Municipal Engineering
Foundation Victoria

STORMWATER REUSE INFRASTRUCTURE & EFFECTS ON STORMWATER REUSE INFRASTRUCTURE DUE TO CLIMATE CHANGE

Study Tour Final Report

MUNICIPALITY VISITS IN USA, SWEDEN AND UK AUGUST/SEPTEMBER 2008

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Abstract

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The purpose of this report is to identify current infrastructure for stormwater reuses found internationally and compare them against examples found locally in Victoria, Australia. Specifically municipal projects in the United States of America (USA), Sweden and the United Kingdom (UK) visited during a Study Tour sponsored by the Municipal Engineering Foundation Victoria in August and September 2008.

This report outlines the type of stormwater reuse initiatives that can provide options for municipalities to collect, treat and reuse stormwater, for uses specific to municipal functions. A summary of these options are designed to inform municipal engineers and other officers what initiatives are being developed and how local stormwater harvesting and storage applications for Victoria, Australia compare.

Acknowledgments

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City of Stockholm, Sweden

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London Borough of Sutton, UK

Bio Regional Development, UK

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Oxley Wood Development, UK

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1. Introduction

1.1 Background

Stormwater, what do we do with it?

Perhaps this water, which we try so hard to remove from roadways and buildings, could be one of our greatest resources. It could be a solution for ever increasing demands on existing water supplies.

Many consider stormwater as a waste product, flowing through pipes and open drains to a river, lake or ocean. What if we could capture it and reuse it for everyday functions, what would be required, what options are there available to do so and are there any other benefits?

Most of us have heard of Climate Change and that it could be the biggest threat to Earth’s long term environmental sustainability, but what role does Climate Change have on stormwater infrastructure, existing or new, and stormwater management.

Victoria, Australia has been in drought conditions with below average rainfall for more than ten years (Victorian Government, 2004) and has forced government departments to fund and implement measures to deliver water to expanding communities as well as impose water use restrictions throughout the state to accommodate low inflows to major water storage supplies.

The future Victoria’s climatic conditions are expected to become ever increasingly drier, with more hot days (Victorian Government, 2004). On the other side to this drier climate, storm intensities are expected to increase. What are the impacts of these predictions?

In this report, I have attempted to address these questions and provide an understanding of stormwater as a reclaimed / reusable resource.

1.2 Horsham Rural City Council

With current drought conditions engulfing the Wimmera Region of Victoria and signs emerging of long term Climate Change effects, municipalities together with the community have identified stormwater as an essential water resource that can be harvested for uses benefiting the community.

Following on from the efforts of government and engineering organisations regarding stormwater reuse initiatives, the Horsham Rural City Council has implemented capture and reuse infrastructure with positive response and encouragement to further develop these projects.

Examples currently being implemented are the retro-fitting of rainwater tanks to municipal and community buildings for connection to toilets for flushing for irrigation purposes.

Due to Horsham's flat open plain topography, stormwater infrastructure is limited, requiring most new development to detain stormwater on-site during storm events until existing stormwater systems are able to cater for the delayed discharge. The most common detention infrastructure to date has been detention basins in the form of large ponds or wetlands. In recent years, pump stations have been installed at these locations to enable stormwater reuse for municipal purposes.

1.3 Water for Municipal Purposes

Currently we use potable water (drinkable water) for many things other than for drinking, but is it necessary? Increasing the use of alternative water resources such as stormwater, can significantly reduce the demand for potable water and have positive outcomes for the environment and the community.

There are many water needs of municipalities, not all of which would require water to be to a potable standard. Generally most of the municipal water consumption is for watering of parks, gardens and sport fields, with swimming pools, community centres and facilities contributing significantly to use total water needs.

Water standard types are potable water, water that is fit for consumption, waste water, not usable for use without treatment and other classes of water, varying in degrees of usability. Details of these standards are outlined later in this report.

The infrastructure studied in this report does not anticipate stormwater to be treated to potable standard, and need only be available to a standard fit for purpose.

2. Stormwater Infrastructure

2.1 Existing Practices

Stormwater from buildings, roadways and parks, through conventional methods of single collection points in stormwater systems, flow through concrete pipes and pits, and end up at the outfall destination with limited water quality treatment incorporated into the system, such as retardation basins and Gross Pollutant Traps (GPT). These types of stormwater infrastructure are now being referred to as “grey” stormwater infrastructure due to the limited environmental benefits and concern of long term sustainability.

Figure 1: Grey infrastructure (Kelly & Sipalia, 2008)

The focus is now on transitioning to the implementation of “green” infrastructure for stormwater management, to address how to treat, store and reuse stormwater compared to these previous “grey” methods of moving the stormwater towards an outfall as quickly as possible. This “green” approach is perceived as a way of living with, and managing the stormwater locally, rather than a single collection point. This is also echoed through Climate Change discussions as to how to deal with long term stormwater system demand.

It can also be said that managing stormwater through “green” Best Management Practices (BMP) can reduce the cost of implementing or upgrading the “grey” infrastructure and provide 50% less runoff, thereby possibly reducing some 60 to 80% local irrigation demand by improved stormwater management and reuse.

Stormwater quality is commonly addressed at the outfall, typically a pipe entering a waterway, but “green” BMP are designed to alleviate the need for dramatic outfall infrastructure through management of the stormwater as it enters the system, so that it is improved as it moves through a treatment train.

BMP is not a new concept, for example stormwater detention basins are classified as management infrastructure, but have various physical and environmental characteristics that are perceived as negative outcomes, such as the unusable parcel of land on which it is constructed, the mosquito and algae risks and maintenance required on vegetation and silt control, which can add to costs. It is also unlikely that the water captured by such infrastructure is reused before it disperses or evaporates, unless further distribution infrastructure is in place.

