PUB SINGAPORE'S NATIONAL WATER AGENCY

BEST PRACTICE GUIDE IN WATER EFFICIENCY

BUILDINGS

VERSION 1

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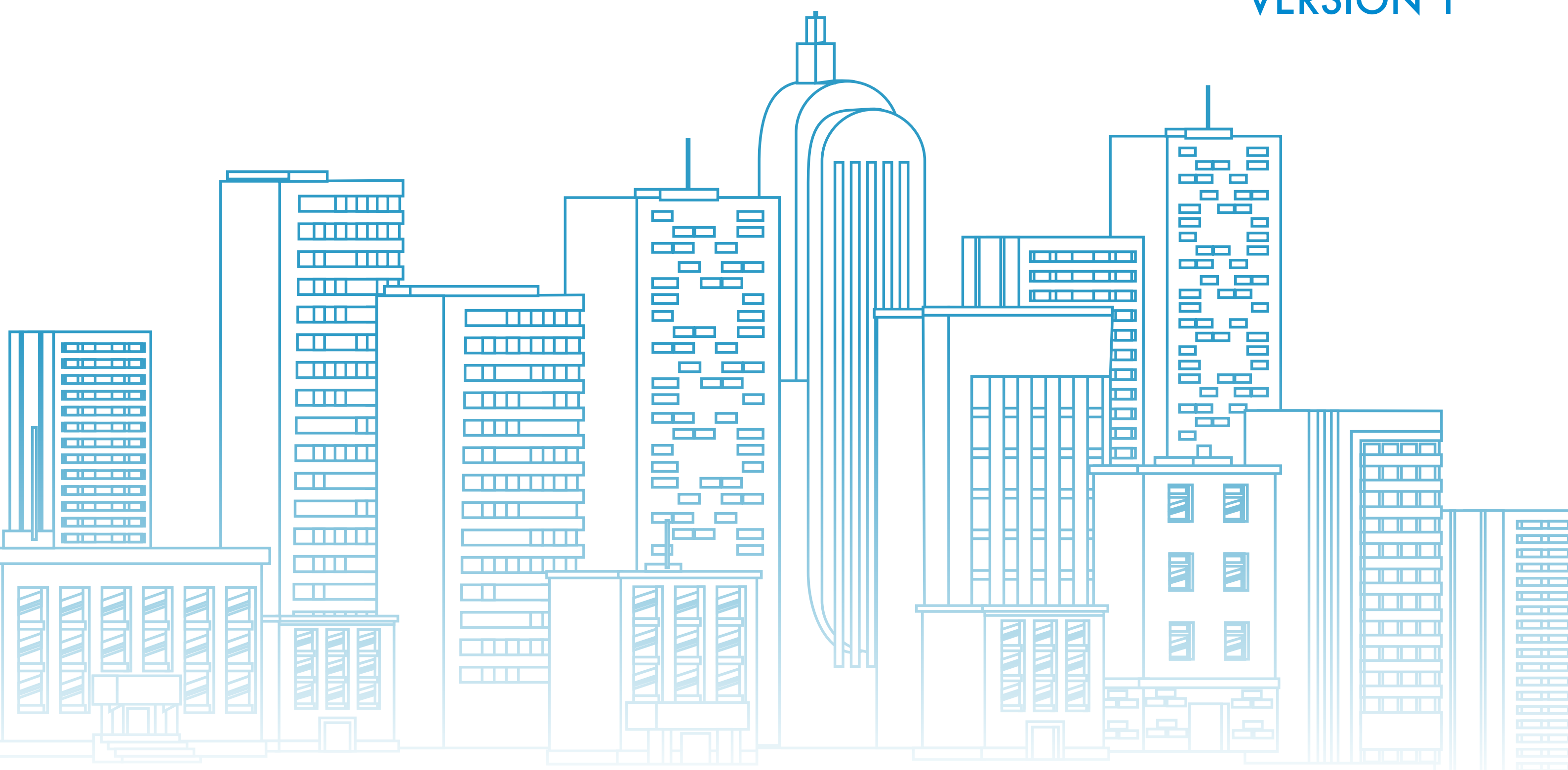

PUB SINGAPORE'S NATIONAL WATER AGENCY

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PREFACE

Singapore's water consumption stands at 430 million gallons a day, with the domestic sector accounting for 45% of total water use, while the remaining 55% comes from the non-domestic sector. By 2060, Singapore's water consumption is expected to double, with the non-domestic sector making up 70% of total water demand. Therefore, it is important that PUB's partners in the non-domestic sector join us in the move to conserve water, and reduce water demand. This will help Singapore in its water sustainability journey.

The aim of this **Best Practice Guide in Water Efficiency - Buildings** is to provide professional engineers, developers, building owners, facilities managers and managing agents involved in water management, with the basic knowledge of designing, maintaining and operating a water-efficient building. We have also compiled best water efficiency practices in this publication to help you in your journey towards sustainable water use.

ACKNOWLEDGEMENTS

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CapitaLand Limited

City Developments Ltd

Marina Bay Sands

Housing and Development Board

Ministry of Education

Surbana Jurong Private Limited

Singapore Plumbing Society

Institute of Water Policy

Building and Construction Authority

Singapore Green Building Council

Singapore Institute of Architects

Board of Architects

AXA Tower

Carlton City Hotel Singapore

Parkway Parade

Mee Toh School

Khoo Teck Puat Hospital

1 INTRODUCTION

Managing water demand is essential in ensuring a sustainable water supply. PUB adopts a three-pronged approach to water conservation – Pricing, Mandatory measures and Facilitation measures.

1.1 Pricing

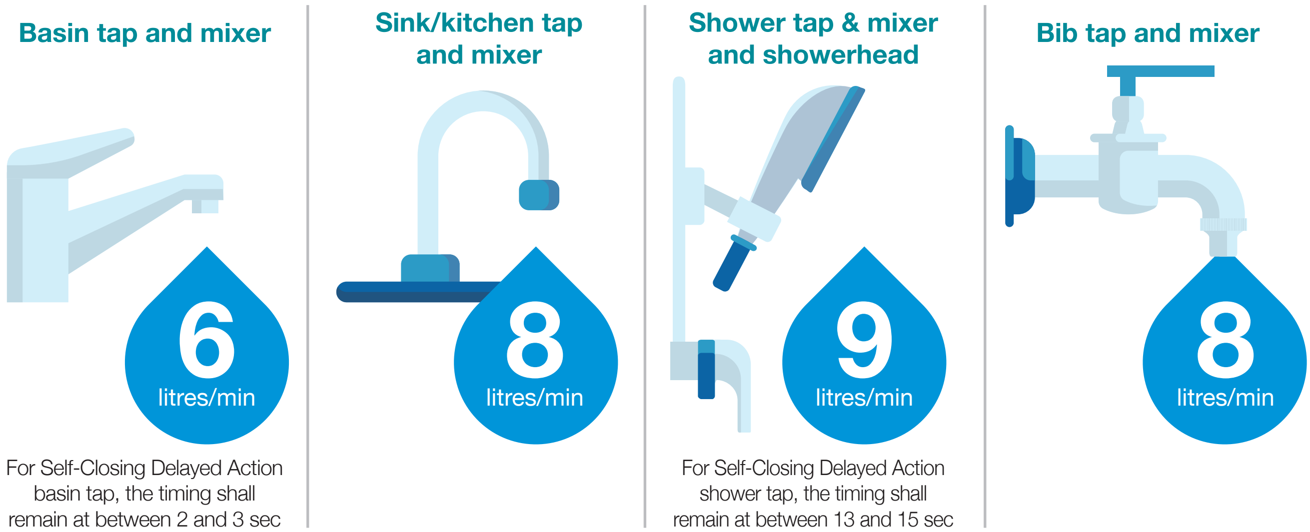
In Singapore, water is priced to reflect its scarcity, value and the full costs of its production and supply.

1.2 Mandatory measures

PUB has mandated measures that help businesses use water more efficiently. These include mandating maximum allowable flow rates, water efficiency labelling for water fittings and appliances, installation of water fittings that meet minimum water efficiency ratings in new developments and existing premises undergoing renovations, and mandating water efficiency management practices for large water users.

1.2.1 Mandatory flow rates requirements

To prevent excessive water flow, PUB limits the maximum allowable flow rates at water fittings. These requirements* are shown below.



These can be found in the Singapore Standard CP 48 - Code of Practice for Water Services and the Public Utilities (Water Supply) Regulations

1.2.2 Mandatory Water Efficiency Labelling Scheme (MWELS)

Water efficiency labelling was made mandatory in July 2009 to help consumers make more informed purchasing decisions and encourage suppliers to introduce more water-efficient products into the market. This scheme covers water fittings such as taps and mixers, dual-flush low capacity flushing cisterns (LCFCs), urinal flush valves and waterless urinals. As part of the scheme, suppliers are required to label the water efficiency of water fittings and appliances on all their displays, packaging and advertisements. MWELS was further expanded to cover washing machines from October 2011.

To complement MWELS, minimum water efficiency standards for water fittings were also introduced in 2009.

All new developments and existing premises undergoing renovation are required to install water fittings with at least a 1-tick water efficiency rating.

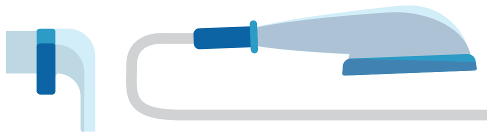
Since October 2015, the minimum standard for washing machines was further raised to at least 2-ticks.

A 4-ticks rating for washing machines was introduced starting from 1 April 2017.

Starting from April 2019, PUB will mandate the sales, supply and installation of water fittings with at least a 2-ticks water efficiency rating in all new and existing premises undergoing renovation to further encourage water efficiency. In addition, MWELS will be extended to dishwashers starting from October 2018. These are part of PUB's plans to eventually phase out non water-efficient fittings and appliances for all new developments.

MWELS Ratings

Shower Taps & Mixers



✓	> 7 to 9 litres/min
✓✓	> 5 to 7 litres/min
✓✓✓	5 litres/min or less

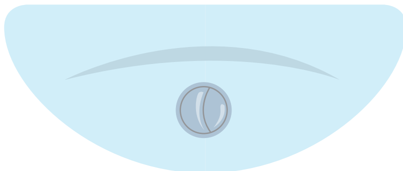
Basin Taps & Mixers

✓	> 4 to 6 litres/min
✓✓	> 2 to 4 litres/min
✓✓✓	2 litres/min or less

Sink/Bib Taps & Mixers

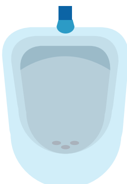
✓	> 6 to 8 litres/min
✓✓	> 4 to 6 litres/min
✓✓✓	4 litres/min or less

Flushing Cisterns (Per Flush)



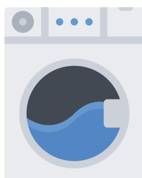
✓	Dual Flush > 4 to 4.5 litres (full flush) > 2.5 to 3 litres (reduced flush)
✓✓	Dual Flush > 3.5 to 4.0 (full flush) > 2.5 to 3 litres (reduced flush)
✓✓✓	Dual Flush 3.5 litres or less (full flush) 2.5 litres or less (reduced flush)

Urinal Flush Valve & Waterless Urinals (Per Flush)



✓	> 1 to 1.5 litres
✓✓	> 0.5 to 1 litres
✓✓✓	0.5 litres or less or waterless urinals

Clothes Washing Machines (Per Wash Load)



✓✓	> 9 to 12 litres/kg
✓✓✓	> 6 to 9 litres/kg
✓✓✓✓	6 litres/kg or less

1.2.3 Mandatory Water Efficiency Management Practices (MWEMP)

Mandatory water efficiency management practices (MWEMP) for large water users were introduced under Part IVA of the Public Utilities (Water Supply) Regulations in January 2015. Consumers with water consumption of at least 60,000 m^3 in the preceding year (or qualifying consumers) are required to effect basic water efficiency management practices. These include installing private water meters at various areas of water use to track and monitor water usage, and submitting a Water Efficiency Management Plan (WEMP) to PUB on an annual basis for at least three consecutive years.

In 2015, more than 600 qualifying consumers submitted their plans, which covered areas of water use and action plans aimed at raising efficiency. The water usage at these premises contribute to about 65% of Singapore's non-domestic water consumption. PUB aims to develop water efficiency benchmarks and good practice guidelines for different sectors with the data collected. With this information, consumers can study their usage patterns and target their water-intensive operations to improve water efficiency and save on their water bills.

1.3 Facilitation measures

Programmes have been put in place to support companies in their efforts to improve water efficiency. These include incentivising companies, building capabilities of building owners and developers, and raising awareness of water efficiency practices.

Raise Awareness

PUB organises activities, seminars, forums and events regularly to share information on best practices. Online resources and publications are also available to help companies understand what common issues exist, and take steps to improve water efficiency.

Build Capabilities

Training programmes such as the Water Efficiency Manager Course (WEMC) and publications such as PUB's series of Best Practice Guides are available to help equip companies with the knowledge and skills to support their water efficiency improvement efforts.

From 2019, companies submitting WEMP are required to send one of their WEMP representatives to attend the WEMC and be certified as a Water Efficiency Manager.

Encourage Adoption

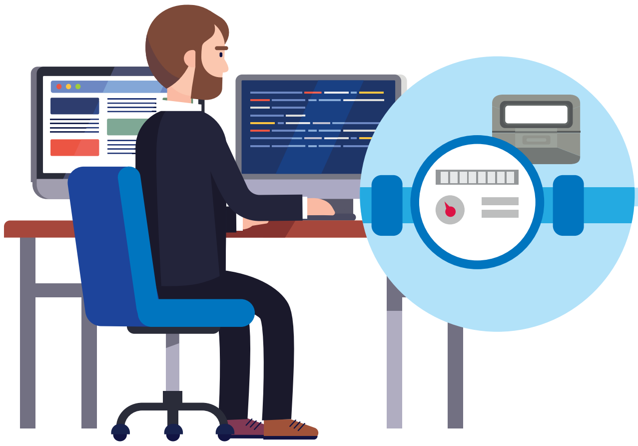
Incentives such as the Water Efficiency Fund are available to encourage businesses to make pro-water efficiency choices in their operations or even the design of new facilities. Recognition such as the Watermark and Water Efficiency Awards, are given to companies that have implemented excellent water management practices and demonstrated tangible results in improving water efficiency.

2 BEST WATER EFFICIENCY PRACTICES

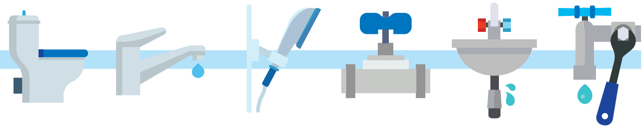
This chapter is a guide on how to implement water efficiency projects and operate a building that is equipped to use water efficiently. Buildings should adopt the 3R strategy – Reduce, Replace and Reuse/Recycle – in managing water usage. These will be detailed later on in this chapter.

2.1 Building owners' guide to accounting for water use

Before implementing water efficiency measures/projects for building premises, one should first understand how much water is being used at different areas, and identify where these areas are. In other words, water usage in buildings should be properly accounted for prior to implementation of measures.



Accounting for water usage can be done through private metering and regular monitoring of water consumption.



Doing so enables you to have a better understanding of water usage patterns, and helps you detect abnormalities in water consumption coming from leaks and inefficiencies.

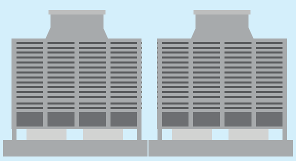
Knowing where, when, and how water is being used in your development can help you to formulate measures that improve your water efficiency. Quick identification of leaks, for example, ensures that they can be fixed early, therefore preventing further water wastage.

