Stormwater Harvesting Guidelines

Draft 01, December 2009

water by design

Water by Design is a program of the South East Queensland Healthy Waterways Partnership

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Draft 01, December 2009

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Contents

Glossary

AHD	Australian Height Datum
ARI	Average Recurrence Interval
AR&R	*Australian Rainfall and Runoff*
ASR	Aquifer Storage and Recovery
BOD	Biochemical Oxygen Demand
CCP	Critical Control Points
CIP	Clean in Place
CLR	Contaminated Land Register
CMS	Community Management Scheme
CT	Concentration x Contact Time
DAF	Dissolved Air Flotation (DAF)
DERM	Queensland Department of Environment and Resource Management
DIP	Queensland Department of Infrastructure and Planning
DO	Dissolved Oxygen
EI	Environmental Impact
EMR	Environmental Management Register
EV	Environmental Value
HACCP	Hazard Analysis and Critical Control Point
HGL	Hydraulic Grade Line
IAF	Induced Air Flotation
MEDLI	Model for Effluent Disposal Using Land Irrigation
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
NPHC	Non-Potable High Contact
NPLC	Non-Potable Low Contact
NPMC	Non-Potable Medium Contact
ORP	Oxidation Reduction Potential
PC	Primary Contact
PRW	Purified Recycled Water
QUDM	*Queensland Urban Drainage Manual*
RL	Reduced Level
RO	Reverse Osmosis
RWMP	Recycled Water Management Plan
SAV	Stormwater Attenuation Volume
SCADA	Supervisory Control and Data Acquisition
SHIP	Stormwater Harvesting Interception Pit
SQID	Stormwater Quality Improvement Devices
SWMM	Stormwater Management Model

Glossary continued

SWTP	Stormwater Treatment Plant
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorous
TSS	Total Suspended Solids

1 Introduction

1.1 What is stormwater harvesting?

In South East Queensland, annual rainfall in urban areas exceeds annual water use. When it rains, most of this water simply runs off into our rivers and streams. Many feel this is a wasted resource that could be put to better use.

Stormwater harvesting diverts, stores, and treats stormwater runoff from urban catchments so it can be reused. Stormwater harvesting is different to roofwater harvesting, which only captures and reuses the relatively uncontaminated runoff from roof areas. Stormwater harvesting is also distinguished from large-scale surface water systems and dams.

While not included in the current South East Queensland Water Strategy as a primary source of water supply, stormwater harvesting has the potential to develop as a substantial new decentralised water source. It could improve regional water security by substitution of potable water for non-potable uses (refer to QWC report, Stormwater Infrastructure to Achieve Multiple Water Cycle Options, Bligh Tanner and DesignFlow 2009).

1.2 Purpose of these guidelines and how to use them

The purpose of these guidelines is to assist engineers and other professionals to plan, design and implement stormwater harvesting schemes. The guidelines focus on developing localised stormwater harvesting in urban areas — harvesting stormwater from local catchments and reusing it within the local community. The guidelines do not address large-scale regional or water-supply augmentation schemes that harvest runoff from multiple, large catchments into a water supply reservoir. The guidelines also apply to the development of both brownfield and greenfield sites.

The guidelines outline typical processes and typical issues that should be addressed when developing a stormwater harvesting scheme. Generic inputs and outcomes are detailed, which are suitable for skilled professionals to adapt for specific situations. Some case studies of stormwater harvesting schemes are provided.

The guidelines should be read in their entirety because the various parts of stormwater harvesting schemes are interconnected. Particular aspects of the guidelines should not be used in isolation.

1.3 Policy and planning context for stormwater harvesting in Queensland

Traditionally, stormwater was managed in Queensland by disposing of it as quickly and as hydraulically efficiently as possible. Local authorities typically required underground minor flow conveyance systems designed for storm events up to an Average Recurrence Interval (ARI) of 10 years or more. Managing overland flows was not considered in detail and flow mitigation was rarely addressed.

Over the last two decades, policy and regulations have shifted focus with greater emphasis on managing stormwater for improved environmental outcomes and on identifying alternative water sources for a range of uses.

In 1992, the first edition of the *Queensland Urban Drainage Manual* (QUDM) (Catchments and Creeks, 1992) was released. This document established the principles of managing minor and major flows and placed more emphasis on the mitigating flow increases that occur as a result of urbanisation. The main focus of the QUDM was drainage and flood management, not the environmental impacts of stormwater management in urban areas. The second edition of the QUDM, released in 2007, includes significant sections and cross-references on managing stormwater for improved environmental outcomes.

Water Sensitive Urban Design (WSUD) has become generally accepted throughout Queensland and particularly in South East Queensland. Some local authorities include WSUD requirements in their planning schemes for managing the quantity and quality of stormwater runoff from developments. Recent amendments to the State Environmental Protection (Water) Policy 1997 — Schedule 1, also provide for protection of the state's waterways. To date, the policy framework supporting WSUD has largely focused on managing stormwater quantity and quality, with little focus on the potential uses of stormwater.

Minimum water-savings targets for all Queensland local governments are set out in the Queensland Development Code (QDC). Mandatory Parts MP 4.2 (Class 1 buildings) and MP 4.3 (all other classes of building) specify water-saving targets for all buildings supplied with water from the reticulated town water supply. Where the supply is provided by a water service provider registered under the Water Act 2000. To achieve these targets, water must be obtained from sources other than the town water supply. Under the Code, acceptable solutions include:

- rainwater tanks
- greywater treatment plants
- alternative water substitution measures (including stormwater harvesting)
- a combination of these solutions.

More recently, the Queensland Government's Department of Infrastructure and Planning released the *Implementation Guideline No. 7 — Water Sensitive Urban Design Objectives for Urban Stormwater Management*, (DIP & HWP 2009) as part of the South East Queensland Regional Plan (2005–2031), which outlines the following design objectives for managing stormwater (refer also to Section 2.5.5):

- Manage stormwater quality: to protect receiving water by reducing the percentage of sediment, phosphorus, nitrogen and litter in stormwater runoff generated by urban development, compared with that in untreated runoff
- Improve waterway stability: to reduce exacerbated in-stream erosion downstream of urban areas by controlling the magnitude and duration of sediment transporting flows.
- Manage the frequency of flows: to protect in-stream ecosystems from the effects of more frequent runoff by capturing the initial runoff from impervious areas. In developed catchments, this will ensure that the frequency of hydraulic disturbance will remain similar to what it was before development.

The *Implementation Guideline No. 7* is specific to South East Queensland but is consistent with the recently released *Draft State Planning Policy for Healthy Water 2009 (DERM 2009)* and the *Draft Urban Stormwater Queensland Best Practice Environmental Guidelines 2009* (DERM 2009).

There is no particular approval or regulatory framework for stormwater harvesting; however, under the *Environmental Protection Act 1994*, there is a General Environmental Duty to protect the environment from adverse impacts. Section 319(1) of the Act requires that 'a person must not carry out any activity that causes or is likely to cause environmental harm unless that person takes all reasonable and practical measures to prevent or minimise the harm'.

Implementing stormwater harvesting schemes can assist developers address these policy requirements.

1.4 Relevant legislation, regulations and policy

These guidelines do not address the implications of current state legislation, regulations and policy on stormwater harvesting schemes. However, it is important that developers of stormwater harvesting schemes recognise that relevant documents exist. Developers should become familiar with the contents of these documents and their implications before implementing a stormwater harvesting scheme. The key Queensland legislation, regulations and policies relevant to stormwater harvesting schemes are outlined in Table 1-1.

Table 1-1: Outline of relevant Queensland acts, regulations and policies

Act, regulation or policy	General application
The Integrated Planning Act 1997	Principal legislation governing development and the effects of development in Queensland. Defines town planning processes in Queensland. Administered by the Department of Infrastructure and Planning (DIP).

Act, regulation or policy	General application
The Water Act 2000	Provides for the sustainable management and efficient use of water in Queensland. Establishes a system for the planning, allocation and use of water. Provides a regulatory framework for provision of water and sewerage services in Queensland. Administered by the Department of the Environment and Resource Management (DERM).
Water Supply (Safety and Reliability) Act 2008	Regulation of recycled water systems to protect public health. Covers non-potable uses and potable water supply augmentation. Focuses on larger scale systems. Allows for declaration of 'critical recycled water schemes' to ensure continuity of essential supplies. Administered by DERM.
Environmental Protection Act 1994 and Regulations [1]	Principal legislation for protection of Queensland's environment and promoting ecologically sustainable development. Defines the General Environmental Duty to protect the environment from harm. Includes the Environmental Protection Policy — Water (EPP Water) for the management of runoff water quality. Administered by the DERM.
Public Health Act 2005 and Regulations	Defines responsibilities for protection of the health of the community. Provides for regulations to be made to address public health risks (including water). Administered by Queensland Health.
Plumbing and Drainage Act 2002 and Regulations	Regulates plumbing and drainage work carried out within property boundaries. Administered by DIP.
Workplace Health and Safety Act 1995	Defines employer and supplier obligations to protect their employees, themselves and others from harm. Administered by the Department of Employment and Industrial Relations.

Federal legislation that should also be considered includes:

- *Environment Protection and Biodiversity Conservation Act 1999*
- *Trade Practices Act 1974*.

1.5 Scope and limitations of the guidelines

Stormwater harvesting schemes require input and skills from many related areas of engineering, including as a minimum: catchment management, stormwater drainage and quality management, flood management, water supply management and treatment, and civil engineering. Stormwater harvesting schemes also have implications for town planning, create ecological impacts, affect project financing and may create governance issues. All these issues and impacts require advice from relevant specialists.

The nature and scale of stormwater harvesting schemes is likely to vary significantly from project to project, depending on influences such as client needs, regulatory requirements, physical constraints (space, land use, water demands) and climate. Given the range of issues involved, these guidelines are necessarily broad and do not attempt to provide detailed technical guidance on designing all aspects of a typical scheme.

[1] SWH is not an 'Environmentally Relevant Activity' (ERA) as defined in the Environmental Protection Regulation and, therefore, does not require EPA development approval; however, the obligation to avoid environmental harm under the General Environmental Duty is relevant.

The guidelines are developed specifically for South East Queensland; however, the principles outlined have wider application.

These guidelines do not address the implications of current state legislation, regulations and policy on stormwater harvesting schemes. However, it is important that developers of stormwater harvesting schemes recognise that relevant documents exist. These documents are detailed in Section 1.5.

2 Getting started: planning a stormwater harvesting strategy

2.1 Introduction

It is unlikely any two stormwater harvesting schemes will be exactly the same. This is due to variability in local and catchment-scale factors, such as climate, rainfall and catchment area, differences in development layouts and types, and differences in the objectives of the scheme at the development and catchment scale.

There are a number of generic processes that must be taken into account in developing a stormwater harvesting strategy. These processes form the building blocks that will be used to create the stormwater harvesting scheme. These generic processes are shown in Figure 2-1, which illustrates a typical stormwater harvesting scheme. The detailed planning considerations for a stormwater harvesting scheme are discussed in Section 3. The detailed scheme development process using these generic components is discussed in detail in Sections 4, 5 and 6.

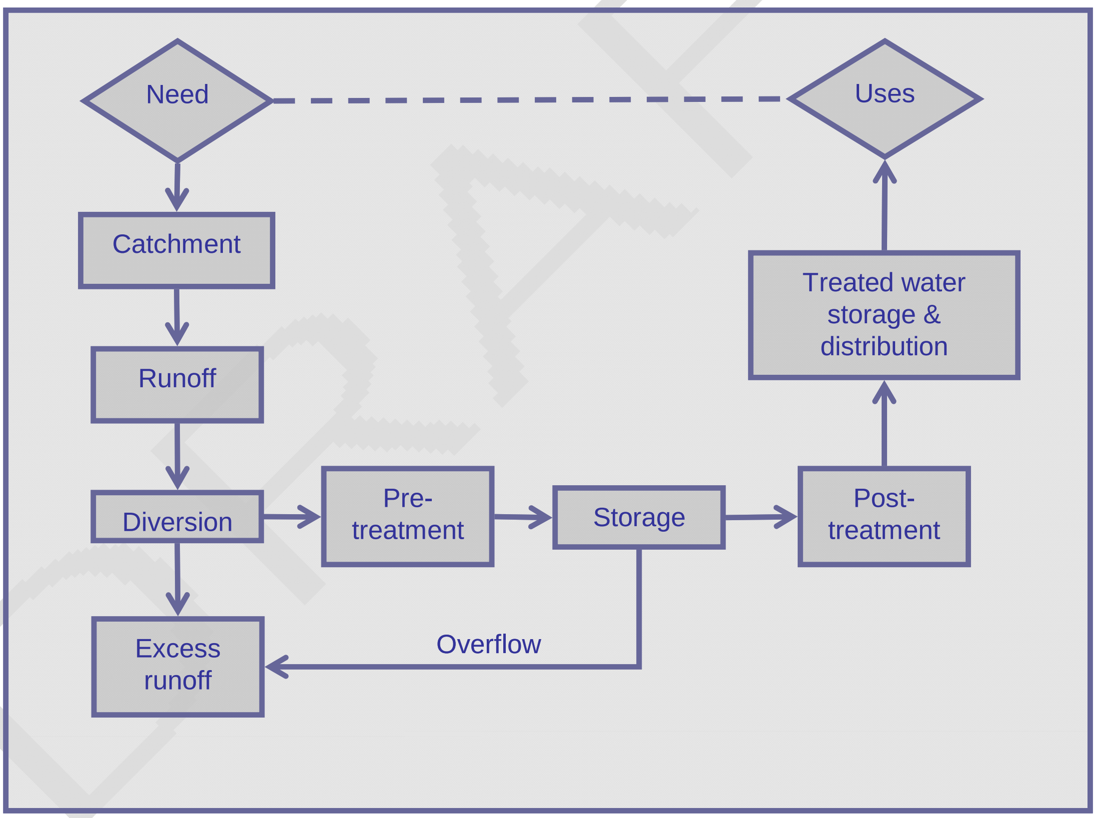

Figure 2-1: Generic stormwater harvesting flow diagram

Firstly, there must be a **need** or demand for water of an appropriate quality. Establishing need or demand is undertaken while developing the strategy.

Once the need is established, considerations about the **catchment** the stormwater is generated from are taken into account. Catchment considerations include:

- size, form and shape of the catchment
- rate of runoff
- likely rainfall
- past, present and future land uses
- management approaches
- governance issues.

The catchment generates **runoff**. The quality of the runoff must be evaluated.

Catchment runoff is **diverted** into stormwater **storage**. Storage considerations include:

- the type of diversion
- the diversion rate (influenced by the water balance)
- the storage type
- the impact of increased or decreased runoff after catchment development and diversion.

Treatment processes are required. This may include pre- and post-treatment requirements. The range of available water treatment options should be considered.

Treated water must be **stored** and a **distribution system** will deliver the treated water to the point of use.

Finally, after stormwater is harvested there is likely to remain an **excess runoff** component.

A further overarching consideration for stormwater harvesting is the question of governance, ie who will own, operate and monitor the completed scheme. This is critical because, without effective operation and maintenance, there is the potential for the scheme to fail to meet its objectives. The governance model will depend on the location and scale of the scheme but could include ownership and operation by either:

- a private entity
- a body corporate under a community management scheme (CMS)
- the regional water authority, or
- a private contractor.

2.2 Project objectives

Design objectives for stormwater harvesting vary significantly between schemes, depending on the purpose and location of the scheme. It is important that the objectives of any scheme are well defined at the planning stage, and refined early in the concept design phase. Scheme designers should set the objectives for the scheme. The parameters usually considered are:

- proposed water uses and associated water quality requirements
- likely water demands and the reliability of supply
- impact on other water supplies
- impact on stormwater catchment waterways measured by estimating pre- and post-development flow and water quality regimes
- ecological impacts of harvesting stormwater on downstream ecosystems
- standards of service
- cost of the scheme and the costs per megalitre of water supplied from the scheme
- benefits such as securing a second water supply providing a buffer to climate change impacts
- energy use
- governance issues.

2.3 The planning process

Water supply systems should be designed to meet the requirements of the development. Considerations include the location, community needs and the financial, economic and environmental impacts of the system.

Designing a stormwater harvesting system is an iterative process. Before designing the *scheme*, it is important to develop a *strategy*. To maximise the efficiency of the design process, all constraints and opportunities should be considered at an early stage in the process. The first step should be to develop a stormwater harvesting strategy to broadly scope and evaluate likely scheme arrangements, then to refine and test these against the scheme objectives.

Successful completion of a stormwater harvesting strategy requires a number of key processes:

- Defining the project objectives — the objectives should be sketched at the outset of the project and refined in the design phase.
- Identification of project needs — any stormwater strategy must be based on needs rather than on specific systems.
- Identification of project constraints and opportunities — site-specific issues must be fully understood before developing a strategy.
- Consultation with key stakeholders — this will ensure a good understanding of the needs and expectations of all stakeholders, including the community, local government and relevant state government agencies.
- Development of strategies — designed to meet needs based on an understanding of all design considerations.
- Evaluation of strategies — using a broad range of both financial and non-financial criteria to ensure that social and environmental impacts and benefits are taken into consideration.
- Identification of the specific systems and processes — these are required for successful implementation of the preferred strategy.

Figure 2-2 illustrates steps in the process of developing a stormwater harvesting strategy.

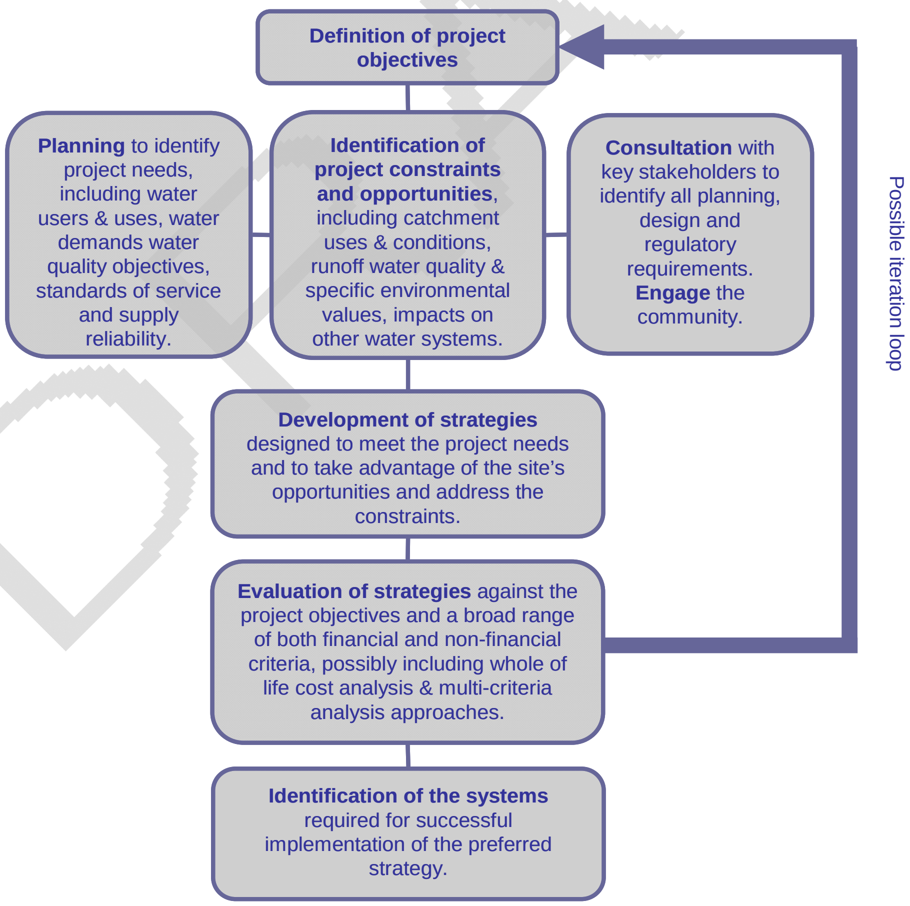

Figure 2-2: Generic stormwater harvesting strategy development

2.4 Is stormwater harvesting feasible at your location?

2.4.1 Key initial considerations

The feasibility of stormwater harvesting at any particular location will depend on the answers to the following questions:

- Is there an adequate runoff catchment?
- Are there any catchment characteristics or land uses that may adversely affect runoff water quality?
- Is there a suitable diversion point in the waterway?
- Are there any legal constraints to harvesting at that particular location?
- Who owns the infrastructure from which harvesting is proposed?
- What is the likely attitude of the Local Authority to a scheme for stormwater harvesting?
- Is there an acceptable and cost-effective storage solution?
- Are there proven uses for the water?
- Is water to be supplied to a 3rd party?

Detailed guidance on these issues is provided through these guidelines. Initial guidance to help determine whether a feasible scheme might exist is outlined below.

2.4.2 Scheme objectives

- Draft out some key objectives e.g. cost, environmental impact and water supply
- Test the outcomes against objectives
- Rework the scheme as required.

2.4.3 Catchment and diversion

- Examine available contour and detail mapping to confirm catchment boundaries and drainage lines
- Examine aerial photography to assess land uses and possible reuse and storage locations
- Examine the DERM contaminated land register
- Undertake a site inspection to visually confirm initial findings
- Estimate the available catchment area
- Estimate the potential annual runoff. For example, a catchment with 50% impervious area will generate approximately 50% runoff (refer to Figure 4-2), ie 1,000 mm of rainfall could yield 5 ML per ha of runoff
- Estimate the proportion of the runoff that may be able to be harvested. Indicatively a capture of 10-30% of runoff would give 0.5 to 1.5 ML per ha of yield.

2.4.4 Uses and demands

- Determine what water uses could be supplied with stormwater
- Estimate the area of open space that could be irrigated
- Estimate possible demand. Indicatively, household demand is approximately 200-250 kL per year of which approximately 130-140 kL could be supplied from stormwater; irrigated open space will use approximately 7.5 ML per ha per year
- Refer to Section 3 for greater detail on estimating water demands
- Compare the demand estimates with the potential catchment yield to assess whether there is the potential for the catchment to meet demands (bearing in mind that the scheme is unlikely to be able to supply more than 80% of total demand).

2.4.5 Storage

- Assess the likely storage size required for the demand and catchment estimated above using the generic yield curves provided in Section 3.8.6
- Assess whether the required storage can be accommodated on the site and how it might be constructed.

2.4.6 Statutory considerations

- Consult with affected landowners to ensure that access is available for construction of the proposed infrastructure
- Consult with Council regarding infrastructure ownership and access, and regarding planning approval requirements
- Consult with DERM regarding whether the water from the proposed waterway can be legally harvested.

2.4.7 Cost

- Refer to QWC report, Stormwater Infrastructure to Achieve Multiple Water Cycle Options, Bligh Tanner and DesignFlow 2009).

3 Detailed planning considerations

3.1 Project need

A needs-based approach to developing stormwater harvesting schemes is recommended. A whole-of-system strategy should then be developed to best meet those needs.

Forecasting for demand should follow three basic steps:

- Step 1: Define the extent of development, including the number of people or residences to be serviced (both peak and average), other non-residential facilities, and on-site activities that will use water.
- Step 2: Define unit average demand rates and, if possible, unit peak demand rates (if peak demand rates cannot be determined use appropriate peaking factors).
- Step 3: Estimate annual average, peak period and peak instantaneous demands.

To size a stormwater harvesting supply system, there are a number of issues to consider:

- Determine annual or monthly average water demands as the basis for evaluating scheme performance and viability.
- Take into account seasonal variations in demand as a result of climatic conditions (e.g. for irrigation) or variable occupancy (such as in a holiday resort). This is required as an input to water-balance modelling to improve the reliability of results.
- Consider the general arrangement of the scheme — for example if the storage is on- or off-stream or if there is a minimum size requirement for the storage.
- Use stormwater inflow patterns to determine pre-treatment capacity and storage size.
- Size treatment and storage systems based on water flow and demand patterns. Flow and demand patterns may need to be daily, hourly or instantaneous rates, so that the sizing can be undertaken with a reasonable degree of accuracy. Typically, the demand and flow considerations would apply:
    - to assess system yield — daily demands and inflows over at least a 10 year period
    - to assess diversion arrangement — daily flows and critical storm duration flows
    - to assess primary treatment capacity — event flows (if on-stream) or diversion rate (if off-stream)
    - to assess final stages of treatment capacity and distribution systems –— daily and instantaneous peak demands as well as the volume of treated water balancing storage required.

3.2 Water uses and demands

3.2.1 Proposed water users and uses

One of the critical issues for a stormwater harvesting strategy is to determine who the likely users are and the uses for the water. This should be done early in the planning phase. Suitable uses for harvested stormwater include:

- residential and commercial non-potable uses such as garden watering, toilet flushing and general maintenance
- industrial uses such as dust suppression, concrete batching or specific process applications
- community facilities uses such as irrigation, toilet flushing and possibly swimming pools
- fire fighting.

The uses are influenced by the feasibility of the stormwater harvesting scheme to deliver the required quantity and quality of water to suit the proposed uses.

Stormwater harvested in a localised scheme is generally considered unsuitable for potable purposes. At a local level, it may not be practical to provide treatment processes and on-going quality controls to guarantee potable quality at all times. This is the same as the current use of recycled wastewater: it can be used for non-potable uses at a local level but can only be considered for potable water supply augmentation at a regional scale, subject to stringent, multiple-barrier treatment and operational controls. This does not rule out the possibility of regional stormwater harvesting for potable water supply augmentation; however, it is not discussed in these guidelines.

Table 3-1 outlines the acceptable uses for harvested stormwater. With appropriate levels of treatment, harvested stormwater is generally considered suitable for all uses that could be provided by treated recycled water including toilet flushing, cold water supply for laundry use, garden watering, general maintenance and car washing. Other uses not fully accepted for recycled water, such as swimming pool filter backwashing and top-up and fire-fighting, may also be possible, however, before this can occur, more specific risk analyses and management plans will need to be developed to satisfy the concerns of the relevant statutory authorities.

The existing *Australian Guidelines for Water Recycling: Stormwater Harvesting and Reuse (Phase 2)* (EPHC, NHMRC, & NRMMC, 2009) do not define specific water quality classes for various uses. Instead, the guidelines provide log reduction targets for various uses for virus, parasite and bacteria concentrations. To assist in defining treated water quality requirements, the following quality levels have been defined:

1. Primary Contact (PC) — for community swimming pools
2. Non-Potable High Contact (NPHC) — for uses with a high probability that people will come into contact with the water during use, e.g. toilet flushing, private garden watering, high-use public facilities
3. Non-Potable Medium Contact (NPMC) — for uses with a moderate probability of contact during use, e.g. low-use public facilities or dust suppression
4. Non-Potable Low Contact (NPLC) — for uses with a low probability of contact, e.g. industrial uses or where public access is effectively restricted during irrigation.

Table 3-1: Acceptable uses for harvested stormwater

Use	Acceptable	Water quality required	Comments
Residential:			
Kitchen	Not suitable	-	
Bathroom	Not suitable	-	
Laundry (cold water)	May be suitable	NPHC	
Toilets	Suitable	NPHC	
Pool filter backwash	Not suitable	-	
Pool top-up	Not suitable	-	
Garden watering	Suitable	NPHC	
Car and house washing	Suitable	NPHC	
Commercial:			
Kitchen	Not suitable	-	
Laundry	May be suitable	NPHC	
Toilets	Suitable	NPHC	
Garden watering	Suitable	NPHC	
Industrial:			
Construction or dust suppression	Suitable	NPMC/NPLC	
Concrete batching	Suitable	NPMC/NPLC	

Use	Acceptable	Water quality required	Comments
Process water	May be suitable	Process dependent	Subject to specific process requirements
Community facilities:			
Parks and gardens	Suitable	NPMC/NPLC	
Streetscape	Suitable	NPMC	
Playing fields	Suitable	NPMC/NPLC	
Water features	Suitable	NPHC/NPMC	Depends on the type of water feature
External washdown	Suitable	NPHC	
Toilet flushing	Suitable	NPHC	
Pool filter backwash	May be suitable	PC	
Pool top-up	May be suitable	PC	
Fire fighting:			
Sprinkler systems and fire hose reels	May be suitable	NPHC	
Fire hydrants	May be suitable	NPHC	

3.2.2 Water conservation

Water-efficient fixtures, fittings and appliances, coupled with the effects of drought, water restrictions and increased community awareness of the importance of conserving water, has lead to significant reductions in the demand for water. This is most clearly illustrated in South East Queensland where average residential demand dropped from around 300L per person per day in 2004, to below 140 L per person per day in early 2008. While the reduction incorporates the effects of external water-use bans, it also reflects internal household water conservation.

Water conservation measures include:

- water-efficient fixtures and fittings such as low- and dual-flush toilets and low-flow shower roses and taps
- water-efficient washing machines and dish washers
- lower water use landscaping — reduced lawn areas, incorporating native plants and mulching to improve water retention
- improved irrigation management systems for community infrastructure
- use of alternative water sources such as rainwater tanks, recycled water or harvested stormwater
- substitution of non-potable water sources where appropriate, e.g. using recycled water for road construction, dust suppression or concrete batching
- water recycling, e.g. recycling of washdown water in a car wash or wash water in commercial laundries.

Demand estimates must take account of how demands will be affected by water conservation measures. In new developments, water savings should be substantial and sustainable. The impacts of water conservation may not be as large in existing developments.

3.2.3 Water demand

Understanding proposed water uses and users can help to define 'water demand'. A number of variables contribute to defining water demand, including:

- Residential uses:

- number of residential dwellings
- average occupancy
- permanency of occupancy
- unit demand rates for internal household uses — peak, average and seasonal variations
- extent of outdoor use
- likely watering rates — peak, average and seasonal variations
- other uses such as car washing requirements.

- Commercial and industrial:
  - land use activities
  - number of staff and customers at each premises
  - unit demand rates for internal uses — peak, average and seasonal variations
  - extent of outdoor use
  - likely watering rates — peak, average and seasonal variations
  - other uses such as industrial water requirements.

- Community facilities:
  - nature of land use
  - number of people using the facilities at each site
  - unit demand rates for relevant uses — peak, average and seasonal variations
  - site areas to be irrigated
  - access control during irrigation
  - likely irrigation rates — peak, average and seasonal variations.

If relevant demand records are available, they should be used to determine demand patterns using the shortest time- step that is available and practical.

Residential uses

Average residential population across developments can be estimated using the occupancy rates provided in Table 3-2. The actual number of people in any house will vary significantly depending on a range of factors.

Table 3-2: Residential occupancy rates

Dwelling type	Size	Occupancy (people per dwelling)			
		Permanent residential[2,3]		Holiday accommodation [4]	
		Peak	Average	Peak [5]	Average [6]
Detached dwelling	1 bedroom	-	1.6	2.0	0.8
	2 bedroom	-	1.9	4.0	1.1
	3 bedroom	-	2.5	6.0	1.3
	>3 bedroom	-	3.4	8.0	1.9
	Overall mixed	-	2.8	6.7	1.5
Townhouse	Studio/1 bedroom	-	1.2	2.0	0.8
	2 bedroom	-	1.6	4.0	1.1
	3 bedroom	-	2.3	6.0	1.3

2 Residential data based on ABS Census data for 2006 Census of Population and Housing.
3 Residential development with stable permanent population and relatively few visitors or transients.
4 Tourist and holiday accommodation with transient populations.
5 Assumes a peak occupancy of two people per bedroom.
6 Assumes between 45% and 65% of rooms occupied on average (Tourism Queensland, 2008) and number of people per room between 35% and 40% of peak.

	>3 bedroom	-	3.3	8.0	1.9
	Overall mixed	-	2	5.4	1.2
Unit	Studio/1 bedroom	-	1.2	2.0	0.8
	2 bedroom	-	1.7	4.0	1.1
	3 bedroom	-	2.2	6.0	1.3
	Overall mixed	-	1.7	4.0	0.8
Resort	1 bedroom	-	-	2.0	0.8
	2 bedroom	-	-	4.0	1.1
Hotel/motel	Standard room	-	-	2.0	0.8
	Family room	-	-	4.0	1.1
Hostel	Per bed	1	0.8	1.0	0.7
Caravan park	Per site	2	1.5	2.0	0.6
Camping ground	Per site	-	-	2.0	0.6

Typical residential demands

Where available, it is preferable to use actual water demand data. Where this is not possible, the data in Table 3-3 provides a guide to estimating demands. While Table 3-3 represents demand estimates based on recent household demand research, there is no inbuilt safety factor. If the design needs to be more conservative, a safety or planning factor of 20% could be added to the demand estimates.

Where developments are supplied by non-standard water supplies, demand rates can be adjusted, taking into account the expectation that consumers relying on alternative sources, such as rainwater tanks, are usually more conscious of their water use and conserve water more effectively.

Table 3-3: Residential internal water demand rates (reticulated water supply)[7,8]

Use	Unit	Per capita internal water demand[9] (litres per person per day)			
		Standard residential[10]	Some water saving devices[11]	Most water saving devices[12]	Full water saving devices[13]
Permanent residential					
Kitchen	Per person	15	15	14	13
Laundry	Per person	50	43	35	26
Bathroom	Per person	82	76	69	63

7 Water demands based on water end use consumption analysis into Gold Coast dual reticulated households presented at OzWater'09 (Willis, R et al., 2009).

8 Assumptions regarding effect of water saving devices based on the Yarra Valley Study in the Draft Urban Water Use Study of South East Queensland (NRM, 2005).

9 Per capita water demand can vary with the number of people in the household.

10 Conventional dwellings without any water saving fixtures or appliances.

11 Conventional dwellings with some water saving devices (i.e approximately 30% penetration of water efficient devices into the development).

12 Dwellings with substantial installation of water saving devices (i.e approximately 50–70% penetration of water efficient devices into the development).

13 Dwellings with full use of all water saving devices.

Use	Unit	Per capita internal water demand[9] (litres per person per day)			
		Standard residential[10]	Some water saving devices[11]	Most water saving devices[12]	Full water saving devices[13]
Toilet	Per person	38	33	26	21
Total	**Per person**	**185**	**167**	**144**	**123**
Holiday accommodation (houses, units, townhouses) [14]					
Kitchen	Per person	15	15	14	13
Laundry	Per person	40	34	28	21
Bathroom	Per person	98	91	82	75
Toilet	Per person	46	40	32	25
Total	**Per person**	**199**	**180**	**156**	**134**
Resorts, hotels, motels [15]					
Kitchen	Per person	15	15	14	13
Laundry	Per person	10	9	7	5
Bathroom	Per person	123	114	103	94
Toilet	Per person	46	40	32	25
Total	**Per person**	**194**	**178**	**156**	**137**
Hostels, caravan parks, camping grounds [16]					
Kitchen	Per person	12	12	11	11
Laundry	Per person	40	34	28	21
Bathroom	Per person	65	61	55	50
Toilet	Per person	31	27	21	17
Total	**Per person**	**148**	**134**	**115**	**99**

Non-residential uses

Non-residential land uses need to be individually assessed to determine the nature of water use on the site and the potential water quality requirements. In many cases, non-residential uses will only generate domestic-type demands, i.e. for toilets, kitchens and showers. Where there are expected to be other uses, a number of issues should be assessed:

- data from existing similar developments
- the nature of the processes
- required daily volumes
- diurnal variations in demand

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14 Assumes 20% higher bathroom and toilet use, a 20% reduction in laundry demand and otherwise equivalent to permanent residential usage.