2.2 Green Opportunities

“Grey” stormwater infrastructure is designed to collect, convey and dispose of the discharge, the concept “green” infrastructure now aims to heal maintain and provide improved amenity outcomes, specifically on a local level. Ideally this means that the effects of “green” infrastructure can start its positive improvements at the very upstream end of the stormwater system, typically on hardstand areas such as sealed roads and continue along the full length of the drainage network.

Figure 2: Green infrastructure (Kelly & Sipalia, 2008)

A simple example of this is the use of “kerb cuts”, permeable paving and other means of allowing surface stormwater to enter vegetated areas, hence having the effect of reducing the amount of stormwater discharge entering drainage systems and reducing the demand for irrigation (Kelly & Sipalia, 2008). These areas can add a positive amenity outcome and improve water quality, particularly the capturing of debris, vehicle wastes and nutrients contained and carried by stormwater flow.

In managing the stormwater discharge it is important to manage the storm event and have the stormwater enter the system in a controlled situation, such as underground storage infrastructure, which can then be reused for irrigation and other purposes. This in effect also reduces the speed of flow and kinetic energy that conventional systems create through steep grades and low coefficient of friction pipes, which often leads to erosion and poor water quality. These types of retention infrastructure treatments can be easily used under sporting grounds, car parks and roadways, allowing for adequate management capacity without the need for passive land use.

A positive outcome from “green” infrastructure is that it is designed to mimic nature so that it naturally filtrates, manages stormwater, controls pollutants and sediments thereby neutralising the negative impacts of the built infrastructure.

A complete move from “grey” to “green” stormwater may not be justified (Grumbles, 2008), but a balance between both is more likely necessary for an adequate stormwater management system to deliver both sustainable stormwater catchment practises and service to the community through efficient water movement.

2.3 Low Impact Developments

I observed on my study tour throughout USA, Sweden and the UK that Low Impact Developments (LID) have been introduced as a holistic approach to sustainability in developments from buildings to roads. The question of sustainability and how stormwater is incorporated into the solution response was one of my key objectives to research and would suggest that sustainability is the reduction in the ecological footprint, while simultaneously improving the quality of life for our future generations, and is often referred to one planet living and is ultimately what LID is trying to achieve.

Although Low Impact Developments are being implemented with high objectives as a one planet living concept, regulation and guidelines are generally still in early stages of development and implementation. The concept of LID is based on 10 key points as shown below:

1. Zero Carbon;
2. Zero Waste;
3. Sustainable Transport;
4. Local and sustainable materials;
5. Local and sustainable food;
6. Sustainable water;
7. Natural habitat/wildlife;
8. Culture & Heritage;
9. Equity and fair-trade;
10. Health and happiness;

LID is a land development strategy that includes stormwater management, applied at the parcel and subdivision scale that emphasizes conservation and use of onsite natural features integrated with engineered, small scale hydrologic controls to more closely mimic predevelopment hydrologic functions (Staeheli, Norris, McKinley, & Thomson, 2008).

LID guidelines for site development require that low impact design be adopted so that the stormwater system protects and incorporates natural site features, such as erosion and sediment control. The process also requires the inception of stormwater management plans to ensure effective outcomes. An example of this was found in the Beddington Zero Energy Development (BedZED) in the UK, where rainwater tanks where installed at the base of each building for connection for toilet flushing as part of its stormwater management and reuse program.

A number of countries including the USA are looking to create legislation that require new developments to incorporate LID, however, these initiatives have met with strong opposition from developers concerned about the significant capital costs, and have become a topic of political discussion. This opposition did not appear to be evident in Sweden and also to a certain extent in the UK, where federal governments are looking to make LID involvement a requirement of new development and have schemes in place for significant changes in favour of sustainability. This may include incentives for LID approaches and also government related benefits / credits.

2.3.1 Water Sensitive Urban Design

A concept similar to that of LID, with focus on roadway and reserves, Water Sensitive Urban Design aims to further protect waterways and minimise the demand for potable water for functions other than drinking water. Water Sensitive Urban Design (WSUD) is a concept that focuses on stormwater control and quality.

Figure 3: Water Sensitive Urban Design, Malmö, Sweden

WSUD is not directly related to stormwater reuse initiatives, other than providing a means to improve stormwater quality before reuse.

This was noticeable particularly in Sweden and the UK, LID and WSUD are being incorporated into “in fill” developments, which are typically disused industrial areas, retrofitted to become multi-function local communities including both residential and business capabilities.

2.4 Best Management Practices

There is a large variety of Best Management Practices (BMP) available, but for the purposes of this report, my focus will be on those that can be incorporated into stormwater reuse initiatives in Australia.

2.4.1 Rainwater Tanks

Tanks are one of the easiest ways to capture stormwater, particularly from buildings. Once stored, the stormwater can be used for most non-potable uses such as irrigation, toilet flushing and laundry.

Figure 4: Rainwater tank retro-fitted to dwelling (Mills, 2008)

The quality of water is generally of a good standard, especially in rural areas where airborne pollutants are generally lower than urban area. Stormwater collection is also not subject to the pollutants found in roadways and other hardstand areas. The limitation with tanks is the space requirements for installation which will reflect the amount of storage capacity available. The water is not likely to be treated before use and does not reduce the need for stormwater systems beyond the property.

2.4.2 Filtration Systems

An example of such a system is the Environmental Passive Integrated Chamber (EPIC) system developed by the company Rehbein in the USA. The system is a management system that captures and filters stormwater as to store it underground for irrigation use, ideal for parks, gardens and sport fields. In the event that the storage is full, stormwater can be directed to secondary storages or continue through to the next part of the drainage system. The method of reuse is based on saturation of the surrounding soil with the use of sand a critical aspect for filtration and water quality as well as a medium at which water can percolate rapidly through. Because of this, clay and silt type soils would have limited ability to function successfully.