2.1.1 Installing private water meters

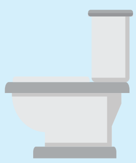
Private meters should be installed at pipes serving different water usage areas in order to help you better understand and analyse water usage patterns. These meters allow you to detect abnormalities in water consumption. Starting from 1 January 2015, buildings with annual water usage level of 60,000m^3 or more are required to install private water meters at various water usage areas within their premises to track and monitor water consumption levels.

Key areas to be monitored by private meters

OFFICE AND RETAIL BUILDINGS

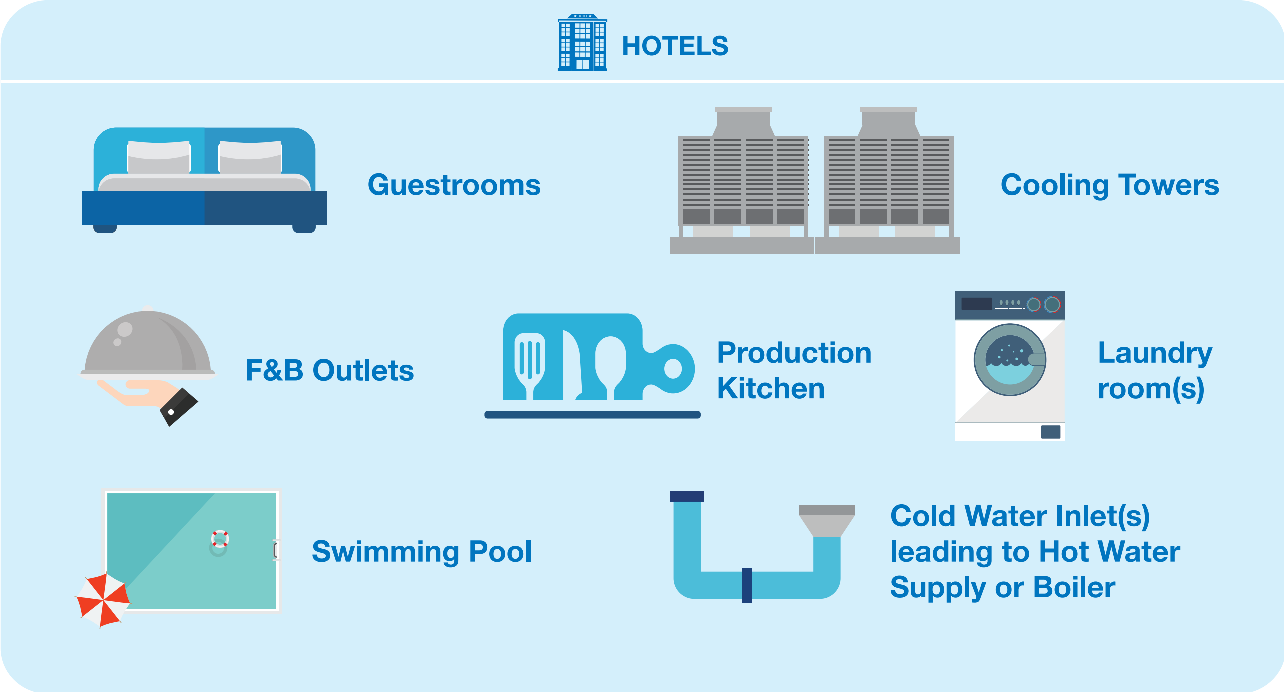


Cooling Towers



Toilets

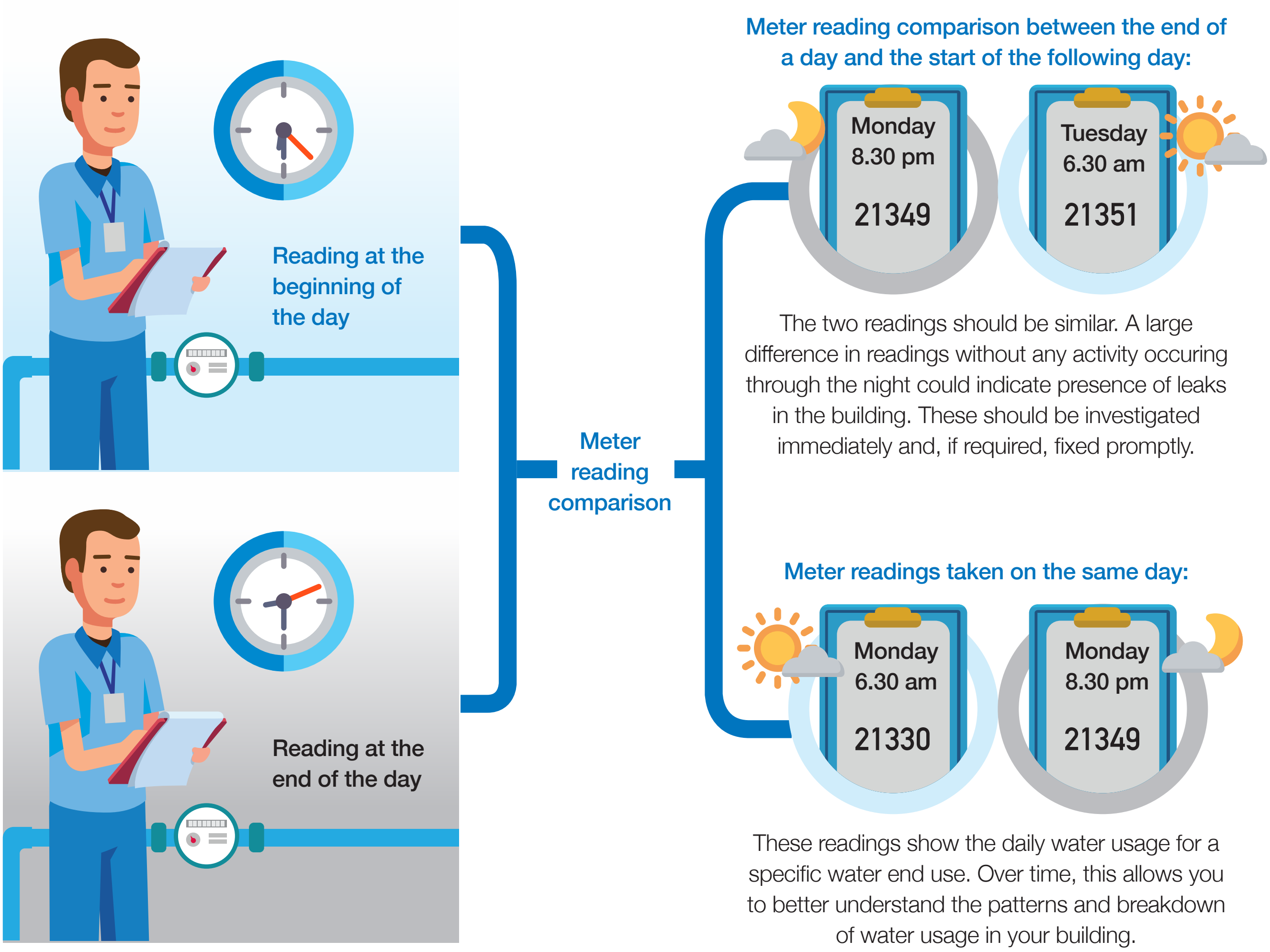
Others: water features, swimming pool and irrigation sites



2.1.2 Water consumption monitoring practices

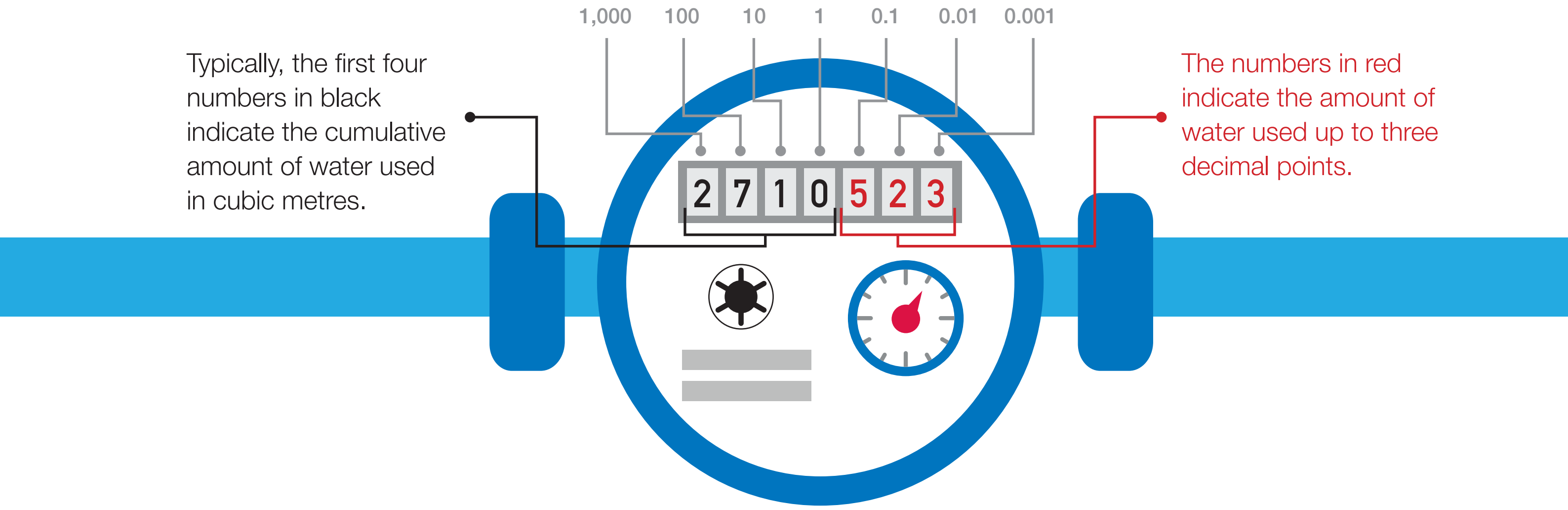
There are two common means of recording private meter readings:

Manual reading of meters



How to read your meters:

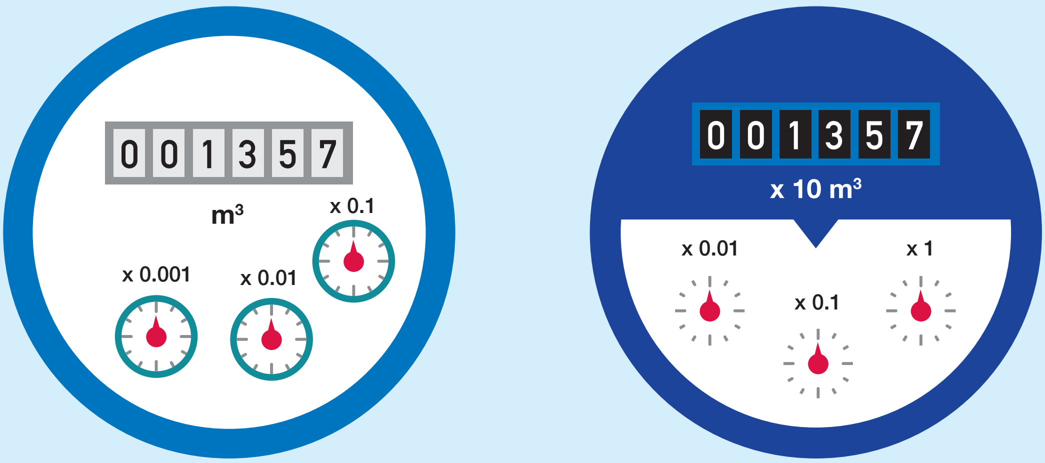
Typically, the first four numbers in black indicate the cumulative amount of water used in cubic metres.



The numbers in red indicate the amount of water used up to three decimal points.

To find out how much water is being used during a certain period, simply calculate the difference between the reading taken at the start and at the end of the period.

Other types of meter dials:



A

Meter A reads 1,357 m^3

B

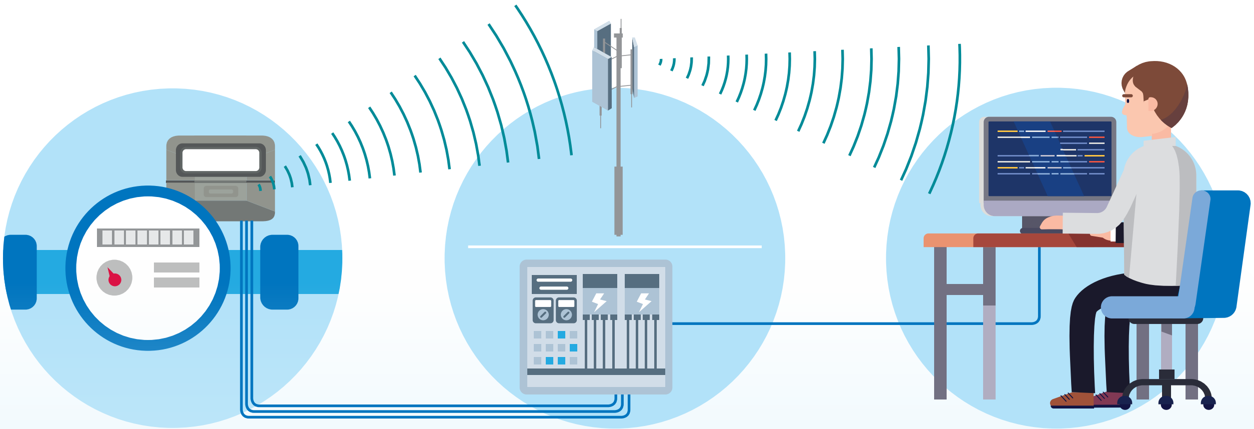
Meter B reads 13,570 m^3

Remote reading of meters

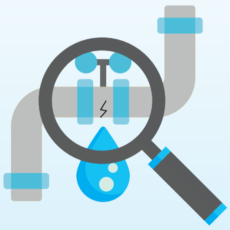
Data loggers are connected to the meters

Meter readings are then transmitted automatically at regular intervals via cellular network or a dedicated wiring system

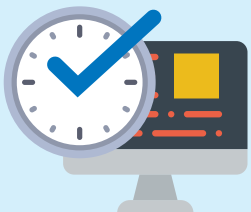
Water consumption information can be accessed through the Building Management System (BMS) or through specified web-based applications from any computer



Helps you save on manpower costs as staff are no longer required to physically read each meter



Increases chances of leak detection



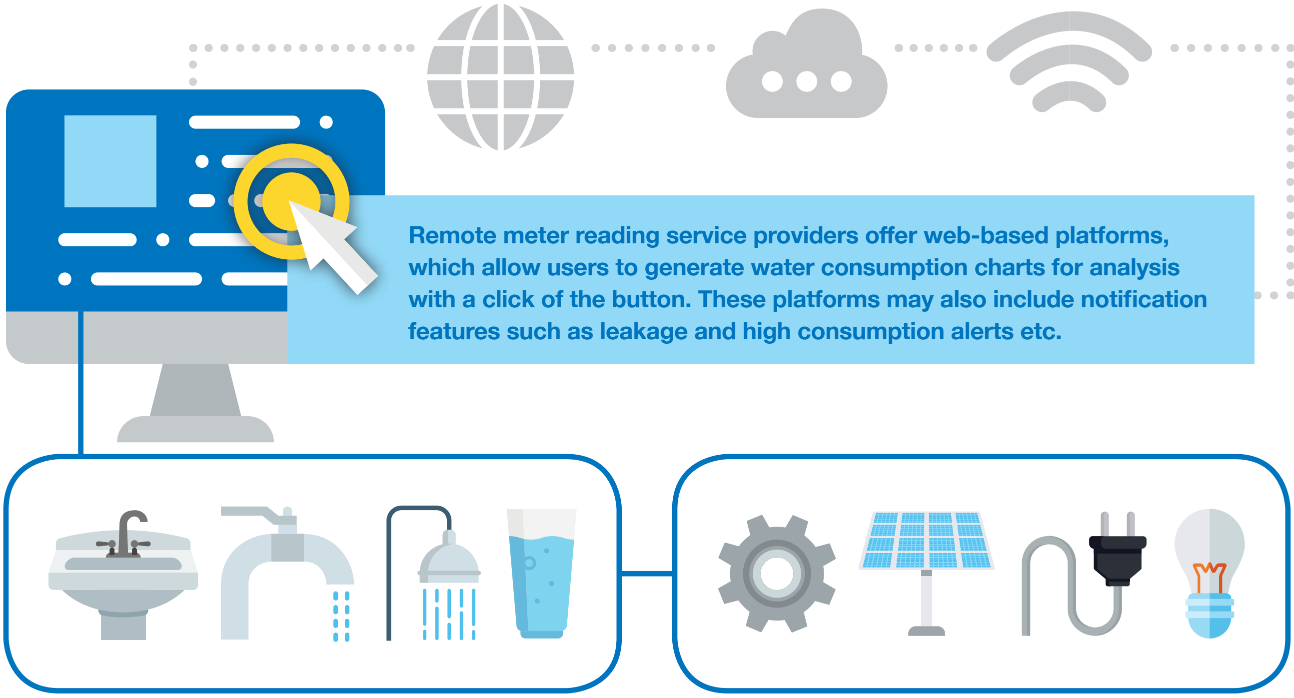
Provides real-time information on water usage activity of the premises

Enables greater understanding of how water usage at certain areas correlate with other factors such as temperature, rainfall etc. Building managers could make use of such information to develop relevant water efficiency measures.