17 Assumes 50% increase in bathroom water demands, 20% increase in toilet demands and 80% reduction in laundry demands (i.e. off-site laundry).

16 Assumes overall usage is 20% lower than normal residential.

- the quality of the water required.

Some guidance can be found for non-residential water demands in the *Water Supply Code of Australia* (WSAA 2002), the *Queensland Planning Guidelines for Water Supply and Sewerage* (NRM 2005) and local government planning schemes.

Typical irrigation demands

There is a range of possible ways to estimate irrigation water demand including:

- discussions with users, particularly commercial operators who understand their usage
- established irrigation water models, such as the Model for Effluent Disposal Using Land Irrigation (MEDLI)[17] (CRC for Waste Management and Pollution Control et al., n.d)
- using simplified models based on applying a crop factor[18] and application efficiency to pan evaporation, i.e. daily irrigation demand x application efficiency = daily pan evaporation x crop factor – effective rainfall:
    - the application efficiency allows for losses due to spray evaporation and interception on leaves and other surfaces (typical value = 80%)
    - the crop factor is seasonally variable and crop dependent (refer to Table 3-4)
    - effective rainfall takes into account any losses due to interception, evaporation or runoff (indicative losses = 3mm/day plus 5% deep drainage)
- using simple 'rules of thumb'.

Table 3-4: Indicative seasonal crop factors for Brisbane[19]

Month	Monthly crop factor[20]
January	0.47
February	0.44
March	0.40
April	0.37
May	0.33
June	0.30
July	0.26
August	0.30
September	0.38
October	0.44
November	0.47
December	0.47
Average	0.38

Rules of thumb are useful as a starting point for planning, but they do not provide a reliable basis for detailed design. Indicative irrigation demands for South East Queensland are:

17 While the MEDLI Model was developed for recycled water irrigation, it is also applicable for use for irrigation with treated stormwater.
18 Refer to Efficient Irrigation (Connellan, 2002) for information on typical crop factors.
19 Based on moderate growth and irrigation of 10% trees, 10% shrubs and 80% turf.
20 Based on crop factors from Handreck and Black (2001) in Connellan (2002).

- average irrigation 1.5–2.0mm per day depending on the site; the lower rate could apply to most private gardens or to low-importance parklands, the higher rate to more highly managed sites
- allowances for peak period irrigation may range from 4.0–6.0mm per day, depending on the nature of the site
- lower peak use is possible if water availability is limited and irrigation is used only for plant survival
- peak irrigation demands may need to be supplied over a limited number of hours; a site with on-site storage may take the water over 24 hours and a site with no storage would need the water only during the irrigation cycle, which could be limited to six hours at night.

Irrigation demands should match the likely irrigation regime rather than the theoretical minimum plant requirements, unless a management scheme is imposed to control typical irrigation water usage.

An Irrigation Management Plan, including irrigation scheduling, and operations plans should be completed before a scheme commences operation.

Peak vs average demands

An understanding of annual and seasonal variation is very important for planning and water-balance modelling. Peak period demands (i.e. the peak week or two) may dictate treatment system capacities, whereas, peak daily demands will affect treated water storage sizing. For example:

- household internal demands in a normal residential setting are usually constant, although garden use will vary considerably with season and weather
- in residential areas with low permanent populations and high holiday populations, internal demands will vary with population
- irrigation use on public parks and sporting facilities varies with weather, season and use.

Water demands also vary diurnally with the highest residential use times typically in the early evening when internal use and garden uses coincide. Industrial and commercial uses peak during working hours and public facility irrigation may peak at night. An understanding of diurnal demand patterns is necessary for sizing treated water storages and water distribution systems, including distribution pumps and pipelines. The *Queensland Planning Guidelines for Water Supply and Sewerage* (NRM, 2005) provides some guidance on typical peaking factors used in water supply design.

Other uses

Water supply for swimming pools, water features and fountains is required for backwashing filters and to replace losses due to evaporation and leakage.

Backwash water use can be determined from manufacturer's information as well as from historical usage records if available. Alternatively, it may be estimated as:

Backwash volume = 0.05% of pool turnover based on a pool turnover every six hours [21].

Losses due to evaporation can be estimated using a simple water balance based on daily rainfall and evaporation data. If there is concern about other losses, an allowance as a percentage of total use or as a fixed daily amount, will need to be made, unless they are already quantified.

3.3 Water quality for stormwater harvesting

3.3.1 Water quality guidelines

The intended end use of harvested stormwater determines relevant water quality targets. Water quality is related to the water's end use because the end use determines the likely exposure of people and the environment to the water. For example a high-exposure use, such as swimming pool top-up, requires much

21 Waste backwash volume based on industry sources. Recommended turnover rate from Queensland Health's *Swimming and Spa Pool Water Quality and Operational Guidelines*, October 2004.

higher water quality than a low-exposure use such as irrigation. There are a number of guidelines relating to water quality that must be taken into consideration when developing stormwater harvesting systems.

Intended uses can be categorised as requiring 'potable' or 'non-potable' water quality, depending on the level of exposure people will have to the water. Indicative potable and non-potable uses are provided in Table 3-5.

Table 3-5: Intended use and potable and non-potable classification

Intended Use	Classification
Irrigation	Non-potable
Water features (not swimming pools)	Non-potable
Toilet flushing, general wash down and cleaning and incidental use	Non-potable
Swimming pool filter backwashing (provided final filter flush uses potable water)	Non-potable
Swimming pool top-up	Potable

The *Australian Guidelines for Water Recycling: Stormwater Harvesting and Reuse – Phase 2* (EPHC, NHMRC, & NRMMC, 2009) is the most relevant reference guideline for specific water quality targets for stormwater intended for non-potable uses.

In addition, there are a number of guidelines that relate specifically to the end use of water that may come from stormwater harvesting. The relevant guidelines discuss water recycling through indirect and direct augmentation. Indirect augmentation is water that is recycled into a receiving water body and mixed with surface runoff before re-treatment and use. Direct augmentation means treated water is put directly into the distribution system for use. Direct augmentation reduces the scope to monitor water quality and intervene before it is delivered to users. Direct augmentation often has a greater level of risk than indirect augmentation and it relies more heavily on the reliability of treatment processes.

The relevant guidelines are shown in Table 3-6.

Table 3-6: Guidelines relevant to stormwater harvesting and appropriate applications

Guideline	Application				
	Toilet flushing	General external washdown	Swimming pool filter backwash & top up	Public space irrigation	Refilling water features
Australian Guidelines for Water Recycling: Managing Health and Environmental Risks (Phase 2): Stormwater Harvesting and Reuse (EPHC, NHMRC, & NRMMC, 2009)	√	√	x	√	√
Managing Urban Stormwater: Harvesting and Reuse (DEC NSW, 2006)	√	√	×	√	√
Australian Guidelines for Water Recycling (Phase 1) (NRMMC, EPHC & AHMC, 2006)	√	√	√	√	√
Water Quality Guidelines for Recycled Water Schemes (NRW November, 2008)	√	√	√	√	√
Public Health Amendment Regulation No.1 (28)	√	√	√	√	√

Guideline	Application				
	Toilet flushing	General external washdown	Swimming pool filter backwash & top up	Public space irrigation	Refilling water features
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, ARMCANZ, 2000)	×	×	√	√	√
Guide to the Workplace Use of Non-Potable Water Including Recycled Waters (Workplace Health and Safety QLD, 2007)	√	√	×	√	√
Water Quality Targets: A Handbook (Environment Australia, 2002)	×	×	√	√	√
Qld Health Swimming and Spa Pool Water Quality and Operational Guidelines (Queensland Health, 2004)	×	×	√	×	×
Australian Guidelines for Water Recycling: Augmentation of Drinking Water Supplies (Phase 2) (EPHC, NHMRC & NRMMC, 2008a)	√	√	√	×	×
Guidelines for Managing Risks in Recreational Water (NHMRC, 2008)	×	×	√	×	×
Queensland Water Quality Guidelines (EPA QLD, 2006)	×	×	×	×	√
Implementation Guideline No. 7 — Water Sensitive Urban Design Objectives for Urban Stormwater Management, (DIP & HWP 2009)	×	×	×	×	×
Draft State Planning Policy for Healthy Water 2009 (DERM 2009)	×	×	×	×	×
Draft Urban Stormwater Queensland Best Practice Environmental Guidelines 2009 (DERM 2009)	×	×	×	×	×

3.3.2 Treated water quality objectives

For environmental and human health risks, the size of stormwater harvesting schemes and the level of risk, assessed in a HACCP plan (refer to Section 3.9.3), are key factors in determining water quality objectives and monitoring requirements (NRMMC, EPHC & AHMC, 2006). Preliminary water quality objectives must be specified by selecting relevant indicators for the intended use based on the guidelines discussed in Section 3.3. A number of issues must be considered in addressing the water quality objectives:

- The presence and concentration of many contaminants in untreated urban stormwater is uncertain. In some cases there is also a lack of reliable knowledge on their human health or ecological impacts.
- Deriving and applying default water quality values for both chemical and microbiological parameters is also uncertain. The guidelines should be used conservatively in conjunction with the risk-based framework (HACCP) for protecting human health and environmental values (ANZECC & ARMCANZ, 2000).

- It is impractical to set health- and environment-based targets for all micro-organisms and chemicals that may be in runoff from an urban catchment (NRMMC, EPHC & AHMC, 2006). There are issues associated with the practicality of testing for some contaminants and the cost associated with these tests.
- In most cases, monitoring does not give a result in real time, i.e. it is a reactive rather than preventative approach. For this reason, a HACCP plan must be prepared to proactively manage risks.

Water quality objectives are important for validating and verifying the treatment process. Final water quality objectives are the indicators of management performance and must be agreed to by all stakeholders (ANZECC & ARMCANZ, 2000). Monitoring the performance of the system and comparing the performance to the objectives is a vital component of a stormwater harvesting scheme.

Water quality objectives must be based on the following criteria:

- availability of guideline target values
- sensitivity of proposed uses to specific contaminants
- reliability of available information on health and environmental impacts
- representativeness of the group, e.g. E.coli as an indicator of bacterial contamination
- ease, accuracy and cost of monitoring.

The water quality requirements associated with each water quality level are outlined in Table 3-7.

Table 3-7: Treated stormwater quality Levels

Level[22]		Indicative requirements[23]	Applicable guidelines
Primary Contact (PC)		Meeting requirements for direct potable reuse	*Australian Guidelines for Water Recycling: Augmentation of Drinking Water Supplies* (EPHC, NHMRC & NRMMC 2008a)
Secondary Contact	Non-Potable High Contact (NPHC)	At least equivalent to recycled water Class A+[24]	*Australian Guidelines for Water Recycling: Stormwater Harvesting and Reuse* —Phase 2 (EPHC, NHMRC, & NRMMC 2009)
	Non-Potable Medium Contact (NPMC)	At least equivalent to recycled water Class A [24]	
	Non-Potable Low Contact (NPLC)	At least equivalent to recycled water Class B [24]	

3.4 Standards of service

Acceptable standards of service form the basis for any supply agreement between the supplier of the treated stormwater and the end user. Standards for service need to address factors such as:

- minimum residual pressure at the point of supply
- minimum flow provided
- supply reliability
- supply continuity
- water quality.

Typical standards of service are defined in:

- planning schemes for services that form part of a publicly owned asset
- the National Plumbing Code for services that are privately owned and administered.

22 There is no direct correlation between these quality levels and the applicable guidelines; however, the levels have been included as a way of highlighting the extent of treatment that may be required.

23 While the recycled water classes do not apply to stormwater recycling, they are included in this table for comparison purposes.

24 As defined in the Queensland Public Health Amendment Regulation (No. 1, 2008) and the Australian Guidelines for Water Recycling (Phase 1) (NRMMC, EPHC & AHMC, 2006).

These standards assume 100% reliability of supply. Stormwater harvesting schemes are unlikely to achieve this target, therefore, the degree of reliability must be assessed and agreed. The need for a backup supply should be considered where a high degree of reliability is required.

Similarly, the standard for flow rates and pressure could vary from the typical standards if the end use for the harvested stormwater requires alternative standards. For example, a flood irrigation scheme is likely to require relatively low flow and pressure, whereas stormwater harvested for industrial processing may need to be supplied at a very high pressure or flow rate.

3.5 Reliability of supply

Supply reliability is a critical issue — does the supply from the stormwater harvesting scheme need to be completely reliable or, if not, what level of reliability is acceptable? For example:

- Water supplied for household uses such as toilet flushing or laundry must be 100% reliable because it provides an essential public health service. To achieve 100% reliability, a backup supply from an alternative water source may be necessary.
- Water supplied for household garden use should also be reliable to meet the expectations of customers. However, under extreme circumstances this supply could be limited by restrictions.
- Water supplied for public open space irrigation can be designed to provide less than full reliability. The scale of activities and the nature of users allows management of supply limitations to be more practical, with a coordinated reduction of supply during periods of low water availability. Reducing the capacity of the system to supply extended high demands may also result in significant cost savings that can be passed onto users.
- Reliability may be achieved using multiple water sources, e.g. stormwater supplemented by potable water.

The reliability of stormwater harvesting supply can be assessed using a daily water balance. This is discussed in further detail in Section 4.5.

3.6 Project constraints and opportunities

3.6.1 Impact on other water supplies

The relationship and impact of stormwater harvesting systems on existing municipal water supplies and other water systems must be considered.

The benefits of a stormwater harvesting system to other water supplies may include:

- reduced potable water demand and therefore reduced system capacity requirements
- reduced impact of water restrictions.

The following impacts should also be considered:

- the impact of backup systems on other water supplies
- the availability of alternative water sources as a backup to the stormwater supply
- the impact of one harvesting scheme on another.

Backup systems

Depending on uses and required reliability of supply, it may be necessary to provide a backup water supply from the municipal water service. Back-up supplies can be provided by:

- supplying backup water into the treated stormwater storage (i.e. mixing the two waters)
- connecting the backup supply directly to the stormwater distribution system, i.e. bypassing the storage.

The advantage of the first option is that by using the stormwater storage to balance variable demand patterns, the backup flow does not need to supply peak flows — the normal operation of the stormwater harvesting scheme can operate uninterrupted. The advantage of the second option is that the pressure in the mains water supply is retained and can be used to distribute backup water to users. It is important that the water quality of the backup source is protected so backflow prevention is incorporated into a backup water connection. The impact of a backup supply on municipal water networks must be agreed with the local authority.

Backup supply from local authority mains may not be available if water is used for purposes not supplied by potable water, for example, irrigation during periods of water restrictions.

Alternative sources

The availability of alternative backup water sources to increase supply reliability should be considered. Possible alternatives include groundwater, recycled water or other surface water sources.

Impact on other stormwater harvesting schemes

The harvesting of stormwater runoff from a catchment may impact on other downstream water harvesting schemes. For example, diversion of the majority of flow from a significant upstream catchment to a stormwater harvesting scheme may have a significant negative impact on the ability of a lower scheme to meet expected harvesting targets. Stormwater harvesting schemes should aim to restore natural flow regimes, not deplete them.

3.6.2 Impacts on runoff flow regimes

The recently released Implementation Guideline No. 7 Water Sensitive Urban Design Objectives for Urban Stormwater Management (SEQ Regional Plan, 2005–2031) (DIP& HWP 2009) provides the requirements for managing the environmental impacts of stormwater runoff from development. In brief, Guideline No. 7 outlines three criteria:

1. Stormwater quality management:

   Achieve the following minimum reductions in total pollutant load, compared with that in untreated stormwater runoff, from the developed part of the site:

   - 80% reduction in Total Suspended Solids (TSS)
   - 60% reduction in Total Phosphorus (TP)
   - 45% reduction in Total Nitrogen (TN)
   - 90% reduction in Gross Pollutants

2. Waterway stability management:

   Limit the post-development peak one year average recurrence interval (ARI) event discharge within the receiving waters to the pre development peak

3. Frequent flow management:

   From the proposed development, capture and manage:

   - The first 10mm of runoff from impervious surfaces where the total impervious surface is 0% to 40%
   - The first 15mm of runoff from impervious surfaces where the total impervious surface is greater than 40%

Implementation Guideline No. 7 provides information relating to the background and recommended application of these objectives, along with suggested tools available to assist in demonstrating compliance.

3.7 Consultation

Community engagement encompasses a broad range of activities designed to inform and seek feedback from members of the community who may be affected by a project. The objective of community engagement must be to use the consultation process to enhance the quality and effectiveness of the project, to accommodate the needs and desires of the community and to minimise any adverse impacts on the community.

The benefits of consultation are:

- better matching projects to the needs of users and other stakeholders
- cost savings and revenue improvement can accrue to a project designed to meet need, with efficient management of the water cycle and earning revenues from water sales
- better specified projects, producing better projects in the long-term.

Consultation usually occurs at all stages of project development. The number and identity of stakeholders varies by project. Some stakeholder groups usually involved are:

- community leaders such as elected officials and interest groups such as environmental groups
- users of the stormwater
- opinion leaders
- the wider community.

A consultation strategy should be part of the overall project planning. The strategy should identify stakeholders, define the objectives for consultation and outline consultation activities. The strategy should focus on optimising stakeholder satisfaction. *Engaging Queenslanders: Get involved — Improving community engagement across the Queensland Public Sector (*DOC 2003*)* may be a useful reference for developing a community consultation program.

Methods for undertaking consultation are set out in Table 3-8.

Table 3-8: Consultation methods [25]

Method	When to use
Personal interviews	When detailed qualitative and quantitative information is required More influential stakeholders providing input When two-way information exchange is required
Telephone interviews	Large amount of data to be collected quickly
Focus groups	Discussion of ideas, generation of new ideas When contextual information is required
Web page comments or blog	Provides detailed information on proposals To obtain written comment on proposals
Community meetings	Presentation of concepts and new ideas Some cross-discussion of ideas
One way communication e.g. newsletters, advertisements, media editorial	To develop community awareness
Written surveys	When detailed statistical information is required
Town hall meetings	When information dissemination is to a larger number of people and their comments are needed
Selling	In situations where there is a need to obtain support for a particular proposal Avoid using selling as an alternative to more appropriate forms of consultation

25 Also refer to Engaging Queenslanders: A guide to community engagement methods and techniques (DOC Undated).

In the project development phase, liaising with key government agencies will enable the project team to test proposals, identify applicable legislation and to confirm approval requirements. The principal agencies to be consulted may include:

- Local government authorities for:
  - local government planning requirements and laws
  - plumbing and drainage approvals
  - access to local government-owned stormwater drainage systems
- Queensland Department of Environment and Resource Management (DERM) for:
  - acceptable environmental outcomes
  - general environmental duty
  - requirements under the *Water Act 2000*
  - requirements under the *Water Supply (Safety and Reliability) Act 2008*
  - specific advice on water recycling.
- Queensland Health for:
  - acceptance of specific uses potentially affecting public health, including uses not well covered by existing guidelines, such as swimming pools
  - requirements under the *Public Health Act* 2005
- Department of Infrastructure and Planning (which incorporates Local Government) for:
  - planning issues associated with the *Integrated Planning Act* 1997
  - issues under the *Plumbing and Drainage Act* 2002.
- Other specific users.

3.8 Development of strategies using typical yield curves

3.8.1 Introduction

The information in this section can assist designers gain an initial indication of the potential performance of a stormwater harvesting proposal. The simplified curves provide an approximation of the anticipated water yield from stormwater harvesting in South East Queensland, covering a range of assumptions about catchment rainfall, catchment development and water demand. The curves do not replace site and project-specific analyses. However, the curves provide order-of-magnitude information to assist in determining the options that warrant further investigation.

3.8.2 Conceptual model

The conceptual model for the stormwater harvesting yield curves is shown in **Error! Reference source not found.**.

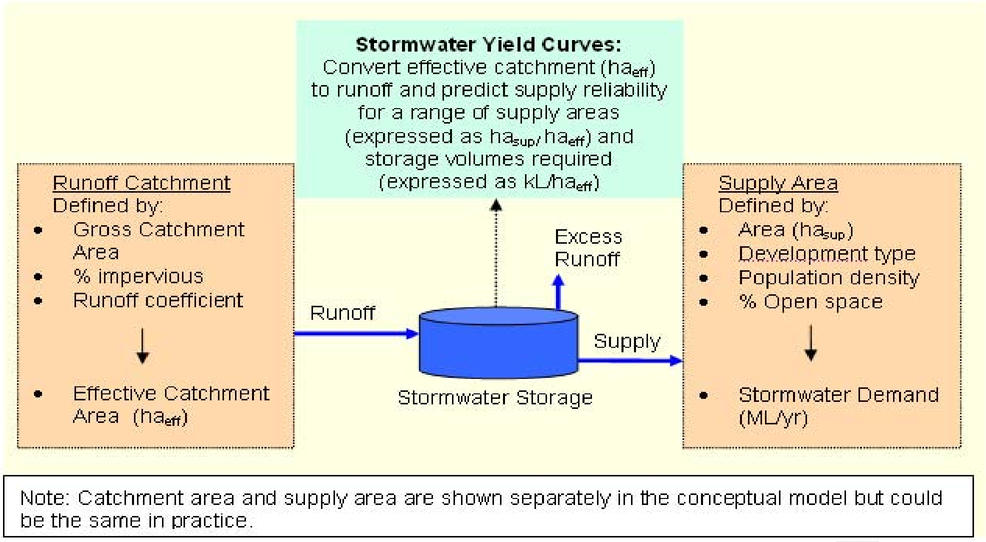

Figure 3-1: Conceptual model for stormwater harvesting yield curves

3.8.3 Rainfall

Analysis of rainfall patterns across Queensland show that the state can be divided into eight Rainfall District Groups (illustrated in Attachment B). Each group represents an area with a similar rainfall distribution, rather than similar rainfall depth. South East Queensland is covered by Group 3. Group 3 is divided into four sub-regional groups (refer to Attachment C) to represent some of the observed regional variability in average rainfall across South East Queensland.[26] Table 3-9 summarises rainfall data for the 4 sub-groups.

Table 3-9: Sub-catchment rainfall for South East Queensland (Group 3)

Sub-group no.	Sub-region	Adopted climate location	Mean annual rainfall for simulation period mm/year[27]
1	Greater Brisbane	Brisbane Airport	1,157
2	North Coast	Nambour	1,681
3	Western Region	Amberley	834
4	South Coast	Nerang	1,435

Other assumptions:

- the impact of climate change (e.g. reduction in rainfall) is not included[28]
- all runoff is captured, i.e. the diversion operates at full capacity for all storm events
- any captured runoff that is not used overflows from the storage back to the waterway
- the stormwater storage starts at 50% full.

26 Sub-groups regions for South East Queensland are based on WSUD Technical Guidelines for South East Queensland — Version 1 (Healthy Waterways Partnership, 2006).

27 Rainfall data is from the NRW SILO database for period between 1 January 1955 and 31 December 2006.

28 The sensitivity of the model to climate change was analysed. Given the large number of factors affecting the accuracy of the model, climate change is not considered to be significant in this broad scale model.

3.8.4 Step 1: Define effective catchment area

The effective catchment area, or effective impervious catchment area, is the area that equates to 100% runoff. It excludes losses, roofwater harvesting areas and infiltration from pervious areas. The steps involved in defining the effective catchment area are:

- determine gross runoff catchment area (ha_{cat})
- estimate the impervious area of the catchment — Table 3-10 provides guidance on typical impervious percentages for different development types
- Figure 4-2 provides the relationship between annual runoff percentage and percentage of impervious surfaces for a range of annual rainfall scenarios
- Effective Catchment or Effective Impervious Catchment Area (ha_{eff}) = Total Catchment Area (ha_{cat}) x Annual Runoff Fraction.

Table 3-10: Typical percentage of impervious areas for development types[29]

Catchment development type	% impervious
Undeveloped or open space	0
Partially developed low density or 50% open space	22–42
Rural residential	10–20
Low-density residential[30]	45–85
Medium-density residential	60–80
High-density residential	70–90
Commercial or industrial	90–100

3.8.5 Step 2: Define supply area and demand

a) Supply area

- Define the size of the supply area
- Define the development type:
    - residential (low, medium or high density)
    - open space.

Refer to Table 3-11 for assumptions regarding development densities for different development types.

Table 3-11: Description of development types and densities

Development type	Dwellings/gross ha	People/dwelling[31]	Garden area irrigated/dwelling m^2	Adopted irrigated open space % of gross area
Low-density residential	12	2.8	100	10%
Medium-density residential	30	2.0	10	25%

29 Based on Queensland Urban Drainage Manual — Volume 1, Second edition (NRW, 2007).
30 Includes roads.
31 Refer to Table 2.2: Residential occupancy rates.

Development type	Dwellings/gross ha	People/dwelling[31]	Garden area irrigated/dwelling m^2	Adopted irrigated open space % of gross area
High-density residential	100	1.7	5	25%
Open space	-	-	-	90%

b) Demands

Internal water demands for each development type are shown in Table 3-12. All internal demands are estimated assuming full water saving efficiency devices plus an allowance for 20% planning factor. Adopted irrigation demands are given in Table 3-13.

Table 3-12: Water demands for development types

<table>
<tr><th>Development type</th><th>Toilet flushing
L/person/day</th><th>Cold water laundry[32]
L/person/day</th><th>External use
L/person/day</th><th>Garden watering/ irrigation</th></tr>
<tr><td>Low-density residential</td><td rowspan="3">25</td><td rowspan="3">23</td><td rowspan="2">5</td><td rowspan="4">Average rate of 1.7–2.0 mm/day varying seasonally and with location (refer to Table 3-13).</td></tr>
<tr><td>Medium-density residential</td></tr>
<tr><td>High-density residential</td><td>0</td></tr>
<tr><td>Open space</td><td>-</td><td>-</td><td>-</td></tr>
</table>

Table 3-13: Irrigation demands[33]

Month		Brisbane average irrigation mm/week	Nambour average irrigation mm/week	Amberley average irrigation mm/week
1	January	22	18	22
2	February	16	12	17
3	March	14	11	15
4	April	11	9	11
5	May	7	6	7
6	June	6	5	6
7	July	6	5	6
8	August	8	8	9
9	September	14	13	15
10	October	18	17	19
11	November	21	18	22
12	December	22	19	22

32 Assumes cold water laundry is 75% of total laundry use (Source: Heathwood/Brazil Development Study (CSIRO, 2002)).
33 Based on crop factors from Handreck and Black in Connellan, G. (2001) and allowance for monthly variation based on Brisbane data.

Month	Brisbane average irrigation mm/week	Nambour average irrigation mm/week	Amberley average irrigation mm/week
Average daily demand	2.0	1.7	2.0
Total annual demand	724 mm/year	623 mm/yr	744 mm/yr

3.8.6 Step 3 Determine stormwater yield relationship

A daily time-step water balance model has been developed to calculate the supply reliability for various stormwater harvesting configurations. The model determines the proportion of stormwater demand met (%) for a range of storage volumes (expressed as kL/ha_{eff}) and a range of demand scenarios based on development type, supply area (ha_{sup}) and effective catchment (ha_{eff}).

Some important points to consider when interpreting the curves are:

- Yield is defined as the proportion of total demand supplied by the stormwater system on average (expressed as a percentage of average demand).
- The curves are presented for a range of supply areas per effective catchment area (ha_{sup} / ha_{eff}) between 0.5 and 6 ha_{sup} / ha_{eff}. That is, for a development area of 6 ha_{sup} and a stormwater harvesting catchment of 2 ha_{eff}, the curve representing this development would be 3 ha_{sup} /ha_{eff}.
- For each supply area, yield curves are shown for the wettest subgroup (Nambour), the driest subgroup (Amberley) and for Brisbane (dashed line).
- All graphs have a shaded red zone that represents the range of tank volumes typically used for each development type. The maximum tank size represents the point beyond which any increase in tank size gives a proportionately small increase in yield. The minimum tank size has been based on what is considered to be acceptable in terms of achieving a reasonable level of beneficial reuse.
- The storage volumes are effective volume and do not take into account dead storage, a top up zone and a possible stormwater attenuation volume (SAV).
- Some allowance could be made for the impact of climate change on reliability (i.e. roughly - 4% reliability).

The generic stormwater yield curves are provided below, ie:

- Figure 3-2: Generic stormwater yield curve to supply low density residential development
- Figure 3-3: Generic stormwater yield curve to supply medium density residential development
- Figure 3-4: Generic stormwater yield curve to supply high density residential development
- Figure 3-5: Generic stormwater yield curve to supply open space irrigation

A worked example of how to use the yield curves is provided as Case Study 2 in Section 7.

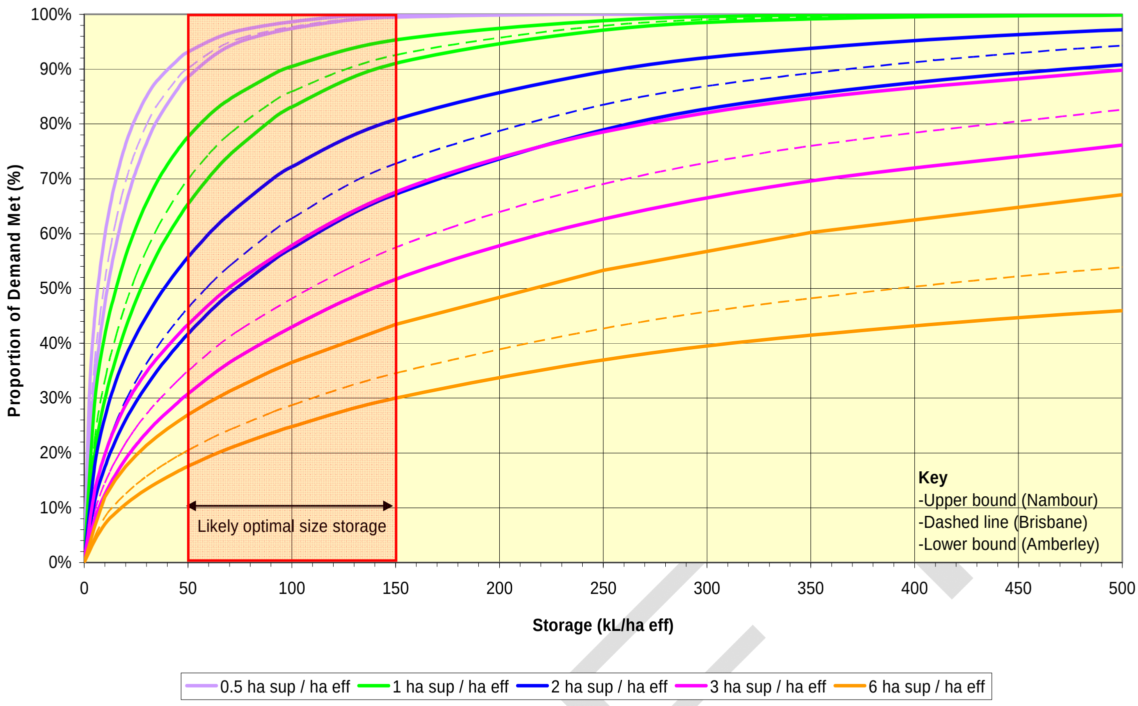

Figure 3-2: Generic stormwater harvesting yield curve to supply low-density residential development [34]

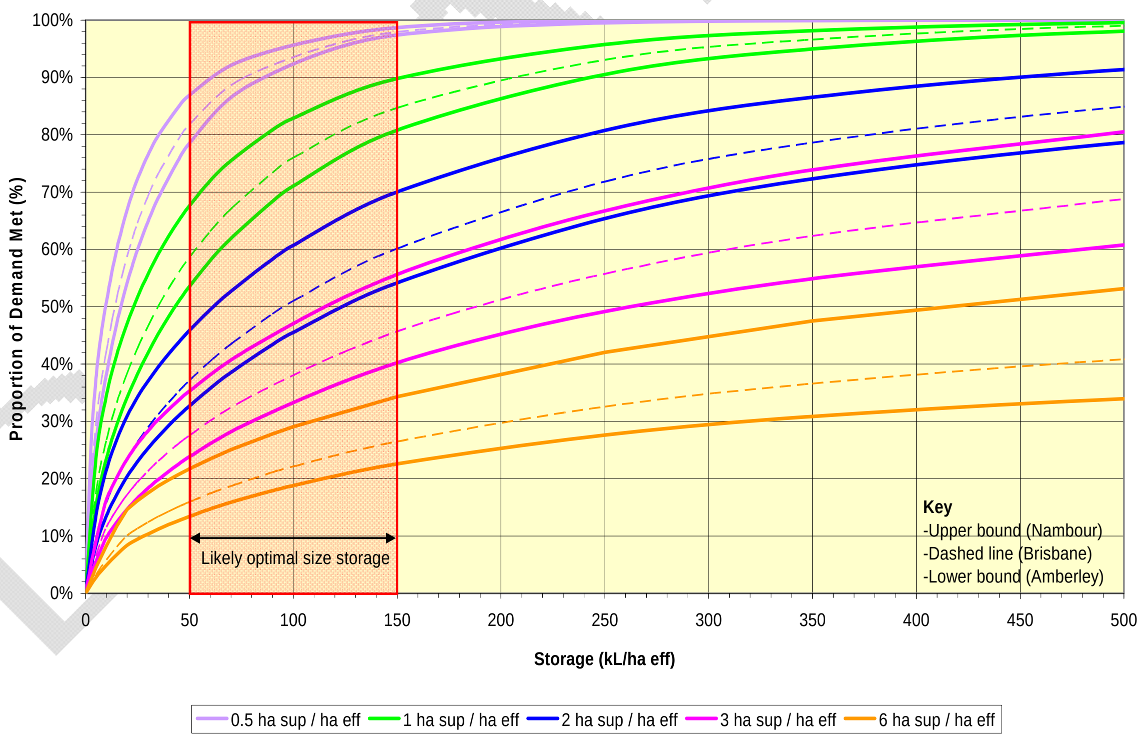

Figure 3-3: Generic stormwater harvesting yield curve to supply medium-density residential development[34]

34 Refer to Table 3-11 and Table 3-12 for assumptions regarding development types and associated water demands including irrigation areas.