Figure 5: Sports field stormwater filtration and storage system (Kelly & Sipalia, 2008)

Figure 6: Sports field a month after completing the system above (Kelly & Sipalia, 2008)

From information received through the implementation of this type of system in the USA, stormwater runoff into downstream systems have been reduced by up to 56% and Phosphorus reduced by up to 85%, while reducing the demand for potable water commonly used for irrigation by approximately 76%, and allowing vegetation areas to be maintained effectively (Kelly & Sipalia, 2008).

Filtration systems are not commonly used as a means to store stormwater for reuse, and not in the above sports field example. However, throughout USA, Sweden and the UK the discharge is often filtered back into groundwater for which is a major water source and provides another type of filtration function on the discharged stormwater. The reasons generally are because of the high expense required to implement such a project, community willingness to change existing methods and as in Sweden, a need to remove stormwater volume.

Filtration infrastructure treats the stormwater before entering groundwater or waterway, unless underground collection pipes have been installed to retain the stormwater. There are other methods of filtrating surface stormwater to sub-surface pavements and storages for mitigation, and these are discussed further in the report.

2.4.2.1 Permeable Pavements

Permeable paving is a way to manage stormwater through infiltration, and can be incorporated into some trafficable areas where loadings permit, thereby reducing the amount of impervious hardstand surface area.

Permeable paving is best used in roadways, car parks and other pavement areas to increase the permeable area to sub-surface infrastructure. Generally there are three (3) types of permeable pavements typically used, paving blocks with gaps between the blocks filled with permeable material, porous concrete and porous asphalt pavements. Unsealed crushed rock or gravel pavements are also able to provide infiltration functions, however are often overlooked in lieu of a finished surface treatment requiring less maintenance and higher amenity for users.

The roadway stormwater catchment can then filter through to the permeable pavement and be directed to the roadside area and into storage drains or collection points (McGlade, 2005).

Figure 7: Interlocking porous paving in car park, Santa Monica, USA

With porous pavement the filtration void or in the case of concrete and asphalt pavements, aggregate size, should be of consistent size to allow stormwater to percolate through to the pavement below. The larger the void or aggregate size, the faster the percolation. The objective being to select the appropriate percolation rate and pavement design with the storm event being catered for.

Figure 8: Asphalt porous pavement in car park, Santa Monica, USA;

Insert is porous concrete mix

This type of pavement design and filtration does allow for large volumes of storage within the pavement before collection, as well as provide limited removal of sediments and flow control. However, it should be noted that this type of surface is not as structurally strong as conventional pavement composites and are often prone to blockages.

2.4.2.2 Rain gardens

A common application of "green" infrastructure I observed during my study tour was the use of "rain gardens" and there appeared to be a simple arrangement to capture stormwater for natural use on vegetation areas. These typically are for small drainage areas, roof, road sides and vegetation islands.

Figure 9: Rain gardens used in brown fill development, Greenwich, UK

There are a number of other positive physical aspects associated with rain gardens, such as not requiring "open" drains on roadsides that can pose risks to road uses. With these capturing initiatives, a flat surface beyond the road's edge is all that is needed.

A project to reconstruct a residential street in Seattle, USA with green infrastructure or "swale drain" was completed with a 98% reduction in stormwater volume through filtration to groundwater (Mills, 2008). The function of "green" infrastructure and the change in both street beautification and community awareness and support were very successful.

A key objective of the development was to create a reclaimed water supply system to reduce potable demand by providing reclaimed stormwater for outdoor, domestic, and municipal irrigation. Stormwater discharge from roofs, paths, roads, and the general area can be collected and treated (U.S. Environmental Protection Agency, 2004), which is encouraged by the U.S. Environmental Protection Agency (USEPA).

2.4.2.2.1 Swale Drain

These can be called by various names, most commonly know as a swale drain when used in road reserves, which both treats and moves the stormwater. They generally are provided along the outside edge of the roadside, shallow in depth, and width dependent on the required standard of treatment area. The stormwater quality is dependant upon the time taken to pass across the vegetation and level of filtration through the soil.

Figure 10: A before and after shot of a reconstructed roadway to incorporate swale drains with curve-linear road alignment (Mills, 2008)

Two types of road alignments had been used in Seattle, USA. A curvilinear alignment which allowed for a small swale on either side of the road and a more commonly used offset alignment which could provide for swales either side or a large swale on one side only. The larger swale was able to accommodate for higher flows and still have an efficient effect managing stormwater (Mills, 2008).

2.4.2.2.2 Pop-up Stormwater Disbursement

This brings underground property stormwater in pipes to the surface through gravity pressure to disperse over a rain garden surface (overland flow) to be treated before returning to the system elsewhere (Eastling & Willenbring, 2008).

Figure 11: Property Drain "Pop-up" within a rain garden, Santa Monica, USA

2.4.2.2.3 Roof Gardens

Green roof implementation can be provided in a similar method to the infiltration process through vegetation and soil layers. Generally in the USA the "intensive" green roof design is implemented to provide a higher amenity and versatile roof area, which will reduce runoff and improve water quality. The main issue for roof gardens is the structural requirements to accommodate for the added roof weight.

Figure 12: Extensive roof garden, Malmö, Sweden

There are three types of roof gardens (Bernstad, 2008).

- Extensive, flat, thin layer, moss type vegetation.
- Semi-intensive, small shrub vegetation moderate soil layer.
- Intensive- full garden, thick soil layer.

Figure 13: Intense roof garden, Malmö, Sweden

Roof gardens, in small flows, are able to treat 100% of storm event, however, higher flows are not able to percolate through vegetated layers fast enough to be completely treated. Phosphorus removal in most events can be removed up to 70% and sediments up to 90% (Eastling & Willenbring, 2008). Rain gardens, including roof gardens can take soluble pollutants out of stormwater through filtration, but also remove anywhere from 50-75% of the stormwater volume that would otherwise be reused.