2.1.3 Charting and analysing water consumption

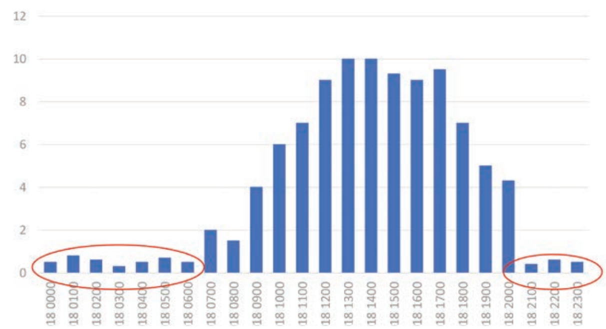
It is essential to maintain a regular (daily, weekly, monthly) effort to chart water consumption at different consumption areas. This will provide first-hand information on abnormalities in water usage. Sudden high consumption patterns could indicate leakages within the building. Prompt action should be taken, if necessary, to fix leaks so as to minimise water wastage.

Example of a water consumption chart with a sudden peak, indicating a probable leak

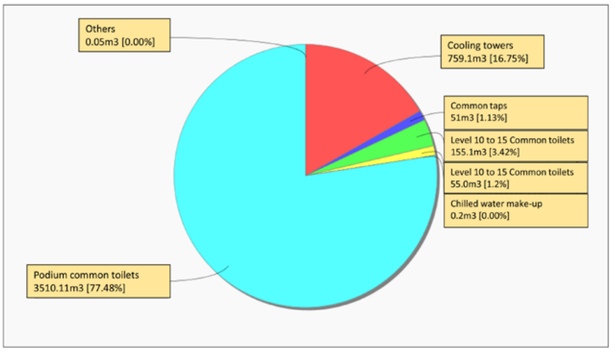


Building managers can have a centralised and holistic view of the energy and water consumption within their premises.

Examples of water consumption charts:



▲ Minimum night flow is present, as shown by the increase in water usage levels being captured by the meters overnight. All activities should have ceased and thus no water should have been consumed. This could be useful in identifying potential leakage and evaluating water loss in the water network within a given premises.



▲ Pie chart generated from the portal, depicting the consumption breakdown at various water end use areas. The patterns of water usage within the building can thus be readily understood.

Location: Location_01 ▼

Alert Type	Enabled	Value
High Consumption	☐	Threshold value: 7.562 (m3/day)
Leakage	☐	Time period: 0200 0500 (0 – 24) Number of days: 7 (days) Threshold value: 1.908 (m3/day)
Static Reading	☐	Numbers of days: 7 (days)

Update configuration

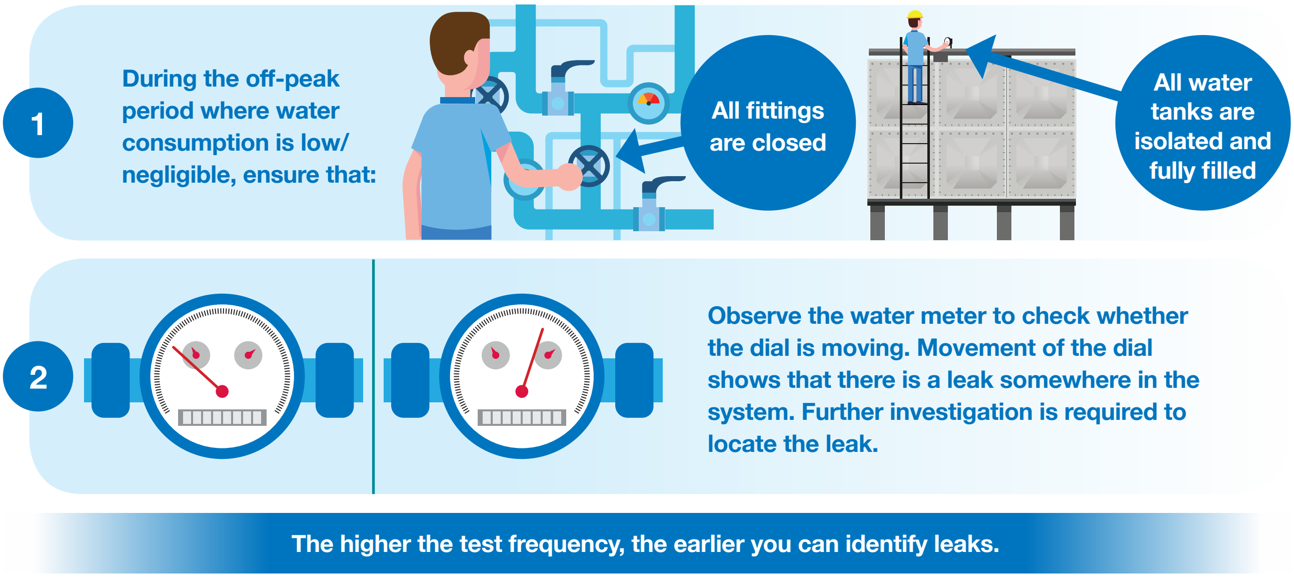
▲ Alerts may be triggered by the system whenever there is a high consumption level, static reading or suspected leakage.

2.2 Identify and repair leaks

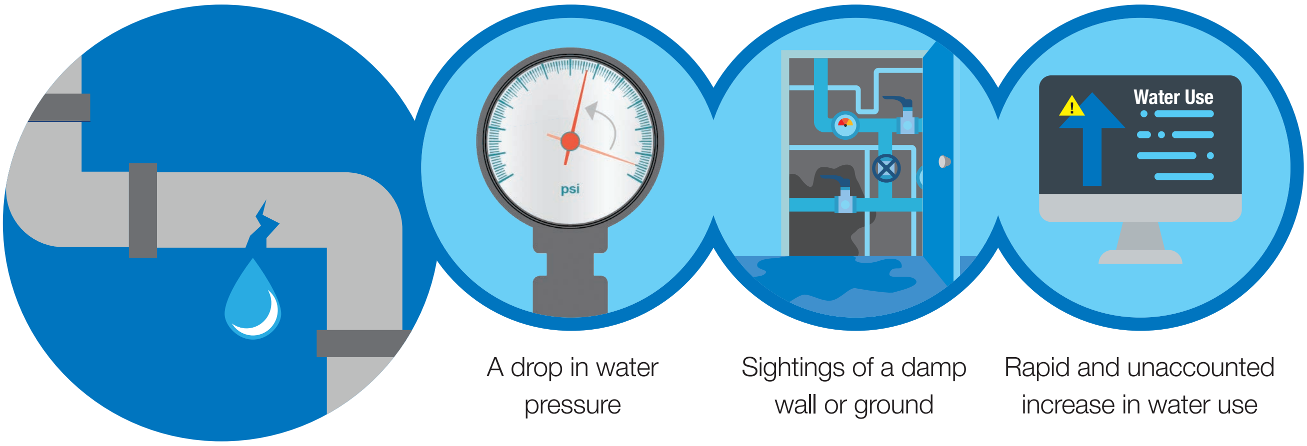
Water leakage is a common problem that may start off small, and almost indiscernible, yet may increase and gradually worsen over time. Leakages in water service installations can lead to wastage of water, damage to properties, loss of revenue, etc. Leaks, if detected, have to be repaired promptly.

2.2.1 Regular leak test

A regular leak test helps in early detection of leaks in the water system. This simple test can be done in the following steps:



2.2.2 Signs of a leak



It is strongly recommended that the facility manager or the water management committee keeps a copy of the as-built drawings of the water reticulation system. This would facilitate any future maintenance or repair of the water reticulation system and detection of leaks on the premises.

2.2.3 Fault-reporting system

It is a good practice for building management to implement a fault-reporting system to minimise wastage of precious water lost due to leaks, faulty water fittings, etc.

Building owners should maintain an established and clear channel of communication (i.e. phone call, email, text message) so tenants can send their fault reports to the relevant building maintenance personnel promptly.

Reports received should be ranked in terms of their severity and urgency, and cases with high potential to result in continued water loss must be prioritised.

Tracking and monitoring the status of these reports, to be done by senior building managers, is necessary to ensure that all cases reported are being attended to, followed up on and resolved within the timeframe specified by building owners.

▲ An integrated fault and building management system

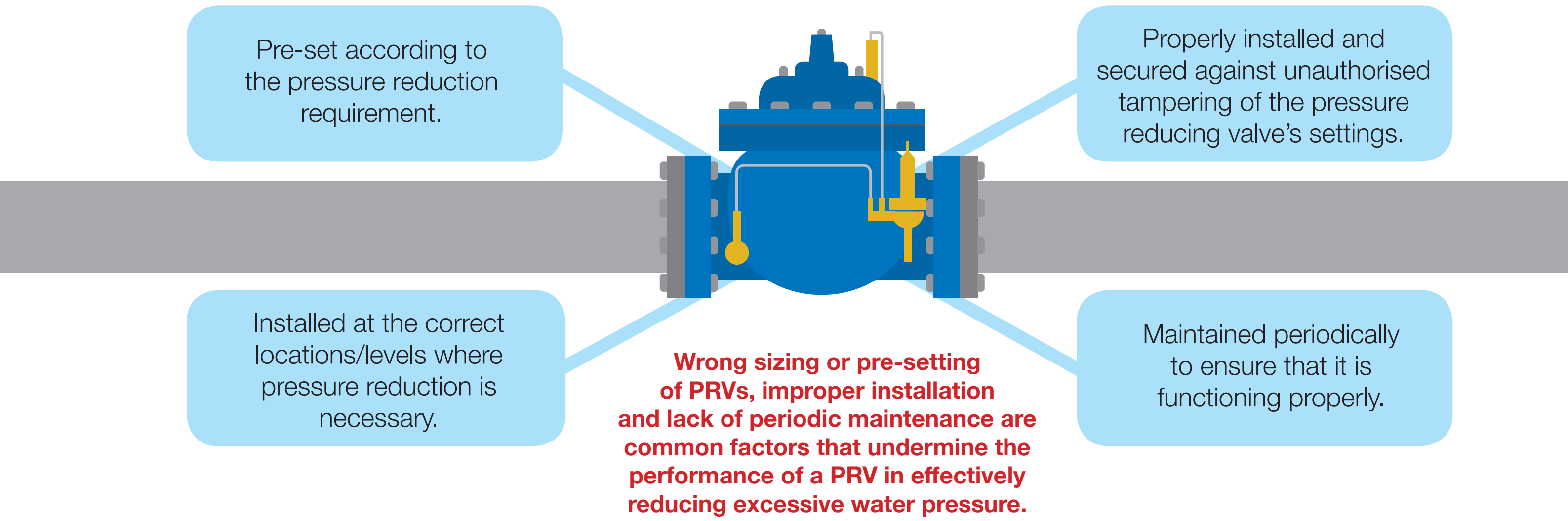
◀ A user reporting a leaking tap to the building maintenance officer

It is paramount for building owners to continually remind building users, including cleaners or cleaning contractors, to look out for and report such cases to the building managers effectively and promptly.

2.3 Adopt a low-pressure water system

Adopting a low-pressure water system can help to reduce excessive water flow in a building, reduce incidence of leaks, and extend the lifespan of plumbing fixtures. This can be done by installing intermediate tank(s) and pressure-reducing valves at suitable levels of the water reticulation system within the building.

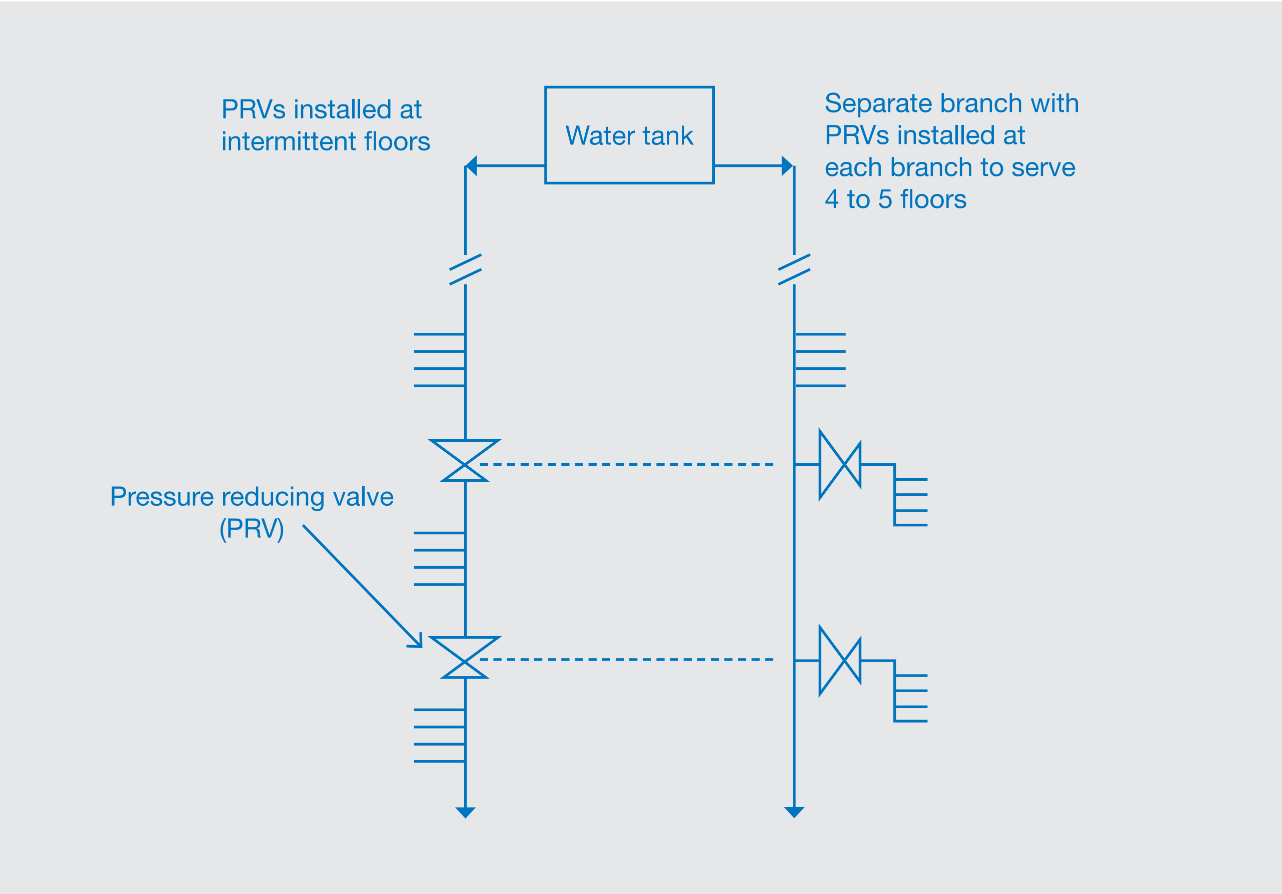
2.3.1 Pressure reducing valve (PRV)



2.3.2 PRV installation configuration

Whenever a PRV is installed, a bypass arrangement should be incorporated to the second PRV as this will serve to isolate any defective PRVs.