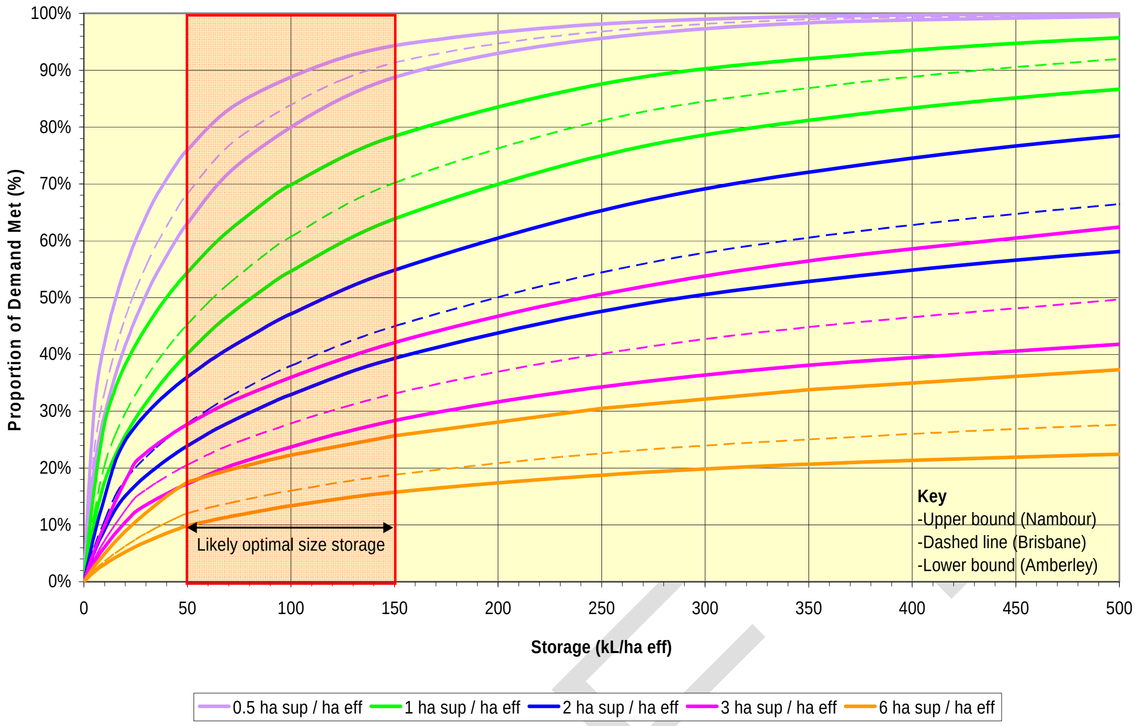

Figure 3-4: Generic stormwater harvesting yield curve to supply high-density residential development[34]

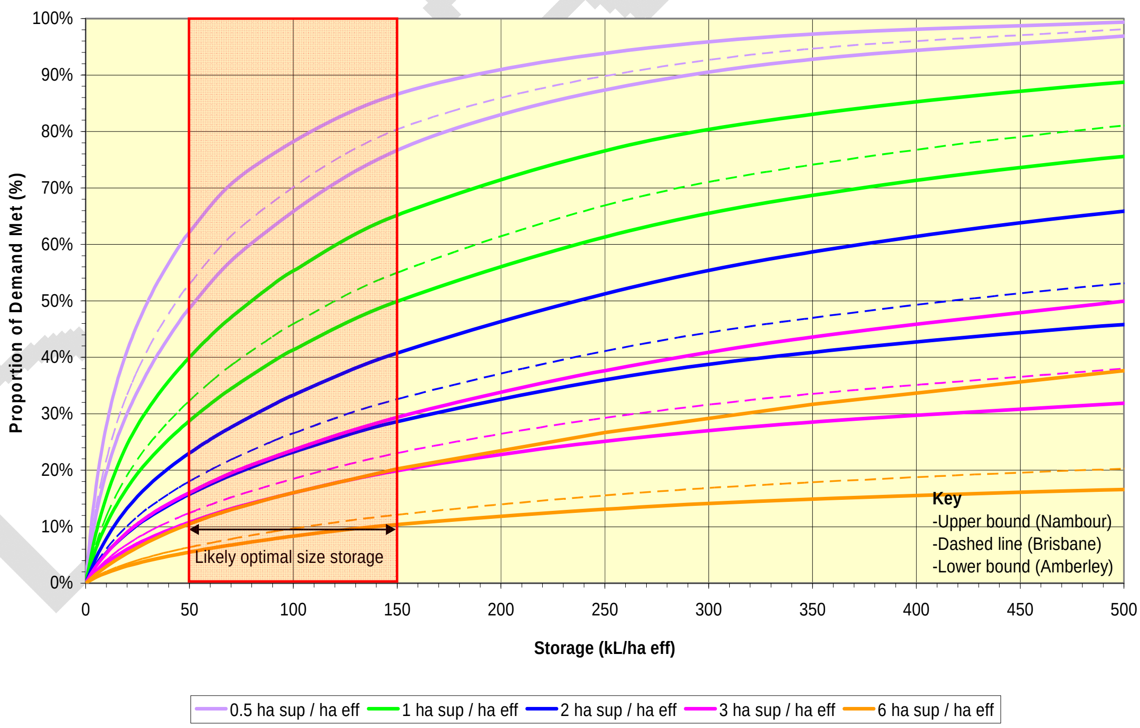

Figure 3-5: Generic stormwater harvesting yield curve to supply open space irrigation[34]

3.9 Evaluation of strategies

3.9.1 Approach

The principal considerations for the evaluation of alternative strategies follow:

- Ensure that schemes being compared are defined in sufficient detail to be able to assess their comparative strengths and weaknesses, as well as the potential beneficial and adverse impacts
- Select a suitable decision support tool / evaluation methodology, such as conventional or multi-stage multi-criteria analysis (MCA), benchmark comparison or ranking system
- Take into account the triple bottom line impacts of the schemes, ie social, economic and environmental impacts and benefits
- Consider whole-of-life cost estimates, including capital costs, recurrent operational costs and income and replacement costs
- Consider whether there are any over-riding considerations that might render the scheme unfeasible, for example legislative or political constraints
- Assess the comparative risks associated with each option and the range of control measure required to mitigate these risks.

3.9.2 Cost estimates

The costs of developing a stormwater harvesting scheme, including design, approvals, construction and operational costs, should be considered early in the development of the project, and reviewed and updated as the project progresses. A civil engineer will usually develop cost estimates, possibly supported by a quantity surveyor for ancillary works such as treatment plant buildings.

A financial analysis should aim to determine the:

- total initial capital cost
- recurrent annual costs
- present value of all costs over (say) 20 years
- unit or levelised cost of the water produced either as present value costs per ML of water produced or operating and maintenance costs per ML of water produced.

Cost estimates should consider items such as:

- diversion, storage, treatment and distribution facilities
- opportunity costs associated with land used
- design and project management fees
- application fees
- licensing fees
- operation and maintenance costs.

3.9.3 Risk assessment framework

A detailed risk assessment should be undertaken to identify the key risks associated with the project, the control systems required to manage the risks, and the key points in the system where the risks should be managed. Risk management frameworks have been adopted as the basis for developing water supply systems in Australia, including in the *Australian Drinking Water Guidelines* (2004). There are a number of similar risk management frameworks that could be used for stormwater harvesting, including AS/NZS 4360:2004 *Risk Management*, ISO 9001:2008 *Quality Management Systems* and HACCP analysis. A risk management framework based on a Hazard Analysis and Critical Control Point (HACCP) analysis is outlined in Attachment D. HACCP has been adopted for illustrative purposes because it has been used successfully on recent stormwater harvesting and water recycling projects in South East Queensland. However, HACCP is not the only risk framework suitable for stormwater harvesting projects. See Attachment D for more details on HACCP analyses.

3.10 Management issues

3.10.1 Governance issues

'Governance' is used here in the context of ownership and administration of stormwater harvesting schemes not in the context of regulation.

The ownership and administration of stormwater harvesting schemes must be addressed in the planning phase. There are two broad ownership options:

- owned as a public asset by a local or state authority
- owned privately usually by a stand-alone entity or body corporate.

Ownership by a public entity is the most straightforward option. All management responsibilities pass to the public entity. There are some issues for consideration for public ownership:

- Public authorities may require construction standards and service to be higher than those that apply to privately held assets. The functional and financial implications of this requirement need to be assessed. The applicable standards, in most cases, are established in guidelines published by the authority.
- Proponents usually need to make a strong case for an over-riding public benefit before a public authority will become the owner and manager of a stormwater harvesting scheme.

Ownership by a private entity is a viable alternative to public ownership. There are some issues for consideration for private ownership:

- The standards of construction and service are usually governed by the Australian Standards. The Australian Standards provide flexibility to designers, resulting in increased opportunities to tailor schemes to the future owners' needs, as well as their budget.
- In the case of a single owner, for example a nursery, ownership is relatively straightforward. Ownership and the responsibilities for operating and maintaining the scheme lie with one entity. Any failures in the system have a direct impact on their service, so there is a clear benefit to them to operate and maintain their system appropriately.
- Body corporates become the owner and operator of some water assets. A body corporate acts on behalf of its members or unit holders. Provided the body corporate is properly funded by its members, has appropriate skills or access to them, and is properly administered, their ownership of a stormwater harvesting system will work well. However, failure in any of these areas increases the chance of poor management of the scheme, particularly if the body corporate is not properly funded.

Governance may influence the risk management regime and end uses. For example, if there is a relatively high risk of failure in the governance of a stormwater harvesting scheme, NPLC may be a more appropriate end use than a high level use requiring more stringent quality controls.

Operating a water supply scheme that supplies to a third party may require the supplier to be registered as a Water Service Provider under the *Water Supply (Safety and Reliability) Act 2008*. Generally, this would exclude private schemes including, for example, one supplying residents in a community title development and operated by the body corporate or a resort supplying water to its guests, staff and facilities. The proponent of any water supply scheme should confirm its legal obligations under these Acts before developing the system.

Whatever the ownership structure, accountability for the proper functioning of the scheme is required and should be agreed early on in the scheme development phase.

3.10.2 Management and operations issues

The management, operation and maintenance requirements for stormwater harvesting schemes depend on a range of factors:

- scale
- nature of the catchment
- nature of the uses

- complexity of diversion, treatment and distribution systems
- ownership.

A management plan for a stand-alone scheme needs to be established, outlining a number of components:

Background information:

- statutory requirements
- relevant permits or approvals
- description and flow diagram or map of the scheme
- 'as constructed' details of the scheme, including variations to the original design
- objectives of the scheme.

Roles and responsibilities:

- a single document setting out the roles and responsibilities of the various parties
- name and address of the entity that owns the scheme
- name and address of the entity responsible for managing the scheme, including contact details such as email and phone contacts.

Operational issues:

- names and contact details of maintenance and operations staff or personnel for call out
- names and contact details of mechanical and electrical component suppliers to the scheme e.g. pump suppliers
- names and contact details of the scheme designers
- names and contact details of the scheme contractors
- copy of the HACCP
- documented procedures for rectification of scheme non-conformance
- health and safety procedures including any documented safe working methods.

Maintenance issues:

- detail inspection schedules
- document procedures for maintenance of scheme components, e.g. pump bearing replacement
- hold critical spare parts to maintain the health and safety of scheme users or to maintain scheme reliability
- document asset management procedures.

Management and monitoring issues

- maintain a sinking fund or other financial measures to provide for the ongoing management and maintenance of the scheme
- list any ongoing regulatory requirements, e.g. submit water quality testing to the local authority on an annual basis.

In some cases, the scheme will be a distributed scheme. A development may have significant distributed storage throughout a catchment or over several catchments. For example, to comply with the 'frequent flow' criteria of *Implementation Guideline No. 7*, the houses and other structures throughout large estates may incorporate stormwater harvesting at an allotment scale. While these schemes may be relatively simple, are small and use standard components, local authorities should establish a database describing the scheme. The database could be incorporated as a condition of the development, handed over to the local authority at the completion of each stage of the development.

4 Design considerations: catchment and runoff

4.1 Introduction

An overview of the design considerations relating to the stormwater catchment is shown in Figure 4-1.

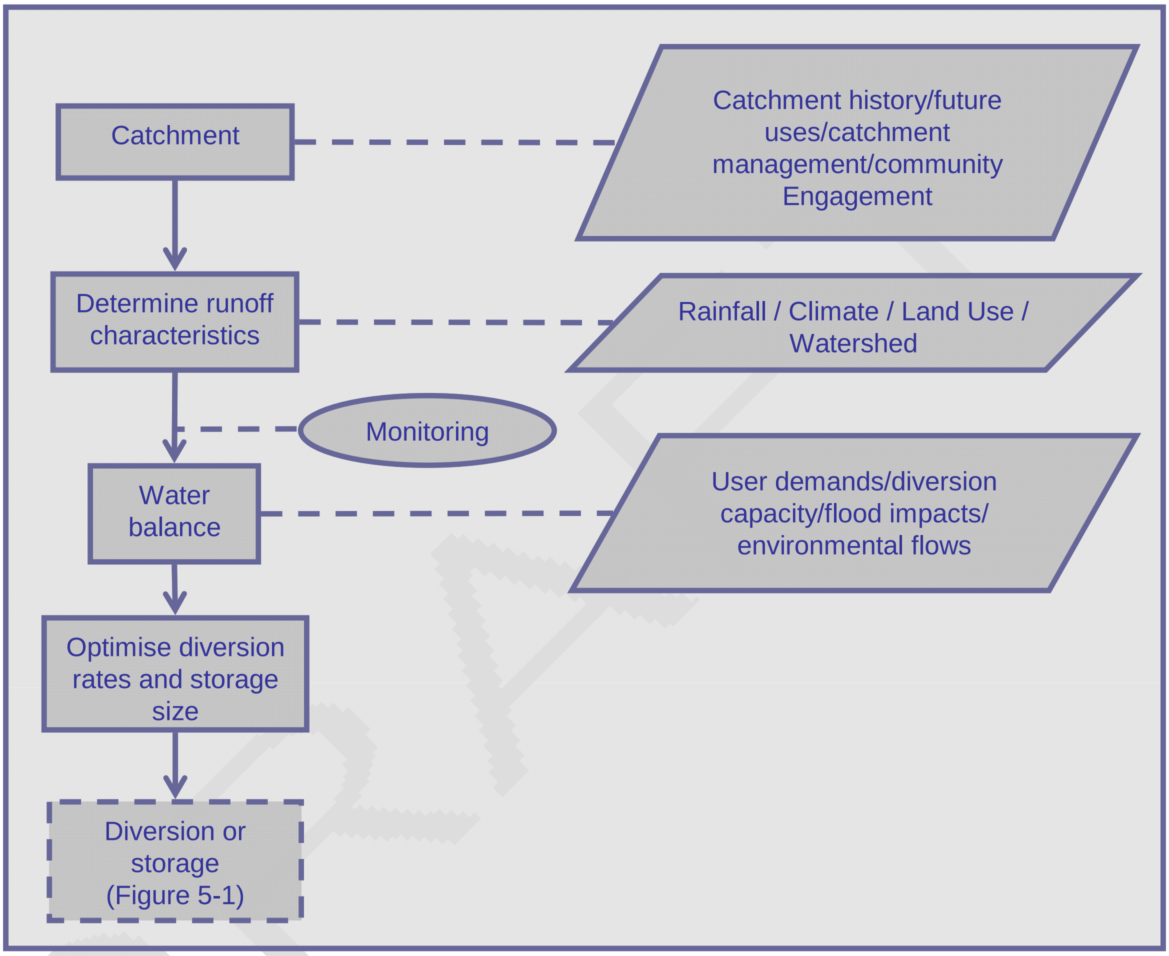

Figure 4-1: Catchment flow diagram

4.2 Catchment considerations

4.2.1 Catchment history

The history of land use in the catchment up to the present day should be considered. In particular, land uses that increase the risk of contaminating the water should be investigated. Specific catchment considerations can be found in Attachment A Table A-1.

4.2.2 Future catchment uses

The likely impacts of future land use on stormwater harvesting should be considered: Will it contaminate the water (contaminated land or hazardous land uses)? Are there services in the catchment that could burst or leak? Will the catchment remain as it is? Is major land use change planned? Will the amount of runoff change? Are there known flood issues?

4.2.3 Catchment management

Management of the catchment is primarily controlled by the town planning scheme (refer to Attachment A Table A-1 for design approaches and considerations). The relevant town planning scheme should be reviewed and assessed to determine if it applies to the proposed stormwater harvesting scheme, particularly in relation to current and future controls over the land. Other issues to consider include:

- planning by state or local authorities for future transport links
- the application of water quality and quantity guidelines to developments occurring in the catchment.

Risks identified in these assessments or in the risk management process may potentially be mitigated by specific amendments to the town planning scheme.

4.2.4 Community engagement

See Section 2.6 for a detailed discussion on community engagement processes.

4.3 Catchment runoff characteristics

4.3.1 Climate and rainfall

Climate data is available from the DERM data drill, available at: <http://www.longpaddock.qld.gov.au/silo/>. This site includes historical daily rainfall and evaporation records.

The annual distribution of rainfall, and the distribution of demand for harvested stormwater, should be considered. Assuming a relatively constant demand pattern, and a consistent rainfall pattern providing regular inflow, the requirement for storage will decrease. Conversely, if the rainfall is inconsistent and not synchronous with demand then storage requirements will increase. A daily water balance will inform this relationship, although sub-daily time steps should be considered if the data is available and practical to use.

Climate change should also be considered, particularly in respect to the likely annual yield and reliability of a stormwater harvesting scheme. The CSIRO, in their report *Climate Change in Australia science updates* (2009a and 2009b) available at <http://www.climatechangeinaustralia.gov.au/resources.php>, predict a decrease in annual average rainfall. Probable climate change impacts for South East Queensland suggest a decrease in average rainfall of approximately 7% based on present conditions between 1971-2000 forecast to 2030 (CSIRO 2009c). Impacts on water demand should also be considered. There is likely to be longer periods of little or no rain, followed by more intense storms carrying an increased portion of the total annual runoff. Antecedent rainfall conditions are likely to be different to those occurring now. Scheme designers should make their own assessments of these impacts.

4.3.2 Land use

Scheme designers should assess the impact of land use on water quality and runoff volumes. Guidance on water quality impacts is available from a number of sources, in particular:

- *Australian Runoff Quality* (Wong et al, 2006)
- local authorities' planning schemes and associated guidelines
- *Queensland Water Quality Guidelines* (Qld EPA, 2006).

4.3.3 Role of stormwater quality improvement systems in runoff quality control

Stormwater quality improvement systems can form an integral part of a stormwater harvesting regime, reducing reliance on treatment by delivering higher quality water to the system 'intake'. There are three main approaches for improving stormwater quality:

- wetlands provide inlet control, water quality control and balance storage
- bioretention systems provide a relatively high level of water quality control for stormwater runoff
- swales provide efficient sediment stripping and conveyance.

Wetlands

Wetlands can be used at the inlet zone to provide a diversion and high-flow bypass, similar to when they function simply as a water quality device. The water quality improvements obtained from the wetland may be sufficient treatment to suit the ultimate water uses, or at least provide a high quality of pre-treatment.

Wetlands can act as a balancing storage, with the deep-water zone as the primary intake point to a harvesting scheme. The impact of the stormwater harvesting scheme on the water balance in the wetland must also be considered.

Bioretention systems

Bioretention systems can connect the underdrainage from the filter to the stormwater harvesting scheme. The extended detention zone of some bioretention systems can provide balancing storage. However, significant volume losses may occur in a bioretention filter.

Swales

Swales could be used to convey water from a distributed urban catchment to the harvesting scheme inlet and to strip sediment loads from the runoff.

Other stormwater quality improvement devices could be considered; however, they may not be as applicable to a stormwater harvesting scheme. The *South East Queensland WSUD Technical Design Guidelines* (Healthy Waterways Partnership, 2006) can provide more guidance on applicable systems.

4.3.4 Model runoff regimes

The runoff rate from a catchment due to storms can be assessed by several methods. These methods are detailed in *Australian Rainfall and Runoff* (AR&R) (Institution of Engineers, Australia 2001) and in the *Queensland Urban Drainage Manual* (QUDM) (NRW 2007). QUDM also provides guidance on the appropriate levels of flood and drainage immunity for developments. Provisions of any local town planning scheme may override the QUDM.

The runoff volume from a catchment can also be assessed by several methods. The simplest method is:

$Q_v = C_v \times$ rainfall depth $\times$ area, where

Q_v is the total volume of runoff

C_v is the annual average volumetric runoff coefficient, described by Mitchell et al (2006) as:

> 'In this regard, the quantity of stormwater generated by an urban catchment is strongly influenced by the proportion of directly connected impervious surfaces in the catchment (or effective imperviousness).'

Fletcher et al. (2004) report on the relationship between imperviousness and the annual runoff fraction (or annual volumetric runoff coefficient), which is a useful graph to provide a preliminary estimate of the volume of water being generated by an urban catchment. Mitchell et al. (2006) proposed that the Annual Runoff Fraction (from In Figure 4-2), based on the percentage of impervious surface and mean annual rainfall, should be considered to be within plus or minus 0.1 of the value read off the curve (although it can never be more than 1.0 or less than 0.0).

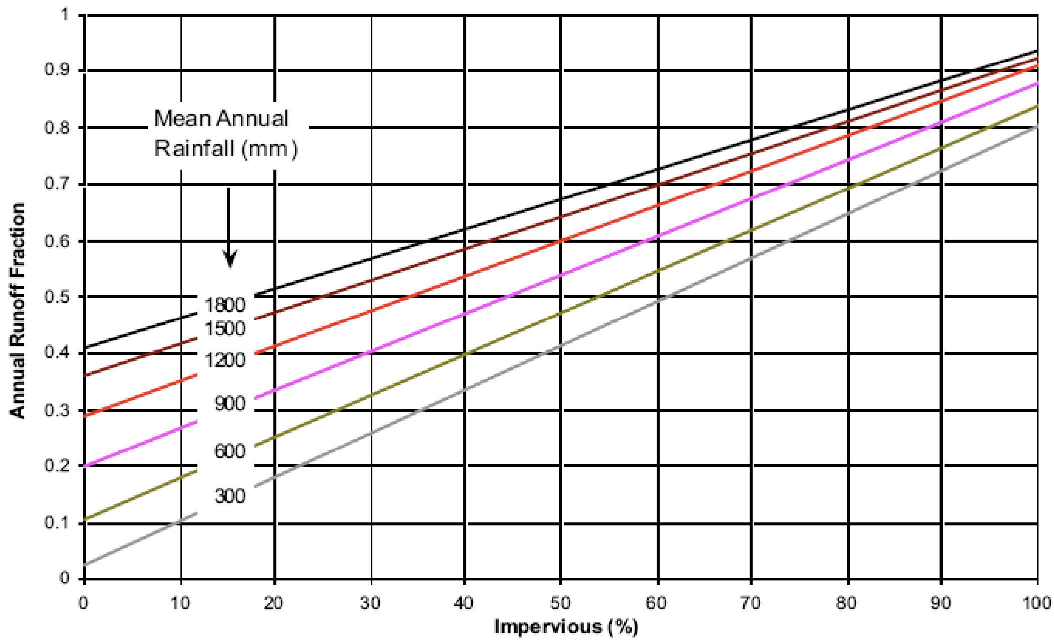

Figure 4-2: Urban runoff coefficient relationships for urban areas in Australia (Fletcher et al. 2004)

QUDM also details the volumetric runoff coefficient, providing a comparison method.

Alternatively, models such as SWMM and MUSIC determine runoff volumes, although considerable care must be taken when selecting time-steps and the loss models, or pervious catchment parameters. As shown in Figure 4-3, more than 95% of annual runoff occurs from rain events with an ARI of three months or less. Therefore, low-intensity rainfall events are critically important in a stormwater harvesting scheme. With low-intensity rainfall events, catchment losses become relatively significant, particularly where the percentage of imperviousness is low. It is recommended that these models are used by skilled professionals. Simple checks should also be undertaken, for example, by accumulating the total runoff over a year (generated by the model), and comparing it to the volume of runoff found from $Q_v = C_v \times$ rainfall depth × area.

Base flows to a system should also be considered. The estimation of base flow is difficult as base flows can result from many different and often unknown factors, e.g. groundwater, leaking sewers or water mains. If base flows are included in runoff quantities, it should be on the basis of monitored records only.

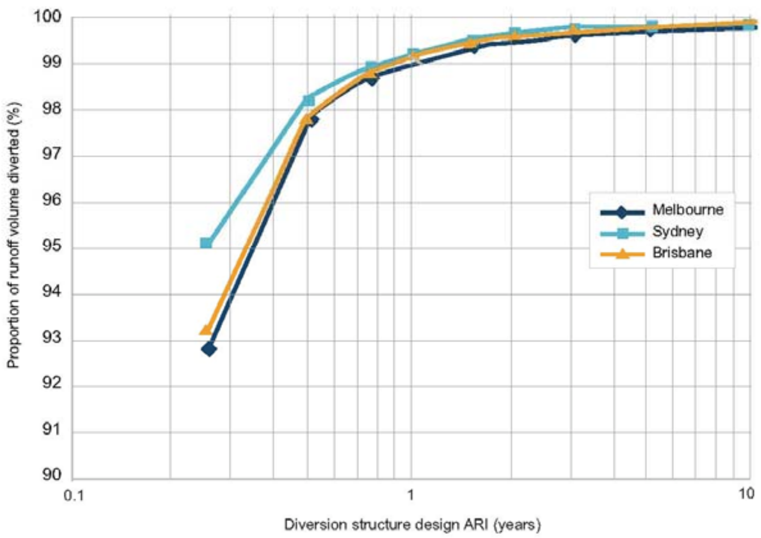

Figure 4-3: Relationship between diversion structure flow and run-off volume (Wong et al., 2000)

4.3.5 Flood impacts

The impacts of the harvesting scheme on flooding and drainage must be assessed. The methods set out in AR&R (2001) and QUDM (2007) deal with the estimation of flood levels and drainage impacts. An assessment of pre- and post-development flood levels should be undertaken. Unless specific agreement is obtained from the local authority, post-development flood levels and flow rates should not increase from the pre-development situation.

Stormwater diversion structures may constrain normal flow regimes, therefore increasing the likelihood of upstream flooding. However, more stored water from rainfall events may decrease the likelihood of downstream flooding.

4.3.6 Runoff quality

The specific issues that will inform the design of water treatment systems, and determine on-going monitoring requirements, include:

- flow rates to estimate water quality
- quality of runoff water from the catchment
- treated water quality objectives
- confirmation that the proposed treatment systems are appropriate.

Water quality needs to be considered in conjunction with the HACCP risk analysis (refer to Attachment D).

Stormwater runoff — potential contaminants

The quality of stormwater is highly variable due to the number of factors that affect water quality in an urban catchment. Mitchell et al. (2006) nominate the major factors influencing water quality as:

- climate — rainfall intensity and duration
- antecedent dry weather periods
- land use including the level of urbanisation and past and present industries
- infrastructure condition
- soil types.

The most common sources of pollution in urban stormwater runoff are atmospheric deposition, motor vehicles, erosion, leachate and chemical spills (Mitchell et al. 2006). These sources can contribute a multitude of contaminants to urban runoff. The types of pathogens found in stormwater are similar to those found in sewage; however, the levels of pathogens in stormwater are of a lower order of magnitude. (NSW DEC, 2006). The diversity of other pollutants could include some 122 pesticides (NHMRC & NRMMC, 2004), 24 herbicides and fungicides, and 24 heavy metals or metalloids (NRMMC, EPHC & AHMC, 2006).

Major contributors to stormwater pollution are roads and traffic. Table 4-1 gives a broad overview of the types and sources of contaminants associated with vehicles and roads (NSW DEC, 2006). In a catchment with major roads and relatively high traffic volumes, the pollutants in Table 4-1 could be expected in untreated stormwater runoff.

Table 4-1: Typical road runoff contaminants and their sources

Contaminant	Primary source
Sediment	Pavement wear, vehicles, atmosphere, maintenance
Nitrogen	Roadside fertiliser applications and rainfall
Phosphorus	Roadside fertiliser applications, wear and weathering
Lead	Vehicle emissions, tyre wear, lubricating oil and grease, bearing wear
Zinc	Tyre wear, motor oil, grease
Iron	Corrosion of vehicles (rust), steel structures, moving engine parts

Contaminant	Primary source
Copper	Metal plating, bearing and brush wear, moving engine parts, brake lining wear, fungicide, insecticide and pesticide application
Cadmium	Combustion, tyre and brake pad wear, insecticide application
Chromium	Metal plating, moving parts, brake lining wear
Nickel	Corrosion of welded metal plating, engines, diesel fuels and petrol exhaust, lubricating oil, brake lining wear, asphalt paving
Manganese	Tyres and brake pad wear, moving engine parts, auto exhaust
Sulfate	Roadway surfaces, fuels
Petroleum Hydrocarbons	Spills or leaks of motor lubricants, anti-freeze and hydraulic fluids, asphalt surface leachate
PCB	PCB catalyst in synthetic tyres, spraying of rights of way, atmospheric deposition
PAH	Asphalt surface leachate

Source: Ball et al. 2000, Hatt et al. 2006, 2006 Burton & Pitt 2002.

Chemical bioassays by Ball et al. (2000) indicate that the environmental toxicity of runoff is most likely due to copper and zinc. This differs from research presented in the *Stormwater Harvesting and Reuse Guidelines* (EPHC, NHMRC & NRMMC, 2009), which suggests that the key environmental hazards from stormwater used for irrigation are nitrogen, phosphorus, cadmium and iron.

The primary contaminants in urban stormwater can be grouped into manageable categories according to broad similarities in physio-chemical properties as follows (NRMMC, EPHC & AHMC, 2006):

- pathogens
- gross pollutants e.g. litter, debris and coarse sediment
- general parameters e.g. pH, odour, BOD, suspended solids, turbidity, TDS
- hydrocarbons and petrochemicals
- nutrients, primarily nitrogen and phosphorus
- surfactants
- metals, metalloids or halides
- inorganics
- organic compounds
- flame retardants
- pesticides or their metabolites including herbicides and fungicides
- algae and algae toxins
- water treatment chemicals and disinfection by-products
- oil spill dispersants.

Other groups of chemicals typically important in water resource management, but not expected to be present in urban stormwater, include:

- radionuclides
- pharmaceuticals
- personal care products
- estrogenic and androgenic hormones
- antiseptics.

4.4 Monitoring

To assist in the design of a stormwater harvesting scheme, monitoring the quality and quantity of runoff from catchments should be considered. Monitoring in this part of the stormwater harvesting scheme will:

- monitor the amount of runoff from the catchment to verify water-balance modelling

- monitor the runoff water quality from the catchment to characterise the water quality as the basis for designing water treatment systems as well as long-term monitoring strategies.

Where these conditions are well known, or where the end use is not sensitive to runoff water quality or quantity, monitoring may not be considered beneficial to the project. The aim of monitoring should be to:

- measure catchment base flows, if they exist
- measure catchment rainfall event runoff flows
- measure concentrations of contaminants of interest
- measure event rainfall depths.

Monitoring may also be useful for identifying triggers for remedial action in the event of a significant pollution event such as a sewer overflow or chemical spill.

A catchment-specific water-quality monitoring program could be considered to obtain data on contaminants and to develop more reliable and targeted long-term water-quality monitoring strategies. It could also be used to calibrate runoff quantity and quality models to assist with the design of the scheme.

The frequency and costs associated with monitoring must be considered because costs will often limit the frequency of monitoring. Nevertheless, it is desirable to:

- monitor inflows at the proposed diversion point at a time-step of, say, one-tenth of the critical storm duration
- monitor water quality as close to the diversion point as possible
- undertake at least some detailed analyses across a broad spectrum of potential contaminants to screen for contaminants of concern
- use the screening level sampling to develop a more focused water quality monitoring program.

4.5 Water balance to optimise diversion and storage

Undertaking a water balance is required to assess the reliability of the harvesting scheme, and to determine optimum sizing of the diversion and storage facilities. Initially, the water balance may be done at a relatively coarse level, for example using monthly demands and supplies. However, ultimately a daily or sub-daily time-step is necessary. The water balance is typically established in MS Excel or other software such as MUSIC or AQUACYCLE. The water balance should at least include the following parameters:

- historical rainfall and evaporation measured daily over a long time period, preferably at least 50 years, taking into account potential impacts of climate change, to determine future yields
- catchment runoff including losses from the catchment to the point at which the water is harvested
- diversion capacity, which requires sub-daily time steps or the use of synthetic storm patterns for critical storm duration (see also Section 5.3)
- storage losses via evaporation, leakage or overtopping in large rainfall events
- fluctuating demand
- any limiting factors such as maximum transfer rates from a balancing storage to treatment plant or similar.

Typically, outputs generated from the water balance are a series of curves exploring the relationships of all the variables for:

- yield vs storage size
- yield vs catchment size
- yield vs diversion capacity.

'Yield' is normally expressed as a percentage of days that demand is met in full per annum, or as a total volume supplied per annum. Only one variable is changed at a time, but a family of curves can be plotted to gain a better appreciation of the impacts of changing parameters. An example of this is shown in Figure 4-4.

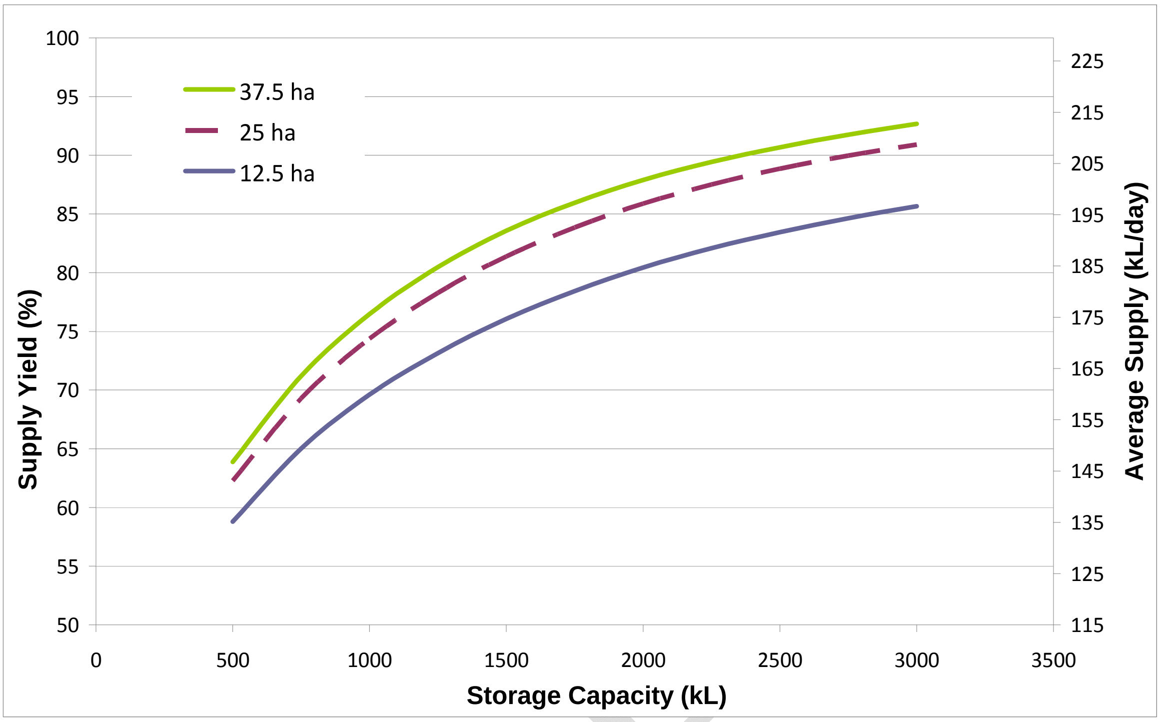

Figure 4-4: Typical yield curves for range of catchment areas and storage sizes

This water balance and associated graph shows that, at a storage size of approximately 2,000–2,500 kL, there is a marked inflection point in the storage~yield relationship. Therefore, increasing the storage size above this point does not give significant increases in reliability. It also shows that as the catchment size increases, the yield curves get closer together indicating that increasing the catchment size above 20–25 ha does not give significant increases in reliability.