Roof gardens are often used throughout Sweden as a means of reducing stormwater volume, but it also provides a treatment to roof stormwater before being captured and stored in tanks for reuse, or before entering the roadway stormwater system.

2.4.3 Basin, Wetlands & Sediment Ponds

Detention basins, retardation basins, wetlands and sediment ponds generally are large enough and hold significant amounts of stormwater so that all that is required for reuse is to install an adequate pump system. I have observed that often this included a stand pipe for filling of transportable tanks, or connection to a separate piped distribution systems for a non-potable water source, for example spray Irrigation.

Figure 14: Common stormwater basin (Kelly & Sipalia, 2008)

I encountered what were often referred to as a dead pool pond, where the stormwater flows in, has a holding time and then flows out (Eastling & Willenbring, 2008). These also have the ability to treat the stormwater for sediments and some pollutants and accommodate large catchment area, but are prone to loses in volume generally through evaporation and seepage.

A retention basin can remove approximately 90% of the suspended solids and 50% of the phosphorus depending on holding time. Although basins remove particulates, it does not remove the soluble phosphorus that can increase risk of algae growth. An option to remedy this can be to pump basins onto parks and fields where these soluble components are consumed by vegetation, in effect the reused stormwater is then treated similar to a rain garden for close to 100% removal efficiency (Eastling & Willenbring, 2008).

Figure 15: Filtration basin in school grounds, Malmö, Sweden

Basins are commonly used, perhaps due to the multiple uses, either as stormwater infrastructure or as an architectural "landscape" feature, which may add to the amenity and aesthetics of an area. The downside to this is the need for relatively large land parcels, which in treatment, only provide limited removal of sediments and pollutants.

The downside of detention basins and wetlands is the amount of space required, limiting other initiatives for stormwater management. Although this "open" style of infrastructure can be aesthetically pleasing, it has the potential to create problems with mosquitoes and other environmental factors as algae if not managed effectively.

2.4.4 Stormwater Treatment Plant

Where localised treatment and reuse of stormwater is not able to be achieved, a single outfall can be treated in the same way a wastewater treatment plant is used, where the quality and volume of water depends on the system selected.

A typical wastewater treatment plant located in one place, with all runoff being accommodated for in one end and usable water discharged the other. All water is treated by mechanical means and there is no reduction in volume, and hence more reusable water.

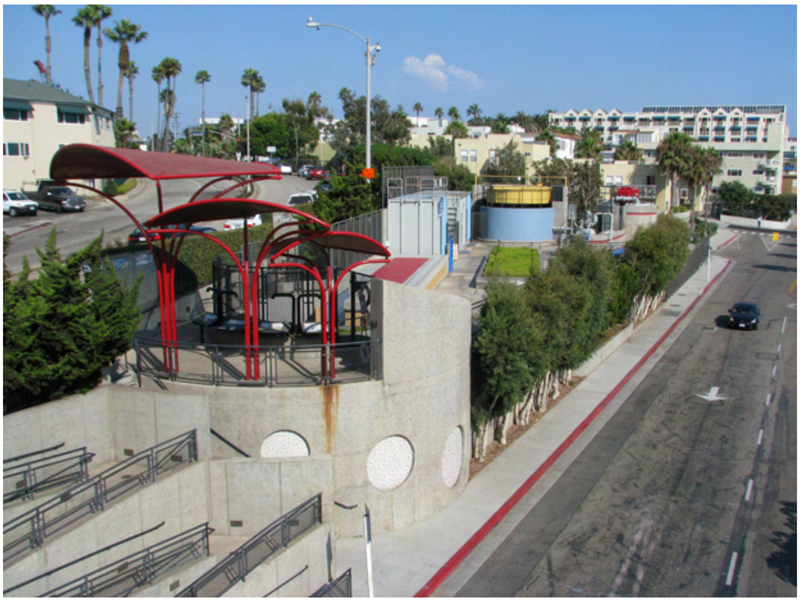


Figure 16: SMURRF, Santa Monica

The Santa Monica Urban Runoff Recycling Facility (SMURRF) visited on the study tour is a state of the art, first of its kind water recycling plant that treats dry weather urban runoff by conventional and advanced treatment systems to remove pollutants such as sediment, oil, grease and pathogens (Shapiro & Parry, 2008). Basically, the SMURRF recycles polluted runoff so it can be reused for municipal water purposes.

The SMURRF is able to treat, clean and reuse up to 2.3 mega litres of runoff per day, which is about 4 percent of the City of Santa Monica's daily water use. This system of treatment can remove 95% of total phosphorus and 99% of the sedimentation. It is an option that provides high standards of treated stormwater for reuse.

2.4.5 Pre-fabricated Infrastructure

Stormwater is directed through physical treatment sections that successful remove debris and limited amounts of sediment. However, these do not provide for any biological treatment of stormwater and are perceived as high maintenance. They are ideal for small flows and because of their size and fabrication and can be constructed in roadways due to their load bearing capabilities.

Figure 17: Prefabricated Stormwater BMP (Humes Water Solutions, 2007)

This type of infrastructure can be installed in series with drainage system and can remove pollutants such as sediment by 70%, phosphorus by 40%, plus debris, oils and metals.

These types of structural treatments are generally used in road reserve areas, where above ground treatment measures and space are not available or can be easily retro-fitted to existing stormwater systems for improving quality. Some products have the provision for pumps to connect to distribution systems.

2.5 Stormwater Quality Regulations

In using stormwater alternative water resources, there is a need to understand the level of treatment required for the use in which it will be allocated.

As stated in the introduction, the aim of this report is not to break down and analyse the numeric standards at which government agencies such as the Environmental Protection Agency (EPA) use, but to make aware the type of stormwater quality expectations.