A pressure indicator should be provided for pressure monitoring, and the associated pipes and fittings must be able to withstand the maximum pressure that may arise upon the failure of the main PRV.

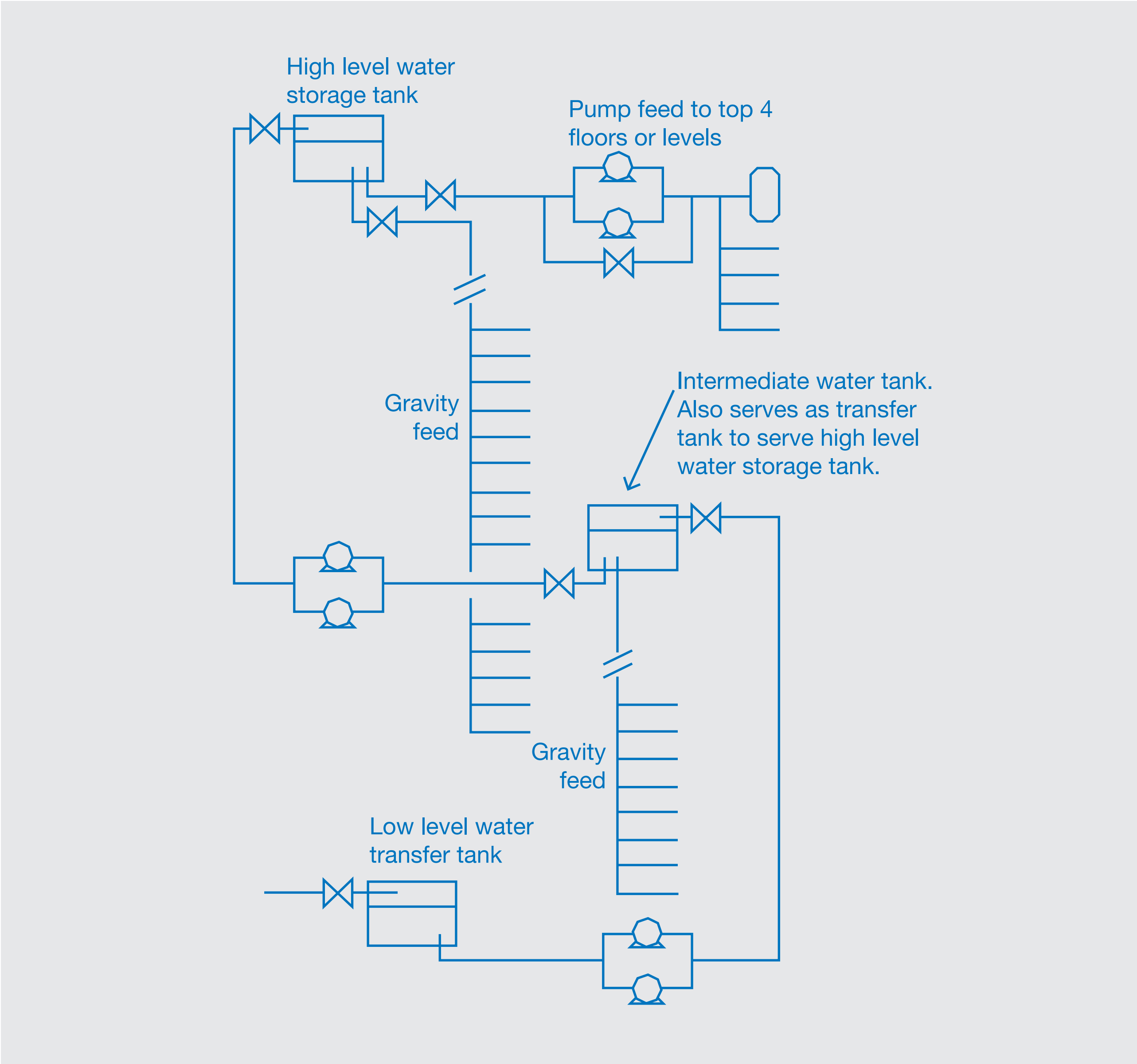


▲ Possible locations for installation of PRVs

PRVs should be installed at locations where the water fittings downstream of the distributing pipe would not be subjected to pressure head exceeding 35 metres.

2.3.3 Intermediate tank

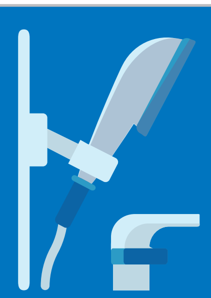
In high-rise buildings, water is typically pumped into storage tanks located on upper floors so that water to the rest of the building is supplied by gravity. This may cause excessive water pressure on the lower floors. Pressure reduction can be achieved by installing intermediate tanks at suitable levels in high-rise buildings. These intermediate tanks installed at levels lower than the high floor water tanks will serve water fittings at designated floors in a tall building.



▲ Intermediate tanks in high-rise buildings

2.4 Use water-efficient fittings

Building owners are encouraged to use fittings labelled 2-ticks and above to reduce water consumption and reap water bill savings. The table below shows the projected annual water savings from water efficiency-labelled products.

	Flow Rates Requirements		Potential savings
 Shower Taps & Mixers	1-tick	**> 7 to 9 litres/min**	–
	2-tick	**> 5 to 7 litres/min**	**25%** (compared to 1-tick)
	3-tick	**5 litres/min or less**	**38%** (compared to 1-tick)

Basin Taps & Mixers	Flow Rates Requirements	Potential savings
✓	> 4 to 6 litres/min	–
✓✓	> 2 to 4 litres/min	**40%** (compared to 1-tick)
✓✓✓	2 litres/min or less	**60%** (compared to 1-tick)

Sink/Bib Taps & Mixers	Flow Rates Requirements	Potential savings
✓	> 6 to 8 litres/min	–
✓✓	> 4 to 6 litres/min	**29%** (compared to 1-tick)
✓✓✓	4 litres/min or less	**43%** (compared to 1-tick)

Flushing Cisterns (Per Flush)	Flow Rates Requirements	Potential savings
✓	Dual Flush > 4 to 4.5 litres (full flush) > 2.5 to 3 litres (reduced flush)	–
✓✓	Dual Flush > 3.5 to 4.0 (full flush) > 2.5 to 3 litres (reduced flush)	**12%** (compared to 1-tick)
✓✓✓	Dual Flush 3.5 litres or less (full flush) 2.5 litres or less (reduced flush)	**18%** (compared to 1-tick)

Urinal Flush Valve & Waterless Urinals (Per Flush)	Flow Rates Requirements	Potential savings
✓	> 1 to 1.5 litres	–
✓✓	> 0.5 to 1 litres	**40%** (compared to 1-tick)
✓✓✓	0.5 litres or less or waterless urinals	**60%** (compared to 1-tick)

Clothes Washing Machines (Per Wash Load)	Wash Volume Requirements	Potential savings
✓✓	> 9 to 12 litres/kg	–
✓✓✓	> 6 to 9 litres/kg	**29%** (compared to 2-tick)
✓✓✓✓	6 litres/kg or less	**43%** (compared to 2-tick)

2.5 Water conservation in cooling towers

2.5.1 Design a water cooling system

The following factors are crucial in choosing a water-efficient cooling system:

Minimise cooling loads

Generally, cooling towers are designed based on a specific cooling load. Minimising cooling loads requires a co-ordinated approach by the design engineer, service personnel and building operators. Transmission, solar radiation, heat infiltration and office equipment are some heat sources that need to be examined to minimise cooling loads. Below are some of the practices/methods to reduce water and energy consumption.

a) Install an economy cycle system to reduce cooling loads when outside air conditions are favourable.

b) Use a hybrid type air conditioning system which utilises natural ventilation via windows whenever outside air conditions are favourable.

c) Use heat recovery systems to reduce cooling loads of cooling towers. The heat recovered can be used for applications such as heating of water for domestic purposes i.e. producing hot water and heating of coils.

d) Reduce the lighting load in buildings by incorporating occupancy sensors as well as making use of natural daylights. Hence, less heat will be produced.

Choice of heat rejection systems

The best time to consider alternative heat rejection systems is during the design of new systems or the retrofitting of existing chillers or cooling towers. There are various alternative heat rejection systems available to reject heat to the environment which can eliminate or dramatically reduce water consumption such as air-cooled/refrigerant-cooled systems.

Use of non-potable water for cooling towers

The use of alternative water sources as makeup water for cooling tower is highly recommended to reduce usage of potable water/NEWater. Some of the common alternative sources include:

a) AHU condensate: As condensate water is relatively lower in conductivity and hardness, it will allow the cooling tower to run at higher cycles of concentration (COC), thus reducing blowdown from the cooling tower.

b) Treated effluent: Reuse treated effluent from other sources as makeup water, provided the quality of the water meets the requirements of the cooling tower system.

c) Rainwater: Install a rainwater harvesting system and channel the collected rainwater to cooling tower makeup tank.

Water-efficient design for cooling towers

A water-efficient cooling tower should adopt the following design criteria:

a) Water meters installed on makeup and blowdown lines to monitor water consumption. Under Part IVA of the Public Utilities (Water Supply) Regulations, it is mandatory for premises with annual consumption of 60,000 m^3 and above to install private water meters at cooling tower makeup water line.

b) High-efficiency drift eliminators are installed. This will reduce the effects of windage that cause the drift to escape through the sides. It should not be transparent or translucent as sunlight can promote the growth of algae, giving rise to the reproduction of legionella bacteria.

▲ Drift eliminator

c) Side stream water filters are installed. Suspended solids tend to clog spray nozzles and erode piping. This can increase blowdown rates or result in chemical by-products. By installing side stream water filters, suspended solids can be removed to maintain cleaner cooling water within the system.

d) Variable speed drive fans which match fan speed to actual cooling load are installed. The fans controlled by the cooling water inlet temperature can reduce water and energy costs. By varying the airflow through the cooling towers, a maximum total chiller plant efficiency is achieved based on building load and ambient wet bulb temperature variation. As the fans slow down to meet load requirements, the fan input power required will be substantially reduced.

e) Automated chemical food systems are installed to control chemical feed based on makeup water flow or real-time chemical concentration monitoring. These systems minimise chemical use while optimising control against scale, corrosion, and biological growth.

f) A conductivity meter is installed to automatically control blowdown. Conductivity of cooling water will be measured continuously and bleed valve will only open when conductivity set point is exceeded.

▲ Louvres

g) Anti-splash louvres or splash mats are installed.

h) A simple and practical design is adopted. Dead logs, loops and bends should be avoided and redundant pipework removed.

i) Easy access to all parts of the system for inspection, sampling, cleaning and disinfection.

j) Construction materials should be non-corrosive, resistant to chemicals (e.g. fibreglass, stainless steel), smooth, non-porous, opaque to sunlight and readily disinfected. Materials used should not support the growth and proliferation of micro-organisms.

k) A drain with a drain-down valve shall be located at the lowest point of the pond so that the entire system can be conveniently and completely drained.

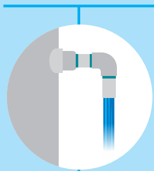
l) Building owners/consultants may refer to Singapore Green Building Council (SGBC)'s list of certified cooling towers (https://sgbc.online/certification-directory/products/) for selection of water- and energy-efficient solutions.

2.5.2 Operate & maintain a water-efficient building

The cooling system in a typical commercial building consumes a substantial amount of water as well as energy. Therefore, it is important to have a basic understanding of the water distribution system in order to properly operate and maintain a cooling tower in a water-efficient manner. Water efficiency of a cooling tower can be optimised by adopting the following approaches.

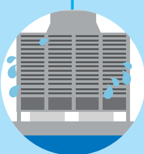
Water consumption reduction

Reduce uncontrolled losses



To prevent overflow

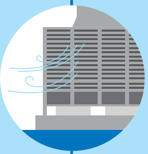
- ✓ Ensure the float valve on the makeup line can close properly to prevent uncontrolled inflow
- ✓ Ensure the overflow pipe is installed at the correct level and is not leaking
- ✓ Ensure that there is no overflow during normal operation
- ✓ Ensure that tower water distribution piping is not oversized or too long
- ✓ Ensure that the operating water levels in multiple tower/cold water basins are equal
- ✓ Replace ball float valves with solenoid valves that are controlled by electronic level sensors



To reduce water splashing

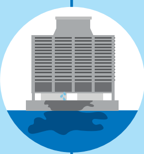
- ✓ Install anti-splash louvres on the tower air intakes
- ✓ Ensure anti-splash louvres are installed correctly and are not damaged

- Install a splash deck above the cold water basin
- Ensure the water supply pressure is within manufacturers' limits
- Ensure that the fan speed and air flow rates are within manufacturers' limits



To minimise drift losses

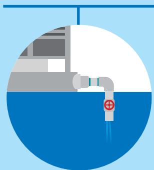
- Install and ensure proper placement of drift eliminators to prevent water droplets and mist from escaping
- Ensure the air flow rates are within manufacturers' limits
- Protect the tower from excessive ambient winds



To arrest leakage

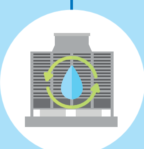
- Conduct regular inspections to monitor whether there is any leakage at the cooling tower, especially at pipe connections and joints
- Pump gland leakage can be reduced by regular pump maintenance and replacing glands with mechanical seals

Reduce controlled losses



To control cooling tower blowdown (bleed)

- Install a conductivity meter to automatically control bleed off of cooling water
- Bleed volume can be reduced by optimising the COC, maintaining and protecting the bleed valve and calibrating the conductivity probes.



To increase cycles of concentration

- Operators should consult service providers to explore possibilities to optimise COC of cooling towers so blowdown water will be reduced and higher COC and substantial water savings can be achieved. Cooling towers should be operated at COC of minimum 7 and 10 for cooling towers using potable water and NEWater respectively

The magnitude of the water savings achievable diminishes with increasing COC, as shown in this table:

		New COC									
		3	4	5	6	7	8	9	10	15	20
Initial COC	2.0	25%	33%	38%	40%	42%	43%	44%	45%	46%	47%
	3.0	-	11%	17%	20%	22%	24%	25%	26%	29%	30%
	4.0	-	-	6%	10%	13%	14%	16%	17%	20%	21%
	5.0	-	-	-	4%	7%	9%	10%	11%	14%	16%
	6.0	-	-	-	-	3%	5%	6%	7%	11%	12%

▲ Water savings achievable at increasing COC

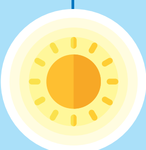
Operators may refer to Singapore Green Building Council (SGBC)-certified products and their associated solution providers on the possible options/methods to optimise COC.

Cooling water quality management

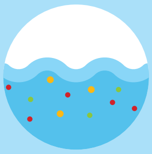
Cooling water should be maintained with a proper water treatment regime to prevent or adequately inhibit corrosion, scaling formation and microbial fouling in the system.