Similar plots for yield versus diversion capacity create similar shapes with a marked inflection point in the curves, indicating the most efficient diversion rate for the scheme, excluding other factors like diversion cost.

More sophisticated methods of assessment are available. For example, long-term simulations can be run using software like SWMM. These methods incorporate dynamic effects, particularly related to diversion facilities like pumps. The short-term impacts of storms can also be simulated. While inevitably these methods take longer to set up and need specialist skills, they can yield more accurate results and integrate the water balance with storm impact analysis.

Water balance will be used at many stages of the design process, typically at the following points:

- Water balance is used at the feasibility stage to derive some preliminary estimates of storage sizes and likely yields. This information is often be used in a feasibility analysis for the project. The preliminary estimates provided in Section 2.8 may be useful.
- Water balance is used when the preliminary civil works' design is complete and better information is available about diversion and storage facilities, as well as more resolved figures for water demand.
- Water balance is used when detailed design is nearly complete to check the anticipated results anticipated remain achievable.

5 Design considerations: diversion and raw water storage

5.1 Introduction

An overview of the design considerations relating to the diversion and storage of stormwater from catchments is shown in Figure 5-1.

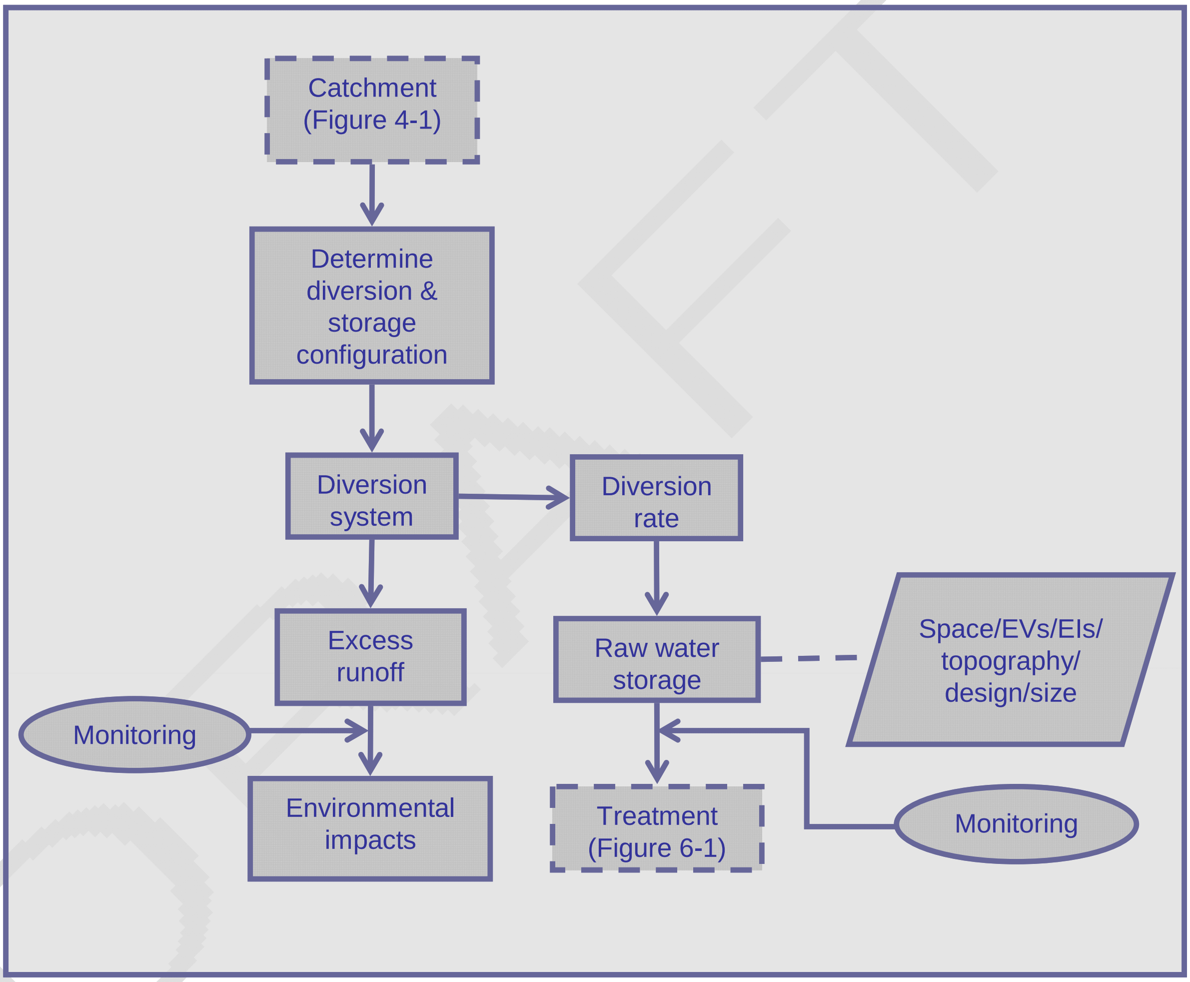

Figure 5-1: Diversion and raw water storage flow diagram

5.2 Diversion and storage configuration

The approach to runoff and storage modelling to optimise the storage volume and diversion rate is detailed in Section 4.5. The following sections outline the design considerations associated with the configuration of stormwater diversion and storage systems.

5.3 Stormwater diversion

5.3.1 Diversion system

The type of diversion system and associated diversion structures depend on a range of issues such as the harvesting location in the catchment, the drainage system, the required diversion rate and the type and volume of storage available. Specific design considerations and approaches are outlined in Attachment A Table A-2.

A primary consideration for determining the diversion type is the aim of the system. One system may seek to harvest water at all stages of flow. Another system may harvest flows only to a certain flow rate. Another system might harvest only at specific stages of flow. A stormwater harvesting system can divert all flows or only divert high flows, known as flood harvesting. Stormwater harvesting systems can also exclude the initial 'first flush'[35] flow as a water-quality control measure. Another consideration is if the storage is on-line or off-stream and whether the diversion can be provided without adverse impacts on the catchment drainage and flooding.

The objectives for the diversion include:

- ability to harvest required stages of flow
- ability to divert water at the required rate
- ability to exclude gross pollutants
- no adverse impacts on catchment drainage
- no increase in the risk of flooding
- no adverse water quality or pest impacts.

Examples of possible diversion systems could include:

- pumped diversion from a stormwater sump, detention structure or basin
- pumped diversion from an existing lake or other water body
- low-flow diversion with a high-flow bypass
- high-flow pumped diversion from a channel or waterway (flood harvesting)
- pumped diversion from behind a constructed flow control structure, such as a weir or barrage
- gravity diversion from behind a constructed flow-control structure
- filling of an in-line storage behind a constructed flow-control structure.

5.3.2 Diversion rate

As noted in Section 4.3.4, the greatest proportion of annual runoff occurs in rainfall events with relatively low ARI. The optimum stormwater diversion rate depends on a range of issues such as the catchment area, anticipated runoff rates, the type of diversion structure, the amount of temporary or buffer storage available at the point of diversion, the available bulk storage volume, water demand and the required system reliability. Specific design considerations and approaches are outlined in Attachment A Table A-2.

Depending on the catchment, the required diversion rate may be significantly smaller than the peak storm runoff rate from the catchment. There is no value in having a pumped diversion rate that can fill the storage too quickly; the optimum rate may be one that can fill the storage over a period of hours taking advantage of the full period of runoff.

Because runoff events occur over periods of hours rather than days, the optimum diversion rate cannot be determined using the daily time-step water balance model used to size the stormwater storage. A catchment runoff model that can evaluate runoff and diversion at time-steps of 6–60 minutes, depending on the catchment characteristics, is required (refer to Section 4.3.4)

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[35] 'First flush' is the concept that the first runoff from a catchment carries a higher contaminant load; however, the proportion of flow that is first flush is debated.

If a static model is used to model the diversion, selecting an appropriate time-step must be considered. Selecting an appropriate time-step for modelling the diversion rate depends on a number of factors:

1. the incoming flow rate and fluctuation pattern at the diversion
2. the diversion rate, which is normally a constant, but may vary
3. the size of any water storage at the diversion point
4. if the raw water storage is relatively small, the size of the raw water storage and its ability to buffer differences between inflow and outflow.

Guidelines that could be used to select a time-step are:

1. The diversion time-step must be equal to, or longer than, the time-step used to derive the incoming flow pattern. For example, if six-minute rainfall data is used, then the diversion time-step is at least six minutes.
2. The diversion time-step must be equal to, or less than, the time-step used to model the raw water storage yields.
3. Typically, a time-step of between 5–10 times the rainfall data time-step is used.
4. Sensitivity analysis of the time-step selection should be considered.

Alternatively, using a dynamic model will overcome these issues.

5.4 Raw water storage

5.4.1 Storage configuration

The type of storage depends on the volume required for proposed uses as well as opportunities at the site to locate and construct the storage. Specific design considerations and approaches are outlined in Attachment A Table A-2.

A small-scale stormwater harvesting scheme may use a small on-stream pond or, preferably, an off-stream tank as the primary storage. Large-scale schemes require a large storage occupying a significant footprint. In a highly developed urban area, the availability of a suitable site to locate a substantial storage may dictate the overall scheme viability.

The requirements for storage include:

- adequate volume for the proposed uses and reliability
- suitable location and site area for the storage
- ability to be accommodated into the available footprint
- inlet and outlet design details
- (ideally) covered to be exclude light and pests and to protect water quality
- aesthetic impacts
- cost-effective construction.

Examples of possible storage systems could include:

- on-line storage, probably with a high-flow bypass such as a lake or pond, a wetland or a stormwater retention system
- aquifer storage and recovery (ASR) — natural or artificial
- off-line storage such as on-ground tanks; buried tanks; or ponds, lakes and wetlands.

5.4.2 Storage size

To optimise storage capacity, a range of issues need to be addressed:

- The results of the water balance provide the optimum size of the storage.

- Storages are usually relatively large, particularly in highly seasonal climates like the majority of Queensland. The space required for a storage facility should be addressed early in the design development phase of a scheme.
- The type of storage also needs to be considered. For example, if space for an open water body is limited, then an underground storage may provide a feasible alternative, allowing for other uses on the same land.
- The cost of the storage is also a critical parameter. Open water bodies may be relatively inexpensive to construct, but the opportunity cost of the land, as well as water quality, should be considered. Aboveground reservoirs are likely to be more expensive. If reservoirs also need a pump and a rising main set-up to deliver water from the diversion, there will be ongoing operation and maintenance requirements. Underground storage is likely to be the most expensive storage option, but because it allows other uses of the land to continue, this may be a significant advantage.

5.4.3 On-line storage

An on-line storage has the advantage of simplicity with water collected into the storage without complex diversion structures and systems. This type of storage may be most appropriate where an existing pond is to be used or where the stormwater harvesting is to be integrated into the stormwater management system.

The disadvantages of on-line storage relate to the successful integration of the storage into the built environment and water quality and environmental impact associated with the storage construction and interruption to the natural stream flow.

5.4.4 Aquifer storage and recovery

Aquifer storage is an option for any water harvesting system, regardless of the source. Requirements for a aquifer storage and recovery (ASR) system include:

- that it is not compromised by adding harvested water
- that it contains the harvested water and does not lose it through lateral flow
- that it does not compromise the quality of the harvested water through mixing with other groundwaters
- that it includes a cost-effective recharge system, i.e. infiltration beds or direct injection
- that it includes a cost-effective water recovery system.

These guidelines do not address ASR in any detail. References containing more detailed information about ASR include *Australian guidelines for water recycling: Managed aquifer recharge — Draft for public comment* (EPHC, NHMRC & NRMMC, 2008b); Chapter 9 of the *Water Sensitive Urban Design Guidelines* (Healthy Waterways Partnership, 2006) and *Water Sensitive Urban Design (WSUD) Engineering Guidelines — Practice Note 10 Aquifer Storage and Recovery (BCC, no date)*.

5.4.5 Off-stream storage

An off-stream storage is relatively independent of the waterway or drainage systems, providing flexibility for locating the storage and minimising the impact on the waterway and the environment. The disadvantage of off-stream storage is that a more complex diversion structure may be required to capture the runoff during a rainfall event and transfer it to the storage.

There is an almost unlimited range of possible storage systems, from proprietary tanks and storage systems to large-scale purpose designed structures.

5.4.6 Storage location

Considerations for siting stormwater storage include:

- proximity to the diversion structure to minimise transfer infrastructure and costs
- proximity to the point of use to minimise distribution infrastructure and costs
- adequate space for the permanent structure and for construction purposes
- suitable geotechnical conditions

- suitable topography, depending on the proposed storage configuration
- potential visual impacts of the storage, particularly if above-ground
- safety issues if accessible to the public.

5.5 Excess runoff

Runoff is subject to the normal range of considerations in the management of stormwater flows. AR&R (2001) and QUDM (2007) provide more details.

5.6 Monitoring of raw water and downstream environments

The role of monitoring in this part of the stormwater harvesting scheme is to:

- monitor the water quality in the raw water storage to ensure acceptability for reuse and effective management
- to overcome a lack of data in order to calibrate or to validate a scheme design
- monitor the impact on the downstream waterways (including tidal) and environment of the stormwater diversion system.

The water entering the storage is essentially untreated except for the removal of gross solids, sediment and hydrocarbons (see Section 6.4). This water will be turbid and contain organic material, pathogens, metals and other chemical contaminants. In addition, there is the potential for the stored water quality to change as solids settle and for the water to change from aerobic to anaerobic. Sunlight may also affect the stored water quality.

Monitoring water in the raw water storage is important for a range of reasons, including:

- to ensure the water in the storage remains in good condition
- to observe changes in feed water quality to the treatment systems
- to optimise and control water treatment systems.

Monitoring downstream water quality and the environment is important to observe for changes in downstream water quality and changes in the downstream environment as a result of the harvesting scheme.

The impact of any changes will need to be considered and ameliorating actions determined.

The frequency and costs of monitoring must also be considered; the costs of monitoring will often limit the frequency with which it is undertaken. It is desirable to:

- provide real-time monitoring of critical parameters in the raw water storage, possibly including salinity, turbidity and pH
- develop a weekly monitoring program for other parameters from the storage, including dissolved oxygen (DO) bacteriological quality, nutrients, hydrocarbons (if expected) and any other parameters expected to change in the short term
- develop an annual or biannual monitoring program for parameters that are only expected to change in the longer-term, e.g. heavy metals and organic chemicals
- develop an annual or biannual downstream water quality and environmental monitoring program.

5.7 Potential environmental impacts

Diversion of stormwater from the drainage system has an impact on the downstream environment. It reduces the total volume of runoff and changes the nature of runoff events. This may impact the availability of water within the downstream environment with associated environmental effects. Monitoring of downstream systems provides a basis for determining if hydrological changes arising from the stormwater harvesting scheme and the associated environmental changes are significant.

6 Design considerations: treatment, treated water storage and distribution

6.1 Introduction

An overview of the design considerations relating to treatment, the storage of treated water and the distribution of stormwater for reuse is shown in Figure 6-1.

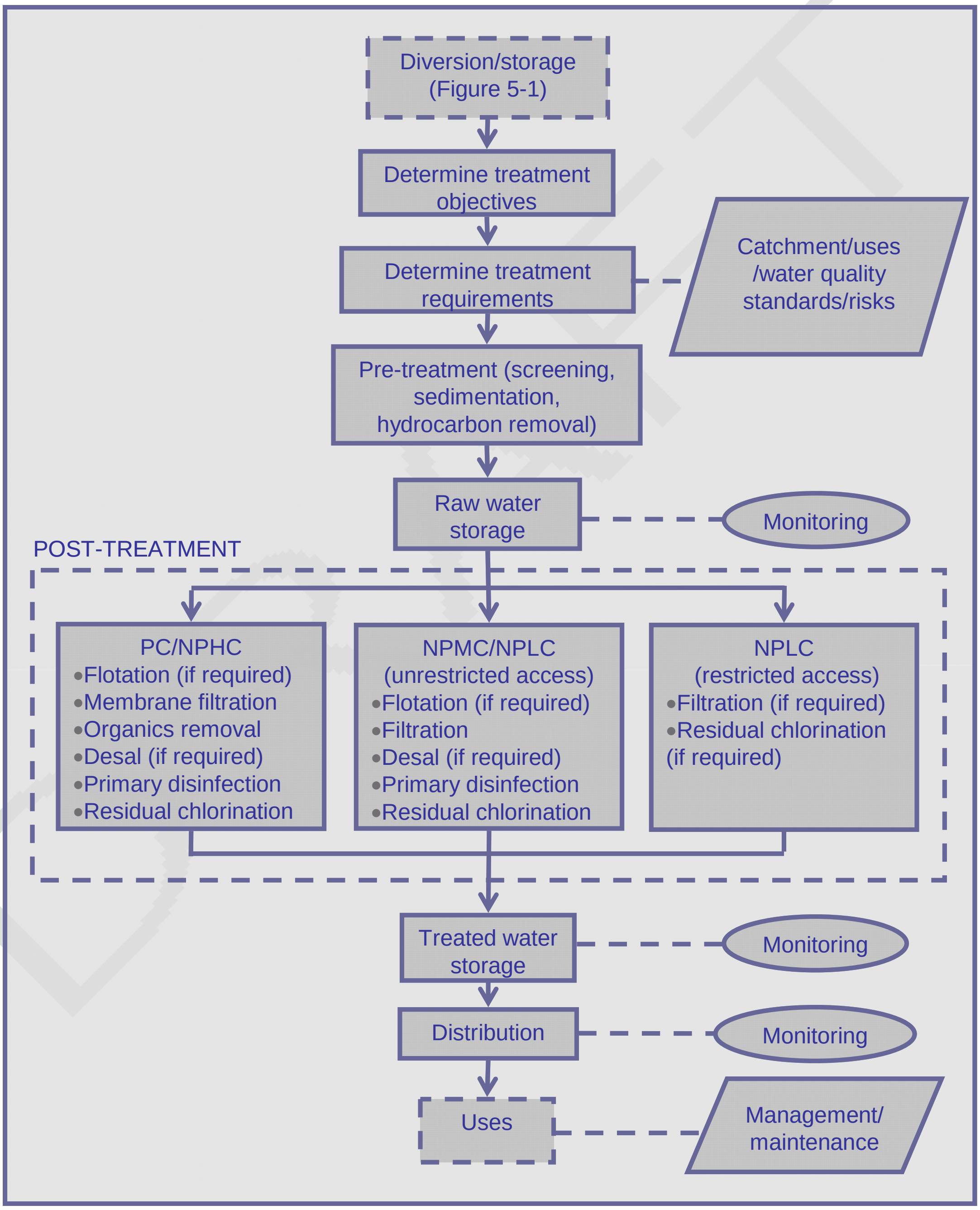

Figure 6-1: Treatment, treated water storage and distribution flow diagram

6.2 Treatment objectives

The objective of stormwater treatment is to provide fit-for-purpose water for a particular use. Treatment reduces the concentration of constituents in urban stormwater runoff likely to occur at concentrations that may be hazardous to human health or the environment. Specific design considerations and approaches are outlined in Attachment A Table A-3. The broad treatment objectives are:

- exclusion of coarse sediment and litter
- removal of settleable solids
- removal of hydrocarbons
- filtration to remove suspended solids and reduce turbidity
- activated carbon filtration or advanced oxidation to reduce organic chemicals
- disinfection to de-nature or kill pathogens
- residual chlorination.

The approach adopted for stormwater treatment can vary considerably, ranging from:

- in-catchment treatment through natural or proprietary stormwater quality improvement systems
- on-stream treatment such as wet basins, wetlands and gross pollutant traps
- side-stream treatment using screening, sedimentation basins, oil and sediment separators, filtration and disinfection processes
- combinations of all these approaches.

6.3 Determine treatment requirements

The factors that determine treatment requirements for stormwater harvesting schemes include:

- the nature of the catchment and whether the catchment incorporates water quality control devices such as wetlands, swales and bioretention filters (see Section 4.2)
- proposed water uses (see Section 3.2)
- minimum water quality standards for the proposed uses (see Section 3.2 and 3.3.2)
- identified risks associated with catchment runoff and uses (see Section 3.9.3)
- the space available for construction of water quality control systems.

6.4 Pre-treatment

6.4.1 Objectives

The objectives of pre-treatment are to remove gross and readily separated contaminants from the harvested stormwater. These contaminants may accumulate in the raw water storage and create water quality and operational issues. It is more cost-effective to exclude these contaminants before storage than to collect them and remove them at a later treatment stage.

The primary pre-treatment objectives are to remove litter, including man-made and natural litter; coarse sediments (gravel, sand, soil); other readily separated suspended solids; organic, heavy metal and chemical contaminants associated with the sediments; and hydrocarbons. A possible secondary objective, depending on the catchment, is to help manage contaminant spills within the catchment before they enter the storage and treatment systems.

6.4.2 Types of pre-treatment processes

Pre-treatment processes include:

- in-catchment stormwater quality improvement systems including detention storage, swales and bioretention filters (see Section 4.3.3)
- screening to remove litter and other large debris and objects
- sediment traps to catch the coarse sediment load

- oil and sediment separators to remove finer suspended solids and hydrocarbons
- natural systems such as constructed or naturally occurring.

Screening

The simplest type of screen is a static bar screen placed across the main flow or the inlet to the diversion system. Static screens can vary from rectangular to round bar screens with spacings of 50–100 mm to fine wedge-wire screens with apertures as low as 1–2 mm.

Use of screening systems need to consider:

- the contaminants targeted for removal
- how will the screens be cleaned
- accessibility of the screen for inspection and cleaning
- the size of the aperture affects the volume of screenings collected, impacting on the risk of blockage and cleaning costs.

Design could consider manually or mechanically raked (cleaned) screens. A range of mechanical systems are available; however, these systems may not be appropriate for stormwater harvesting schemes as they require additional space and add significant capital and operational costs.

If the primary objective of screening is to remove larger solids, and there is further treatment downstream, it is likely that a relatively coarse bar screen (25–50 mm) is adequate. If a large quantity of finer material is expected, e.g. grass clippings, then finer screens may be more appropriate.

Cleaning of the screen must be considered. Issues include access for manual raking and removal, access for vacuum trucks, or access if more substantial plant is required to remove the screen. The potential for screen blockages should be considered as part of the design process.

Sediment traps

Stormwater harvesting systems can act as a trap for the sediment load from the catchment. This needs to be anticipated in the design, providing for sediment capture and removal.

Sediment load ranges from readily settled coarse sands and gravel to suspended colloidal material. A sediment trap should be considered as part of the pre-treatment phase, working with the oil and sediment separator, to control the solids load on the raw water storage and post-treatment processes. The sediment trap can be incorporated into the diversion structure to capture the coarsest part of the sediment load before diversion.

The coarse sediment load depends on the nature of the catchment. For example, a developing catchment is likely to generate a significant amount of sediment, whereas an undeveloped, pristine catchment, or a fully developed and well-maintained catchment may generate relatively small solids loads.

A sediment trap should be sized in accordance with *Best Practice Erosion and Sediment Control* (International Erosion Control Association (Australasia), 2008).

Oil and sediment separators

Depending on the catchment, it is expected that stormwater runoff will, at times, contain elevated suspended solids and turbidity, as well as hydrocarbons from motor vehicles and roads. The inclusion of a specific oil and sediment separator should be considered.

There is a range of proprietary systems currently available on the market. Manufacturers claim removal efficiencies in the following ranges:

- 100% of gross pollutants greater than 3–5 mm
- 75 to 95% removal of Total Suspended Solids (TSS)
- up to 99.9% floating hydrocarbons.

Manufacturers' claims should be substantiated through independent peer-reviewed studies.

The oil and sediment separator needs to be sized for the full diversion flow rate; however, since this is likely to be relatively low compared with the peak stormwater discharge from the catchment, the separator sizing should be relatively efficient. Cleaning out the separator is generally undertaken by a vacuum truck, and the frequency of clean out should be in accordance with the manufacturer's instructions.

Provision needs to be made for access to the separator for inspection and for cleaning out.

Sediment loads can be estimated. Further information can be found in documents such as *Best Practice Erosion and Sediment Control* (IECA, 2008).

Natural systems

Natural systems may, in some circumstances, be considered as alternatives to the treatment processes. For example, open water bodies incorporating sedimentation zones and wetlands can be effective at reducing suspended solids, hydrocarbons and nutrients. Depending on the opportunities available, these systems can be incorporated into the main stormwater drainage system or be provided in a side-stream as pre-treatment prior to storage. Refer to section 4.3.3.

6.5 Raw water storage

The design considerations for the raw water storage are discussed in Section 5.4. Monitoring requirements are discussed in Section 5.6.

6.6 Post-treatment

6.6.1 Objectives

The objective of post-treatment is to polish the harvested stormwater to make it suitable for its intended use. The extent of treatment and the processes required depend on the nature of the intended use and the minimum water quality requirements for that use. As discussed in Section 3.3.2, an end-use that involves irrigation of open space with very low human exposure may require little, if any, additional treatment over and above pre-treatment. Uses that have the greatest potential for human contact will require the highest standards of disinfection and other contaminant removal.

6.6.2 Treatment plant sizing

As discussed in Section 3.2.3, irrigation water demands from stormwater harvesting systems vary seasonally. The maximum daily usage is expected to be significantly higher than the average water use.

The most cost-effective treatment capacity is based on supplying a relatively constant flow rate into a balance storage, rather than meeting short-term peak demands directly from the plant. The lowest cost treatment plant should be designed for average flow into a large storage tank; however, in most cases, the tank volume and cost is high and may outweigh any savings from the treatment plant. The most cost-effective system optimises treatment capacity and cost with storage volume and cost.

Another important consideration is, in many cases, stormwater harvesting systems are not totally reliable — there will be times when demand cannot be met. There is little value in a high-capacity treatment plant that can empty the raw water storage quickly, supplying the full demand for only a short period before running dry. As part of the overall management strategy, it may be preferable to treat the water at a lower rate and extend the period of supply, although at a rate that is less than the peak demand rate.

The water balance model discussed at Section 4.5 should be used to determine the optimum treatment and storage combination.

6.6.3 Types of post-treatment processes

There are many different treatment suppliers and systems. The system adopted depends on both the designer and on the method of procurement. The following process is provided as a generic description of a conventional approach to water treatment. However, each scheme must be assessed individually.

Post-treatment processes include:

- flotation if there is a need to remove difficult to filter particles such as algae
- filtration to reduce suspended solids and turbidity levels and make the water suitable for disinfection (with or without the addition of chemical coagulants and flocculants to enhance efficiency)
- activated carbon adsorption or advanced oxidation to remove organic chemicals if they are expected in the raw water and if the proposed uses are sensitive to them
- reverse osmosis if dissolved salts are of concern
- disinfection to destroy or inactivate human pathogens and to provide residual protection in the water distribution system.

Flotation

Algae may be a problem in raw water storages if the storages are uncovered and if there are elevated nutrient levels in the water. Algae is difficult to remove by conventional filtration and, under adverse conditions, may be present in concentrations that overload the treatment processes. If algae is anticipated to be a significant problem, a dissolved or induced air flotation separation system should be considered as a pre-cursor to filtration and disinfection.

Filtration

Unless stormwater is to be used for broad-scale irrigation with controlled public access, some form of filtration is necessary. Filtration reduces suspended solids and turbidity as a precursor to disinfection, especially for UV disinfection where high transmissivity (low turbidity) is required.

Conventional water treatment includes:

- in-line filters such as cartridge filters, screens or disc filters
- in-line media filtration, possibly including use of a coagulant such as alum and a flocculant
- media filtration as pre-treatment for membrane filtration
- membrane filtration.

Activated carbon and advanced oxidation for organics removal

Depending on the catchment and end uses of the water, it may be appropriate to provide a process to remove residual amounts of organics that may cause a health risk, or may result in unacceptable colour or odour in the water. For most non-potable uses, especially irrigation, this process is not warranted. However, if the water is proposed for higher human contact uses, removal of organics may be appropriate.

Treatment process for organics removal include activated carbon adsorption or advanced oxidation. Advanced oxidation has been adopted for the South East Queensland Purified Recycled Water (PRW) scheme. It uses a strong oxidant in conjunction with UV light to oxidise residual concentrations of organics.

Desalination

Stormwater runoff is expected to contain dissolved salts, but generally not at concentrations of concern for reuse. However, dissolved salts may be an issue, for example, in a low-lying area with saline groundwater intrusion or if the proposed uses require very low Total Dissolved Solids (TDS) concentrations.

The most commonly used desalination method in Australia is reverse osmosis (RO) membranes because they are more cost effective than alternatives given local economic conditions. The disadvantages of any desalination process include high energy use, high membrane replacement costs, and low yield.

Primary disinfection

Stormwater runoff quality varies depending on a range of factors. It will be contaminated with micro-organisms that may be pathogenic to humans. Much of the contamination originates from the soil and animal casting; however, it may also contain contaminants that have human origins. For example, in a developed catchment, particularly an older area, dry weather leakage can occur from sewerage systems through cracked or broken pipes and joints or as a result of blockages. Wet weather sewerage losses can occur as a result of surcharging and overflows.

If there is likely to be significant human contact with the treated stormwater, effective disinfection is required (see Section 3.3).

A range of disinfection processes is available. The common methods include chlorination, ultraviolet (UV) irradiation and ozonation. Using membranes, alternative disinfectants such as chlorine dioxide and permanganate, and systems such as ultrasonics and plasma arc denaturing are also possible.

The primary considerations in selecting a disinfection system include:

- the effectiveness of the disinfectant against the pathogens of concern
- the ability to achieve minimum pathogen removal or inactivation
- the minimum dose rates required for effective disinfection
- ease of implementation
- safety and ease of handling
- capital and operating costs.

Residual disinfection

Maintenance of a residual disinfectant in the treated water storage and distribution system can maintain water quality throughout the system and control the growth of biofilms. This may also be a requirement of the relevant local authority.

The simplest approach is to dose liquid sodium hypochlorite into the treated water upstream of the treated water storage. Dosage is flow paced. Residual concentrations should be maintained based on automatic chlorine residual monitoring in the treated water storage and in the distribution system.

6.6.4 Alternatives to treatment

The *Australian Guidelines for Water Recycling: Stormwater Harvesting and Reuse* (EPHC, NHMRC, & NRMMC 2009) permit the use of alternatives to treatment. For example, restricting access to irrigation areas or using sub-surface irrigation both reduce the risks of contact with the irrigated water and allow lower quality water to be used.

6.6.5 Typical conventional water treatment trains

Figure 6-2, Figure 6-3 and Figure 6-4 illustrate typical water treatment trains that could be provided for different end uses. The treatment processes represent current conventional best practice and are based on equipment that is commercially available from a number of local suppliers.

Particular treatment requirements and processes will vary depending on catchment runoff water quality and end use. Site-specific risk assessment should be undertaken and independent expert advice sought to determine the best treatment processes.

The treatment systems shown in the Figures are not the only available treatment systems. A range of different treatment processes are commercially available. The figures simply illustrate readily available technologies.

Figure 6-2 shows a sophisticated treatment train based on membrane filtration that might be used to treat stormwater for Primary Contact uses. Figure 6-3 shows a simpler train based on conventional media filtration that would be adequate for most non-potable uses, including toilet flushing, laundry (cold water) and garden and landscape irrigation. Figure 6-4 shows a very basic treatment approach that could be used where the risk of human contact with the water during irrigation is very low (eg irrigation of community open space with no public access during irrigation).

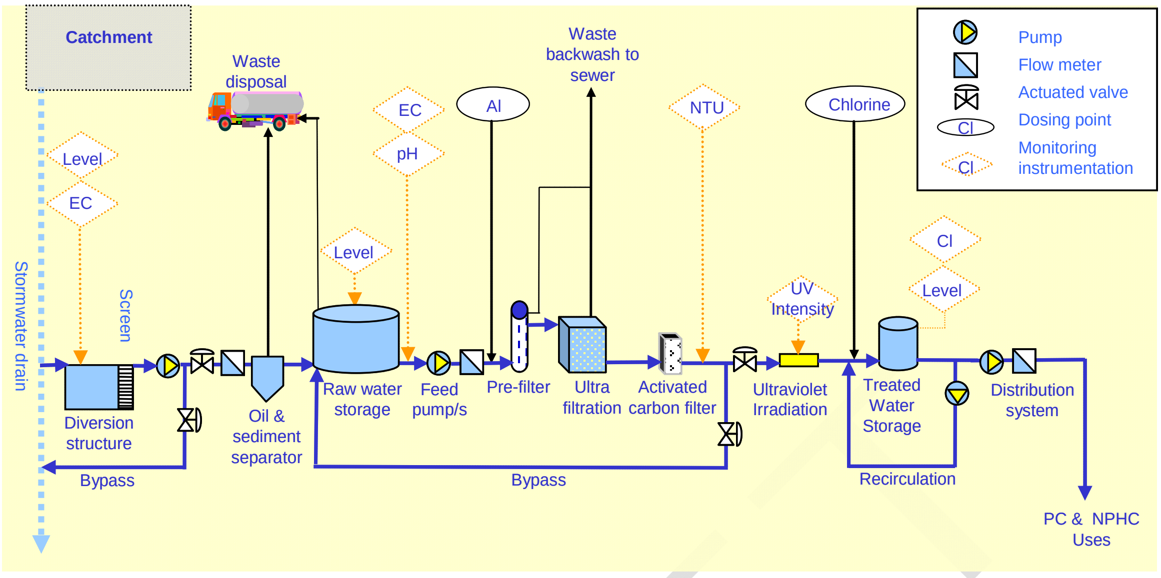

Figure 6-2: Typical treatment train — primary contact uses

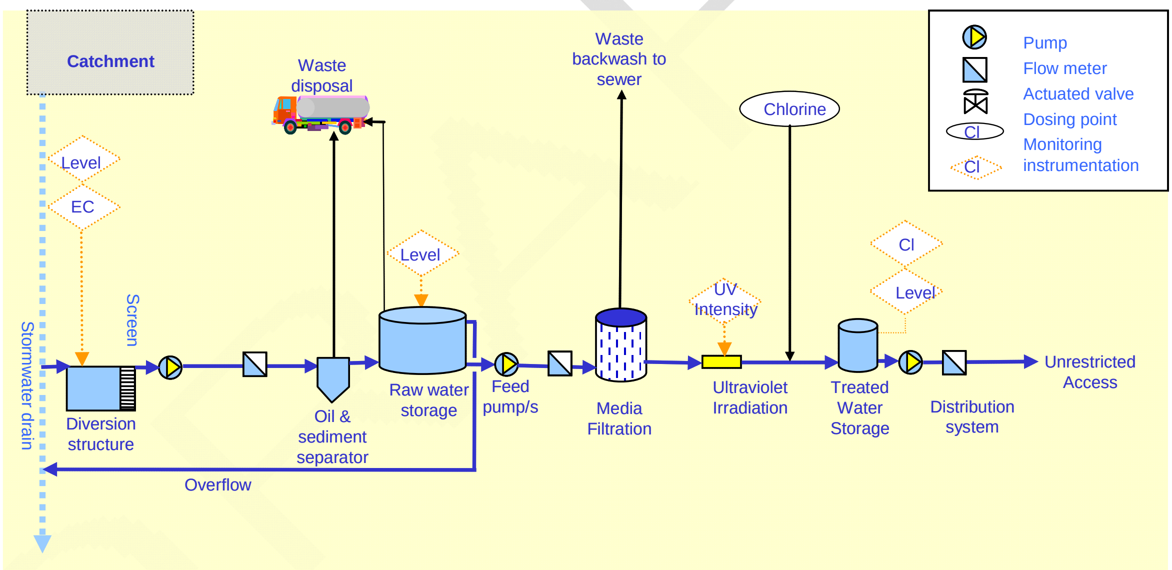

Figure 6-3: Typical treatment train — all non-potable uses (NPHC, NPMC and NPLC) with no access restrictions

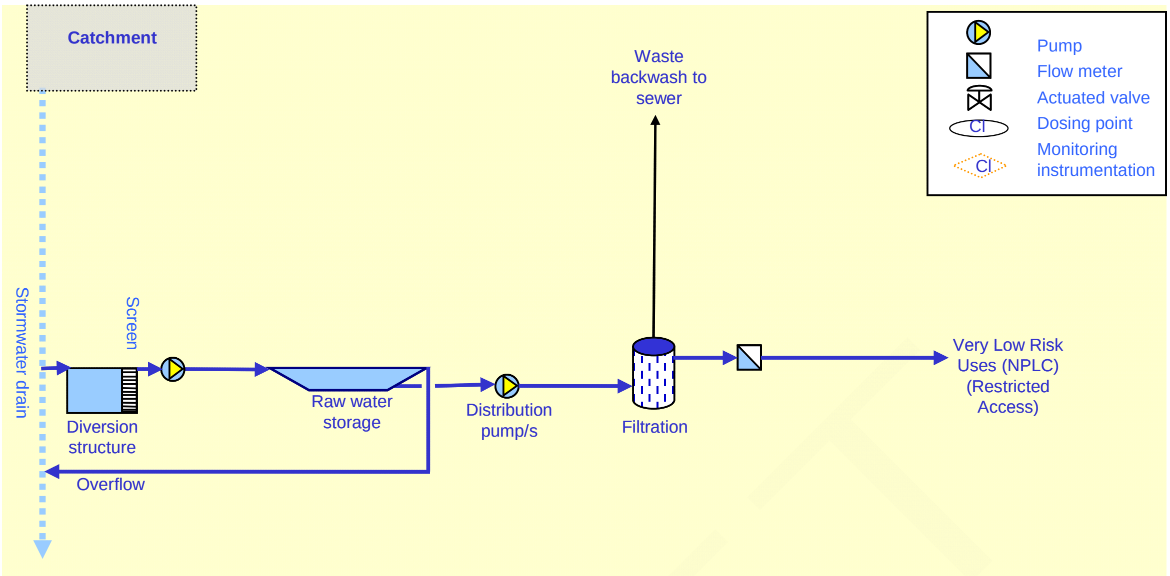

Figure 6-4: Typical basic treatment train for non-potable low contact (NPLC) uses with restricted access

6.7 Treated water storage

In most cases, treated water should be discharged into a treated water storage before distribution for use. Storage allows the capacity of the treatment plant to be reduced and balances short-term peaks and troughs in demand.