Stormwater may poses health risks if contaminated, where contaminates are deposited between major storm events. Collection of rainfall at a local level from roof areas have lower health and environmental risks, however, in major urbanised areas and industrial areas may not be recommended for use due to airborne pollutants and sediments. Rainfall can wash animal faeces, oil spills, fertilisers and many other pollutants into the stormwater system. As detailed below, dependent on the type of land involved, the appropriate stormwater plan should be adopted.

Typical Concentrations of Phosphorus and Total Suspended Solids in Stormwater Discharge		**Phosphorus**	**Total Suspended Solids (TSS)**
	Impervious (%)	**Event Mean Concentration (L/mg)**	**Event Mean Concentration (L/mg)**
Agriculture	4	0.75	215
Commercial	60	0.22	90
Industrial	45	0.26	100
Multi Family Residential	35	0.32	140
Open Space	5	0.1	50
Single Family Residential	28	0.3	140
Institutional	27	0.18	80

Table 1: Typical concentrations of phosphorus and Total Suspended Solids (Eastling & Willenbring, 2008)

I noticed on the study tour that in many countries, stormwater and sewerage are discharged to the same infrastructure due to the need to treat both and the convenience of a single system, but this is not common in Australia.

Urban runoff is the single greatest source of water pollutants, contributing from 50-60% of the pollutant load in a receiving water body. Urban runoff includes all water drainage from streets, parking lots, driveways, lawns etc and flowing through the stormwater drainage system. In most cases noticeable on the study tour, urban runoff receives no treatment before draining to an ocean or other waterway. Urban runoff picks up oil and grease, litter, trash, bacteria and viruses, debris, sediments, organic chemicals like pesticides, fungicides, insecticides and heavy metals like copper, cadmium and zinc.

The level of treatment of stormwater will also affect the health of the surrounding environment. Even with storage and reuse implementation, overflow or bypass systems will need to be installed to allow excess stormwater to move to downstream infrastructure in the stormwater system and hence has the potential to adversely impact on the health of waterways.

What are we treating for? Most countries have EPA regulations or legislation such as the Clean Water Act in the USA, which are guidelines for improving stormwater quality, but do not always set numeric standards for require quality of stormwater (McGlade, 2005).

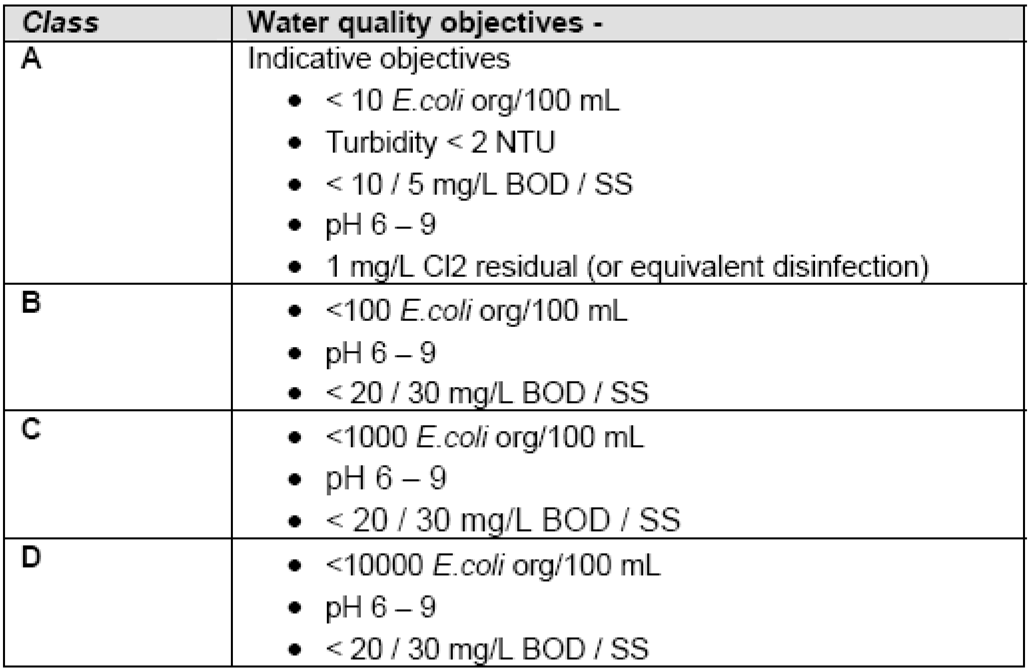
In the USA the EPA is developing a national guideline for the treatment of stormwater which could be in place in the next 12 to 18 months (Grumbles, 2008). This will set technical standards for BMP infrastructure and will involve references to the Clean Water Act and a permit process through local government departments.

The aim is to include in subdivision and similar developments, the requirement for stormwater management plans in line with the guideline to decrease the amount of sediment and pollution entering waterways (Grumbles, 2008).

The highly treated SMURRF water is be used for landscape irrigation and for indoor commercial building use (Shapiro & Parry, 2008). Once treated, the water is safe for all landscape irrigation and dual-plumbing. California has need for reuse water similar to Victoria with comparable drought condition currently being faced.

Stormwater reuse initiatives are usually required to meet standards for dispersion or entry to natural waterways (point of discharge), but in some cases this is not practical to implement because of the high costs for infrastructure to treat stormwater to the levels of treatment required (Staeheli, Norris, McKinley, & Thomson, 2008).

Below is a list of Australian classes of treated water for which none are potable, however Class A can be used for most water uses other than consumption.