Bio-fouling control

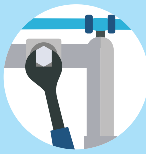
Rapid growth of micro-organisms within the recirculation water will lead to the formation of microbial slimes. The sticky slime layers trap particles/foulants and eventually lead to microbial fouling within the system. Other attributing factors for microbial growth include:



Presence of sunlight

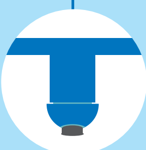


High concentration of nutrients in cooling water

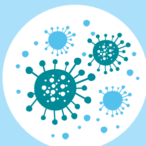


Process leak within the cooling system

Growth of micro-organisms within the cooling tower can result in the following operational setbacks:

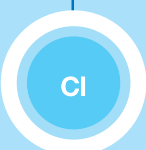


Plugged nozzles that hinder heat transfer

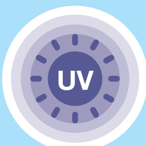


Presence of biofilm, causing deterioration of water quality, drop in flow rate as well as lower heat transfer efficiency

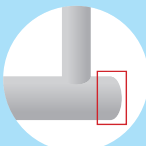
Therefore, it is important to perform necessary disinfection to control proliferation of micro-organisms in the system. Below are some commonly used treatment methods and preventive measures:



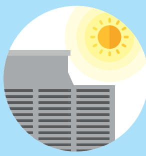
Chlorination



Ultraviolet disinfection



Elimination of dead-ends



Minimising exposure of basins/ distribution deck to direct sunlight

For the control of legionella bacteria, operators shall comply with Part III of the "Code of Practice for the Control of Legionella Bacteria in Cooling Towers". A copy of the guideline is available at http://www.nea.gov.sg/

Deposit and scale control

Accumulation of scale deposits in the cooling system diminishes not only heat transfer efficiency but also the capacity of the water distribution system. Scale deposits are formed when solubility of scale-forming compounds such as calcium carbonate in the water is high. Important factors leading to formation of scales are:

- High water surface temperature (some compounds have inverse solubility above 60°C)
- High water hardness (above 400 ppm $CaCO_3$)
- Unacceptable level of silica (above 120 ppm)

Operational control is crucial to minimise formation of scales and deposits within the cooling system. Effective methods to inhibit scaling are indicated below:

- *Addition of acid to reduce pH
- Dosing of chemical additives
- Water softening to remove hardness from water through ion exchange or membrane filtration
- Operating at sub-saturation conditions
- Installing an electromagnetic descaler

*The effect of scale control caused by creating an acidic environment is compromised by its potential to promote substantial increase in corrosivity. Therefore, proper pH control is essential to inhibit corrosion and scaling at the same time.

Corrosion control

Corrosion in the cooling system will result in structural strength weakening of metal compounds and eventually lead to equipment failure. Apart from that, formation of deposits caused by corrosion may potentially plug water passage within the cooling system.

Factors affecting corrosion include:

- pH level of circulation water (galvanised steel is susceptible to corrosion with pH levels below 6.5 or above 9)
- High water conductivity
- High ammonia concentration (corrosive to copper alloys as low as 0.3 ppm)

Corrosion monitoring shall be in place to ensure that corrosion control measures adopted are effective and any abnormal conditions are instantly detected. Methods of corrosion control are described as follows:

- Dosing of corrosion inhibitors
- Selection of non-corrosive construction materials
- Application of protective coating
- pH adjustment – corrosion rates decrease when pH increases from 4 to 10

Temporary shutdown of cooling towers

If certain cooling tower units are required to be shut down for more than five days, operators shall conduct sampling tests (bacteria counts, biocide levels) at least once a week to ensure the water quality is within control limits. Alternatively, water within the unit(s) shall be completely drained off and dried with blowers. Makeup water and bleed valves shall be fully shut as well.

Standby cooling tower units that are filled with water shall be put into operation on a rotational basis to avoid a unit from being left idle for an extensive period of time. Ideally, this should take place at least once a week. Regular water sampling shall also be performed to ensure that cooling water is maintained at good conditions.

For more details, please refer to ***Technical Reference for Water Conservation in Cooling Towers*** *published by PUB.*

2.6 Adopt water-efficient landscape designs & irrigation systems

Water efficiency is the ability to use the least possible amount of water while allowing the landscape to flourish. There are many water efficiency methods in landscaping, spanning areas like landscape design, usage of technologies and irrigation practices.

2.6.1 Landscape design

The right landscape design is the building block of any good water conservation plan. It can be achieved through smart planning of the types of plants and soil used and hydro-zones allocation.

Use of water-efficient, drought-resistant plants

These plants generally require little irrigation. A list of drought-resistant plants which can be used for landscapes and rooftop gardens can be found at NParks Flora & Fauna website: **https://florafaunaweb.nparks.gov.sg/Home.aspx**

Limit turf area

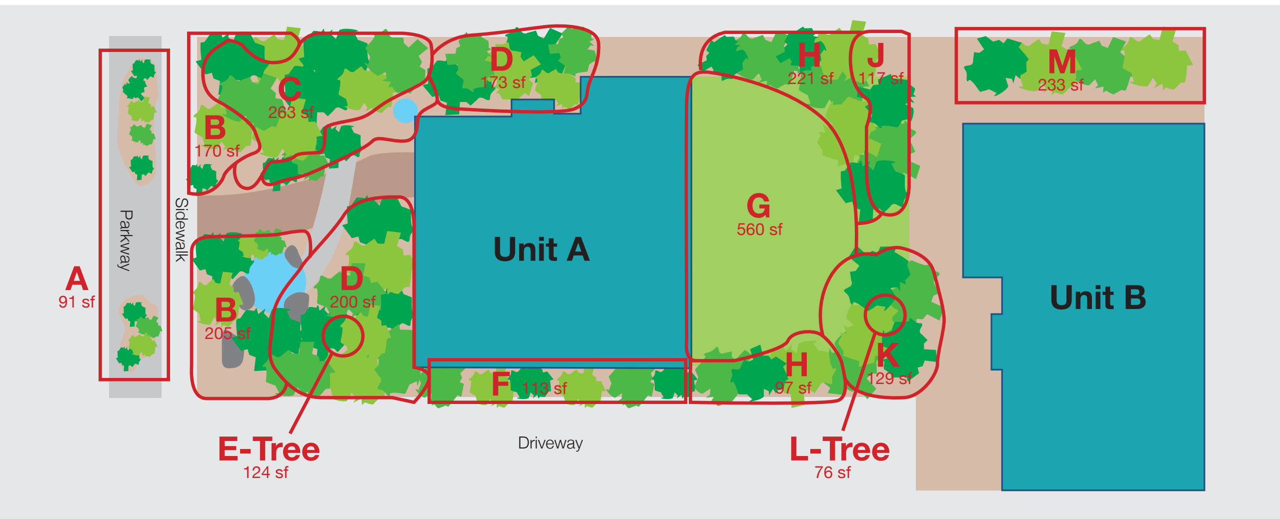
Most turf grass requires high water consumption and continual upkeep.

Select or group plants (hydro-zone)

Hydro-zoning is the practice of clustering together plants with similar water requirements in an effort to conserve water. Irrigation amounts vary, depending on the types and species of plants. High water usage areas include lawns, and sites of ornamental and new plants. Medium water usage areas include shrubs or ground covers. Low water usage areas include ground rooted trees.

If plants of different water requirements share a zone, water will be wasted on plants that do not require much irrigation. In addition to saving water, hydro-zoning will also enable a more efficient allocation of resources, such as on-going maintenance and fertilisation.

Once hydro-zoning has been planned, a zoned irrigation system can be designed to match the water requirements of the different zones.



▲ Examples of hydro-zones

Soil selection

Choosing the right type of soil mixtures would enable maximum retention of water and nutrients in the soil for plant uptake. Understanding the depth and type of soil enables users to determine the frequency and quantity of water required for irrigation.

Water-retaining gels or granules can also be used to maximise water retention in soil and reduce the frequency of irrigation. However, using these may lead to water accumulation in local spots.

Commercial products in liquid form can be applied to an entire irrigation area to prevent water accumulation. Such products help to save water in two ways. They reduce water loss through surface runoff during irrigation with their quick absorption ability and, secondly, they reduce the frequency of irrigation with their moisture-retaining capabilities. The reduction in water use during irrigation can exceed 50%.

3.6.2 Understanding water use in the landscape

Understanding water usage is the first step in improving water efficiency in the landscape. Gradually reduce the amount/frequency of irrigation to observe how a decrease in water affects the landscape and make adjustments as needed. Monitor the water consumption for irrigation through the following measures to arrive at the optimal amount of water required by the plants.

Monitoring water consumption for irrigation

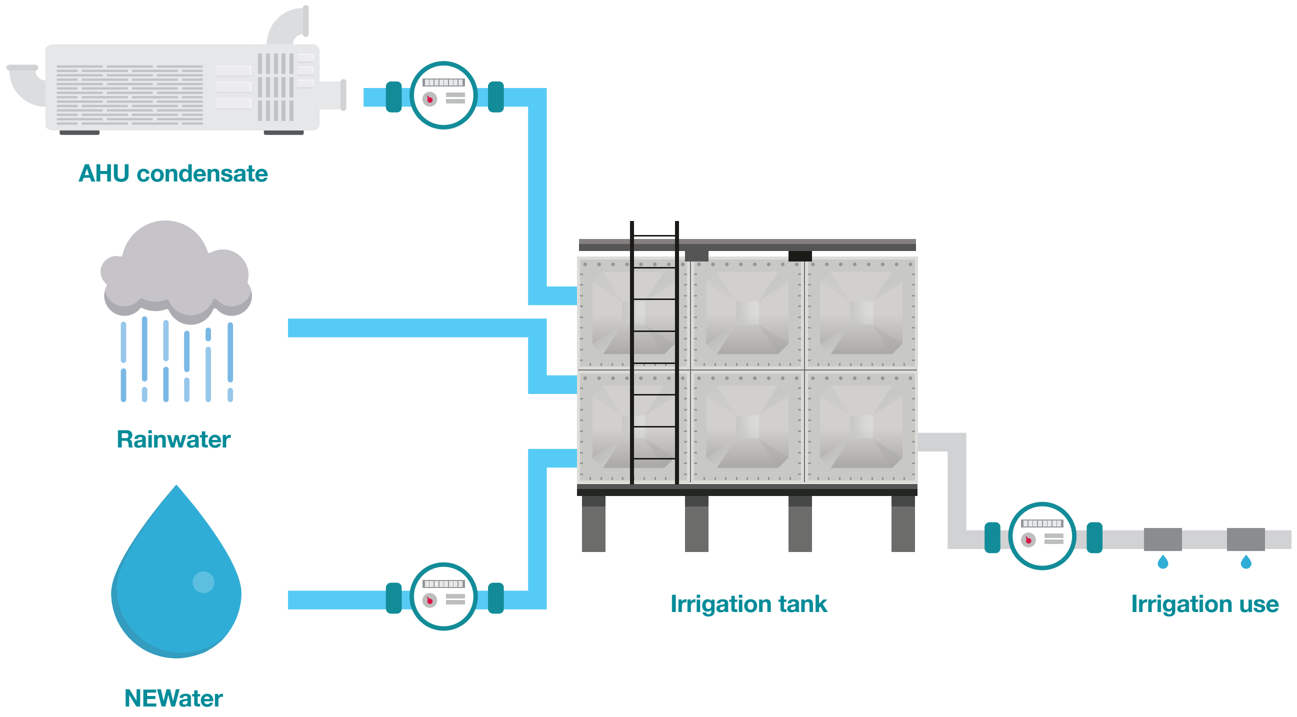
This can be done either by using private water meters to compile simple data records or installing data logging equipment to monitor the water consumption for irrigation. Compiling comprehensive data records enables users to monitor water consumption for irrigation from time to time and assess if practices lead to better water efficiency.

Private water meters

Private water meter readings with proper daily/weekly/monthly records enable users to have a better estimate of the water consumption for irrigation. The following is an example of an irrigation meter record that monitors water consumption:

Irrigation meter at B1			
(Month)	NEWater top up	Rainwater	AHU condensate
1	0	3	5
2	1	2	6
3	3	0	5
......			
31	0	4	6

▲ Example of irrigation meter records



▲ Example of private water meters being used to monitor water usage for irrigation

Data logging equipment

Data logging equipment such as remote metering systems enable users to have constant consumption feedback through a centralised system and empowers users to closely monitor their water consumption for irrigation.

Manual data collection

Areas with many tap points render the use of private water meters or automated data logging equipment infeasible. A simple way to estimate the irrigation consumption on your premises is to determine the tap flow rates at the various zones used and the duration of irrigation activity for each zone. An estimate of water usage for irrigation activity can be calculated using the formula below:

*Water usage for irrigation (m^3) = (M1 * F1) + (M2 * F2) + (M3 * F3) + (M4 * F4) + ...*

	Zone 1	Zone 2	Zone 3	Zone 4
Tap flow rate (m^3/min)	F1	F2	F3	F4
Time (start)				
Time (End)				
Duration (min)	M1	M2	M3	M4

2.6.3 Water-efficient irrigation practices

Complementing the available technologies available, good irrigation practices would enable users to be more water-efficient. Irrigation should be done in the early mornings or late evenings when the evaporation-transpiration rate of the plants is low. This will ensure that most of the water will reach the plant roots and not be lost due to evaporation or wind. Either a manual or an automated irrigation system could be adopted to distribute the water required by the plants.

Manual irrigation

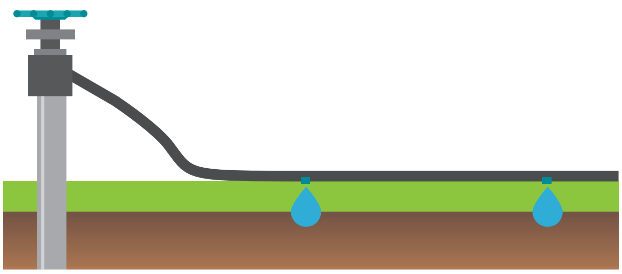
Manual irrigation can be done using a bucket and pail or through a water hose. If a water hose is used for manual irrigation, it is mandatory to attach a controlled device to the hose used.

Irrigation practices such as not irrigating for the next two days if it had rained the day before, and monitoring the weather forecast to determine irrigation activities are also best practices that help to conserve water.

Automated irrigation system

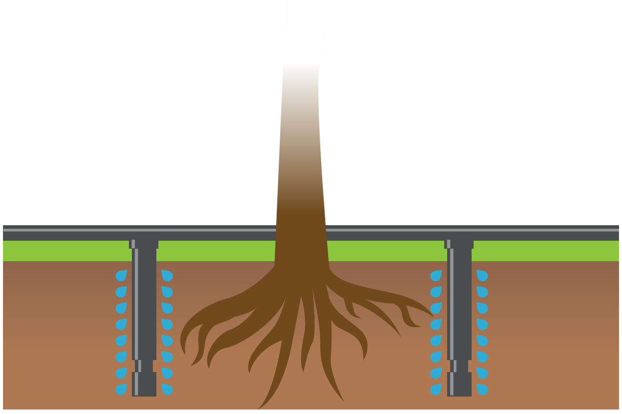
An automated irrigation system is a powerful way to monitor and supervise irrigation practices for landscapes in many types of developments. Systems and proprietary products designed by professionals are helpful in formulating the best irrigation system for a particular landscape with the aim of conserving water.

Constant checks and monitoring of the irrigation system need to be conducted to ensure that the settings are efficient. For instance, during rainy season, the irrigation frequency can be lowered, while during the drought season, irrigation frequency can be increased. Constant checks on the pipes are also crucial to rectify pipe leaks and clogged emitters to ensure efficiency.