As discussed in Section 6.6.2, storage should be sized taking into account seasonal and diurnal demand variations and optimised in conjunction with the treatment plant capacity.

The treated water tank must be covered to exclude light and be sealed to keep out insects (including mosquitoes) and vermin. If a residual chlorine dose is provided upstream of the storage, mixing or recirculation of the water in the tank may be required to maintain chlorine at acceptable levels.

6.8 Monitoring treated water quality

The role of monitoring in this part of the stormwater harvesting scheme is to:

- monitor critical parts of the treatment process for control purposes
- monitor the water quality in the treated water storage to confirm minimum standards for reuse
- monitor the water quality in the distribution system to confirm the water delivered to the point of use meets minimum requirements.

Monitoring of the treatment process is important for optimising and controlling water treatment systems and observing changes in treated water quality at critical points in the treatment process, such as immediately following filtration.

Monitoring water in the treated water storage is important to:

- monitor for changes in treated water quality from the treatment systems
- confirm that the treated water meets the minimum standards required and is suitable for distribution
- control residual chlorination systems.

Monitoring water in the distribution system is necessary to ensure that the safety of the end user is protected.

The frequency and costs associated with monitoring must be considered; the costs of monitoring often limit the frequency at which it is undertaken. It is desirable to:

- provide real-time monitoring of critical parameters in the treatment process, possibly including flow, turbidity, UV intensity and pH
- provide real-time monitoring of critical parameters in the treated water storage, including chlorine residual and pH
- develop a weekly monitoring program for other parameters from the storage and distribution system, including bacteriological quality and nutrients.

6.9 Distribution

Conventional water supply systems supply treated water into elevated service reservoirs located throughout the community. Supply into service reservoirs is typically at a rate equal to the average of the peak period demand (weekly or daily). Water supply to consumers is then provided from the reservoirs, and the reservoirs maintain system pressure and balance the short-term diurnal variations in demand.

In most cases, stormwater harvesting schemes will not include elevated storages and rely on pumping to maintain system pressure and meet short-term demand. The distribution system and pumps must be designed to maintain a relatively constant system pressure over the full range of diurnal demands (essentially zero-to-peak instantaneous demand). Pumping systems provide multiple pumps of varying sizes and speed drives depending on the design requirement. Using pressure controls, variable speed pumping systems can supply varying demands while maintaining constant supply pressure. Pumped system design should also consider the energy. The long-term net present value of the system, including capital and operating costs, can assist in assessing the efficiency of the system.

6.10 Operational requirements

6.10.1 Management

Management requirements are described in detail in Section 3.10.

6.10.2 Monitoring

Treatment processes need to be closely monitored to ensure proper continued operation and to confirm that the processes are meeting performance requirements. Monitoring can take a number of forms, including on-line and sample-based monitoring.

On-line monitoring includes instrumentation to monitor performance in real time and as input to the control system. In some cases, on-line monitoring provides data acquisition, e.g. flow metering. In other cases it provides process modulation, e.g. chlorine dose, and in others cases it provides for an emergency response and plant shut-down, e.g. in situations of high turbidity or low water levels. On-line monitoring includes flow, water level, turbidity, UV intensity, chlorine, pH, electrical conductivity, oxidation reduction potential (ORP), dissolved oxygen and hydrocarbons.

Where it is not practical to provide on-line instrumentation for all parameters, manual sampling and analysis is required. Manual analysis is necessary for most inorganic parameters, BODs, solids (suspended and dissolved), nutrients, pathogens, metals, chemicals and pesticides.

On-line monitoring is not currently available for all parameters and manual sampling and analysis must be relied on. This creates a problem of quality excursions being identified only after events, preventing early response and rectification. Using indicators such as turbidity, UV intensity and residual chlorine must be relied on to show that the system is continuing to operate as designed.

6.10.3 Control

The nature and complexity of the control system depends on the scale of the scheme and the end water uses.

The simplest scheme irrigating water from a below ground storage to open space irrigation with only an in-line filter as treatment may operate satisfactorily with a local automatic controller with minimal remote input or monitoring. Large-scale urban harvesting schemes supplying water for residential uses require more complex treatment processes and more sophisticated control and monitoring systems. More complex systems can include on-line instrumentation for critical parameters with a local automatic control system for normal operation. The system should be monitored remotely (possibly through a Supervisory Control and Data Acquisition (SCADA) system) or an internet-based system. Alarms would be generated to a central point in the event of a problem and remote assessment and adjustment of systems developed.

6.10.4 Operation and maintenance

Any water treatment plant requires a relatively complex installation with significant operational commitment and resourcing. Appropriately skilled operators are required and access to specialist mechanical and electrical service technicians is necessary.

7 Case studies

7.1 Introduction

There are very few good examples of urban stormwater reuse, except for some parks and golf courses where runoff is collected into dams and used for irrigation. There are few formal stormwater-harvesting systems that treat water for higher value uses.

Four case studies are used in this section to highlight various aspects of designing and implementing stormwater harvesting as described in these guidelines.

Case study 1 applies to managing the impacts of stormwater harvesting in accordance with the *Implementation Guideline No. 7 Water Sensitive Urban Design Objectives for Urban Stormwater Management* (DIP & HWP 2009).

Case study 2 discusses how to use of the generic stormwater harvesting yield curves.

Case studies 3 and 4 are more detailed case studies that apply the principles outlined in these guidelines to the design of stormwater harvesting systems for two developments in South East Queensland. Case study 3 applies these guidelines to a small, high-density development. Case study 4 is a detailed example of a significant urban stormwater harvesting project with a diverse range of design considerations and requiring a high level of treatment.

7.2 Case study 1 — Managing the impacts of stormwater runoff in accordance with Implementation Guideline No. 7

As discussed in Section 3.6.2, the recently released Implementation Guideline No. 7 Water Sensitive Urban Design Objectives for Urban Stormwater Management (SEQ Regional Plan, 2005–2031) (DIP & HWP 2009) outlines three criteria for managing the environmental impacts of stormwater runoff from development:

1. Stormwater quality management:

   Achieve the following minimum reductions in total pollutant load, compared with that in untreated stormwater runoff, from the developed part of the site:

   - 80% reduction in Total Suspended Solids (TSS)
   - 60% reduction in Total Phosphorus (TP)
   - 45% reduction in Total Nitrogen (TN)
   - 90% reduction in Gross Pollutants

2. Waterway stability management:

   Limit the post-development peak one year average recurrence interval (ARI) event discharge within the receiving waters to the pre development peak

3. Frequent flow management:

   From the proposed development, capture and manage:

   - The first 10mm of runoff from impervious surfaces where the total impervious surface is 0% to 40%
   - The first 15mm of runoff from impervious surfaces where the total impervious surface is greater than 40%

Implementation Guideline No. 7 suggests calculation methods to demonstrate compliance with these three criteria. Case study 1 is an example of how stormwater harvesting can help to achieve these criteria. This case study is based on a relatively high-density development for a 'town centre' as shown in Figure 7-1. The density of the development is approximately 100 dwellings per hectare, achieved with a mix of townhouse and 5-storey unit developments.

Figure 7-1: Town Centre

The plots shown in Figure 7-2 are an accumulation of runoff volume throughout a year for a range of scenarios including:

- an undeveloped scenario
- a developed scenario with no stormwater management
- a developed scenario with flood mitigation only
- a developed scenario with flood mitigation plus water sensitive urban design to manage pollutant loads (stormwater volume losses in bioretention filters have not been allowed)
- a developed scenario with flood mitigation, WSUD, and stormwater harvesting for irrigation (labelled 'SWH')
- a developed scenario with flood mitigation, WSUD, and stormwater harvesting to reuse of all rainfall less than 15mm (labelled SWH plus external reuse).

These plots show that flood mitigation and WSUD have virtually no impact on total runoff volumes. However, if stormwater is harvested for irrigation reuse, the accumulated runoff volume starts to drop towards the pre-development runoff volume. If runoff from rainfall events less than 15mm is captured and re-used, the runoff volume almost matches the pre-development runoff volumes.

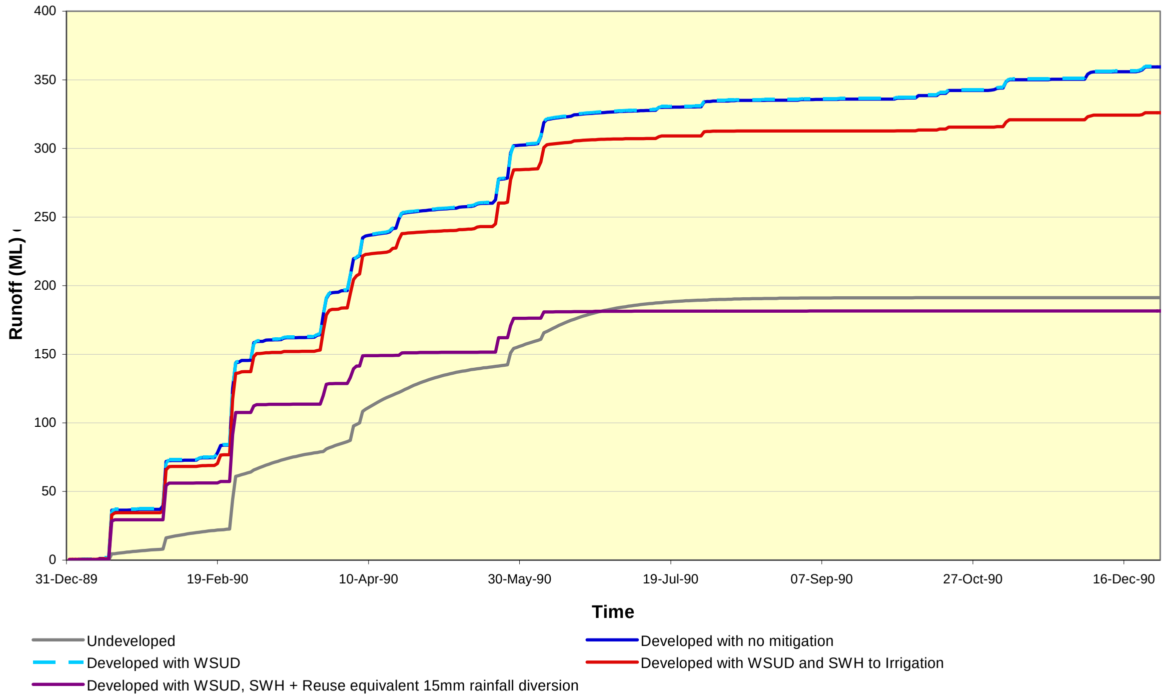

Figure 7-2: Impact of stormwater harvesting on cumulative runoff volume

Table 7-1 lists the effect of the tested scenarios on water quality outcomes. The impact of stormwater reuse on the efficiency of removing pollutants was analysed by setting up a model treatment train to achieve the target outcomes for the WSUD case, then leaving these unchanged as increased amounts of reuse were introduced. The resulting rise in treatment efficiency is considerable for the 15mm rainfall and runoff reuse scenario.

Table 7-1: Impacts of stormwater harvesting on catchment runoff water quality

Parameter	Load reduction compared with developed case[36]					
	Un-developed	Developed	Developed with flood mitigation	Developed with flood mitigation & WSUD	Developed with flood mitigation, WSUD & SWH reuse	Developed with flood mitigation WSUD, SWH (15mm rainfall diversion)
Flow (ML/yr)	191	365	365	365	330	182
Total Suspended Solids	-	3%	3%	83%	83%	87%
Total Phosphorus	-	6%	6%	69%	70%	80%
Total Nitrogen	-	14%	14%	45%	49%	68%

36 Rainwater tanks assumed in all 'developed' scenarios.

Parameter	Load reduction compared with developed case[36]					
	Un-developed	Developed	Developed with flood mitigation	Developed with flood mitigation & WSUD	Developed with flood mitigation, WSUD & SWH reuse	Developed with flood mitigation WSUD, SWH (15mm rainfall diversion)
Gross Pollutants	-	33%	33%	100%	100%	100%

Figure 7-3 illustrates an alternative analysis with plots of rainfall and discharge with no control or with large stormwater harvesting storages to capture runoff. This demonstrates how diversion of stormwater runoff to a storage for reuse can assist with limiting the runoff from impervious areas.

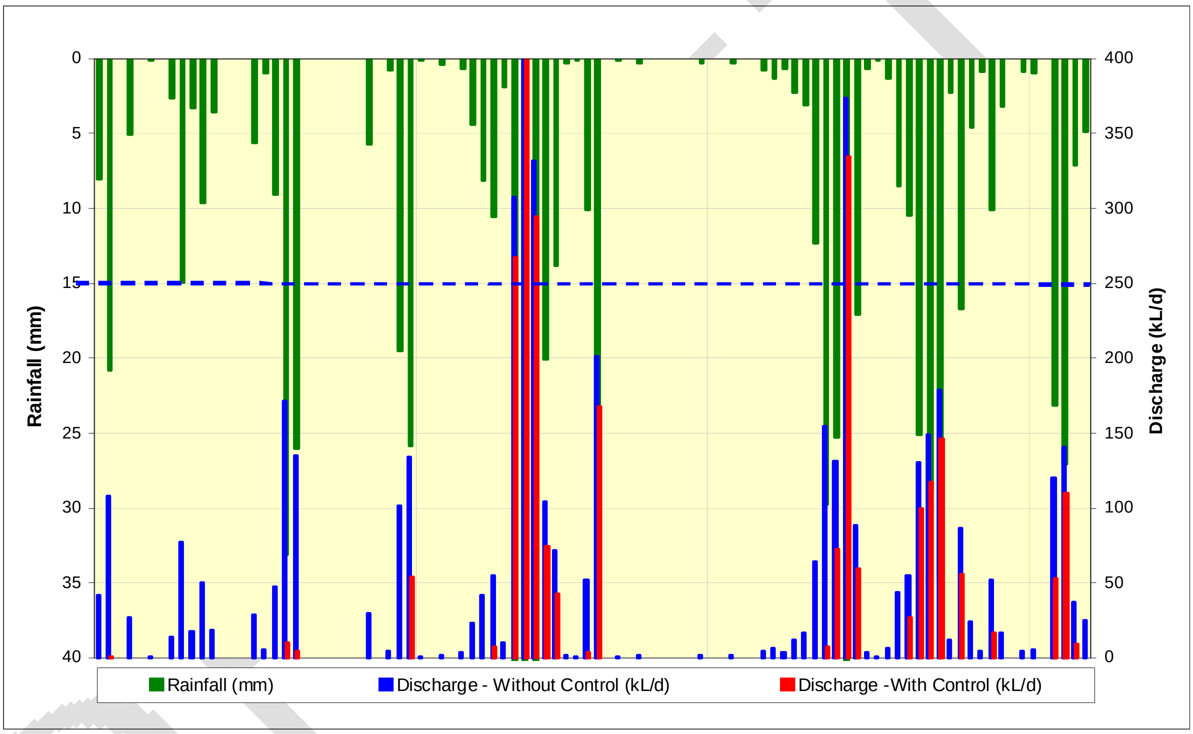

Figure 7-3: Impacts of stormwater harvesting on runoff rate (alternative analysis)

Other key considerations for stormwater management, usually set out in local authority planning schemes or policy or development guidelines, include:

- no increase in post-development flow rates compared to the pre-development flow rates for 1-year ARI to 100-year ARI
- no increase in the post-development flow levels (heights) compared to the pre-development flow levels (heights) for ARI1 to ARI100
- no nuisance to neighbouring properties, e.g. a concentrated flow discharge at a boundary or ponding.

The impact on the ecology of waterways downstream from stormwater harvesting schemes should also be reviewed to ensure that too much water is not taken way from the waterway. There is little guidance on what constitutes 'too much' flow reduction. However, as Figure 7-2 shows urbanisation significantly increases waterway flows and large amounts of stormwater reuse are required to revert to pre-development flows or less.

Subject to the provisions of applicable planning schemes and the scale and arrangement of any stormwater harvesting scheme, it may be necessary to obtain a licence from DERM to extract water. Applications for a licence often require an assessment of the environmental impact.

7.3 Case study 2 — How to use stormwater harvest yield curves

Introduction

A developer in Brisbane is planning to provide a low-density residential development with treated stormwater for non-potable uses including toilet, cold water laundry, general external cleaning and garden watering. The harvested stormwater will be supplied through a dual reticulation system to individual houses and will also be used for public open space irrigation.

The yield curves presented in Section 3.8 are used to provide an initial indication of the potential performance of a stormwater harvesting proposal.

Step 1 — Define the effective catchment area

- The gross stormwater runoff catchment area is defined by the topography of the site and is estimated to be 8 ha_{cat}.
- The runoff catchment has 6.4 ha_{cat} (80%) of low density residential and 1.6 ha_{cat} (20%) of high density residential. Based on Table 7-1, the impervious area is estimated to be 60% for the low-density residential and 80% for the high-density development. Therefore, the overall percentage of impervious surfaces is:

  (80% low density x 60% impervious) + (20% high density x 80% impervious) = 64% impervious.

- The percentage of impervious surfaces and mean annual rainfall of approximately 1,200 mm/year is used to estimate the annual runoff fraction (refer to Figure 7-4) for the development, i.e. 0.68.
- Effective catchment = 8 ha_{cat} x 0.68 = 5.44 ha_{eff}

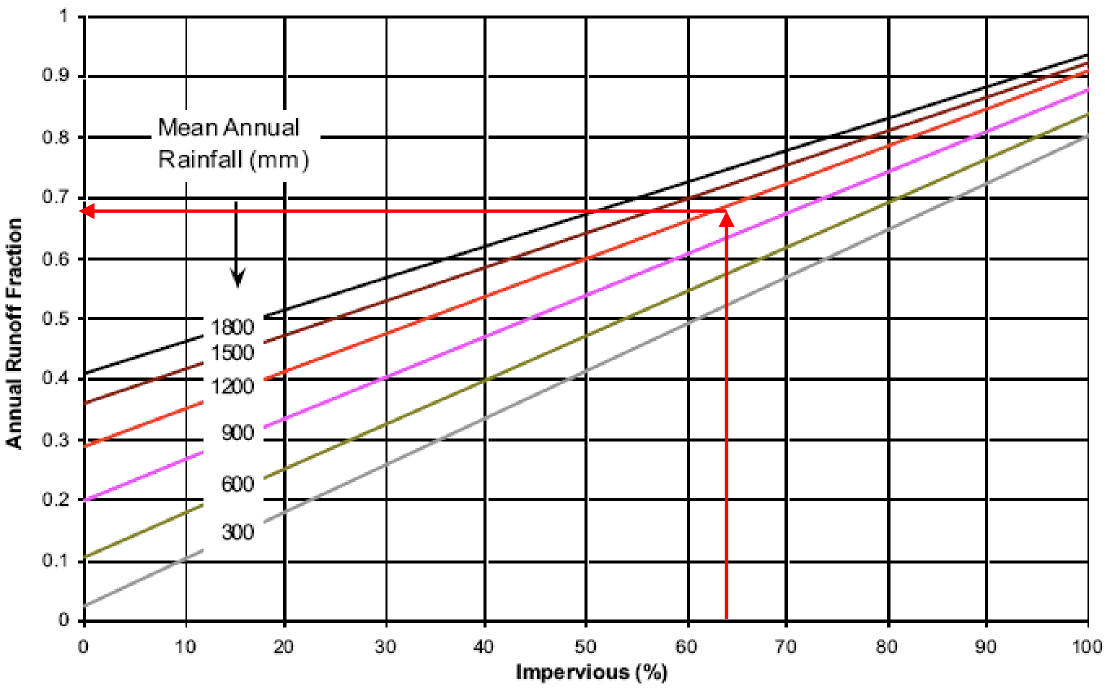

Figure 7-4: Urban runoff coefficient relationships for urban areas in Australia

Step 2: Define supply area and demand

- The supply area is 6.4 ha_{sup} of low-density residential development, which is also part of the catchment area.
- Typical density and stormwater demand estimates for this type of development are provided in Table 3-11, Table 3-12, and Table 3-13.
- The estimated stormwater demand for this development is shown in Table 7-2.

Table 7-2: Estimated average water demands for case study

Component	Average demand kL/day
Toilet flushing	5.4
Cold water laundry	5.0
External use	1.1
Garden watering	10.9
Open space irrigation	13.1
Total	35.5

Step 3 Determine stormwater yield relationship

The yield curves are represented using supply area per effective catchment area (ha_{sup} / ha_{eff}). The effective stormwater harvesting catchment is 5.44 ha_{eff} and the supply area is 6.4ha_{sup}. Therefore 6.4/5.44 = 1.2 ha_{sup} / ha_{eff}.

Using the yield curves, the storage volume required (kL/ha_{eff}) is extracted to supply the development at a given reliability. This example supplies the water to a low-density residential development and this plot together with an interpolated curve for 1.2 ha_{sup} / ha_{eff} are provided in Figure 7-5. If 85% reliability is required, a storage equivalent to 118 kL/ha_{eff} would be required to supply 6.4 ha_{sup} from a 5.44 ha_{eff} catchment. Therefore, the total storage volume required = 118 kL/ha_{eff} x 5.44 ha_{eff} = 642 kL.

The model shows that an 8 ha_{cat} (5.44 ha_{eff}) stormwater harvesting catchment could supply on average 35.5 kL/day (85% of demand) of stormwater to a 6.4 ha_{sup} low density residential development with an effective storage of 642 kL.

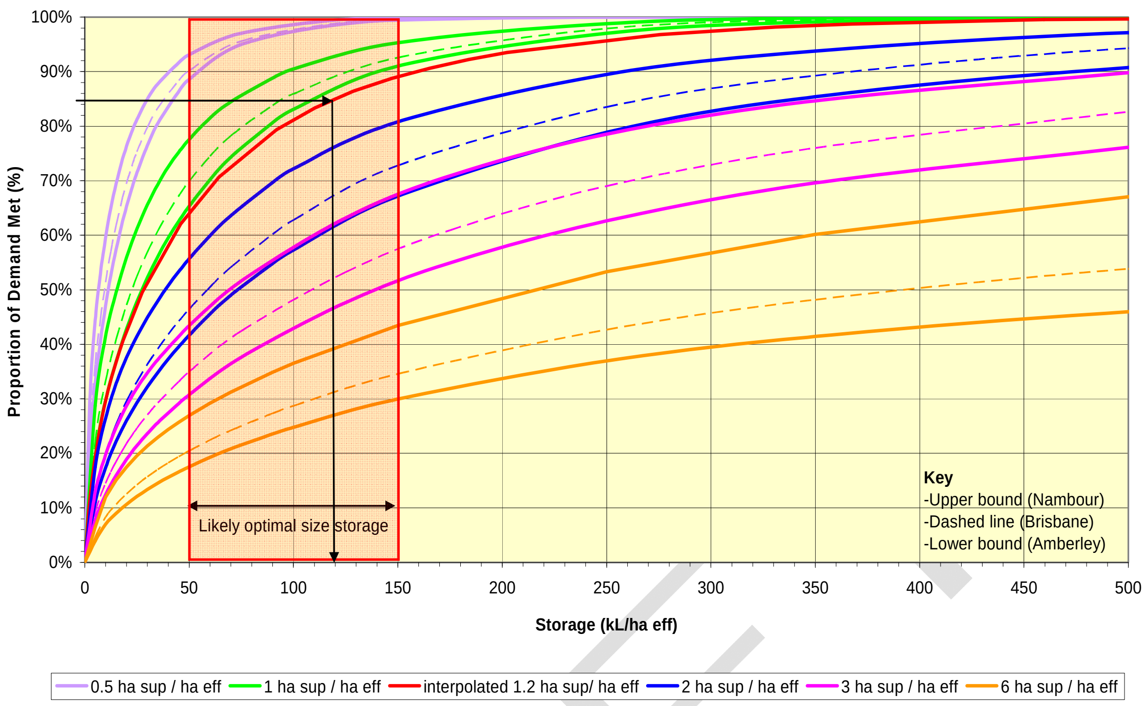

Figure 7-5: Generic stormwater harvesting yield curve for low residential development — Case study

7.4 Case study 3

7.4.1 Project need

This case study highlights planning issues for the concept design of a stormwater harvesting system for a new, high-density residential development in the greater Brisbane area (refer to Attachment C — Sub-regional climatic zones for yield curves). Under recent water restrictions, potable water could not to be used for irrigation. High-amenity public open space and landscaping is important for this development to create an appealing aesthetic and enhance sales. Stormwater harvesting was preferred to rainwater harvesting for irrigation due to drought restrictions that limit the amount of rainwater that is available. This scheme aims to use an integrated approach to provide a reliable supply of water, while achieving stormwater quality and flood mitigation objectives.

7.4.2 Project background

The development block has a total area of approximately 0.75ha, which includes 1–3 storey apartments, car parks and communal open space. The development layout and main catchment plan is shown in Figure 7-6. The development breakdown is described in Table 7-3.

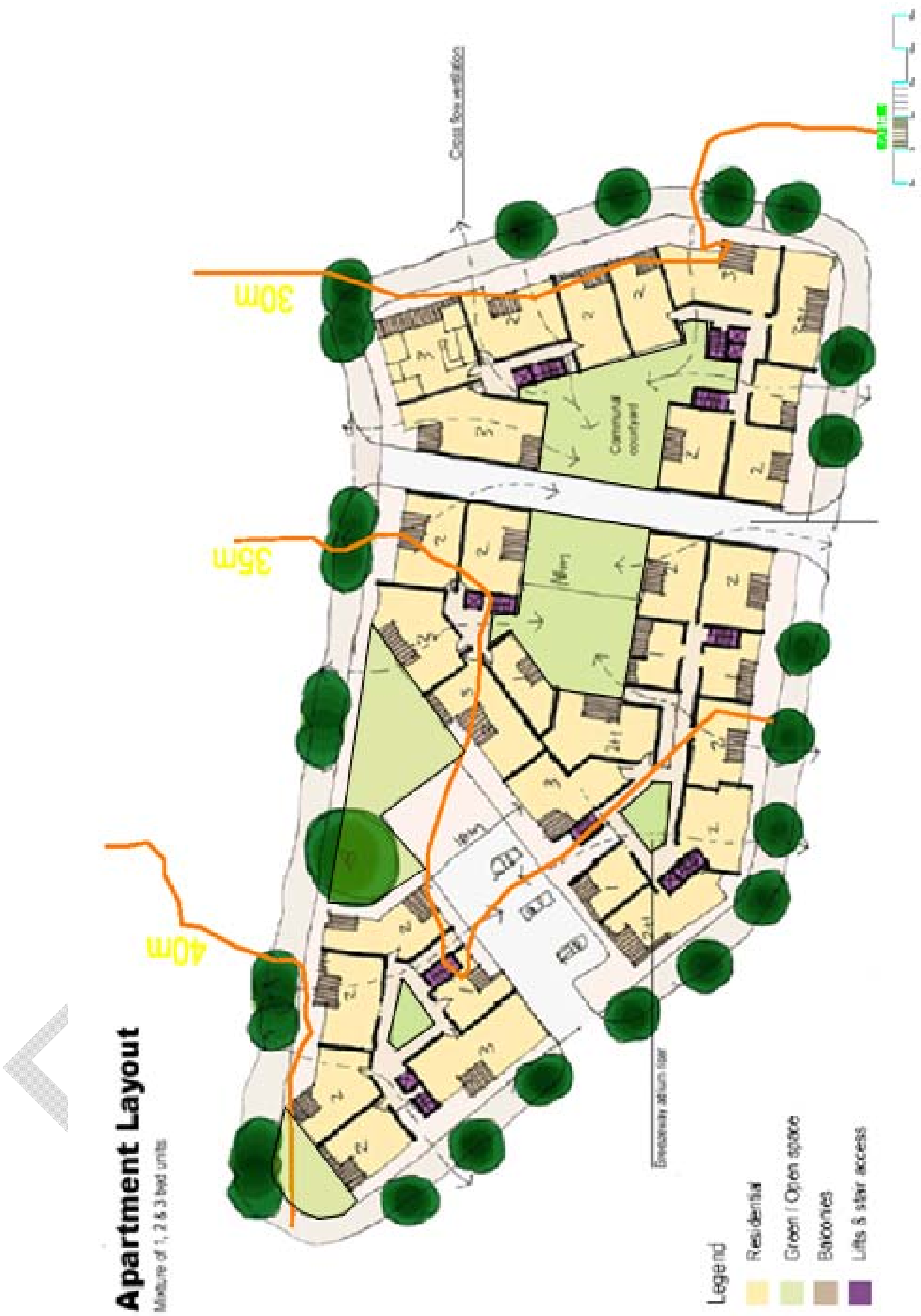

Figure 7-6: Case study 3 — development layout

Table 7-3: Development description

Land use description and characteristics	Development area
Gross Development Area	0.75ha
Private Open Space (to be irrigated)	0.14ha open space (18%) Allow additional 1.5m x 375m perimeter streetscape irrigation area Total irrigated area = 0.19ha (25%)
Driveways	0.04ha driveways 0.05ha car park
Number of dwellings [37]	81 dwellings
Population [37]	138

A schematic overview of the development and proposed stormwater management concept is shown in Figure 7-7.

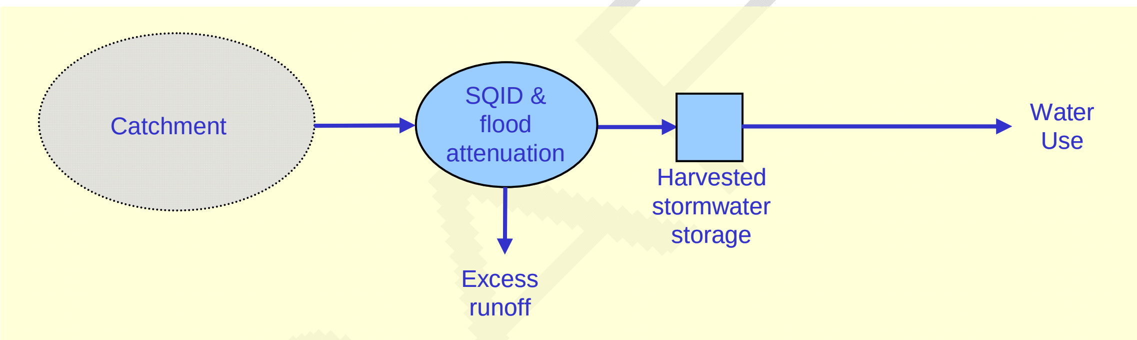

Figure 7-7: Schematic stormwater harvesting system

7.4.3 Planning considerations

Design objectives

This scheme will use an integrated approach to provide a reliable supply of water while achieving stormwater quality and flood mitigation objectives (refer to Section 2.2 for stormwater harvesting objectives). The water management requirements for the development include:

- meeting South East Queensland Regional Objectives[38] including waterway stability, pollutant and frequent flow objectives
- mitigating peak flow rates up to a 100-year ARI[39]
- ensuring an independent water supply system for irrigation and non-potable internal use with harvested stormwater.

Refer to Section 7.4.4 for detailed plans of stormwater quality devices and flood attenuation areas.

[37] Based on residential occupancy rates presented in Table 2-2.
[38] Based on the *Final Draft Implementation Guideline No 7 Water Sensitive Urban Design Objectives for Urban Stormwater Management* (SEQ Regional Plan, 2005–2026).
[39] Based on *Queensland Urban Drainage Manual, Volume 1 Second Edition* (NRW, 2007).

Proposed uses and water quality requirements

Residential uses for this scheme are toilet flushing, cold water laundry and irrigation of community private open space. The proposed water uses and water quality requirements are described in Table 7-4.

Table 7-4: Proposed uses and water quality requirements

Proposed uses	Water quality	Relevant guidelines
Residential toilet flushing, cold water laundry and general external use	NPHC	*Australian Guidelines for Water Recycling: Stormwater Harvesting and Reuse* — Phase 2 (EPHC, NHMRC, & NRMMC 2009)
Irrigation of streetscape and community parks and gardens	NPMC	

HACCP risk assessment

The water quality requirement of NPHC and NPMC reflects the likely risks associated with treated stormwater for the end use. A site-specific risk assessment will be required as part of detailed design (refer to Section 3.9.3).