Class	**Water quality objectives -**
A	Indicative objectives • < 10 *E.coli* org/100 mL • Turbidity < 2 NTU • < 10 / 5 mg/L BOD / SS • pH 6 – 9 • 1 mg/L Cl2 residual (or equivalent disinfection)
B	• <100 *E.coli* org/100 mL • pH 6 – 9 • < 20 / 30 mg/L BOD / SS
C	• <1000 *E.coli* org/100 mL • pH 6 – 9 • < 20 / 30 mg/L BOD / SS
D	• <10000 *E.coli* org/100 mL • pH 6 – 9 • < 20 / 30 mg/L BOD / SS

Table 2: EPA reclaimed water classes and quality requirements (Municipal Association of Victoria, Institute of Public Works Engineering Australia, Civil Contractors Federation, 2008)

It may be of importance to note what recycled water or reused stormwater cannot be used for due to the possible health risks and listed as follows (Gold Coast City Council, 2008):

- Filling of domestic rainwater tanks or other storage vessels
- Filling of swimming pools or spas
- Drinking (by humans or animals) or food preparation
- Wash down of hard surfaces (such as pavement) where there is a likelihood of uncontrolled flow to stormwater
- Filling of fountains, lakes or other water storages unless under agreement with the local water authority
- Recreational activities

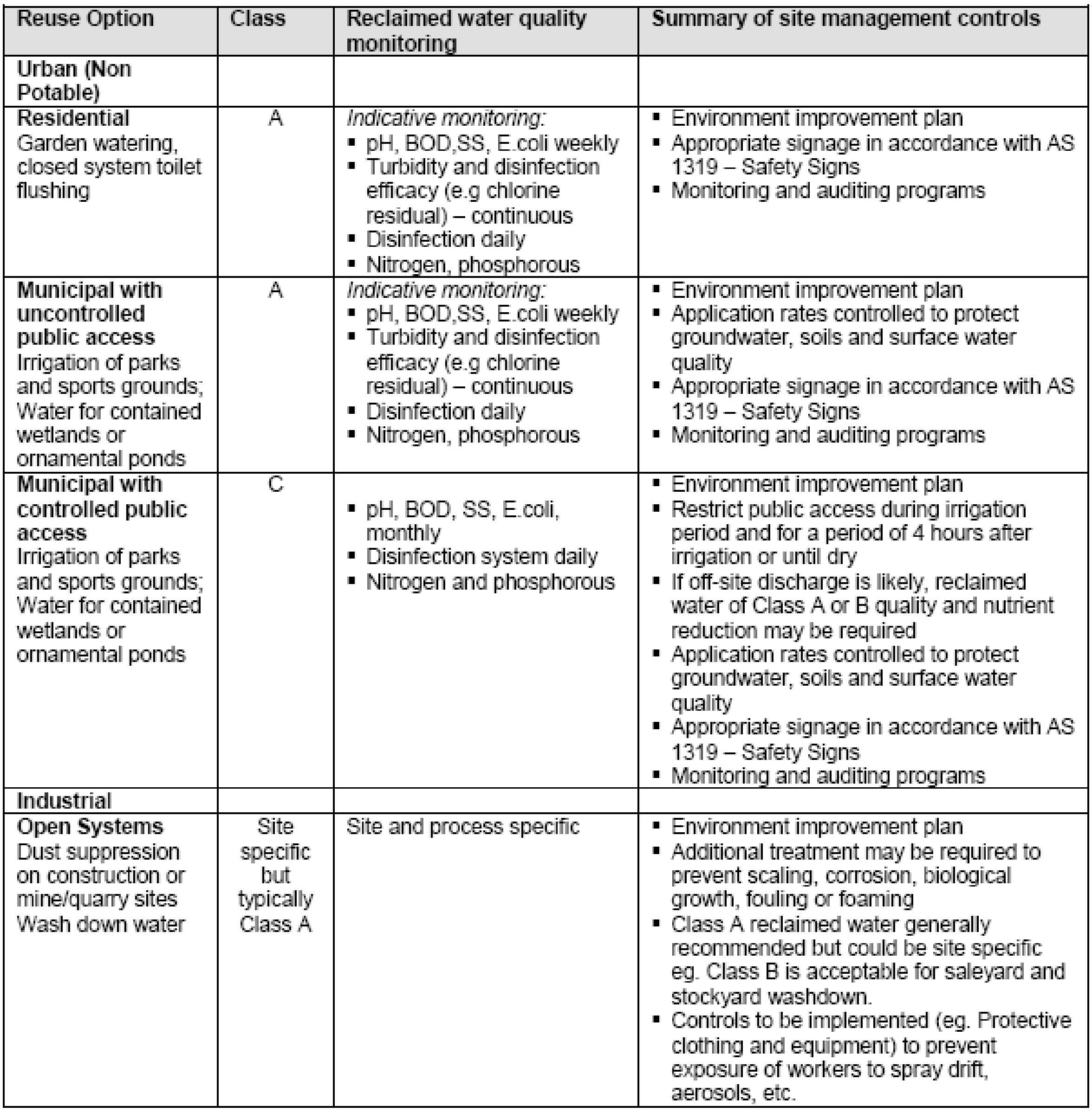
- Household cleaning
- Irrigation of food crops that will not undergo significant processing prior to consumption
- Any purpose within a food premises (including outdoor dining areas)

Below are some examples of where water is used for municipal purposes. All of which may currently be supplied with potable water, but not all requiring potable water quality for that use.

Administration Offices
Town Halls
Childcare Centers
Depots
Markets
Shopping Centers
Function Centers
Cultural Buildings
Community Centers
Toilet Facilities
Residences
Open Spaces
Playing Fields
Gardens / Planter Boxes
Nurseries
Swimming Pools
Water Trucks
Vehicle Wash

Table 3: Examples of municipal water uses (Victorian Government, 2005)

Although most would be able to use stormwater, the quality of treatment of the stormwater varies between the uses. Below is a table developed as a guide for the class of water quality expected for some of the above uses, including possible management processes that can be undertaken as to reduce public health risks.