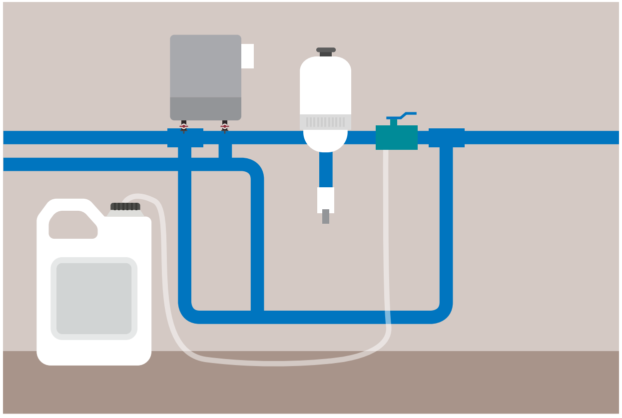
Drip irrigation system

Drip irrigation is the frequent, slow application of water to the specific root zone area of the flora through small flexible pipes and flow control devices (emitters). It provides a constant level of sub-surface moisture to the root ball of the plant for optimum growth or maintenance. Since water is applied directly to the roots, evaporation and runoff are minimised.



Roots watering system

A roots watering system allows water to be filtered from tubes that have been pegged into the ground surrounding the roots of trees. In this case, water is directed near to the source of intake. The system is submerged, as opposed to the drip irrigation system.

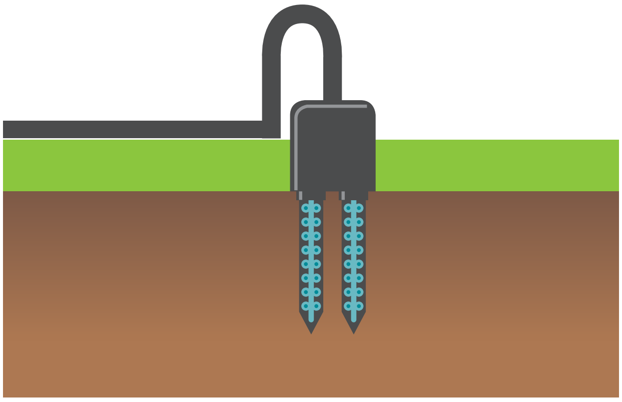


Rain sensors

Automatic controllers should be used to turn off the irrigation system and control the water flow through the various zones according to a pre-set schedule. Rain sensors should be incorporated to automatically turn off irrigation systems during rainy days.

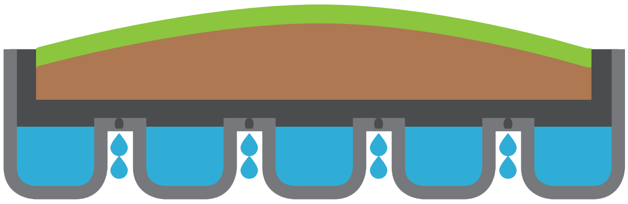
When the rain sensor activates due to sufficient rainfall, the selected irrigation system will remain inactive until the hygroscopic discs inside the sensor have dried out. This dry out rate will be about the same as the soil drying rate and re-activated once the disc is dry again. The dry out rate can be set to different levels. After the rain sensor dries out, the controller will resume its normal watering schedule.

The rain sensor should be mounted as close to the controller as possible, away from the irrigation system, is exposed to unobstructed rainfall, and with similar sun exposure as the landscape being watered. Ideal locations are in the pitched edges of rooftops and fences.



Soil moisture sensors

Installing a soil moisture sensor will prevent the controller from activating the watering system if the soil is sufficiently moist. It determines the soil moisture content by measuring the impedance of the soil between the two sensor pads. As the soil gets wetter, the impedance of the soil reduces. The sensor takes measurements of the landscape's soil moisture at regular intervals. Using a pre-set moisture level as a benchmark prevents the watering system from operating until the soil has become drier than the pre-set moisture level.



Water retention and drainage tray

A water retention and drainage tray system is a lightweight, cost effective array of trays that store appropriate amounts of water for the subsequent needs of the flora. This slows down the drainage of water after rain or watering. The water will be absorbed later as needed. This promotes the growth of healthier plants and reduces irrigation frequencies.

2.7 Adopt water-efficient general washing practices

General washing of a building can be practised using pails, mops, cleaning scrubber machines, high-pressure jets and water brooms. Good general washing practices include:

- Using more water-efficient cleaning equipment such as cleaning scrubber machines and mops, in place of hoses, wherever possible.
- Using a high-pressure jet, which provides quicker and more efficient cleaning than a regular hose. Consider using water-efficient or green-labelled high-pressure jets.
- Re-evaluating the schedule for general washing and cleaning:
  - A high frequency cleaning regime for high use areas such as entrances, exits and walkways will prevent the build-up of dirt and grime, thus eliminating the extra effort needed to remove ingrained dirt. This should involve regular sweeping and spot mopping i.e. cleaning activities that require little use of water.
  - In areas of low use, evaluate if the frequency of general washing can be reduced.
  - Assess the cleaning requirements of areas before proceeding to ensure that cleaning occurs on a need-to basis. For example, it may not be necessary to wash windows if it has just rained.
- Using non-potable sources of water such as recycled water (e.g. rainwater, AHU condensate) for general washing.
- Installing flow restrictors in the water supply lines leading to hoses which will help to reduce the flow rate of water used for general washing.
- Installing drains close to areas where more cleaning is required in order to minimise the need to use a hose as a broom.
- Checking and adjusting nozzle spray patterns for hoses in order to optimise application of sprays.
- Floor mats may be used to minimise the spreading of dirt throughout the building.
- Ensure that cleaning staff are supervised and educated on water saving practices.

2.8 Use alternative water sources for non-potable water usage areas

To reduce the use of potable water for non-potable purposes, it is essential that we explore the use of alternative water sources for non-potable uses such as cooling tower use, irrigation, toilet flushing, general washing, etc. Some examples of alternative water sources include harvested rainwater, collection of AHU condensate and greywater. Substituting potable water with alternative water sources helps to meet the demand of precious quality water and economise use of the water around us.

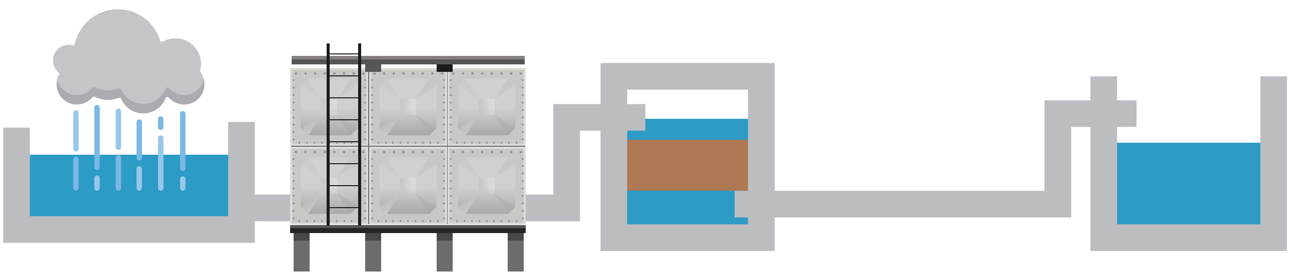
NEWater is presently supplied to commercial and industrial premises for cooling towers, suitable process uses, general washing and irrigation. All new non-domestic (both commercial and industrial) development proposals, including existing non-domestic premises with cooling towers and/or processes undergoing addition/alteration (A&A) works are required to provide a dedicated NEWater pipe system during planning and construction/A&A works to incorporate NEWater for such usage when it becomes available in future.

2.8.1 Rainwater harvesting

Rainwater harvesting is one of the alternative sources of water that can be used in commercial buildings and operation-based premises. It is a process of collecting, filtering, storing and using rainwater for potable and non-potable purposes.

In Singapore, collected rainwater should be used strictly for non-potable uses such as toilet-flushing, cooling tower makeup, landscape irrigation, general washing (excluding washing of hands/face, showering, bathing and brushing of teeth as these activities may lead to accidental ingestion of the non-potable water) and other various purposes. To prevent the unwitting use of harvested rainwater for potable purposes, it is always a good practice to display clearly a “non-potable use only/not for drinking” sign at the point of use.

Essentials of a rainwater harvesting system



A collection system at the catchment area (usually the roof top)	A storage tank with pumps to pump the water from the storage tank to the water usage area(s). Depending on the location of the collection and storage tank, a pump may be required.	Filters	Water pipes direct the rain water from the collection point to the storage location and to the water usage area(s).	Reuse area

Considerations before implementing a rainwater harvesting system

- **Available space:** In existing building set-ups, space is the primary concern for implementing such a system. Detailed planning and careful consideration are often required to ensure that the storage tank and the water usage areas are located close to each other to avoid unnecessary pipe works and the use of pumps, which result in energy wastage. Possible locations for storing such a system include basement car parks and landscape areas.

- **Regulations:** Prior to installation of the rainwater collection system, the owner or developer is required to appoint an appropriate qualified person (who is a Professional Mechanical Engineer) to submit an application for the rainwater collection system to PUB's Building Plan Unit (BPU) for approval and supervision of the installation in accordance to Section 31 of the Sewerage and Drainage Act.

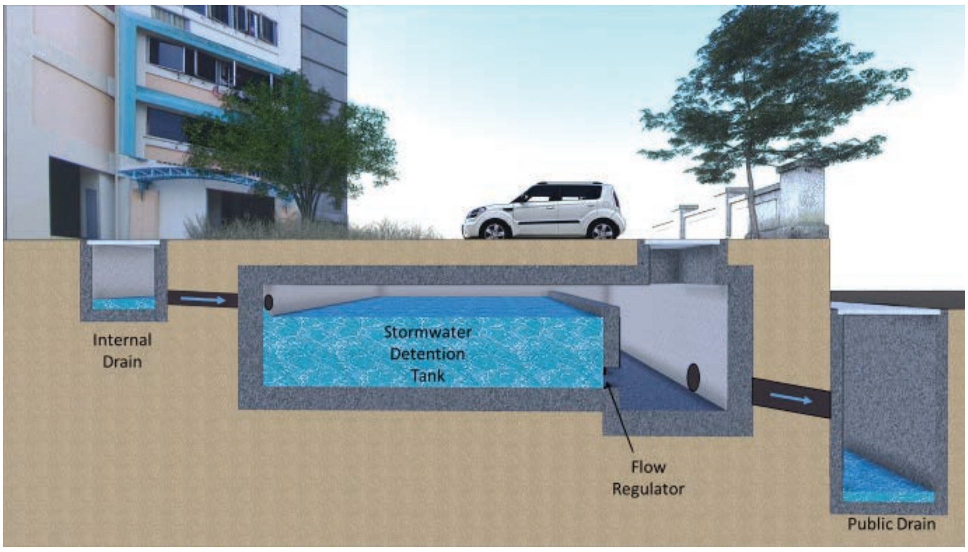
- **Health and safety:** Rainwater tanks provide a breeding place for disease-carrying mosquitoes. To avoid creating a mosquito breeding habitat, measures should be in place to ensure tank inlets and overflows are properly screened to exclude mosquitoes.

- **Maintenance:** Proper operation and maintenance of rainwater harvesting systems help to protect water quality and ensure that the system is running efficiently. Regular inspections such as cleaning of catchment areas, gutters, pipes, filters and tanks reduce the likelihood of contamination and blockage. Managing agents should check with system vendors on proper maintenance techniques, train the site staff on proper system maintenance, and include them in the daily routine checks.

- **Responsible manufacturing:** Materials/substances used for the manufacturing or construction of rainwater harvesting tank should be non-hazardous to human health and well-being. Operators may refer to Singapore green building products which address responsible procurement holistically.

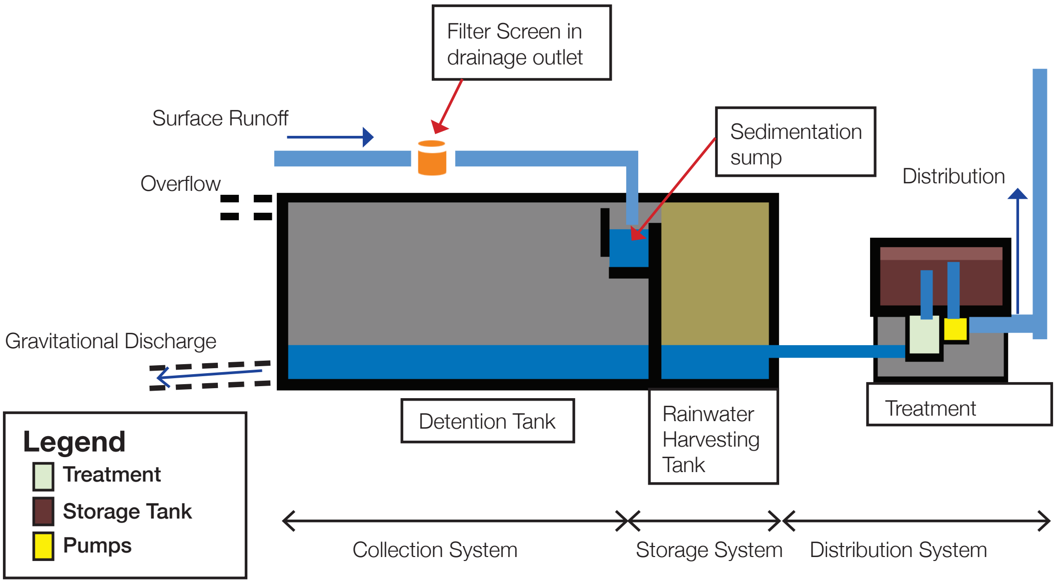
Storm water detention tank systems

Detention tanks collect and store storm water runoff during a storm event, then release it at controlled rates to the downstream drainage system, thereby attenuating peak discharge rates from the site. With such systems in place, the drainage system as a whole can cater for higher intensity storms brought about by increasing uncertainties due to climate change. Detention tanks may be located above ground on buildings, on ground levels and even underground. The figure below shows an example of an on-site detention tank system.



The volume of the detention tank is then emptied within 4 hours after a storm event. The maximum allowable peak runoff to be discharged to public drains and the required detention volume are stipulated in the **Technical Guide for On-site Storm water Detention Tank Systems** which is published on PUB's website[1].

It is critical that the detention tank serves its intended function, which is to empty its contents within the stipulated 4 hours after a storm event, and not over a longer period of time, so as to cater for sufficient space in the tank for the next rain event. Notwithstanding, it is still possible for the Professional Mechanical Engineer to design the rainwater harvesting tank system to discharge the harvested rainwater (within the rainwater harvesting chamber) over 24 hours according to required usage. An example of how the rainwater harvesting tank could be designed without compromising the function of the detention tank is shown below. Based on HDB's existing concept, surface runoff flows into the rainwater harvesting tank and excess runoff overflows into the detention tank which will be emptied within 4 hours after a storm event.



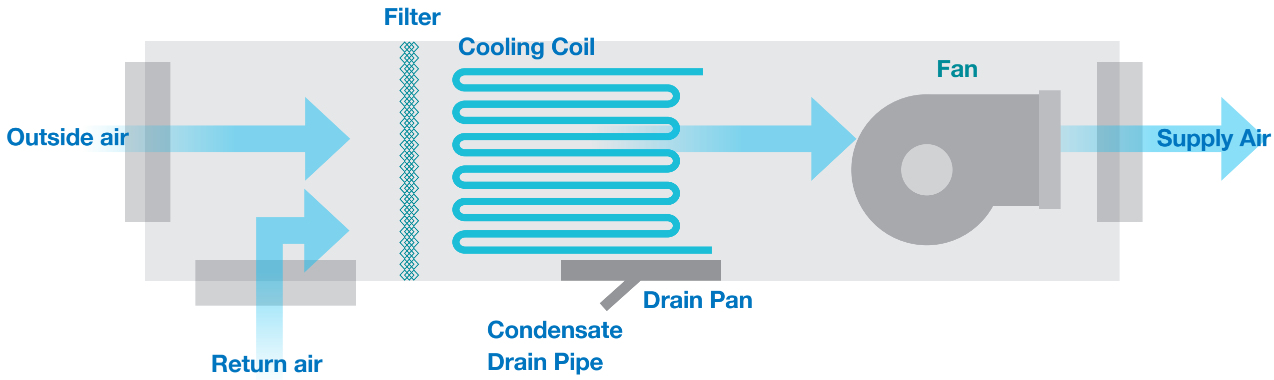
Patented system of HDB, with Singapore patent no. 10201507989U (Patent Pending in HongKong and China)

2.8.2 Air conditioning condensate reuse

The typical air conditioning system in a commercial building consists of air-handling units (AHUs) that circulate air to indoor spaces to maintain comfort as part of a heating, ventilating, and air conditioning (HVAC) system. Fan coil units (FCUs) are smaller modular versions of AHUs. A make-up air unit (MAU) is a type of air handler that conditions only non-recirculated air, i.e. fresh outside air.