Key planning considerations

Standards of service

The desired standards of service are:

- minimum residual pressure at point of supply: 50m for irrigation and 30m for internal uses
- supply reliability: supply to toilets and cold water laundry must be 100% reliable, therefore mains back-up is necessary
- water quality: to meet the relevant guidelines based on end use (refer to Section 3.2 and 3.3).

Impacts of the scheme on other water supplies

The impact of the scheme will be to reduce demand for Council's potable water supply.

Impacts on stormwater runoff regimes

The development will use a range of strategies including stormwater harvesting, bioretention systems and flood attenuation to achieve WSUD targets and reduce adverse impacts on the environment, including capture and management of peak flows (refer to Section 7.4.4 for further details).

Cost estimates

Budget cost estimates could be prepared on the basis of the scheme concepts though these have not been prepared to date.

Governance issues

The majority of the stormwater infrastructure will be distributed throughout the site. Within lots the infrastructure will be owned and operated by the lot owner. The lot owner will be responsible for maintaining the scheme standards. A 'skeleton' community management scheme (CMS) for the water management elements is also required.

Management and operational issues

The CMS scheme will own and operate the water management elements, and will need to develop operational and maintenance procedures.

7.4.4 Catchment considerations

Stormwater diversion and flood mitigation

Stormwater will be conveyed through underground drainage to the bioretention system and underground stormwater storage for treatment and reuse. Overflow from the stormwater harvesting storage will be directed to the flood attenuation storage. For storm events of say Q1 or greater, stormwater will accumulate in the major flood mitigation areas. The flood mitigation priorities are illustrated in Figure 7-8. For extreme storm events (>Q100) conveyance will be via an overland flow path.

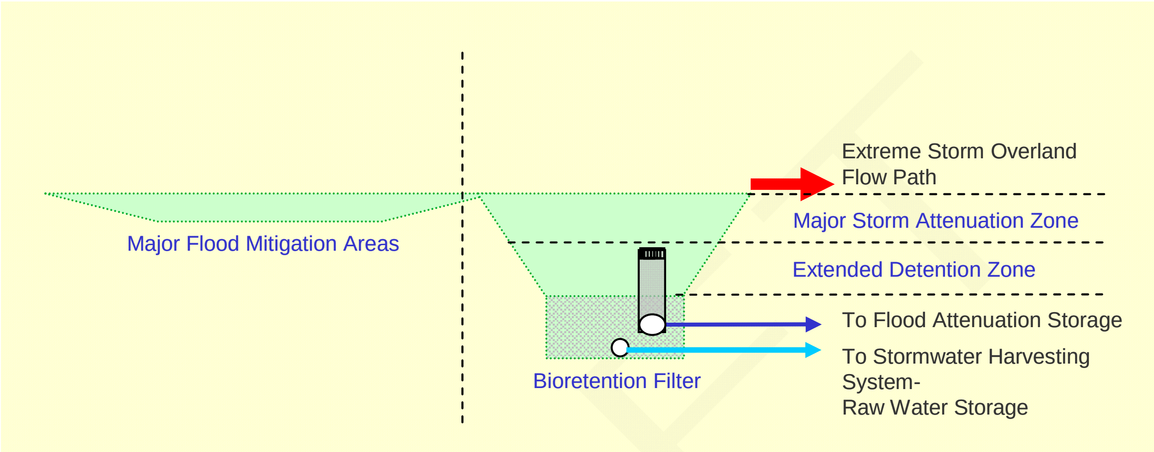

Figure 7-8: Conveyance and flood mitigation priorities

Peak stormwater flows from the development were estimated to ensure enough space is allocated for flow conveyance. The *Queensland Urban Drainage Manual* (NRW 2007)[40] was used to calculate peak flows and the stormwater attenuation volume. The total stormwater attenuation volume required for flood mitigation is 208 kL.

The flood mitigation volume can be provided in four ways:

1. Allow a detention zone of approximately 20% of the stormwater harvesting storage volume (Bligh Tanner 2004) indicated that the probable initial air space in a stormwater tank with constant use is at least 20–25% at the start of a major storm event. Therefore, the probable initial air space in the stormwater harvesting storage tank, based on internal use is 20% of 68[41] kL = 14kL.
2. Detention in the bioretention filter's (BRF) extended detention zone is 150 m^2 BRF at 0.3m depth = 45kL.
3. Shallow detention areas (major flood mitigation area) in the development's private open space areas[42] (private open space of 1375m^2 – 150m^2 at 0.1m depth = 123kL).
4. An additional 26kL of flood storage will be required. This can be provided as an underground storage added to the stormwater harvesting system in the basement of one of the residential buildings. An outflow pipe will be required to draw down the flood storage.

[40] Based on the 'rational method' and Section 5.05 of the *Queensland Urban Drainage Manual , Volume 1 Second edition* (NRW, 2007).
[41] Refer to Section 7.4.5 for details on stormwater harvesting storage estimation.
[42] This assumes that WSUD elements are allowed in public open space.

Water quality

WSUD practices require that new developments have stormwater quality improvement devices (SQIDs) such as BRFs on 2.0% of the development site[43] (refer to Figure 7-9). Some of the drainage will need to be diverted to the BRFs through underground drainage structures.

A layout of the stormwater harvesting system, flood mitigation system and bioretention filters are provided in Figure 7-9.

[43] Based on the *Water Sensitive Urban Design Technical Guidelines for South East Queensland* (Healthy Waterways Partnership, 2006).

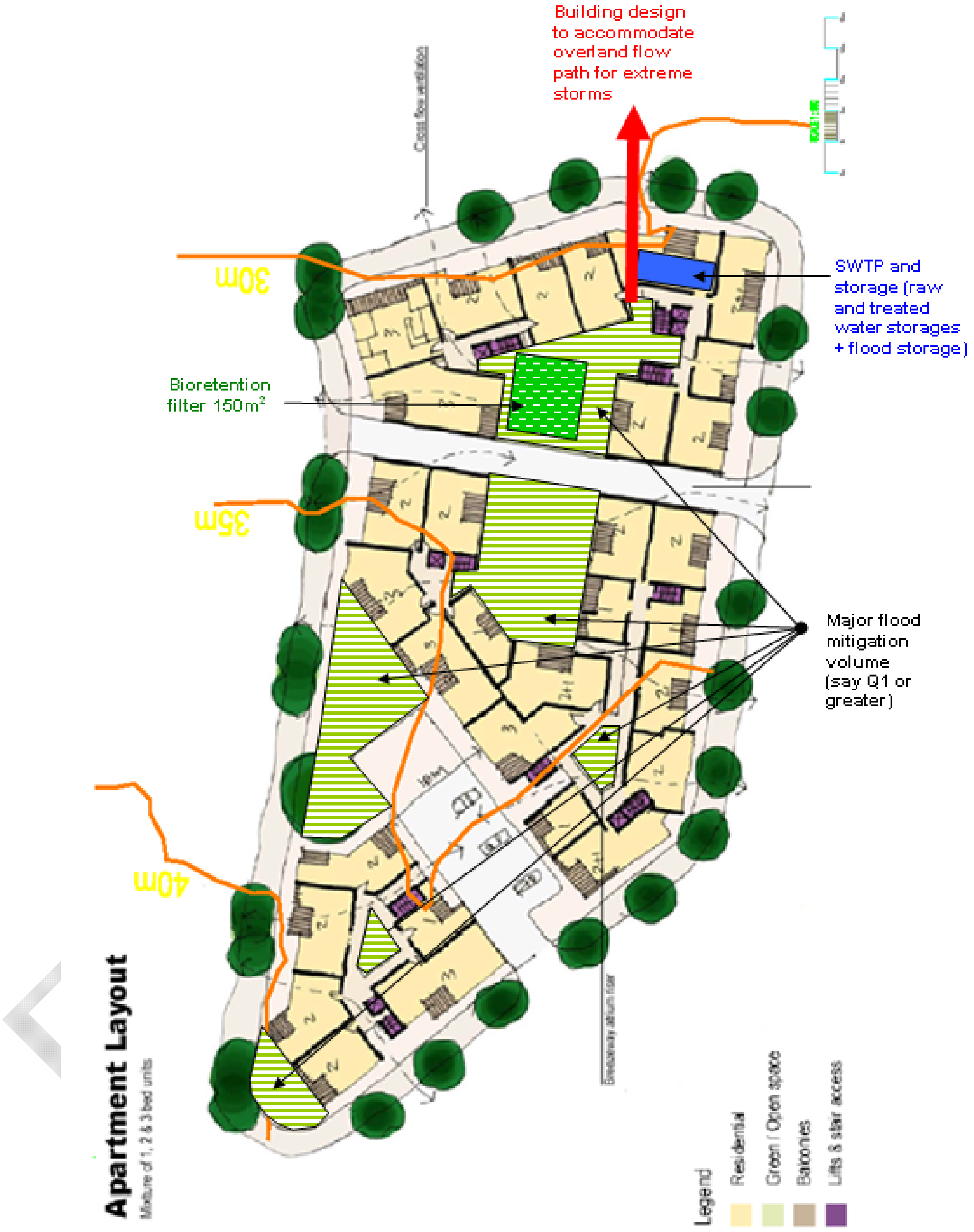

Figure 7-9: Stormwater harvesting and WSUD system layout

7.4.5 Storage requirements

The stormwater harvesting storage was calculated using the yield curves shown in Section 3.8. It is assumed that all stormwater can be collected at the low point of the catchment.

- The effective catchment (or effective impervious catchment area) is the area that equates to 100% runoff. In this development, it is assumed there is no rainwater harvesting; however, some losses will occur from the bioretention filters. The gross runoff catchment is 0.75 ha (i.e. ha_{cat}).
- The runoff catchment is high-density residential and, based on Table 3-10, the impervious area is estimated to be 75%.
- The percentage of impervious surface area and mean annual rainfall of approximately 1,200 mm/year was used to estimate the annual runoff fraction (see Figure 4-2) for the development, i.e. 0.75.
- Effective catchment is 0.75 ha_{cat} x 0.75 = 0.56 ha_{eff}
- An estimated loss of 20% was taken into account due to bioretention filters. Therefore, the new effective catchment is 80%*0.56 ha_{eff}= 0.45 ha_{eff}
- The supply area is the catchment area of 0.75 ha_{sup} and is high-density residential development.
- Typical density and stormwater demand estimates for this type of development are provided in Table 3-11 and Table 3-12[44].

The yield curves are represented using the supply area per effective catchment area (ha_{sup} / ha_{eff}). The effective stormwater harvesting catchment is 0.45 ha_{eff} and the supply area is 0.75 ha_{sup}. Therefore, 0.75/0.45 = 1.7 ha_{sup} / ha_{eff}.

Using the yield curves, the storage volume required (kL/ha_{eff}) to supply the development at a given reliability is extracted. This example supplies water to a high-density residential development in greater Brisbane. This plot and an interpolated curve for 1.7 ha_{sup} / ha_{eff} are shown in Figure 7-10. If 52% reliability is required, a storage equivalent to 150 kL/ha_{eff} is needed. As the storage volume increases above this level, the increased percentage of reliability per unit storage volume decreases because the curve begins to flatten out. The total storage volume required is 150 kL/ha_{eff} x 0.45 ha_{eff} = 68 kL effective storage.

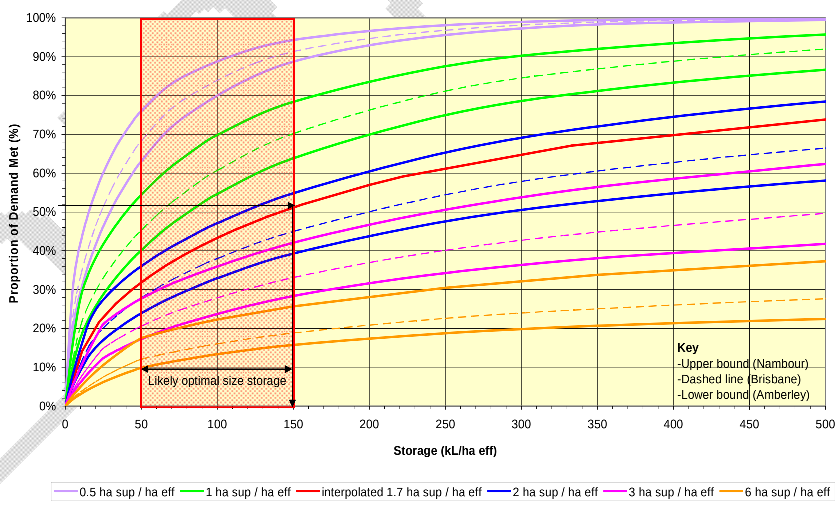

Figure 7-10: Generic stormwater harvesting yield curve for a high-density residential development — case study 3

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44 The typical water demands in these tables include an allowance of 5m^2 of irrigated area per dwelling to allow for body corporate areas such as landscaped gardens. This could potentially increase the reliability of the curves for this development depending on the extent of the gardens developed at this site.

7.4.6 Treatment requirements

The stormwater must be treated to an appropriate level based on the proposed end use (refer to Section 6). Water used for cold water laundry and toilet flushing requires a higher water quality compared to irrigation uses. End uses determine the stormwater treatment plant requirements. A treatment train as suggested in Figure 6-3 is appropriate for this development. However, the front end of the treatment train, including the oil and sediment separator, would not be required due to the use of bioretention filters.

7.4.7 Conceptual design

The overall scheme concept for stormwater harvesting, flood mitigation and stormwater quality improvement is illustrated in Figure 7-11.

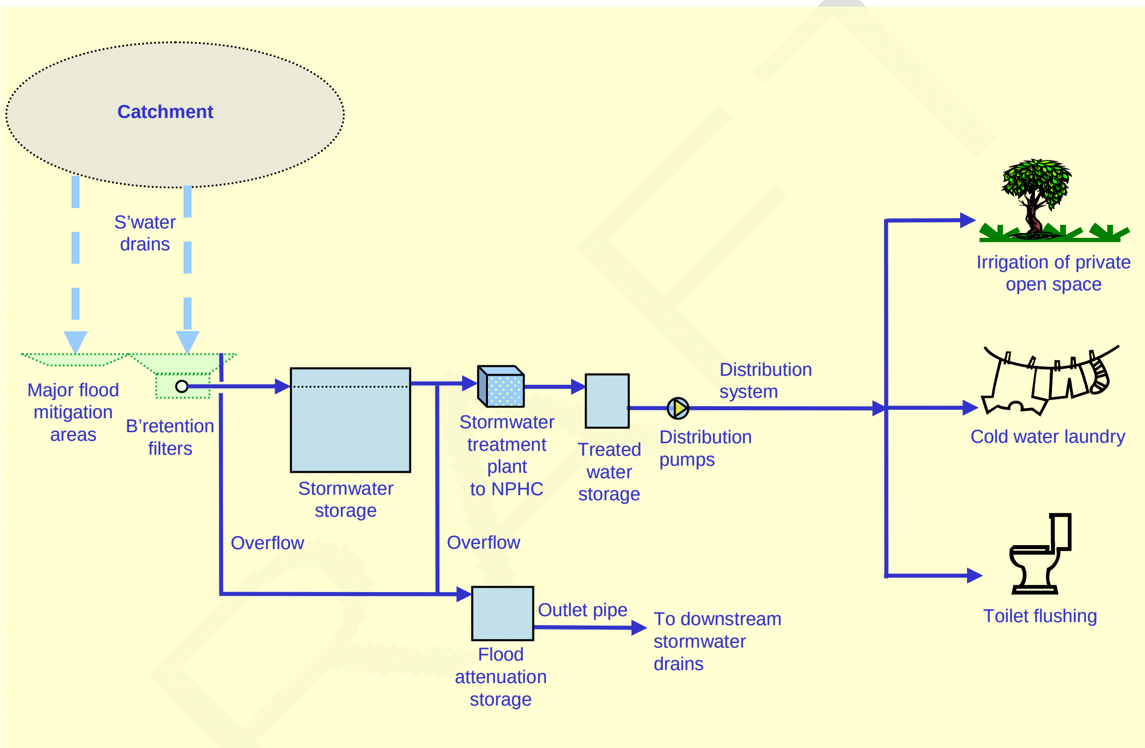

Figure 7-11: Schematic overview of stormwater harvesting system

7.5 Case study 4

7.5.1 Project need

As a result of the drought and water restrictions in South East Queensland, a large public corporation needed to implement strategies to improve water-use efficiency and reduce potable water consumption. The corporation owns and operates a large public facility including parkland, a large swimming pool, commercial operations and residential units. Under water restrictions, potable water cannot be used for irrigation or water features and its use for swimming pools is limited. The corporation required a reliable water source to maintain the substantial economic investment and public amenity of the public facility. Following a lengthy review of alternatives, the organisation committed to developing a stormwater harvesting scheme to help 'drought-proof' the facility.

7.5.2 Overall project description

The stormwater harvesting scheme is relatively large scale and will collect stormwater from a highly urbanised catchment of 30ha in total. The catchment includes old and new commercial development, a large area of parkland, a large school, some residential areas and major road and rail corridors. The scheme will divert water from a central stormwater pipeline draining to a river. A weir will be used to divert water to a pump well. It will then be pumped to the raw water storage tank. When required, water will be drawn from the tank for treatment and distribution around the site. The water will be used for landscape irrigation, refilling water features, flushing public toilets, external cleaning, event use, swimming pool filter backwashing and, potentially, swimming pool top-up.

Since the introduction of water restrictions, recycled pool filter backwash water has been used for irrigation. This will continue to be used on site to supplement the stormwater harvesting system and was taken into account in the water balance modelling.

An aerial photograph of the scheme area and a schematic overview of the scheme are shown in Figure 7-12 and Figure 7-13.

Figure 7-12: Stormwater harvesting catchment

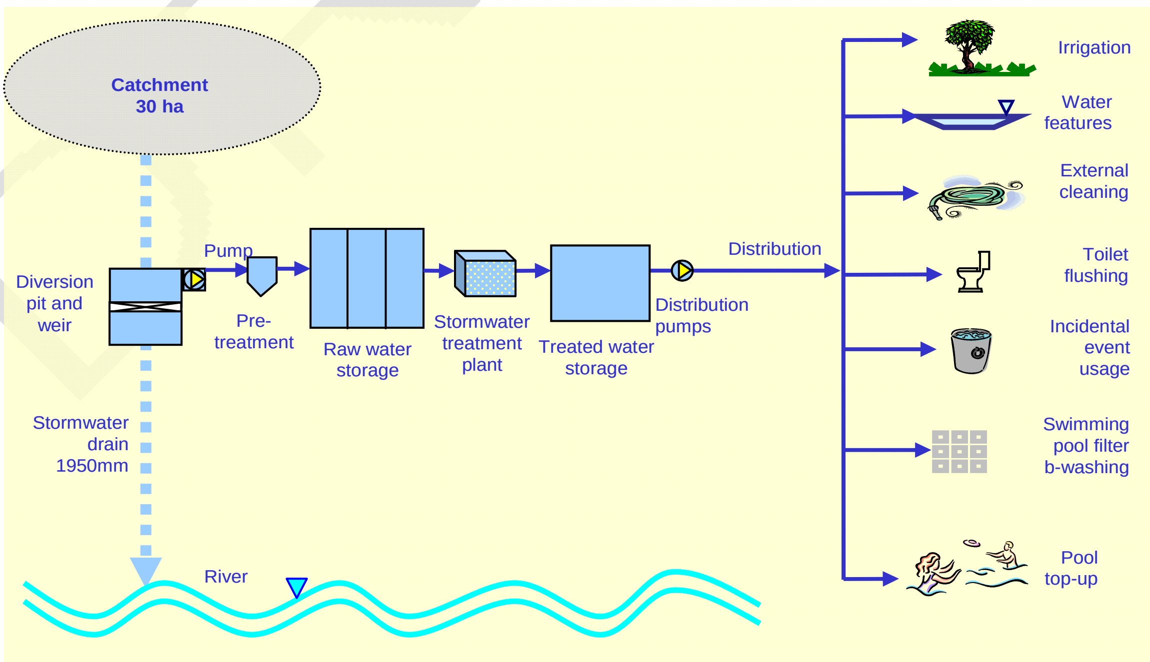

Figure 7-13: Schematic overview

7.5.3 Key planning considerations

Design objectives for the scheme

The key design objectives for the stormwater harvesting scheme were:

- to provide a reliable water source to help maintain the quality of a high-use public facility, particularly in times of drought
- to manage the hazards associated with stormwater harvesting from a highly urbanised catchment to use in a sensitive public area.

Water uses and water quality requirements

The uses for the water from this scheme are for facilities that have unrestricted public access and a high level of visitation. Water quality requirements must be conservative to ensure no risk of adverse health effects or environmental impacts. The risk of impact must be low. Based on Table 7-5, the water quality requirements were determined. Adopting pool top-up as the 'controlling water use' indicates that water quality 'PC' is required.

Table 7-5: Proposed uses and water quality requirements for case study 4

Proposed uses	Water quality	Relevant guidelines
Irrigation of landscaped gardens and parklands (unrestricted access)	NPMC/NPLC	*Australian Guidelines for Water Recycling: Stormwater Harvesting and Reuse — Phase 2* (EPHC, NHMRC, & NRMMC, 2009)
Refilling water features (unrestricted access)	NPHC/NPMC	
Public toilet flushing	NPHC	
General external washdown and cleaning		
Incidental event usage		
Pool filter backwashing (final filter flush with potable water)	PC	*Australian Guidelines for Water Recycling: Augmentation of Drinking Water Supplies* (EPHC, NHMRC & NRMMC 2008a)
Pool top-up (if acceptable)[45]		

HACCP risk assessment

A HACCP plan was required for this scheme because of anticipated risks from the highly urbanised catchment and the need to protect public health and the environment in a highly sensitive site (refer to Attachment D for methodology).

Key hazards

Numerous microbiological and chemical hazards associated with the various catchment land uses were identified.

The most significant sources of pollution identified in the land use study are from road runoff and chemical spills or other emergencies in the catchment. (See Attachment D for the methodology and Section 7.5.4 for an extract of the land use study). The key contaminants of concern were pathogens, turbidity, suspended solids and hydrocarbons. The key hazards were the likelihood of people coming into contact with the water, high-exposure end uses such as pool top-up and the inability to measure contaminants in real time.

An extract of the hazard identification and risk assessment is provided in Table 7-6. This is an example only and not a complete risk assessment; it does not cover the full range of identified risks.

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45 There was some reluctance to use treated stormwater for pool top-up and this has been deferred until experience in operating the system is obtained.

Control of key hazards

Critical Control Points (CCPs) and critical limits were defined based on the criteria outlined in Attachment D. Key CCPs for the hazards outlined in Table 7-6 are shown in Table 7-7 Supporting programs, which are not CCPs but are considered important for achieving the overall objectives and risk mitigation, were also identified, for example enhanced catchment management.

Other issues were highlighted in the HACCP

The HACCP identified the need for:

- preliminary water quality monitoring
- a strategy for auditing and reviewing compliance with the HACCP
- documentation and record keeping procedures.

Table 7-6: Extract of hazard identification and risk assessment for case study 4

ID	Hazard		Type C, B, P, R[46]	Maximum risk[47] (no control measures)			Proposed control measures	Residual risk		
	Source	Consequence		Likeli-hood	Severity	Risk Level		Likeli-hood	Severity	Risk level
1	Chemical spills e.g. pesticides, solvents, fuels, organics or inorganics	Chemicals in raw water storage	C	4	4	Very high	- Emergency services response - Protocols between emergency services and project owner to notify of incidents - Emergency response procedures - Register of accidents recording type and location of spill - pH & EC sensors at SHIP - GPT and screens in SHIP - Oil and sediment separator - Monitoring of raw water at intake and at RWS	3	3	Med
2	Breakthrough of pathogens - supply for pool top-up	Human health impacts	B	2	3	Medium	- Upstream controls including treatment - Monitoring of treated water quality including turbidity monitoring and automatic bypass - Monitor for customer complaints - Alternative water supply - Record keeping	1	3	Low

[46] C, B, P, R = Chemical, Biological, Physical and Radiological.
[47] For scoring guidance refer to Attachment E.

Table 7-7: Extract of critical control, critical limit, corrective actions and monitoring requirements for case study 4

CCP No.	CCP	Critical limit or target	Monitoring					Corrective action
			What	Where	Who	How	When	
1	Protocols — Emergency Services and Council	- Emergency notification received - No water diverted to raw water storage in event of spill or fire	- Emergency notification - Response to notification - Response time	Catchment	- Emergency services, council, Brisbane Water - Project owner — operators	Records of notification response and response times	During and after each event	- Shutdown diversion system - Empty water behind interception pit weir to waste - If necessary, empty raw water storage and clean out
2	- Ultrafiltration - Turbidity meter - Automatic bypass	- Filtered water below turbidity target levels - Bypass valve operating correctly based on turbidity	- Ultrafiltration membrane integrity - Turbidity (NTU) - Bypass valve operation	Downstream of ultrafiltration	Project owner operators	- Manufacturers membrane integrity system - In-line turbidimeter - Regular inspection, maintenance, calibration - Check automatic operation of valve	- Membrane integrity and turbidimeter — continuous - Inspection monthly - Calibration every three months	- Bypass out of spec water back to raw water storage - Determine cause of problem - Shutdown distribution system - Fix problem

Water demand

Water demand estimates were based on historical data obtained from the project owner and council metering records. Some assumptions regarding future use were made. Estimates of long-term average and peak water use are shown in Table 7-8. Average demands and seasonality were important for the water balance. Peak demands were important for sizing the storage and treatment system.

Table 7-8: Estimates of long-term water demand

Use	Average water demand (kL/day)	Peak water demand (kL/day)
Irrigation of parklands	205	549
Refilling water features	23	61
General external washdown and cleaning	negligible	negligible
Public toilet flushing	8	21
Pool backwashing	85	228
Pool top-up	85	228
Total	406	1,087

Minimum service standards

In consultation with the owners of the site, the minimum standards of service were determined:

- Minimum residual pressure at point of supply — 50m for irrigation, 22m for other uses.
- Minimum flow — pump rate 0–22L/s to meet a range of uses, with the higher end of the range representing night-time peak irrigation rates.
- Supply reliability — no minimum level of reliability was set for supply and the water balance model was used to optimise the configuration to achieve the most cost-effective system yield and reliability. The proposed supply will not provide 100% reliability and will need to be managed to make the best use of available water. Using pool backwash water will help to provide a reliable and constant base source of water.
- Supply continuity — a high level of continuity is desirable though not essential for irrigation and water features. 100% continuity is required for pool water supply or toilet flushing. 100% continuity can be achieved by having an alternative source available when required.
- Water quality — water quality will meet the relevant guidelines based on end use (refer to Section 3.3).

Impact on other water supplies

The scheme will reduce demand on the council potable water supply.

Other potential environmental impacts

There are a number of possible environmental impacts of the stormwater harvesting system:

- Increased flooding may occur due to the diversion weir. The weir on the stormwater outlet pipe is designed to ensure no increase in upstream flooding. Refer to Section 7.5.4 for further detail on modelling.
- Some water quality improvement in downstream environments is expected due to the capture of stormwater pollutants. More importantly, if there is a spill in the catchment, the stormwater harvesting weir provides the opportunity to contain the spill preventing contamination of the river.

Budgeted cost estimates

Cost estimates were prepared for the scheme including capital and operating and maintenance costs. These costs were calculated on a cost per kL of water supplied. The estimates were used to compare the benefits of increasing the storage size of the system and of varying usage of the harvested water.

There were a number of major findings from the cost analysis:

- While there is an additional capital cost associated with increasing the size of the storage, when expressed as a rate per kL of stormwater supplied, the costs are very similar for each of the demand scenarios.
- Using more water, such as including pool water use, significantly reduces the unit supply cost.
- When compared with other charges, the calculated unit costs were higher than potable water charges (with all costs included), but significantly lower than the cost of imported recycled water.
- As potable water is not expected to be available for irrigation, at least in the short-term, the higher cost of importing recycled water is a good representation of value of the scarcity of water under drought conditions.
- Using recycled water to meet any shortfall increases the relative benefit of providing a more reliable stormwater supply.

Community and stakeholder consultation

Stakeholder consultation, particularly with key government agencies, occurred during the design of the project. The key government stakeholders for this project were:

- the local council as owner of the stormwater drainage system, who issued a licence to allow stormwater harvesting at this location
- DERM in relation to protection of the river environment
- Queensland Health regarding protection of public health and water quality requirements.

Apart from the council licence, there were no specific approvals required for this scheme. Engagement with these agencies was considered prudent to ensure a robust and supported outcome. DERM's interest relates to the proponent's responsibility in terms of 'General Environmental Duty' as defined in the *Environmental Protection Act* 1994. DERM approval may also have been required for water extraction if the scheme was located above the tidal limit of the river.

A community engagement and education program was identified as a requirement and as a CCP in the HACCP plan. Community engagement and consultation commenced during construction and will be ongoing.

Governance issues

This project is owned and operated by the private corporation. The water produced from the scheme will be used by the corporation within its lands. No water will be supplied to third parties.

This structure avoids consideration of whether the organisation is a 'water service provider' under the *Water Act 2000*, or the *Water Supply (Safety and Reliability) Act 2008*.

Management and operational issues

Before commissioning the scheme, an overarching management plan will be prepared to provide detail on operational and maintenance issues, including:

- catchment management strategies, including emergency response measures
- operation of the diversion system to maximise yield without exacerbating flooding
- inspection and cleaning requirements for the diversion pit, oil and sediment trap and raw water storage
- treatment plant operation
- storage operation to optimise supply in dry weather
- catchment and treated water monitoring programs
- environmental impact monitoring programs
- system monitoring for pest management, e.g. mosquitoes.

7.5.4 Design considerations for catchment and runoff

Catchment history

A search of EPA (now DERM) databases was used to identify sites within the catchment that could be contaminated based on past or current land use (refer to Section 4.2). A search of the Contaminated Land Register (CLR) revealed that there were no sites within the catchment known to have contamination (i.e. registered on the CLR). However, 25 'Notifiable Activities' were identified as being in, or near, the catchment. Further investigation of these land uses was conducted by a walk-around survey to establish the potential for current contamination.

Future considerations for the catchment

No significant land use changes are anticipated in the catchment, though the progressive redevelopment of the commercial areas will continue. However, changes to the arterial road network will result in increased traffic in the catchment. This could increase the chemicals and heavy metals associated with road and traffic deposition.

Catchment management

Issues that will need to be considered in any catchment management strategy include:

- detailed investigation of existing stormwater drainage arrangements to confirm and improve the understanding of the location and function of infrastructure
- retrofit WSUD over time to improve runoff water quality
- regulate any industrial uses to avoid contamination
- maintain stormwater conveyance structures — pipes and roads
- rehabilitate leaking or overflowing sewerage networks, if required
- development of relationships and protocols with emergency services to develop responses to spills or fires in the catchment.

Determining catchment runoff

Local climate and rainfall

Daily rainfall data was obtained from DERM's SILO database. The average rainfall over the 50 years analysed is 1080mm/year and the climate is sub-tropical (refer to Section 4.3.1).

Land use

A land use study was completed to characterise the catchment and determine potential sources of contamination. This was based on aerial photos combined with a visual survey. The land use types and their approximate areas are provided in Table 7-9.

Table 7-9: Land use type and area in the catchment

Land use type	Proportion of total catchment (%)
Offices and business (e.g. retail/restaurants)	28
Paved areas including roads, footpaths, car parks and busway	21
Railway	2
Residential (includes churches and vacant land)	8
School	13

Land use type	Proportion of total catchment (%)
Mixed use	9
Parks an gardens	19
Total	100

Of the land uses in the catchment, the types of businesses in the catchment are not expected to have a major impact on stormwater quality. The businesses are not expected to use or store large quantities of chemicals. Research also indicates faecal contamination in commercial areas is significantly lower than in residential areas (Duncan, 1999 in EPHC, NHMRC & NRMMC, 2009). Business activity is more likely to have an impact on stormwater via gross pollutants such as litter.

Paved surfaces, including, roads, footpaths and above car parks, account for a relatively large proportion (21%) of the catchment and will contribute a broad range of contaminants associated with traffic deposition. Given the catchment carries relatively high traffic volumes, pollutants such as sediment, phosphorus, nitrogen, copper, lead, zinc, cadmium and iron could be expected in the untreated stormwater runoff.

In addition to the land use study, potential specific sources of contamination were considered based on the likelihood of chemical storage, use or other mechanism for stormwater contamination. Activities identified in this study included a hardware shop, printing shop and educational facilities.

The other possible source of contamination is from wastewater leakage or overflow from the sewerage system.

Role for WSUD in runoff quality control

The existing stormwater catchment is fully developed leaving limited opportunities for retrofitting WSUD measures, at least in the short term. However, in the long term, there may be opportunities to incorporate WSUD features into the catchment associated with new developments or infrastructure upgrades.

Runoff monitoring

Flow gauging was undertaken to obtain actual catchment runoff data to verify the runoff model. A flow meter was installed and flow was recorded for significant events over a number of months.

Model runoff regimes

The objectives of the modelling were to:

- assess the implications of the proposed stormwater harvesting interception pit (SHIP) on catchment drainage
- determine the optimum harvesting pump rate.

The stormwater modelling was completed using SWMM software. The stormwater catchment was split into a number of sub-catchments representing the hydraulic behaviour of the existing drainage system. Sub-catchments were characterised by average slope and percentage imperviousness to give an estimation of runoff.

The purpose of event simulation was to determine the best possible weir configuration and its impact on upstream water levels during extreme storm events. The model was tested for storm events with a range of recurrence intervals (1, 2, 10, 20, 50 and 100 year ARIs) for a range of rainfall durations (15, 30, 60 and 90 and 120 minutes). The results indicated that a 60-minute rainfall event is the critical event for the design. The model was then run for a range of 60- minute rainfall events and a number of possible weir configurations as shown in

Table 7-10.

Table 7-10: Scenarios tested in design storm simulation

Scenario		Outfall condition	Weir crest level (m AHD)	Weir length (m)
1	With weir	MHWS = 0.98 m above AHD	1.0 m, 1.2 m, 1.4 m	2.5 m, 3.0 m, 4.0 m
2 (current design standard)	No weir	MHWS = 0.98 m above AHD		
3	With weir	HAT = 1.55 m above AHD	1.0 m, 1.2 m, 1.4 m	2.5 m, 3.0 m, 4.0 m
4	No weir	HAT = 1.55 m above AHD		

The purpose of the long-term simulation was to investigate how stormwater yield would vary over a range of harvesting pump capacities to determine an optimum diversion rate. The long-term simulation was used to assess the variation in yield as the pumping rate was increased from 10 L/s to 70 L/s.

Flood considerations

A weir was required across the pipe to keep the tidal saline river water from the stormwater harvesting system. The tidal variation was critical in setting the weir level. The weir must be high enough to exclude most tides, yet not too high that it causes upstream flooding if the weir is overtopped. The weir is designed to open in the event of high storm flow. To provide a full understanding of the tidal range, 33 years of hourly tide level data were obtained. The percentile analysis presented in Figure 7-14 illustrates how the tide level varies over time.

Detailed modelling of the stormwater catchment was completed using the SWMM model.