Reuse Option	Class	Reclaimed water quality monitoring	Summary of site management controls
Urban (Non Potable)			
Residential Garden watering, closed system toilet flushing	A	*Indicative monitoring:* ▪ pH, BOD,SS, E.coli weekly ▪ Turbidity and disinfection efficacy (e.g chlorine residual) – continuous ▪ Disinfection daily ▪ Nitrogen, phosphorous	▪ Environment improvement plan ▪ Appropriate signage in accordance with AS 1319 – Safety Signs ▪ Monitoring and auditing programs
Municipal with uncontrolled public access Irrigation of parks and sports grounds; Water for contained wetlands or ornamental ponds	A	*Indicative monitoring:* ▪ pH, BOD,SS, E.coli weekly ▪ Turbidity and disinfection efficacy (e.g chlorine residual) – continuous ▪ Disinfection daily ▪ Nitrogen, phosphorous	▪ Environment improvement plan ▪ Application rates controlled to protect groundwater, soils and surface water quality ▪ Appropriate signage in accordance with AS 1319 – Safety Signs ▪ Monitoring and auditing programs
Municipal with controlled public access Irrigation of parks and sports grounds; Water for contained wetlands or ornamental ponds	C	▪ pH, BOD, SS, E.coli, monthly ▪ Disinfection system daily ▪ Nitrogen and phosphorous	▪ Environment improvement plan ▪ Restrict public access during irrigation period and for a period of 4 hours after irrigation or until dry ▪ If off-site discharge is likely, reclaimed water of Class A or B quality and nutrient reduction may be required ▪ Application rates controlled to protect groundwater, soils and surface water quality ▪ Appropriate signage in accordance with AS 1319 – Safety Signs ▪ Monitoring and auditing programs
Industrial			
Open Systems Dust suppression on construction or mine/quarry sites Wash down water	Site specific but typically Class A	Site and process specific	▪ Environment improvement plan ▪ Additional treatment may be required to prevent scaling, corrosion, biological growth, fouling or foaming ▪ Class A reclaimed water generally recommended but could be site specific eg. Class B is acceptable for saleyard and stockyard washdown. ▪ Controls to be implemented (eg. Protective clothing and equipment) to prevent exposure of workers to spray drift, aerosols, etc.

Table 4: EPA summary of reclaimed water uses (Municipal Association of Victoria, Institute of Public Works Engineering Australia, Civil Contractors Federation, 2008)

Another regulation for improving standards, particularly internationally is the need to separate the stormwater and wastewater infrastructure systems as seen on the study tour in the USA, Sweden and the UK, particularly where stormwater can be treated locally for reuse. In the past stormwater has been seen as a waste product and has often been discharge to traditional wastewater systems. During high flows, environmental issues such as flooding have been of concern.

2.6 Re-using Stormwater

2.6.1 Storage

Having looked at how stormwater is captured, the stormwater is required to be stored so that it can be used as needed. For small volumes of stormwater, such as roofs, a rainwater tank may be an option, but that does not include a treatment process.

For the uses as indicated above for municipally functions, typically large catchments and therefore volumes of stormwater are required to be harvested. Unless there is access to lakes, rivers etc for storage, constructed storages are required.

One option for storage is the use of a basin or wetland, having both a treatment and reuse function. Also as discussed above, the land availability and negative attributes may not be ideal. A good solution is to have an underground storage system such as the pre-fabricated products shown typically below, which are commercially available.

Figure 18: Storage cubes that are used to for storage to any size required (Ausdrain Stormwater Solutions, 2006)

The idea of module type storage construction is to allow for flexible storage size and rely more on impervious ground material or fabricated liners to hold stormwater within the storage. They simply provide a means to reuse the water through sump pits and pumps, which are dependent on the location and distribution method. There is significant work required in construction of these types of storages and have high capital cost associated with the product.

Possibly for higher volumes of storage and more convenient construction methods, fully integrated pre-fabricated underground storage, much like large cisterns are also available.

Figure 19: Pre-fabricated underground storage vault (Humes Water Solutions, 2007)

Certainly these products and methods are already in use, particular in the USA and UK. The Santa Monica Library, USA runoff from roofs, decks and surface parking areas is collected and piped through 17 downspout filters before entering the 909 kilolitre concrete cistern BMP (Shapiro & Parry, 2008). Downspout filters are capable of removing some pollutants. Stored water is pumped to the library's sub-surface irrigation system.

These underground storages have the ability to be constructed under roads and other hardstand areas, and are ideal for low loading areas such as sporting field and park lands, especially given that these areas would have the higher water demand and therefore have the resource in close proximity to the use.

2.6.2 Re-use Arrangement

The process of capture, storage and reuse can be arranged many ways and is dependent on the location and use.

Capturing stormwater in buildings, roads, parks and other hardstand areas can easily be filtered through to underground storage areas for reuse. The treatment process undertaken by filtration can treat stormwater to a useable standard and distributed for use by pit, pump and pipe arrangements.

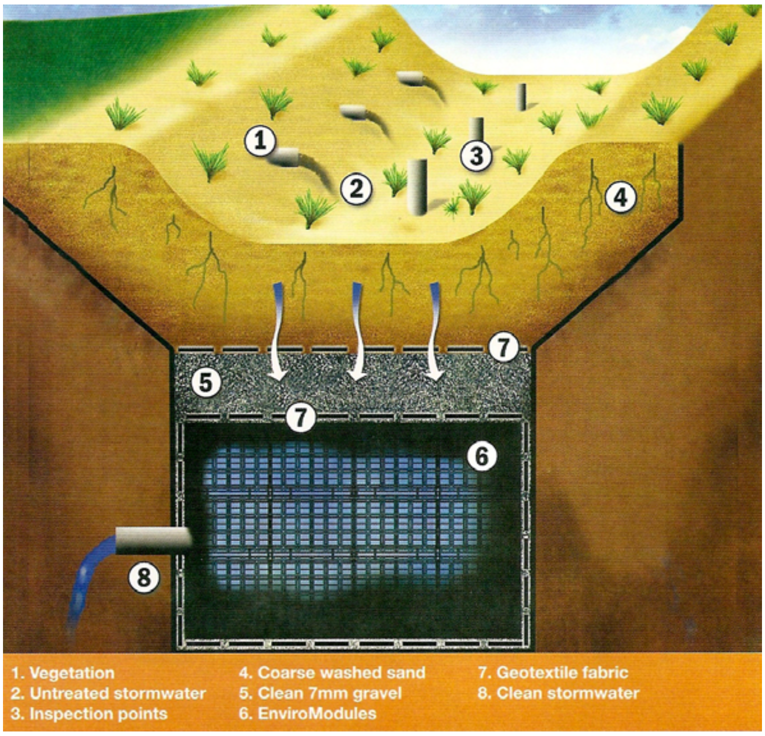


Figure 20: Arrangement for collection in rain gardens (Ausdrain Stormwater Solutions, 2006)