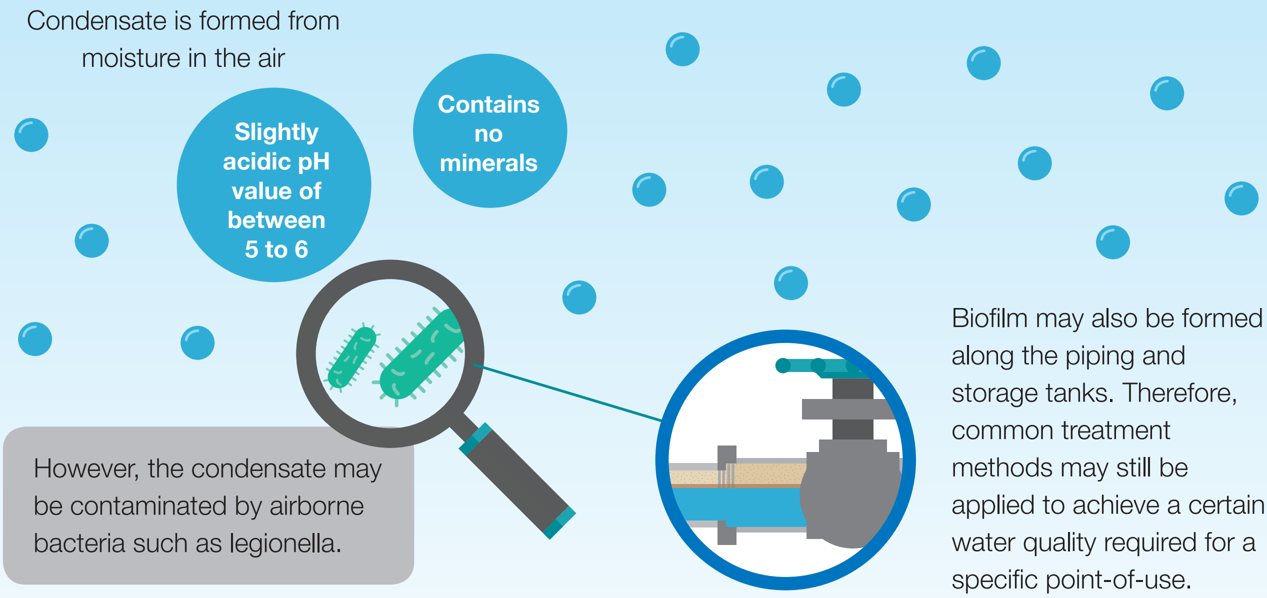
Air returning from the indoor space tends to be mixed with fresh outside air so as to maintain a healthy environment. As the mixture of air passes through the AHU, it goes through a cooling coil where its temperature drops. Humidity from both outside and return air is removed as condensate. Condensate is generally collected in internal cooling coil drain pans before they are discharged by gravity to the drain pipes on the outside. They can then be collected and reused at various points-of-use in a building.

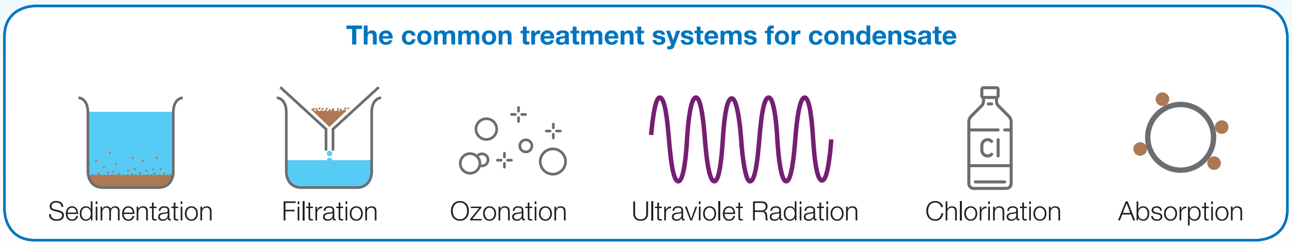
[1]https://www.pub.gov.sg/Documents/detentionTank.pdf



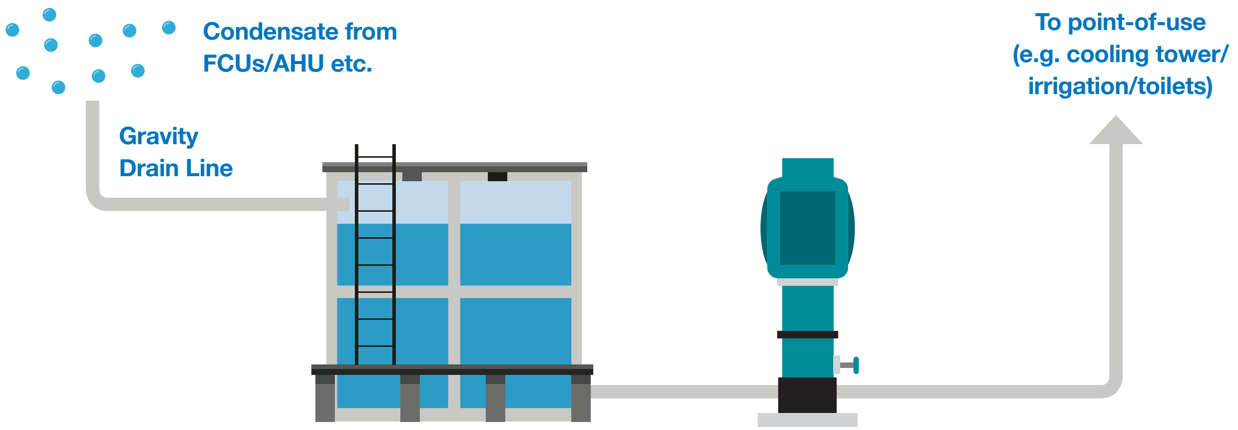
Typical condensate recovery and reuse system

Condensate can typically be reused for non-potable areas such as for cooling tower makeup, irrigation, water features, process cooling water and even for toilet flushing. This will help to reduce the demand for potable water or NEWater, which will in turn reduce utility cost. Condensate reused for cooling tower makeup is recommended as condensate water is generally cold with low dissolved mineral content.





A typical condensate recovery and reuse system consists of drain pipes, pumping lines, a condensate water collection tank and pumps. Depending on condensate water quality and stipulated requirements, appropriate simple treatment systems can also be included.

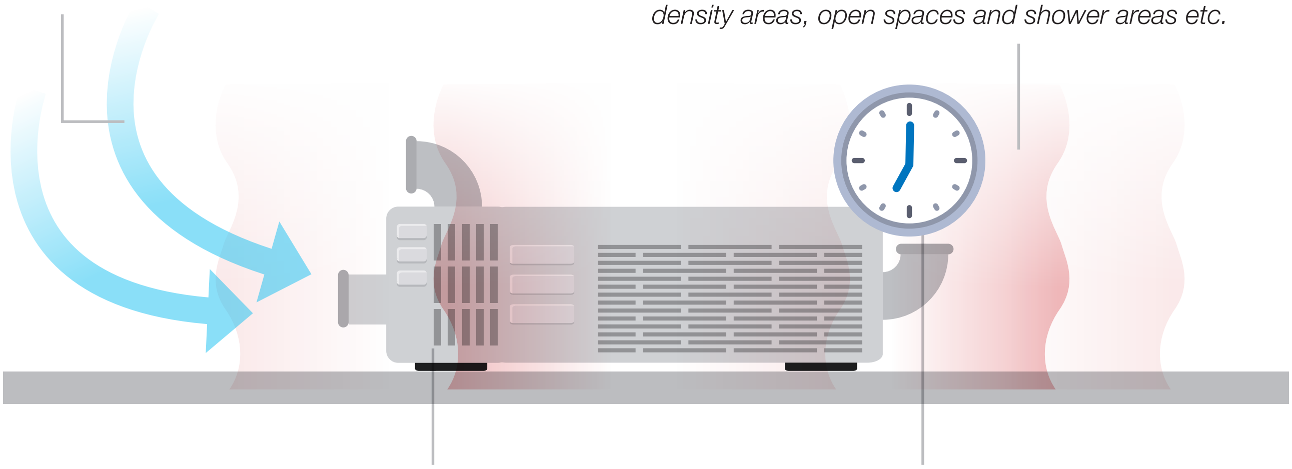


Factors affecting amount of condensate collection

There are a number of factors affecting the amount of condensate that can be recovered. These include:

Amount of fresh air exchange
As fresh air is more humid than return air, more condensate can be generated by AHUs with larger fresh air exchange proportion.

Heat load of the building
Heat load will be affected by the number of occupants and nature of activity. For example, more condensate is expected for AHUs serving restaurants, high human density areas, open spaces and shower areas etc.



Tonnage of AHU

Operating hours and AHU operating capacity

Location and ease of condensate collection

It will be easier to recover condensate from AHUs/FCUs located in the same stack where condensate can be collected via the same condensate drain pipe. On the contrary, it will not be cost effective to collect condensate from AHUs/FCUs that are scattered across the building.

In general, retail buildings, hotels and hospitals are able to achieve high rates of condensate collection due to the higher heat load and higher fresh air exchange requirement.

Best practice guidelines on optimisation of condensate recovery and reuse

Good design guidelines for condensate recovery and reuse system are:

Minimised equipment (piping/ pumping) cost

- It is recommended that the AHUs/FCUs be located along the same vertical stack so that condensate generated can be collected easily via a vertical drain pipe. Alternatively, AHUs/FCUs can be cluster-located in large AHU rooms. These arrangements will help in reducing piping cost.
- Points-of-reuse should be centrally located as much as possible to reduce piping cost.
- As much as possible, points-of-reuse should not be located too high up the building to minimise pumping and piping cost. For example, cooling towers located at an intermediate plaza would be a better choice as compared to cooling towers located at the rooftop.

Maximised condensate recovery

- As condensate collection is facilitated by gravity, the condensate water collection tank and associated pumps should be located in close proximity to each other and at the bottom of the vertical condensate collection drain pipe stack. This is to maximise the amount of condensate that can be collected and help to reduce piping cost.
- FCU drain pipes should be connected to the same AHU vertical drain pipe so as to maximise condensate collection.
- Regular maintenance of the AHUs should be carried out to ensure that the cooling coils inside are clean. This maximises heat transfer between the coil fins and on the coil fan.
- Vent cowl can be provided at the vertical condensate drain stack to ensure smooth flow of condensate water.

Reduced maintenance cost

- An optimally sized condensate collection tank should hold a maximum of 1-day storage capacity. This reduces the green footprint and minimises bacterial growth, hence lowering treatment costs.
- A good pipe gradient of 1:20 to 1:60 should be adopted in drain pipes so as to avoid slime and bacteria growth.

An example of AHU condensate reuse at Khoo Teck Phuat Hospital

Khoo Teck Puat Hospital has implemented AHU condensate reuse for its cooling tower makeup since its opening in 2010. This measure has helped them to save approximately 1,900 m^3 of water annually.

2.8.3 Greywater recycling and reuse

Greywater refers to untreated used water which has not come into contact with toilet waste. It includes used water from showers, bathtubs, wash basins and clothes washing. It does not include used water from urinals, toilet water closets, kitchen sinks and dishwashers.

Greywater recycling refers to the use of treated greywater that has gone through treatment such as membrane filtration and disinfection, in compliance with the required water quality suitable for its specific use.

Treated greywater shall only be used for the following applications:

- Flushing of water closet (WC)/urinal
- General washing (excluding high-pressure jet washing and general washing at markets and food establishments)
- Irrigation (excluding irrigation sprinklers)
- Cooling tower makeup water

Design, treatment and disinfection

Greywater collection pipework shall be designed, sized and installed in accordance with the Code of Practice on Sewerage and Sanitary Works. Pipes and fittings of equal material, quality and construction for sanitary plumbing system shall be used. They should also be prominently labelled.

A greywater treatment system typically consists of biological and filtration (microfiltration/ultrafiltration or other membrane filtration) steps as well as disinfection processes. A chlorine dosing facility shall also be provided at the treated greywater storage and supply tank for final disinfection to ensure that the supplied water is sterile with residual chlorine maintained throughout the storage period.

If treated greywater is to be reused at the WC flushing cisterns/urinals, a colouring dye dispenser device shall be provided to inject blue dye to the treated greywater so that users are aware that the water is non-potable. The blue colour also reduces the risk of cross-connections and the possibility of greywater being used for inappropriate purposes. A safe and environmentally-friendly food-grade dye shall be used.

Raw/untreated greywater shall be stored temporarily in a tank for less than 24 hours. It is also recommended for storage of treated greywater to be limited to 24 hours. All storage tanks should be cleaned at least once annually. All storage tanks shall also be mosquito-proof in accordance with the **Guidelines on Mosquito prevention in domestic rainwater collection system for non-potable uses**[2].

Back-up supply of PUB-supplied water (potable water/NEWater) shall be made available to the treated greywater supply tank to ensure that there will be no disruption of water supply to the water end use area in the event of power failure, overflow, equipment failure or maintenance shutdown. The back-up water supply shall be fitted with a backflow prevention mechanism capable of preventing backflow of non-potable treated greywater to the potable water or NEWater mains. Suitable overflow and bypass pipes shall also be fitted to all storage tanks to allow excess greywater to be discharged into the sewage.

Water quality and sampling requirements

The treated greywater is required to meet the treated greywater quality requirements as per the table below:

Requirements for treated greywater quality for recycling

Parameters	Unit	Requirements for treated greywater quality for recycling	Applicable to
Odour		Non offensive	Toilet flushing, general washing*, irrigation* and cooling tower makeup
Colour	Hazen Units	<15	
pH		6-9	
Total Residual Chorine	mg/l	0.5-2.0	
Turbidity	NTU	<2	
BOD_5	mg/l	<5	
Total Coliform	CFU/100 ml	<10	
E Coli	CFU/100 ml	N.D.	
Standard Plate Count/ Heterotrophic Plate count (SPC/HPC)		<500 CFU/ml	cooling tower makeup only
Total *Legionella* count		Non-detectable when tested using the latest ISO 11731, BS6068-4.12, or equivalent method that is able to test total *Legionella* count at or below 1000 CFU/L	cooling tower makeup only

The minimum sampling and monitoring regime for the treated greywater quality, as per the table below, shall also be strictly adhered to.

[2]A copy of the guidelines is available at: http://www.nea.gov.sg/docs/default-source/training-knowledge-hub/guidelines-on-mosquito-prevention-in-domestic-rainwater-collection-system-for-non-potable-uses.pdf

Minimum sampling regime and monitoring frequency for treated greywater

Parameters	Toilet flushing, general washing, irrigation	Cooling Towers
Odour	Non offensive at all times	Non offensive at all times
Colour	Monthly	Monthly
pH	Monthly	Continuous online
Total Residual Chorine	Continuous online	Continuous online
Turbidity	Monthly	Continuous online
BOD_5	Quarterly	Quarterly
Total Coliform	Monthly	Monthly
E Coli	Monthly	Monthly
SPC/HPC	N.A.	Monthly
Total *Legionella* count	N.A.	Quarterly

Note:

(a) Necessary sampling points (minimally at the treated greywater tank outlet) shall be installed so that sampling can be carried out at the above-mentioned frequency.