Based on the modelling, a weir with a crest level at RL 1.2 m and an overall weir crest length of 3.0m was recommended. The analysis of catchment drainage under design storm events with, and without, the weir indicated:

- introducing the weir would increase the upstream HGL under design storm events
- the weir control should be set to open the weir when the upstream water level reaches RL 1.8 m AHD to ensure that the upstream HGL level does not exceed the Q100 HGL without the weir
- if, in the worst case scenario, the weir fails to open, the analysis showed that the upstream HGL level will increase by 0.7 m for a Q100 event and that it would still be contained within the underground drainage system.

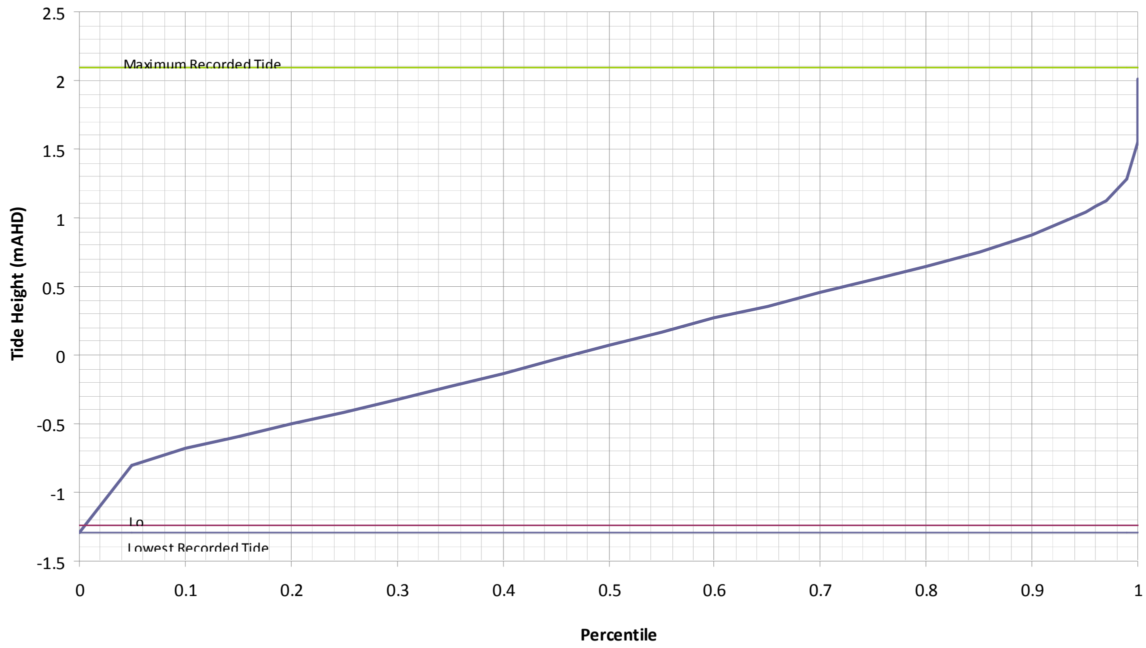

Figure 7-14: Percentile analysis of tidal variation

Climate change allowance

The potential future impact of climate change was assessed allowing:

- a 30% increase in rainfall intensity of 100-year ARI – 60 min event
- a 200 mm sea level rise.

The assessment indicated:

- there would be a significant increase in peak runoff flows reaching the weir, which would increase water levels upstream of the weir; however, there would be no surcharge at any point in the drainage system
- the expected increase in sea level would not have any significant effect on upstream water levels.

Runoff quality

Runoff quality was addressed in the form of a detailed water quality discussion paper and the risks associated with contaminants were considered in the HACCP plan.

Water quality monitoring

Because of the wide range in water quality results from published sources, a water quality monitoring program was initiated to provide baseline catchment-specific data. The initial screening tests included:

- catchment baseflows to identify possible groundwater infiltration or water supply leakage
- two event flows to characterise runoff during storm events.

The data obtained from the monitoring showed that the runoff from the catchment was generally similar to typical reported concentrations found in urban runoff.

7.5.5 Design considerations for diversion and raw water storage

Water balance modelling

A water balance was completed assuming three transfer rates; an effective catchment of 22 ha, taking into account runoff from pervious and impervious areas; and a range of raw water storage volumes from 500 kL to 3 ML as shown in Figure 7-15. The results indicate that a storage volume of between 2–3 ML is the optimum size for the anticipated demand.

The storage optimisation process is an iterative process with a broad range of options tested based on different demand scenarios, different catchment areas and storage sizes, overlaid with refining estimates of input parameters. In this case, yield is defined as the proportion of demand supplied on average.

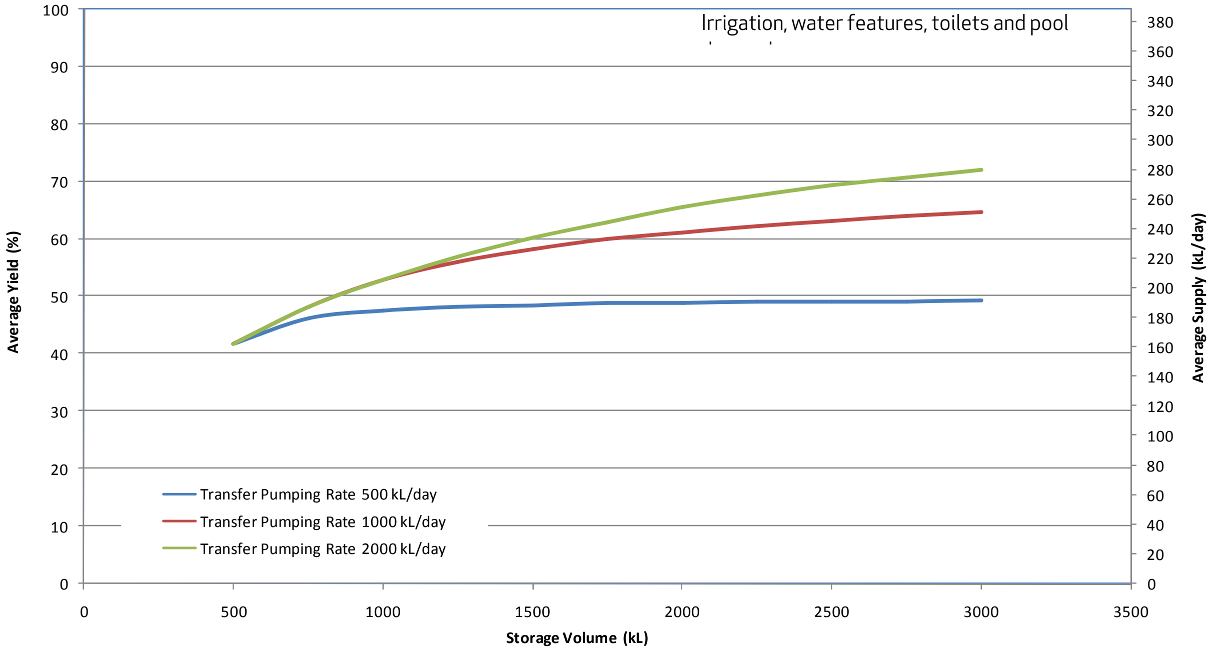

Figure 7-15: Stormwater harvesting water balance

Supply reliability can also be represented as a percentile analysis plot as shown in Figure 7-16, generated from the daily water balance model results. The analysis illustrates the percentage of time a particular proportion of total demand can be supplied. The analysis indicated that for lower demands (i.e. irrigation and water features) a 2 ML storage could supply no less than 75% of the daily demand, 80% of the time. It could meet 100% of the daily demand 78% of the time.

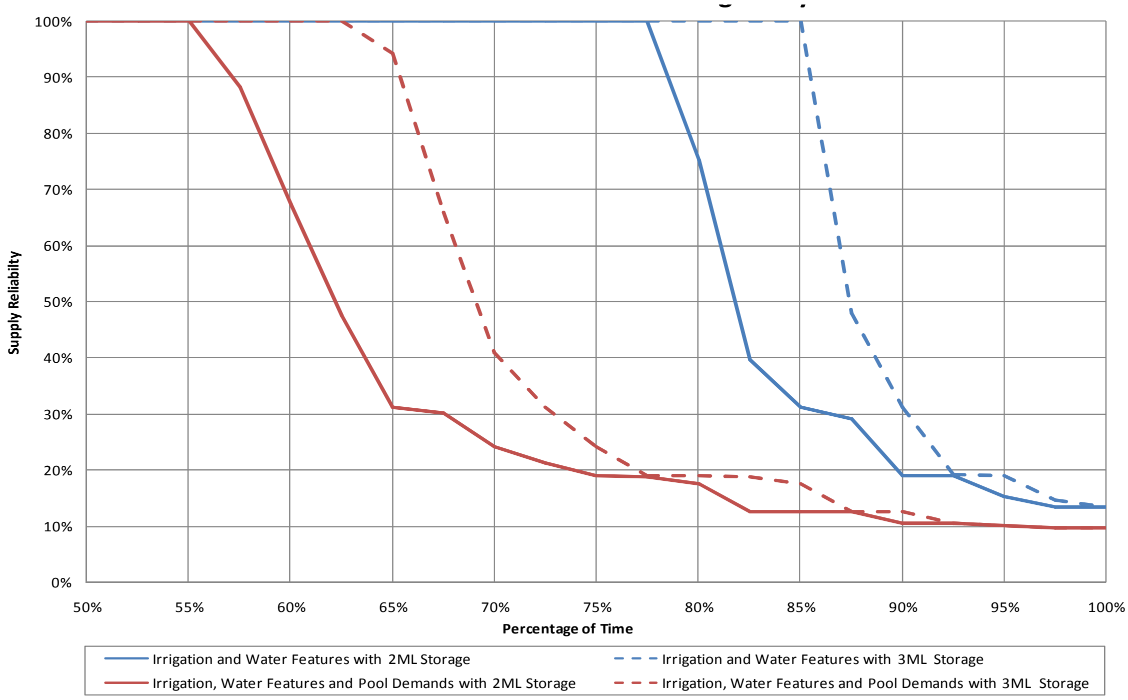

Figure 7-16: Supply reliability curves for case study 4

Diversion rate

Initially, the water balance, as shown in Figure 7-15, showed that a transfer pumping rate of 2000 kL/day was optimal. A detailed long-term model of the stormwater catchment and runoff was completed using SWMM. The model showed:

- The optimum pumping rate is approximately 20 L/s, which maximises the potential yield over a range of expected water demands. This is equivalent to a maximum daily transfer rate of 1.7 ML.
- Even though the catchment runoff rates for many storm events are significantly higher than the pumping rates, harvesting water is limited by the rate at which the storage can be filled.

Raw water storage

The site is highly urbanised and an off-stream storage was required. Due to limited space at the site of the stormwater harvesting scheme and the relatively large size of the tank, an underground storage was proposed.

7.5.6 Design considerations for treatment, treated water storage and distribution

Design parameters

The stormwater distribution system was designed for an estimated peak daily demand of 1.1 ML/day. To treat the water at this rate over 24 hours requires a minimum plant capacity of 12.6 L/s. Allowing for a safety factor (i.e. supply over 20 hours rather than 24 hours per day) the design capacity increases to 15 L/s. To reduce costs, and to reduce the rate of depletion of the storage, the treatment plant capacity was reduced to 7 L/s. Modelling showed this only marginally reduced the average reliability and supply from the system.

Proposed treatment

This stormwater harvesting and reuse system is designed to treat urban runoff and pool waste backwash water only. The broad treatment objectives are as detailed in Section 6.2. The proposed treatment train is shown in Figure 7-17 and the unit processes are outlined:

- Stormwater harvesting interception pit:
    - the weir intercepts stormwater flow in the stormwater drainage pipe, acting as a temporary stormwater storage and preventing salt water intrusion
    - a sump behind the weir acts as a gross pollutant trap for coarse sediment retention
    - coarse screens exclude litter and other gross pollutants from the pump well
    - bypass valves allow water of unacceptable quality (high/low pH or EC) to be discharged below the weir
    - instrumentation is provided for the continuous monitoring of pH, water level and conductivity (upstream of weir), and water level (downstream of weir)
- Stormwater harvesting, treatment and reuse:
    - primary treatment including oil, hydrocarbon and fine sediment separator
    - compartmentalised raw water storage to enhance sedimentation
    - instrumentation in the raw water storage for the continuous monitoring of turbidity, ORP, pH, water level and conductivity
    - polyelectrolyte dosing for enhanced coagulation and removal of solids
    - pre-filtration as pre-treatment for ultra-filtration
    - ultra-filtration (effective pore size 0.01 μm) for removal of suspended solids or turbidity as precursor to UV disinfection
    - activated carbon filtration to provide some removal of organic chemicals
    - ultraviolet disinfection
    - instrumentation is provided for the continuous monitoring of turbidity (downstream of ultrafiltration) and UV intensity
    - residual chlorination — Sodium hypochlorite dosing to provide a residual chlorine concentration of approximately 1mg/L
    - treated water storage recirculation to maintain water quality and chlorine residual
    - instrumentation in treated water storage for the continuous monitoring of water level and free chlorine residual.

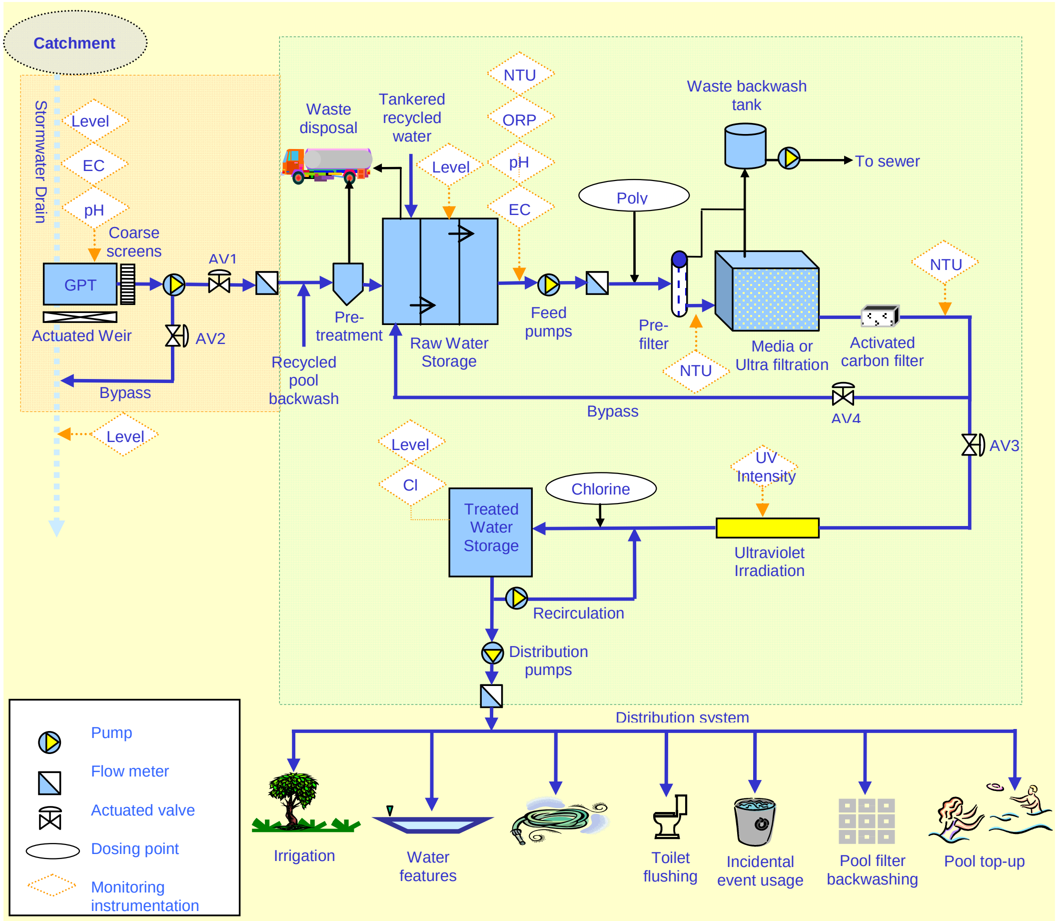

Figure 7-17: Schematic of stormwater harvesting system for case study 4

Requirements for treated water storage and distribution

The minimum treated water storage volume of 250 kL was provided to adequately balance the treatment plant capacity and diurnal variations in instantaneous demand.

Variable speed pumping units will deliver up to 22 L/s into the distribution system, depending on demand.

Treated water quality monitoring

An extract of the preliminary water quality monitoring requirements for the initial validation and the first year of operation is shown in Table 7-11. Initially, the monitoring will target a broad range of contaminants with frequent sampling to assist in characterising the water quality of the scheme (refer to Section 6.8). Long-term monitoring will be defined in the future. It will most likely be narrower in scope based on contaminants of concern identified in the validation and short-term monitoring.

Table 7-11: Extract of preliminary water quality monitoring program for case study 4

Parameter	Sampling frequency[48]							
	Raw water inlet		Raw water storage		Treated water storage		Distribution system	
	Val[49]	Ver[50]	Val[49]	Ver[50]	Val[49]	Ver[50]	Val[49]	Ver[50]
	c = continuous, e = event related, w = weekly, m = monthly, q = quarterly, a = annually, - = none							
Pathogens								
E. coli	e	e	w	w	w	w	w	m
F-RNA bacteriophage	e	e	w	w	w	w	-	a
Somatic coliphage	e	e	w	w	w	w	-	a
Clostridium perfringens	e	e	w	w	w	w	-	a
General parameters								
Turbidity	e	e	w	w	c[51]	c[51]	m	q

7.5.7 Summary

The planning and design of the project in a high-use public area without comprehensive stormwater harvesting research and guidelines required all aspects of the project to be thoroughly addressed, including stakeholder consultation, risk assessment, stormwater modelling and water quality monitoring. This stormwater harvesting project highlights the degree of complexity for some stormwater harvesting systems in urban catchments.

Some of the key challenges were:

- water-balance modelling to determine whether a stormwater harvesting system was likely to be effective at this location
- identifying whether there were feasible locations for the diversion structure, the large raw water storage and the treatment plant
- determining the likely runoff water quality and the associated HACCP analysis to confirm treatment requirements
- catchment runoff modelling to confirm runoff volumes and diversion rates, and to check that the diversion weir will not cause upstream flooding
- the iterative nature of the analyses as new information became available and a broad range of options was evaluated.

The final concept design successfully took advantage of the opportunities of the site to meet the objectives and needs of the corporation.

Figure 7-18 and Figure 7-19 illustrate the sketches produced as part of the concept design for this scheme.

48 Sampling frequencies adapted based on: NHMRC & NRMMC 2004; NRMMC, EPHC & AHMC 2006; and EPHC, NHMRC & NRMMC 2008a.
49 Val = Validation (commissioning).
50 Ver = Verification – Short term only (1st year of operation post validation).
51 In-line treated water monitoring for turbidity post ultrafiltration.

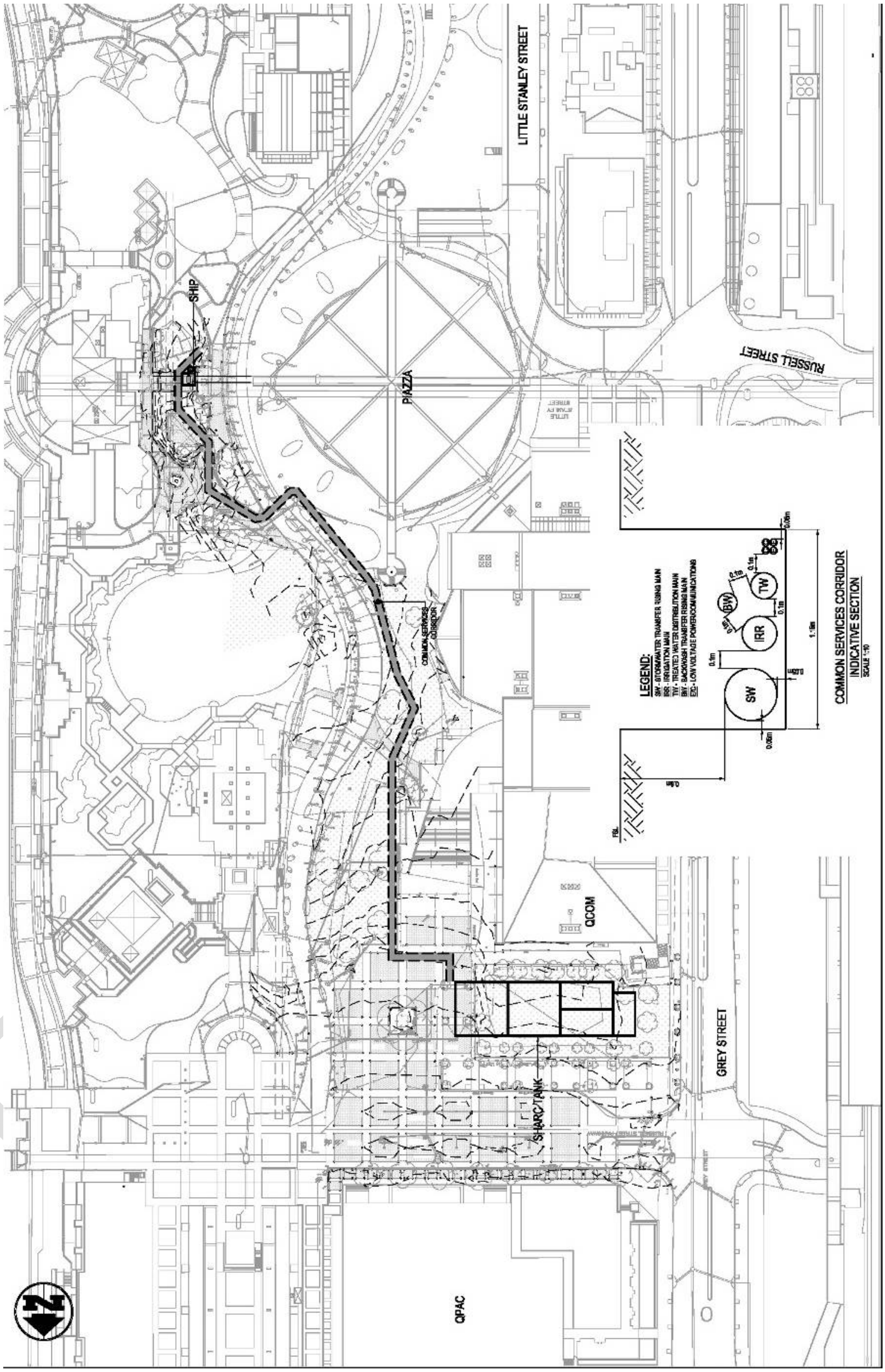

Figure 7-18: Layout of diversion and services corridor to storage tank

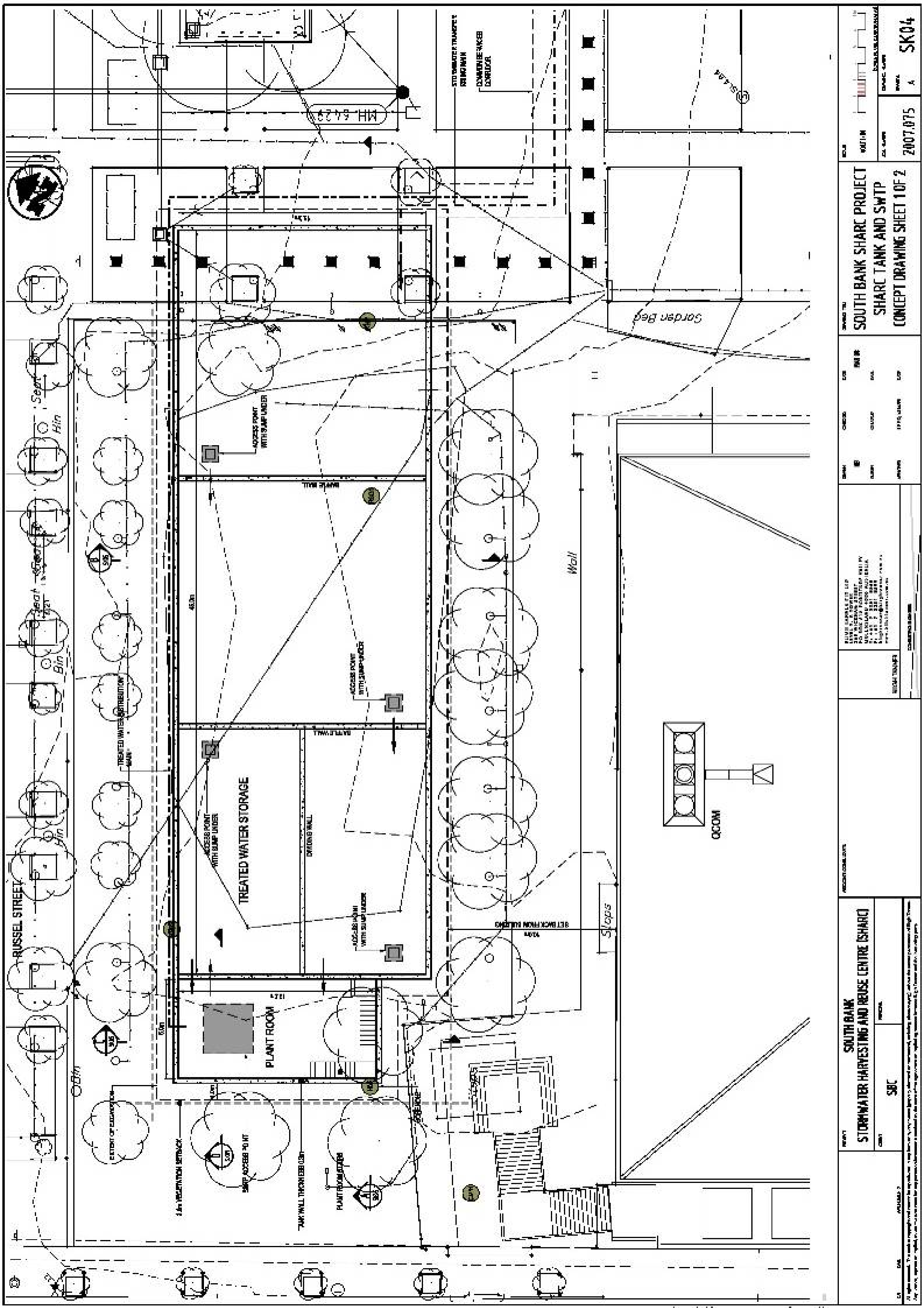

Figure 7-19: Layout of storage tank and plant room

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Attachment A – Design Tables

Section 4

Table A-1: Design considerations — catchment level

System component	Design considerations	Design approaches	System alternatives
Catchment (Section 4.2):			
Catchment history (Section 4.2.1)	What was the historical use of the site? Is the land contaminated?	Local authority records DERM search — Contaminated Land Register (CLR) and Environmental Management Register (EMR) Local historical society or residents' association Council library Aerial photography (DERM)	
Future land use (Section 4.2.2)	What does the local town planning scheme provide for? Are there any significant works planned in the catchment?	Review town plan and strategic plan Review planning by state authorities e.g. Main Roads Check Development Applications	
Catchment management (Section 4.2.3)	What are the land uses defined by the local Town Planning Scheme? Is the catchment sewered? Is the sewer in good or poor condition? Is there likely to be sewer overflow to stormwater runoff? Is that catchment developed? What type of development: urban, commercial, industrial, agricultural, recreational? Is there a possibility of diversion or overflow of this catchment into others, or conversely other catchments to this one?	Review town plan Review the local authority's 'as constructed' records of built infrastructure e.g. sewer, water, stormwater Obtain aerial photography (DERM) Walk the catchment, observe land uses and built infrastructure Obtain contour mapping from ortho photos or land surveys Obtain detailed land survey at critical components e.g. stormwater pipes, levels at potential overflows from other catchments, at the likely diversion and storage facility	

System component	Design considerations	Design approaches	System alternatives
Catchment runoff (Section 4.3):			
Climate (Section 4.3.1)	What is the rainfall and evaporation?	BOM or SILO climate records	Local council records
Quantifying runoff rates (Sections 4.3.4)	Land use ~ % impervious surfaces	Determine C_{vol}, or use other loss models	Calibrate to recorded stream flows (if available)
Flooding (Section 4.3.5)	Unless agreed otherwise with the local authority flood levels and flows must not increase as a result of the stormwater harvesting scheme	Refer to AR&R, 2001 and QUDM, 2007, supplemented by local authority requirements	Upstream water level monitoring and alarms
Runoff water quality (Section 4.3.6)	Impact of existing and future land use on runoff quality Sources of contaminants Pre-treat runoff before diversion or storage Contaminants impact on the diversion and storage, particularly sediment build-up	ARR quality and other local guidelines MUSIC, SWMM or other software can be used to model the water quality of runoff and to determine appropriate treatment measures if these are required, for example as pre-treatment to a stormwater harvesting scheme Consider available reference material (Section 1.4 Existing guidelines for stormwater harvesting) for other potential contaminants Consider undertaking background monitoring to characterise catchment runoff water quality (Section 3.5)	
Monitoring of catchment runoff quality and quantity (Section 4.4):			
Monitoring and instrumentation (Section 4.4)	Monitored flow rates and contaminant concentrations can be used to calibrate runoff models Characterisation of catchment specific runoff water quality	Measure catchment base flows, if they exist Measure catchment rainfall event runoff flows Measure concentrations of contaminants of interest Measure event rainfall depths	Permanently installed instrumentation Periodic manual sampling and analysis

System component	Design considerations	Design approaches	System alternatives
Water Balance (Section 4.5):			
Water balance (Section 4.5)	Set up a spreadsheet or use other more sophisticated modelling techniques to determine the reliability of the stormwater harvesting scheme and efficient storage sizes and diversion rates. Parameters to include are: • historical rainfall and evaporation • catchment runoff including losses • diversion capacity • storage losses • the fluctuating nature of demand • any limiting factors.	Plot curves exploring the relationships of all the variables for the following: • yield ~ storage size • yield ~ catchment size • yield ~ diversion capacity. Determine the preferred sizes of the scheme components.	Use more sophisticated modelling techniques, such as XP-SWMM to run long-term simulations including hydraulic effects of diversions etc.

Table A-2 Design considerations — diversion and storage

System component	Design considerations	Design approaches	System alternatives
Diversion (Section 5):			
Location (Section 5.3)	Is diversion from a natural waterway, man-made channel, pipeline or surface water body? What is the best location on the waterway to construct the diversion? Is the site subject to tidal inundation? Is it accessible? Does it provide safe access for construction and operations?	Obtain catchment mapping. Obtain as-constructed details of existing drainage infrastructure from the local authority or by inspection and survey. Confirm invert levels at key locations, by survey if necessary. Ensure the site is accessible for construction and operations activities. Assess whether there are any adverse visual impacts on adjacent land uses and users. Check tidal level variation.	Lake or pond Channel Pipeline

System component	Design considerations	Design approaches	System alternatives
Diversion structure (Section 5.3)	Is there an existing point to harvest from that does not require a flow control structure? Is a weir required across the flow path to divert the flow? Can the weir be fixed or does it need to be removed during flood events or for maintenance? Will the structure result in temporary or permanent upstream ponding of water after rain events? Is the impact of inundation upstream of the weir acceptable? Will the weir cause upstream flooding under storm events? Will the construction of a weir have any adverse impact on the downstream environment, e.g. through reduced flows or water quality? Is a pit required to access the diversion structure?	Consider alternatives to a weir. Use the catchment runoff model to determine the minimum weir height required. Use the water balance model to assess the expected upstream inundation periods. Use the catchment runoff model to assess impacts on upstream drainage and flooding. Consider the need to incorporate pre-treatment systems into the diversion structure. Consider access requirements for operations, maintenance and cleaning. Assess the extent of upstream ponding as a result of the diversion structure. Assess safety issues associated with the upstream ponding. Assess aesthetic issues associated with the upstream ponding. Assess possible pest issues associated with the upstream ponding.	Use the existing diversion point to avoid a new structure. Hydraulic control alternatives include: • fixed concrete or steel weir • moveable weir gate (manually or electronically actuated) • spillway over embankment.
Pre-treatment	Refer to Sections 6.4		
Diversion system (Section 5.3.1)	Can flow be diverted by gravity to the storage? What is the best way to install diversion pumps? Are duty or standby pumps required? What power supply is required for diversion? Is a suitable power supply available? If not, what are the options to provide a power supply? Is an automatic diversion system required to pump unwanted water downstream of diversion structure?	Gravity diversion as an alternative to pumping. Evaluate alternative pumping configurations, e.g. submersible or surface mounted pumps. Determine level of redundancy required, i.e. are duty or standby pumps needed? Consider cost of providing power to the site in scheme evaluation.	Submersible pumps. Self-priming surface mounted pumps. Flood harvesting.

System component	Design considerations	Design approaches	System alternatives
Diversion rate (Section 4.5 and 5.3.2)	What is the optimum diversion transfer rate?	Use the catchment runoff model to optimise system yield over a range of possible diversion transfer rates. Use small time-step modelling (not >30mins). Minimise transfer rate to minimise capital and operating costs.	
Excess runoff (Section 5.5)	Can flows in excess of the capacity of the diversion system bypass to the downstream waterway? Does the reduction of downstream flows affect the downstream waterway? Do bypassed flows have the potential to affect the downstream waterway?		
Other possible considerations	Are there any possible water quality concerns in any permanent or temporary impoundments created at the diversion? Is there any risk of pests (e.g. mosquitoes) or vermin associated with any local impoundment?	Ensure, where possible, that storages are covered. Ensure water quality monitoring is implemented. Avoid shallow, protected ponded areas. Ensure that a pest monitoring and management program is implemented.	
Control	What controls are required to trigger diversion? What controls are required to prevent diversion? What telemetry systems are required? What remote supervisory and control systems are required?	Provide local automatic control system to ensure independent operation as required. Determine the appropriate type of remote supervisory control and data acquisition (SCADA) system for the scheme. Provide telemetry for remote monitoring and control. Provide alarms to centrally monitored location. Ensure procedures and protocols to monitor and maintain the system.	Local automatic control only; no remote supervision. Local automatic control with remote monitoring of alarms and operation but no remote control. Local automatic control with remote monitoring and control. Dial-in systems via modem. Hard-wired or radio controls. Automatic dial-out alarms.

System component	Design considerations	Design approaches	System alternatives
Monitoring and instrumentation (Section 5.6)	What parameters must be monitored? What is the required sampling frequency? Can these be monitored in real-time? What instrumentation is required for monitoring and control? What water quality sampling is required? What water quality parameters will need to be analysed in the laboratory?	Develop an appropriate water quality monitoring program. Instrumentation could include: • level sensor upstream of the diversion structure • level sensor downstream of the diversion structure • water quality monitoring at diversion structure, e.g. pH, EC, ORP • diversion flow meter • determine other water quality monitoring requirements for manual sampling and laboratory analysis.	On-line instrumentation. Manual grab samples. Automatic, event and flow-paced samplers.
Operations and maintenance	What resources are required for monitoring, operations and maintenance of the system? What are the minimum requirements for operation and maintenance of the diversion structure and diversion system? What are the minimum requirements for operation and maintenance of the instrumentation and control systems?	Develop a comprehensive operation and maintenance program. Ensure that the appropriate financial and labour resources are available and costed.	
Financial	Is the proposed diversion affordable, including both capital and on-going operations and maintenance costs?	Undertake a cost–benefit analysis for the scheme. Assess the unit cost of water ($/kL). Compare stormwater costs with other sources of water.	
Raw water storage (Section 5.4):			
Storage configuration (Section 5.4.1)	Is the storage on-stream or off-stream? Are there any specific constraints to the storage configuration that can be provided? What space is required? Is the space available? What is the opportunity cost of the land?	Investigate land options by survey and site assessment. Financial analysis of land costs.	

