and scale of the scheme, but could include the information shown in table 7.4.

Various sources provide guidance on water management planning for recycled water. This information can be modified to suit stormwater and applications other than irrigation:

- New South Wales – site management plan (DEC 2004, ARMCANZ et al. 2000)
- Queensland – recycled water management plan (EPA Queensland 2005a)
- Victoria – environment improvement plan (EPA Victoria 2003)
- South Australia – irrigation management plan (EPA SA 1999).

As part of the operator's commitment to continuous improvement, the management plan for the scheme should be reviewed regularly (e.g. every three to five years and after any major incident) and updated as required.

Checking the stormwater irrigation system at Greenway Park, Cherrybrook

Table 7.4	Indicative contents of a scheme management plan
Section	**Contents**
Background information	• Statutory requirements • Relevant permits or approvals • Description and flow diagram or map of the scheme, including the location of public warning signs and all underground pipes • Treatment objectives (against which monitoring data is compared)
Roles and responsibilities	• How responsibilities are shared between treated stormwater suppliers and end users (if applicable) • Responsibilities of any third parties (e.g. councils)
Operational information	• Information on operating plant and equipment • Information on operating the irrigation scheme (if applicable), such as loading rates, access restrictions, irrigation timing • Procedures for responding to non-compliance with scheme objectives (e.g. water quality criteria) • Occupational health and safety procedures, including any associated safe work methods for operations • Qualifications of personnel involved in the scheme's operations
Maintenance information	• Inspection schedules • Maintenance requirements • Safe work methods for maintenance • Asset management procedures
Incident response/ contingency actions	• Incident response protocols • Incident communications procedures • List of key stakeholders with current contact details
Monitoring information	• Operational monitoring requirements, including sampling methods • Reporting procedures