(b) The testing of water samples shall be done by Singapore Accreditation Council (SAC)-SINGLAS accredited laboratories qualified to conduct general water quality testing.

For additional information, please refer to the following links:

(a) Guidance Notes for Treated Greywater Quality: https://www.pub.gov.sg/Documents/greywaterRequirements.pdf

(b) Technical Guide for Greywater Recycling System: https://www.pub.gov.sg/Documents/greywaterTech.pdf

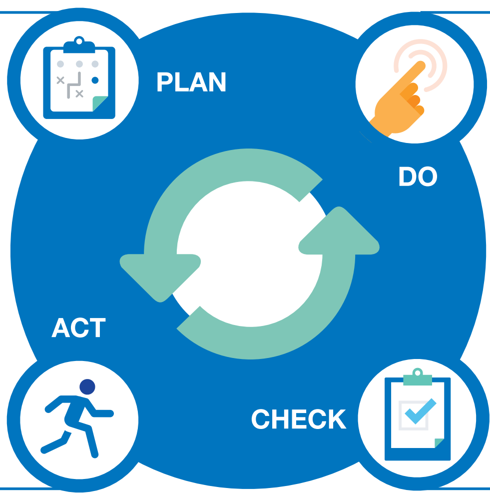
2.9 Adopt water efficiency management systems (SS 577)

Achieving sound water efficiency performance requires organisational commitment to a systematic approach towards continual improvement of a water efficiency management system (WEMS).

The Singapore Standard SS 577: Water Efficiency Management System adopts a Plan-Do-Check-Act (PDCA) continual improvement framework, to enable organisations to assess and account for their water usage, and to identify, plan and implement measures to achieve water savings through the systematic management of water within the building.

Plan-Do-Check-Act (PDCA) continual improvement framework

- Set policy and objectives.
- Identify business activity indicators.
- Identify legal and other requirements for compliance.
- Conduct water usage review.
- Establish baseline water efficiency indices, targets and action plans



- Implement the water efficiency management action plans.

- Monitor and measure the key characteristics of operations that determine water efficiency against water management policy, objectives, legal and other requirements.
- Report the results.

- Take actions to continually improve water efficiency and the WEMS.

SS 577 can be used by organisations of all types and sizes, to implement a water efficiency management policy and establish objectives, targets and action plans for their water usage. It can also be implemented independently or integrated with other management systems and standards.

2.10 Water conservation efforts during dry weather

Singapore experiences dry spells in certain months of a year. A dry spell is defined as a period of at least 15 consecutive days where daily rainfall totals less than 1mm in many parts of the island. Reservoir stock levels are impacted during drier weather and times of lesser rainfall. In response, PUB usually ramps up the production of NEWater and desalinated water to maintain reservoir stock and to ensure our nation's water availability.

PUB urges communities and businesses to continue with their water conservation efforts, and encourage premises to embark on further measures during the dry spell to help stretch our nation's water resources.

Further measures can be taken. These include, but are not limited to, the following:

Check for leaks and stop them promptly

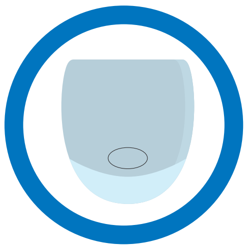
- Take water meter readings more regularly
- Check if the counter water meter is moving during off peak periods when there is no consumption

Stop or restrict vehicle washing

- Use rain and moisture sensors
- Stop unnecessary watering of plants & turf

If it is necessary to irrigate, reduce frequency of irrigation to every third day and not more than 15 minutes

Avoid new plantings



Convert urinals to the waterless type by shutting water supply to urinals and using waterless products

Stop the use of high-pressure jets and hoses for washing activities; use mops instead

Postpone facade cleaning until after the dry weather and reduce frequency of floor washing

- Stop running water features, fountains, water play areas and cascades
- Stop outdoor misting fans

Reduce the operating hours of water-cooled air conditioning systems (e.g. start up the air conditioning system 30 min later and shut down the air conditioning system 30 min earlier compared to usual practices)

3 CASE STUDIES

3.1 Office building case study

Perennial Shenton – AXA Tower

AXA Tower is a 50-storey office building situated within Singapore's Central Business District. It adopts various water-saving practices such as reusing condensate water for toilet flushing, using NEWater for cooling tower operations, constant re-calibration of water closet and urinal flushing systems to ensure that they are within the water-efficient flow rates, and providing a hotline number for feedback on leakages/faulty fittings.

A remote metering system is installed to closely monitor major water usage areas and leakages. Tenants are also educated on water-saving measures.

3.2 Retail mall case study

Parkway Parade

Parkway Parade, one of Singapore's largest and first major suburban malls, has put in place water efficiency measures such as using waterless urinals and using 3-ticks water-efficient fittings. Managed by international property and infrastructure group Lendlease, the mall uses rainwater for irrigation and flushing, installs private water meters at key water usage areas to monitor daily consumption, and has established a reporting system tracking leaks and water wastage.

In addition, Parkway Parade has implemented the Green Lease initiative, providing guidelines and resources to encourage its tenants to pursue green initiatives such as 3-ticks water-efficient fittings and certification under Singapore Standard SS577: 2012 Water Efficiency Management Systems. These efforts have resulted in close to 30% water savings each year, which is enough to fill up approximately 25 Olympic-sized swimming pools. The mall is committed to its ongoing efforts to achieve operational excellence in water efficiency.

3.3 Hotel case study

Carlton City Hotel Singapore

As part of the hotel's sustainability initiatives, Carlton City Hotel Singapore closely monitors its water consumption and has developed a systematic fault-reporting system and enforced daily inspections to prevent water wastage through leakages.

The hotel adopted 3-ticks MWELS fittings in their guestrooms and common area toilets in their efforts to conserve water. They also actively educate guests and staff on the importance of water conservation by placing water conservation posters all around the premises. The hotel also recovers AHU condensate and reuses it for the cooling tower. Through these efforts, Carlton City Hotel Singapore has seen a drop of about 4233m^3 in water consumption between 2014 and 2016.

3.4 School case study

Mee Toh School

Environmental education has always been a mainstay of Mee Toh School's programme, and the staff and students take personal responsibility to take care of the environment, guided by the school value of "Care".

Mee Toh School's environmental education has extended to include a comprehensive water conservation programme aimed at staff, students and stakeholders.

A Water Efficiency Management Team (WEMT) was formed in early 2017 to review the school's water consumption levels and practices. The school conducts water audits within its premises to identify additional water conservation measures.

As part of the school's effort to promote water conservation, it commemorates World Water Day and involved environment champions selected from the student body to create awareness of the event. The school instils water awareness into various subjects. For example, the Social Studies learning journey to the NEWater plant for all Primary 4 students has made them more aware of Singapore's water resources.

The school also provides students with routines like cleaning activities to cultivate good environmental conservation habits, while encouraging them to make these habits a part of their lives.

Mee Toh School has also 'adopted' Lorong Halus under the "Friends of Water" programme to promote experiential learning of the ecosystem in the waterways. Students also actively participate in water conservation through CCA sessions.

4 WATER SAVING PRACTICES CHECKLIST

General operations

	Yes	No	N.A.
Record and monitor the bulk meter readings regularly (daily or weekly) to identify any abnormal increase in water consumption due to leakage. Alternatively, an automatic monitoring system (e.g. Building Management System) can be used.			
Install a private meter at different water use areas such as toilets/pantries, cooling towers, water features, irrigation sites, swimming pools and more. Record and monitor the readings regularly to monitor the performance of the system and identify possible leakage for prompt rectification.			
Conduct regular (daily or weekly) inspections of the water reticulation system and water fittings to identify leaks and repair them immediately.			
Conduct a water audit to identify ways to reduce, replace (use alternative water sources) or recycle water used within the premises.			
Management spearheads water conservation efforts.			
Form a committee/team to coordinate and oversee water conservation initiatives. Review them regularly. Appoint someone responsible for water efficiency and encourage them to liaise with PUB officers on matters pertaining to water conservation.			
Educate workers/employees on the need to conserve water through pre-work briefings, talks, discussions, publicity materials, etc.			
Engage all employees to come up with new water conservation ideas and reward them accordingly.			

Toilets

Measure	Yes	No	N.A.
Adopt a water-efficient flow rate of 2 litres/min at wash basins in toilets and 6 litres/min for sink/ kitchen/bib taps.			
Adopt at least a 2-ticks WELS-rated or water-efficient flow rate of 7 litres/min for self-closing delayed action shower taps where the timing is between 13 and 15 seconds.			
Adopt 3-ticks WELS dual flush low capacity flushing cisterns (LCFCs).			
Adopt waterless urinals.			
Remove ball valves' handles to prevent any tampering of flow rates.			
Remove loose head handles of bib taps to avoid misuse.			
Display contact numbers for public to call should they came across any water leakage or faulty fittings or assign cleaners to individual toilets to take responsibility.			

Cooling towers

Measure	Yes	No	N.A.
Installation of an economy cycle system to reduce cooling loads when outside air conditions are favorable.			
Use of a hybrid type air conditioning system which utilises natural ventilation via windows whenever outside air conditions are favourable.			

	Yes	No	N.A.
Use heat recovery systems to reduce cooling loads of cooling towers. The heat recovered can be used for applications such as heating of water for domestic purposes, i.e. producing hot water and heating of coils.			
Use alternative water sources as makeup water for cooling tower.			
Install water meters on makeup and blowdown lines to monitor water consumption.			
Install side stream water filters. Suspended solids can be removed to maintain cleaner cooling water within the system.			
Install variable speed drive fans which can match fan speed to actual cooling load.			
Ensure the float valve on the makeup line can close properly to prevent uncontrolled inflow.			
Ensure the overflow pipe is installed at the correct level and is not leaking.			
Ensure that tower water distribution piping is not oversized or too long.			
Ensure that the operating water levels in multiple tower/cold water basins are equal.			
Replace ball float valves with solenoid valves that are controlled by electronic level sensors.			
Install anti-splash louvres on the tower air intakes and ensure they are installed correctly and are not damaged.			
Install a splash deck above the cold water basin.			

	Yes	No	N.A.
Ensure that the fan speed and air flow rates are within manufacturers' limits.			
Operate at cycles of concentration of minimum 7 and 10 for cooling towers using potable water and NEWater respectively.			
Both volume and conductivity of makeup and blowdown water should be monitored, logged and charted.			
Clean the conductivity sensor on a monthly basis and re-calibrate it at least once every 6 months.			
Conduct regular inspections to monitor whether there is any leakage at the cooling tower, especially at pipe connections, pipe joints and pumps.			
Carry out routine maintenance work in a timely manner.			
Examine monthly routine maintenance reports provided by the respective maintenance contractors, identifying opportunities to minimise water usage and eliminate water wastage.			
Ensure follow-up actions are taken and documented in the maintenance reports.			
Require the water treatment contractors to commit to a pre-determined minimum level of water usage and make this a key performance indicator.			

Irrigation

	Yes	No	N.A.
Water the plants every third day early in the morning (4 to 7am) or late evening (6 to 9pm) to reduce evaporation loss. Reduce the frequency of watering the plants during rainy days.			

	Yes	No	N.A.
Water the plants with a watering can instead of a running hose. If a hose is used, a spring-loaded nozzle must be attached to the hose.	◯	◯	◯
If an automatic irrigation system is used, incorporate a rain sensor and soil moisture sensor that will automatically turn off during rainy days or when the soil is still moist.	◯	◯	◯
Adopt an efficient irrigation system by choosing the right nozzle design and technologies.	◯	◯	◯

General washing

	Yes	No	N.A.
Use more water-efficient cleaning equipment such as water brooms, cleaning scrubber machines and mops, instead of hoses, wherever possible.	◯	◯	◯
Review the schedule for general washing and cleaning frequently. For areas of low use, the frequency of general washing may be reduced.	◯	◯	◯
Use non-potable sources of water such as NEWater and recycled water (e.g. rainwater, AHU condensate) for general washing.	◯	◯	◯
Check and adjust nozzle spray patterns for hoses accordingly, in order to optimise application of spray.	◯	◯	◯
Floor mats may be used to minimise the spreading of dirt throughout the building.	◯	◯	◯
Ensure that cleaning staff are supervised and educated on water-saving cleaning practices.	◯	◯	◯

Recycling/replacing with an alternative source of water, wherever possible

	Yes	No	N.A.
Install an AHU condensate recovery system to meet non-potable water demand.			
Install a water recycling system (e.g. greywater) to reclaim water for reuse for non-potable purposes such as toilet flushing, irrigation and cooling tower makeup water.			
Harvest rainwater for other non-potable purposes			

Guestrooms

	Yes	No	N.A.
Install a private meter at the riser connected to the guestrooms to monitor water consumption.			
Install a water-efficient fitting with flow rate of ≤ 2 litres/min at basin taps and a water-efficient fitting with flow rate of ≤ 7 litres/min at shower taps and 3-ticks LCFCs.			
Check for overflow in toilet cisterns.			
Do not use the toilet's water closet suite as a trash basket.			
Encourage guests to reuse the towels or linen whenever possible.			

Laundry

	Yes	No	N.A.
Install a private meter to monitor water consumption.			

	Yes	No	N.A.
Use a washing machine with a higher water efficiency rating.	○	○	○
Operate washing machines only when fully loaded.	○	○	○
Recycle the final rinse water for pre-wash in the next load.	○	○	○
Turn off and isolate the steam supply to equipment when not in use.	○	○	○
Carry out regular maintenance to ensure water valves and dump drains are free from leaks.	○	○	○

Swimming pool

Install a private meter to monitor the water usage for backwashing and ensure backwashing follows the manufacturer's recommended frequency and health guidelines.	○	○	○
Carry out manual cleaning/use a skimmer regularly to reduce filter load.	○	○	○
Use a more effective filter medium such as zeolite.	○	○	○
Ensure the pool is chemically balanced to prevent water quality problems, therefore reducing the frequency of backwash and cleaning.	○	○	○
Conduct regular checks for leaks by carrying out a bucket test or looking out for tell-tale signs and repair promptly.	○	○	○
Lay exposed pipes where possible for easy detection of leakage.	○	○	○

	Yes	No	N.A.
At the design phase, where possible, site the swimming pool at a suitable location which has minimal direct sunlight and lesser wind speed. Alternatively, use a pool cover to reduce evaporation loss.	○	○	○
Install a private meter to monitor usage of and identify possible leakage(s) in the swimming pool.	○	○	○

Kitchen/Cooking area/Pantry

	Yes	No	N.A.
Install at least 2-ticks WELS fittings or adopt a water efficiency fitting flow rate of ≤ 6 litres/min at sink taps.	○	○	○
Wash dishes with a low flow rinser or in a filled sink instead of under running taps.	○	○	○
Soak utensils and dishes in a basin of water before cleaning for easy removal of food residues.	○	○	○
Use pressure sprays to pre-rinse the dishes effectively and reduce water consumption.	○	○	○
Use a suitable detergent and avoid excessive use of it.	○	○	○
Turn off the dishwasher when not in use. Run dishwashers at full load.	○	○	○
Recycle rinse water from dishwashers to wash away food residue on dishes.	○	○	○

	Yes	No	N.A.
For manual dishwashing, have 3 compartment washing basins for soaking, washing and rinsing separately so as to reduce water use and enable easy recycling of rinse water.			
Do not defrost food or wash vegetables under running taps. Defrost in the refrigerator, or install an air pump to the defrosting sink, to speed up the defrosting process.			
Retrofit existing water-cooled wok stoves to air-cooled wok stoves.			
Install a private meter to monitor washing activities.