System component	Design considerations	Design approaches	System alternatives
Storage sizing (Section 5.4.2)	How large does the storage need to be for the proposed water use and reliability? Cost of storage options, e.g. underground, aboveground, open water body. Impacts on scheme reliability.	Cost estimates of alternative storage types. Is the estimated yield reliability suitable?	
Storage type — on-line (Section 5.4.3)	Can the required volume be achieved at the available site? Is the ratio of water depth to surface area high enough to ensure acceptable evaporative losses? Can the geological and soil conditions retain the water effectively without a liner? Can a suitable hydraulic control be constructed at the site? What is the impact of the storage on the waterway? Is the aesthetic impact of the water body acceptable to surrounding land uses? What is the anticipated stored water quality? What is the impact of flood flows on the storage? What is the role of the storage in the overall stormwater management system? Does the storage need to be covered? If so, how will the storage be covered? Will the storage accumulate sediments? How will any accumulated sediments be removed from the tank? How will safe access to the tank for maintenance be provided?	Identify the range of storage systems available and the potential suppliers.	On-stream lake or pond Wetland Stormwater retention storage

System component	Design considerations	Design approaches	System alternatives
Storage type — aquifer (Section 5.4.4)	Is there a suitable aquifer close to the diversion system? Is the aquifer confined or unconfined? What is the quality of the existing groundwater in the aquifer? What are its current uses? What is the available storage volume within the aquifer? What is the impact of stormwater storage on groundwater levels, water quality, hydraulic gradients and movement? Are there any potential or perceived environmental or economic impacts associated with artificial recharge of the aquifer? What is the best means of recharging the aquifer, i.e. infiltration basins, gravity injection or pumped injection? What are the requirements for stored water recovery, including number and depth of bores and pumping rates? What are the investigation requirements to map the existing subsurface system and prove the scheme feasibility? What are the on-going groundwater level and quality monitoring requirements? Are there other environmental monitoring requirements?		Natural or artificial aquifer systems

System component	Design considerations	Design approaches	System alternatives
Storage type — off-stream (Section 5.4.5)	Can the required volume be achieved on the site? Are the geological conditions suitable for storage construction? Will the aesthetic impact of the storage be acceptable to surrounding land uses? What is the anticipated stored water quality? What is the role of the storage in the overall stormwater management system? Can the storage be aboveground? Does it need to be buried? If buried, is there a potential for high groundwater levels? What provision is required to protect the tank against floating? Does the storage need to be covered? If so, how will the storage be covered? Will the storage accumulate sediments? How will any accumulated sediments be removed from the tank? How will safe access to the tank for maintenance be provided?	Identify range of storage systems available and potential suppliers.	Off-stream open pond or basin. Custom built above- or below-ground tank, typically concrete or steel. Proprietary on-ground tank including polyethylene, fibreglass, corrugated steel or bolted steel systems. Proprietary below-ground tanks including various plastic, fibreglass and concrete systems. Proprietary systems using buried concrete pipe or fibreglass cylinders. Proprietary systems using cellular plastic modules with membrane liner. Bladders. In-situ blockwork structures with membrane liners.
Storage location (Section 5.4.6)	What are the opportunities at this site for locating a storage? Are there any specific constraints to the storage location? Are the geotechnical conditions suitable for the construction of the storage? Is the storage close to other existing development? Are there any safety issues associated with the storage, e.g. unauthorised access by the general public or children?	Obtain site specific contours. Undertake geotechnical investigations as required. Assess adjacent land use planning.	
Monitoring raw water and downstream environment (Section 5.6):			

System component	Design considerations	Design approaches	System alternatives
Monitoring and instrumentation (Section 5.6)	What parameters need to be monitored? What is the required sampling frequency? Can these be monitored in real-time? What instrumentation is required for monitoring and control? What water quality sampling is required? What water quality parameters will need to be analysed in the laboratory?	Develop an appropriate water quality monitoring program. Instrumentation could include: • level sensor in the storage • water quality monitoring in the storage, e.g. pH, EC, ORP • other water quality monitoring requirements for manual sampling and laboratory analysis.	On-line instrumentation Manual grab samples Automatic, event- and flow-paced samples
Operations and maintenance	What resources are required for monitoring, operations and maintenance of the system? What are the minimum requirements for operation and maintenance of the storage? What are the minimum requirements for operation and maintenance of the instrumentation and control systems?	Develop a comprehensive operations and maintenance program. Ensure that the appropriate financial and labour resources are available and costed.	
Financial	Is the proposed storage affordable?	Consider all costs as part of the overall cost–benefit analysis. Consider alternative assessment methods, e.g. multi- criteria assessment.	

Table A-3 Design considerations — stormwater treatment, treated water storage and distribution

System component	Design considerations	Design approaches	System alternatives
General: Section 6			
Need for pre-treatment (Section 6.2 and 6.3)	What is the nature of the catchment? Will the catchment yield any specific pollutants of concern? Is there any catchment-specific runoff water quality data? What is the anticipated runoff water quality?	Refer to Sections 3.3 and 3.4, specifically 3.3.3 — Catchment Management	
Need for post-treatment (Section 6.2 and 6.3)	What are the proposed end uses? Are uses likely to change over time? What are the applicable water quality standards? What is the quality of the harvested stormwater?	Refer to Section 2.3.2 Proposed water users and uses	
Pre-treatment (Section 6.4):			

System component	Design considerations	Design approaches	System alternatives
Pre-treatment objectives (Section 6.4.1)	Is information available on the catchment land uses and management? Is any site-specific data available on runoff water quality? Are WSUD systems implemented within the catchment?	Identify catchment details, including land uses, catchment management practices and existing stormwater quality improvement systems. Assess catchment-specific water quality data, if available. If not, consider taking water quality samples for analysis. Identify literature sources regarding runoff water quality (see Sections 3.4.3 and 3.4.6. Determine runoff raw water quality to be adopted for design. Consider need to remove: • gross solids including litter and other floating objects • coarse sediments (soil, sand, gravel) • hydrocarbons (fuel, oils) • event related spills, e.g. factory spillage, from fires or due to road accidents.	
Pre-treatment process — gross pollutant removal (screening) (Section 6.4.2)	Is screening required? Where should the screens be located for best access and effect? What is the appropriate screen aperture? Are manually raked screens adequate? How will the screens be cleaned? How will collected screenings be removed? Would there be any benefit in providing mechanically raked screens?	Determine screen type and bar spacing based on catchment and runoff information. Identify the best location for installation of the screen. Confirm access provisions for inspection and cleaning.	Manually raked bar screen Mechanically raked bar screen Step screens Self-cleaning wedge-wire screen
Pre-treatment process — gross pollutant removal (sediment trap) (Section 6.4.2)	Is a sediment trap required? Where should the trap be located for best effect? Is the trap accessible for inspection and maintenance? What trap volume is required? How will the trap be cleaned out and sediments removed?	Determine sediment trap dimensions based on catchment and runoff information. Identify the best location for installation of the trap. Confirm access provisions for inspection and cleaning.	Sediment trap at upstream end of surface water body Sump in diversion structure

System component	Design considerations	Design approaches	System alternatives
Pre-treatment process — fine sediment removal (Section 6.4.2)	What is the anticipated suspended solids load from the catchment? If solids are not removed at this stage, will they cause problems in the storage and post-treatment stages?	Determine design inflow rate based on catchment runoff and diversion modelling. Identify and evaluate alternative proprietary systems based on performance against the required objectives. Identify the best location for installation of an oil and sediment separator. Confirm access provisions for inspection and cleaning.	Various proprietary systems
Pre-treatment process — hydrocarbon capture (Section 6.4.2)	Does the catchment have the potential to discharge hydrocarbons in the runoff? What is the anticipated hydrocarbon load from the catchment? If hydrocarbons are not removed at this stage will they cause problems in the storage and post-treatment stages?	As above	As above
Pre-treatment process — spill and accidental discharge controls	Does the catchment have the potential for significant accidental discharge, e.g. due to traffic accidents, industrial incidents, pipeline failure or fire? What is the nature of the possible discharge, i.e. specific contaminant, frequency of event and volume discharged? Is there potential to stop the spill before it enters the stormwater system? What are the Emergency Services' protocols governing notification and actions in the event of an incident? Is there potential to contain the spill before it enters the environment or the stormwater harvesting system?	Assess the potential for significant spills to occur in the catchment (see Section 2.7.4). Identify Department of Emergency Services and local authority protocols for incident response and notification. Consider non-infrastructure approaches to control, e.g. emergency notification leading to immediate system shutdown by local operator. Consider potential for stormwater diversion system to capture spills before they enter the environment or are diverted to the storage.	
Post-treatment (Section 6.6):			

System component	Design considerations	Design approaches	System alternatives
Post-treatment objectives (Section 6.6.1)	Are pre-treatment systems implemented? How effective are the pre-treatment systems expected to be? What end uses are proposed (Section 2.3.2)? What water quality standards apply to the proposed end uses (Section 2.3.5)?	Determine raw water quality expected following pre-treatment to be adopted for design. Consider need to remove: • algae • suspended solids and turbidity • metals • organic chemicals • pathogens.	
Treatment plant sizing (Section 6.6.2)	What are the peak water demands on a daily, weekly and monthly basis (Section 2.3.3)? What are the peak diurnal water demands? How big is the raw water storage and how quickly can it be emptied if there is no rainfall event to top it up? How large is the treated water storage? What are the backup water supply provisions? What is the supply management strategy when the stormwater harvesting system runs low on water (Section 2.5.1 and Section 2.5.2)?	Use the demand estimates and the daily water balance model to optimise the plant capacity and treated water storage. Consider the treatment plant capacity in the context of the raw water storage and how long that water would last without rainfall. Consider the treatment plant capacity in the context of the backup water supply and the 'no rainfall' supply management strategy.	
Post-treatment process — algae removal (Section 6.6.3)	Is algae a potential issue from the storage (unlikely to be the case with a covered storage but possible from open storages)? Can the algae problem be reduced or eliminated at source, e.g. by covering the storage or aerating? Is an algae removal process necessary? What is the best technology to remove algae? Where will the waste stream be discharged? Will the local authority accept the waste to sewer? Is a Trade Waste Agreement required?	Identify suitable treatment systems for algae removal and available suppliers. Size the system based on required plant output rate allowing for losses in treatment. Determine backwash volume and quality. Identify where backwash stream will be discharged to waste (sewer).	Dissolved air flotation (DAF) Induced air flotation (IAF)

System component	Design considerations	Design approaches	System alternatives
Post-treatment process — solids or turbidity removal (Section 6.6.3)	Are suspended solids or turbidity expected to be an issue in the raw water following pre-treatment? Is a solids removal process necessary? What is the best technology to remove solids taking into account the proposed end uses and downstream treatment processes? Where will the waste stream be discharged? Has provision been made in design for backwash storage and discharge? If a membrane system is proposed: • are the membranes suitable for operating conditions and feed water quality? • do the membranes need to be chlorine resistant? • have the requirements for membrane cleaning been taken into account, including chemical mixing and storage tanks? • is a membrane integrity testing system included?	Assess type of filtration system required, e.g. in-line filter, media filter or membranes depending on end use and water quality (Section 5.11 Typical conventional water treatment trains). Identify suitable treatment systems for solids removal and available suppliers. Size the system based on required plant output rate allowing for losses in treatment. Take into account the requirements for backwash pumps and air scour blowers. Take into account the requirements for membrane clean in place (CIP) systems including chemical storage and handling areas;. Determine backwash volume and quality. Assess need for backwash storage to buffer discharge rates. Identify where the backwash stream will be discharged to waste (sewer).	In-line filters such as: • cartridge filters • disc filters • screen filters. Media filtration: • pressure sand filters • pressure multi-media filters. Membrane filtration: • microfiltration (typically 0.2 μm pore size) • ultrafiltration (typically 0.01 μm pore size) Configuration: • spiral wound, flat sheet and hollow fibre • cross-flow vs dead end • submerged systems.
Post-treatment process — organic chemicals removal (Section 6.6.3)	Are organics, taste, colour or odour expected to be concerns in the raw water following pre-treatment? Do the proposed end uses necessitate removal? What is the best technology to remove organics taking into account the proposed end uses and downstream treatment processes?	Assess whether removing organics is required. Identify suitable treatment systems for removing organics and available suppliers. Size the system based on required plant output rate allowing for losses in treatment.	Granular or powdered activated carbon filters Advanced oxidation

System component	Design considerations	Design approaches	System alternatives
Post-treatment process — disinfection (Section 6.6.3)	What standard of disinfection is required for the treated water? (Section 2.3.2 Proposed users and uses) Will suspended solids or turbidity be effectively reduced in the filtration stage? What is the best disinfection technology for the project, taking into account the proposed end uses and downstream treatment? If chlorine disinfection is proposed: • In what form will the chlorine be used, i.e. gas, liquid hypochlorite, crystalline? • What CT (concentration x contact time) value is required for effective disinfection? • What monitoring and control system is required (Section 5.9)? • Is dechlorination required prior to reuse or discharge? If ultraviolet (UV) disinfection is proposed: • What intensity dose is required for effective disinfection? • What filtered water transmissivity is required? • Is lamp integrity and UV intensity monitoring provided? If an alternative disinfection is proposed: • What dose rate is required? • What ancillary systems are required to produce, store or dose the disinfectant? • Are there any limitations to use, e.g. adverse impacts on other systems? • What monitoring systems are required (Section 5.9)? If residual chlorination is required: • In what form will the chlorine be used, i.e. gas, liquid hypochlorite, crystalline? • What dose rate is required? • What monitoring and control system is required (Section 5.9)?	Assess type of disinfection system required depending on end use and water quality. Identify available suppliers. Size the system based on required plant output rate.	Ultraviolet (UV) disinfection: Chlorination: • gas chlorination • liquid sodium hypochlorite injection • solid calcium hypochlorite addition (manually or in tablet form)

System component	Design considerations	Design approaches	System alternatives
Chemical dosing (Section 6.6.3)	What chemical dosing systems are required as part of the adopted treatment processes, e.g. coagulant (alum), flocculent, pH adjustment (lime or MHS) chlorine? What control systems and instrumentation is required? If chemical dosing is required: • What chemicals are proposed? • What are the dose rates? • How much chemical needs to be stored on site? • What is the hazard rating of the chemicals (Section 2.7.4)? • Are there any special handling and storage requirements for the chemicals?	Use non-hazardous chemicals wherever possible. Minimise the volumes of chemicals held in inventory at any one time. Consider requirements of relevant Australian Standards for safe storage and handling of chemicals. Consider need for secure housing for chemical storage. Consider need for bunding storage areas. Consider need for ventilation and spill alarms.	Bulk chemical delivery and storage. Containerised storage, e.g. 1 m^3 'Bulkiboxes'. Small container storage, i.e. 20 L containers or smaller.
Pumping systems	What pumping systems are required as part of the treatment process, eg feed pumps, backwash pumps, waste discharge pumps, chemical dosing pumps? What level of redundancy is required, i.e. are duty and standby pumps needed or is a single duty pump sufficient? What is the availability of replacement pumps in the event of breakdown? Do pumps need to be fixed or variable speed? How will the pumps be controlled? What instrumentation is required to enable pump control?	Select pumps based on: • required duty (flow and head) (Section 2.5.3) • nature of material pumped, e.g. water vs chemical • materials requirements • installation requirements, e.g. submersible vs dry mounted • redundancy required (duty/standby) • fixed vs variable speed.	

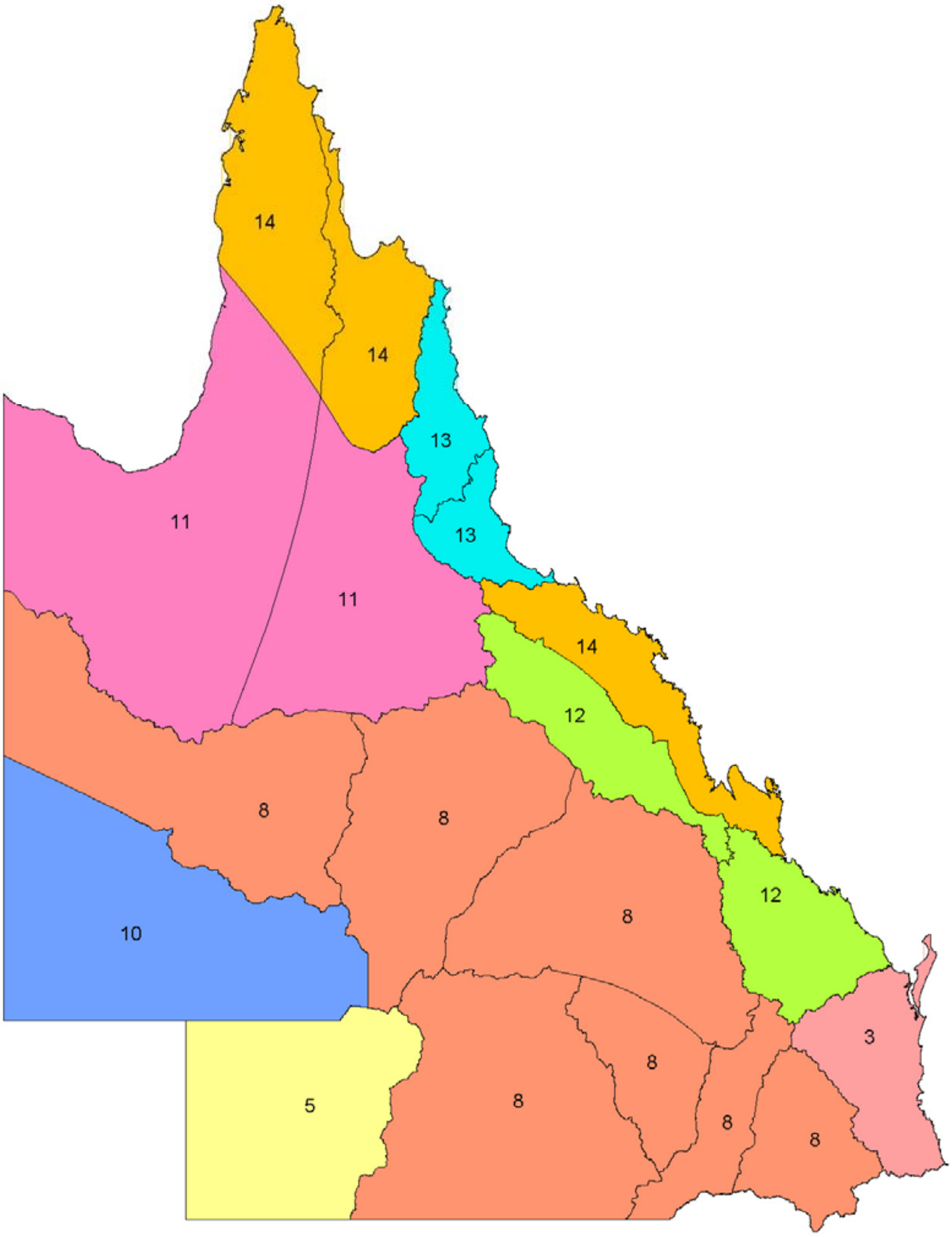
System component	Design considerations	Design approaches	System alternatives
Treated water storage (Section 6.7):			
Storage configuration	What is the best location and configuration for the storage? Are there any specific constraints to the storage configuration that can be provided? Should the storage be below ground or on-ground? If buried, is there a potential for high groundwater levels? What provision is required to protect the tank against floating? How will the storage be covered? How will safe access to the tank for maintenance be provided? What is the most cost-effective way to provide storage in this location?		Custom built above or below-ground tank (typically concrete or steel) Proprietary on-ground tank including polyethylene, fibreglass, corrugated steel or bolted steel systems Proprietary below-ground tanks including various plastic, fibreglass and concrete systems Proprietary systems using buried concrete pipe or fibreglass cylinders Proprietary systems using cellular plastic modules with membrane liner Bladders In-situ blockwork structures with membrane liners
Storage sizing (Section 6.6.2 and 6.7)	How large does the storage need to be to balance the treatment plant capacity with estimated peak demand?	Refer to Section 5.7.2 Treatment plant sizing.	
Storage location	What are the opportunities at this site for locating a storage? Are there any specific constraints to the storage location? Is the storage close to other existing development? Are there any safety issues associated with the storage, e.g. unauthorised access by the general public or children?		

System component	Design considerations	Design approaches	System alternatives
Distribution (Section 6.9):			
Distribution pumps (Section 6.9)	What are the design demands and how are these distributed over time? What are the peak water demands on a daily, weekly and monthly basis? How will demand vary over the short- and long-term? What are the peak diurnal water demands? What minimum supply pressure is required to be maintained in the distribution system? What level of redundancy is required, i.e. are duty and standby pumps needed or is a single duty pump sufficient? What is the availability of replacement pumps in the event of a breakdown? Do pumps need to be fixed or variable speed? How will the pumps be controlled? What instrumentation is required to enable pump control?	Select pumps based on: • required duty (flow and head) • nature of material pumped, e.g. water vs chemical • material requirements • installation requirements, e.g. submersible vs dry mounted • redundancy required (duty or standby) • fixed vs variable speed.	
Operational requirements (Section 6.10):			
Control (Section 6.10.3)	What controls are required? What telemetry systems are required? What remote supervisory and control systems are required?	Provide local control system to ensure independent automatic operation as required. Determine the appropriate type of remote supervisory control and data acquisition (SCADA) system for the scheme. Provide telemetry for remote monitoring and control. Provide alarms to centrally monitored location. Ensure that procedures and protocols exist to monitor and maintain the system.	Local automatic control only; no remote supervision. Local automatic control with remote monitoring of alarms and operation but no remote control. Local automatic control with remote monitoring and control. Dial-in systems via modem. Hard-wired or radio controls. Automatic dial-out alarms.

System component	Design considerations	Design approaches	System alternatives
Monitoring and instrumentation (Section 6.10.2)	What parameters need to be monitored? Where should samples be taken from? Has provision been made for sampling? What is the required sampling frequency? Can these be monitored in real time? What instrumentation is required for monitoring and control? What water quality sampling is required? What water quality parameters will need to be analysed in the laboratory?	Develop an appropriate water quality monitoring program. Instrumentation could include: • level sensor in raw water storage • water quality monitoring in raw water storage, e.g. pH, EC, ORP, DO • feed flow monitoring to treatment plant • in-line turbidity meter for real time monitoring of filtered water quality as primary control to detect filter breakthrough • UV intensity meter and lamp integrity monitoring as primary control to detect lamp failure or deterioration • level sensor in treated water storage • water quality monitoring in treated water storage, e.g. free chlorine residual • distribution flow meter. Ensure that the instrumentation sensitivity is adequate for the parameters and levels being monitored. Provide for logging of the data collected. Determine other water quality monitoring requirements for manual sampling and laboratory analysis.	On-line instrumentation Manual grab samples Automatic, event- and flow-paced samplers
Operations and maintenance (Section 6.10.4)	What resources will be required for monitoring, operations and maintenance of the system? What are the minimum requirements for operation and maintenance of the treatment system? What are the minimum requirements for operation and maintenance of the instrumentation and control systems?	Develop a comprehensive operations and maintenance program. Ensure that the appropriate financial and labour resources are available and costed.	

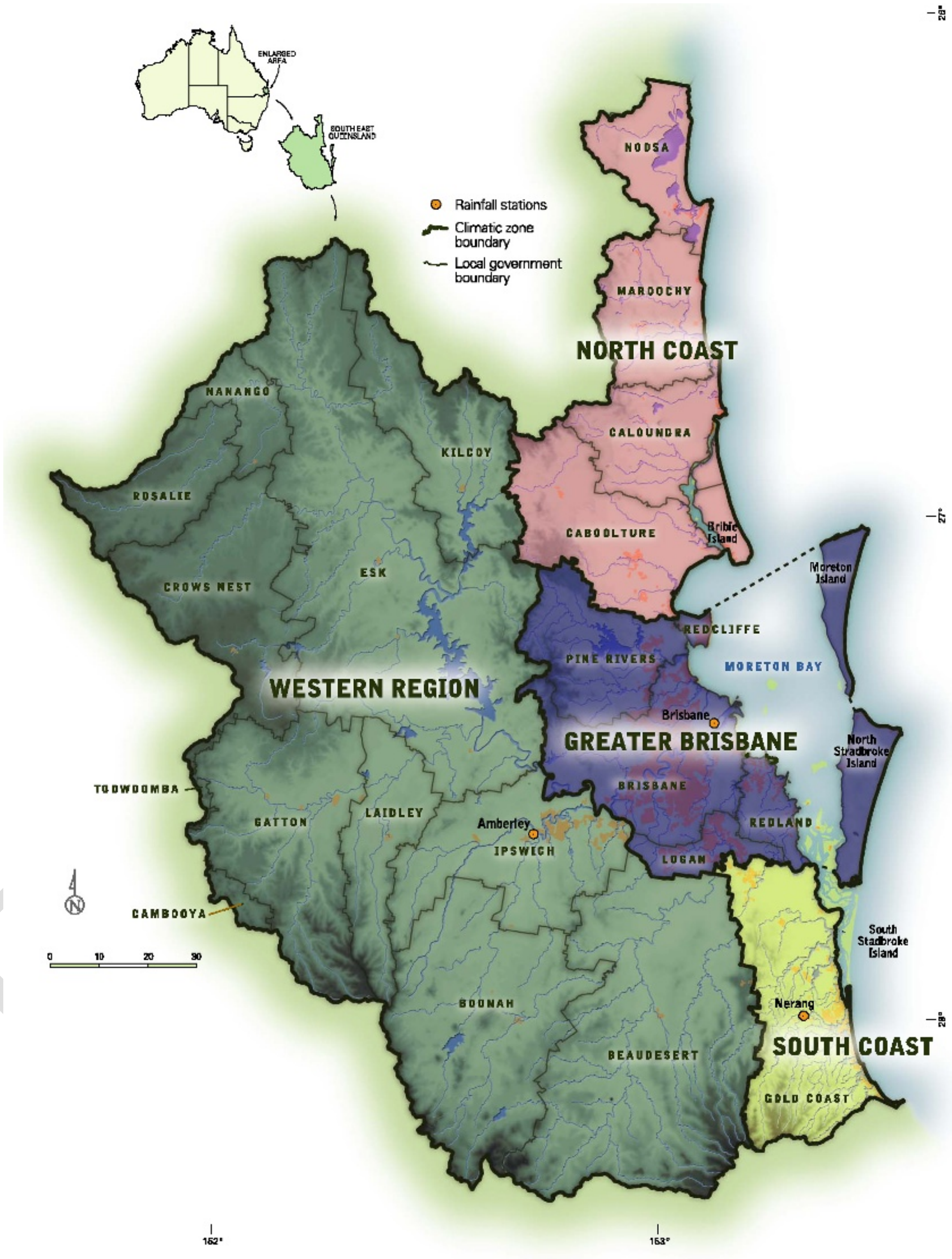
System component	Design considerations	Design approaches	System alternatives
Financial	Is the proposed treatment system affordable, including both capital and on-going operations and maintenance costs?	Undertake a cost–benefit analysis for the scheme. Assess the unit cost of water ($/kL). Compare stormwater costs with other sources of water.	

Attachment B — Queensland rainfall districts



Source: Adapted from BOM 2004.

Attachment C — Sub-regional climatic zones for yield curves



Source: Healthy Waterways Partnership 2006.

Attachment D — HACCP Plans

A risk management framework based on a Hazard Analysis and Critical Control Point (HACCP) analysis is outlined in Attachment A. HACCP has been adopted for illustrative purposes because it has been used successfully on recent stormwater harvesting and water recycling projects in South East Queensland. HACCP is not the only risk framework suitable for stormwater harvesting projects.

The purpose of HACCP plans is to quantify the likelihood and impact of hazards associated with schemes and outline the qualitative requirements, management practices, and corrective actions for the safe use of stormwater within the scheme. The key emphasis is to protect human health and the environment.

What is a HACCP Plan?

The HACCP concept was originally established as a food microbiological safety system in early US space programs as a preventative approach to ensure the safety of food for astronauts (Mortimore & Wallace, 1998). The practical and easy to follow principles of HACCP have made it an internationally recognised concept that is now being applied to a broad range of industries and processes, including water supplies in Australia.

Why HACCP?

HACCP systems are globally recognised as fully documented, transparent, systematic, preventative and qualitative risk assessment processes. HACCP systems aim to ensure that any biological, chemical, physical or radiological hazard is identified, evaluated and managed. Risks are managed at each step in the treatment process where a control can be implemented. This makes HACCP a useful tool for application in any water supply strategy, including stormwater harvesting.

The *Australian Drinking Water Guidelines* (NHMRC & NRMMC, 2004) promote water quality management based on risk management. The guidelines outline comprehensive preventative measures including HACCP plans. The *Australian Guidelines for Water Recycling* (NRMMC, EPHC & AHMC, 2006; EPHC, NHMEC & NRMMC, 2008a) also support using a comprehensive HACCP-based risk assessment. The key feature of HACCP systems is the application of proactive preventative measures rather than reactive management to preserve water quality.

Objectives of HACCP

The objectives of a HACCP plan for a stormwater harvesting scheme are to:

- apply a systematic, independent and documented methodology
- identify land uses and activities in the catchment that could contaminate stormwater
- outline proposed treatment processes in the risk assessment process
- identify hazards and undertake risk assessment to prioritise risks
- identify control systems for each hazard including supporting programs
- determine if CCPs or supporting programs exist where risks should be managed
- document CCPs and associated critical limits and corrective actions where required
- develop a preliminary water quality monitoring program
- develop monitoring and documentation systems for each CCP
- establish verification systems and audit requirements for the HACCP plan
- make recommendations on the appropriateness of intended uses of the treated water based on the findings of the risk assessment.

Principles of HACCP

The HACCP system is based around seven established principles. These principles are as set out in the *Hazard Analysis and Critical Control Point (HACCP) System and Guidelines for its Application* (CAC, 1997). They are:

- conduct a hazard analysis[52]
- determine the Critical Control Points (CCPs)
- establish critical limits
- establish a system to monitor control of the CCPs
- establish the corrective action to be taken when monitoring indicates that a particular CCP is not under control
- establish procedures for verification to confirm that the HACCP system is working effectively
- establish documentation concerning all procedures and records appropriate to these principles and their application.

HACCP principles are usually applied in a sequence of 12 logical steps as outlined in Table D-1.

Table D-1: HACCP process

Step	Name	What is involved?
Initial	Supporting programs and procedures	Review any existing HACCP/ Management systems and identify the supporting programs and procedures that have a role in this HACCP.
HACCP Steps		
1	Assemble HACCP team	Assemble the HACCP team to ensure that the appropriate knowledge and expertise is available for the development of the HACCP plan.
2	Describe the product	Thoroughly describe the product or project to assess the risks. Risks include biological, chemical, physical or radiological properties of the raw and treated water. The description should also outline treatment processes and storage and distribution systems.
3	Identify intended uses	Identify the intended use of the water determines the level of environmental and human exposure to the water and therefore the likely hazards to human health or the environment.
4	Develop a flow diagram	Develop the flow diagram based on input from the HACCP team and cover all steps in the treatment process.
5	Confirmation of flow diagram	Compare the treatment process against the flow diagram. The HACCP team should amend or confirm the flow diagram.
6	Hazard identification and risk assessment	Identify all hazards at each stage of the process and estimate the likelihood and severity of these hazards to give a level of risk. The HACCP team should also consider control measures to reduce the level of risk associated with each hazard.

52 Refer to
Attachment E – Risk matrix for guidance on risk evaluation and scoring.

Step	Name	What is involved?
7	Determine Critical Control Points (CCPs)	Base CCPs on whether the control measures: - are associated with a significant risk before controls are considered - significantly reduce the likelihood or severity of the hazard - can be measured and compared against a critical limit - have corrective actions - can be monitored in real time or regularly so timely corrective actions can be taken - require corrective actions where there are deviations from critical limits.
8	Establish critical limits	Specify and validate, if possible, a critical limit at each critical control point.
9	Monitoring	Schedule measurement of relevant criteria at CCPs to establish compliance with critical limits. Data should ideally be provided in a timeframe that allows changes to the process before the critical limit is breached. In practice, this is not always practicable and indicators may be used as a substitute parameter for monitoring the actual characteristic in some instances.
10	Establish corrective actions	Establish corrective actions to control deviations from the CCP.
11	Establish verification Procedures	Establish verification procedures to prove that the HACCP system is working.
12	Establish documentation and records	Documentation and record-keeping is a crucial aspect of the HACCP system. The amount of record-keeping is directly related to the size and nature of the scheme.
Source: Codex Alimentarius Commission (CAC, 1997)		

Attachment E – Risk matrix

Table E-1 Qualitative measures of likelihood or frequency of hazards associated with stormwater harvesting

Level	Likelihood	Description
1	Rare	May occur in exceptional circumstances such as once in 100 years
2	Unlikely	Could occur within 20 years
3	Moderate	Might occur or should be expected to occur within a 5–10 year period
4	Likely	Will probably occur within a 1–5 year period
5	Almost Certain	Is expected to occur with the probability of multiple occurrences within 1 year

Source: NRMMC, EPHC & AHMC, 2006 p. 39; EPHC, NHMRC & NRMMC, 2008a p. 40.

Table E-2 Qualitative measures of potential severity associated with stormwater harvesting

Level	Severity	Example description			
		Human health	Environment	Media/Community / Political	Financial
1	Insignificant	No detectable human illness	No detectable adverse environmental impact	No public complaint, no media or political interest	No financial loss
2	Minor	Short term, low-level illness, affecting few people	Localised, short term, reversible environmental impact	Some public complaints, no media or political interest	Small financial loss — hundreds of dollars
3	Moderate	Short term, low-level illness, affecting many people or more severe illness affecting few people	Localised environmental impact requiring remediation with medium-term recovery expected	Numerous complaints, local media coverage or political involvement	Medium financial loss — thousands to hundreds of thousands of dollars
4	Major	Severe illness affecting many people	Severe impact on entire ecosystem requiring remediation, with long-term recovery	Many complaints, state level media coverage or political involvement	Large financial loss — hundreds of thousands of dollars
5	Catastrophic	Death of one or more people	Severe, irreversible impact on entire ecosystem; loss of threatened species or populations	Major community objection, national media interest or significant political involvement	Major financial loss — millions of dollars

Source: Queensland EPA, 2005 p. 25.

Table E-3 Level of risk

Likelihood	Severity				
	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
1. Rare	Low	Low	Low	Medium	High
2. Unlikely	Low	Low	Medium	High	High
3. Moderate	Low	Medium	Medium	High	Very High
4. Likely	Low	Medium	High	Very High	Very High
5. Almost certain	Low	Medium	High	Very High	Extreme

Source: Queensland EPA, 2005 p. 25.