For more local reuse arrangements, such as individual buildings, similar systems can be implemented.

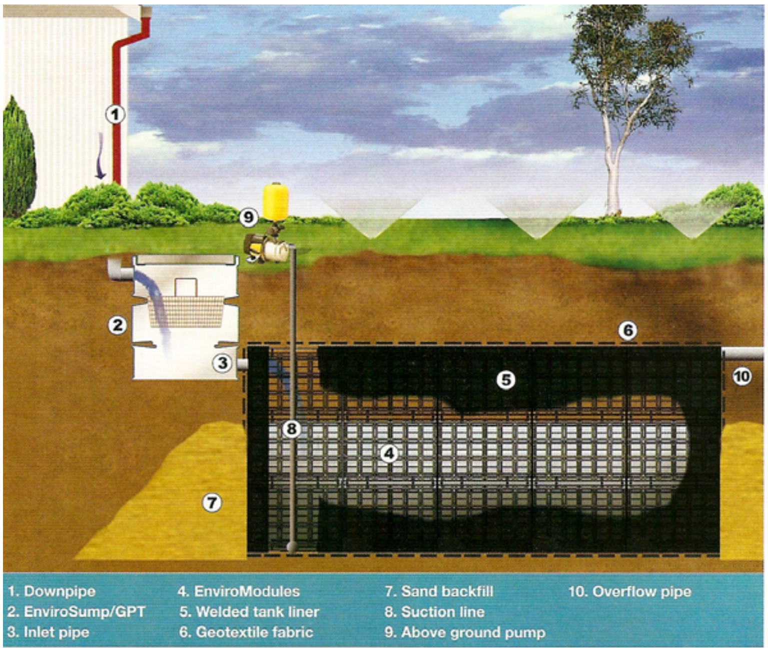


Figure 21: Arrangement for collection at buildings (Ausdrain Stormwater Solutions, 2006)

There is no one arrangement and no one stormwater reuse solution, but as awareness of the available “green” infrastructure increases, and guidelines are being further developed, public works engineers are able to implement such initiatives.

2.7 Maintenance

New initiatives and changing of the way in which we construct stormwater infrastructure has an impact on the maintenance and operating regimes which also are to change. When implementing these stormwater initiatives, it is important to fully understand the future operational demand as to identify the appropriate infrastructure (Staeheli, Norris, McKinley, & Thomson, 2008).

For rain gardens, swales etc. more intensive vegetation can be more time consuming to maintain. Washington, USA implemented a maintenance agreement with the community to participate in maintenance programs to keep costs down and create a sense of ownership for community members. This maintenance can be easily be undertaken by the community, following education and training.

Any material that builds up in the top portion of filtration system are expect to be removed by the plant roots, bugs, worms etc (Kelly & Sipalia, 2008) in the vegetated areas, where the biology cycles can break down the nutrients, silts etc. Depending on the level of pollutants and treatment type, filtration systems can be designed to be re-surfaced approximately every 20-30 years, including sport field surfaces.

Maintaining porous pavements may require addition equipment to keep leaves, rubbish and other obstructing debris from the surface. Maintenance is no more complicated, but requires a change in methods (Staeheli, Norris, McKinley, & Thomson, 2008).

It is important to reflect on the stormwater infrastructure benefit versus not only the capital costs, but long term costs. Cost versus benefit analysis, based on the three (3) aspects, suspended solids, phosphorus and treatable stormwater volume had been undertaken in the USA in choosing a treatment process or BMP. Costs from an analysis in the USA were assumed borrowing at 5% interest over 30 years to cover capital costs (Eastling & Willenbring, 2008), based on current construction and maintenance costs in the USA.

BMP	**Capital Cost ($)**	**Life Cycle Cost ($)**	**Phosphorus Removal Cost ($)**	**TSS Removal Cost ($/kg)**	**Volume Removal Costs ($/cumec)**
Basins	336,000	38,840	1,554	11	196
Rain Gardens	100,000 to 210,000	8,000 to 15,250	2,460 to 8,715	20	113
Reuse Irrigation System	10,000	3,150	533	1	13
Wastewater Treatment Plant	Dependant on system	10,430	220	3	No Benefit
Underground Treatment Devices	1,200,000	83,000	830	6	No Benefit

Table 5: Summary of cost versus benefit for common BMP (Eastling & Willenbring, 2008)

Cost of land for a basin, wetland or pond is approximately worth one subdivision allotment, as needed for construction and would effectively be an un-ratable allotment. They typically have high maintenance costs and low treatment values.

Rain garden capital costs are smaller, treat smaller areas at low flows with higher return than basins, although more areas may be needed to treat large catchment areas.

For the street reconstruction project done in Seattle, USA a Homeowner Maintenance Manual was developed for the abutting property owners as a guide to encourage them to maintain the swale drain aesthetics and provide assistance in maintaining appropriate vegetation. It was determined that the function of the swale drains were to be the responsibility of local government (Mills, 2008).

With underground storages and treatment processes, it is important to keep a regular maintenance routine as to avoid buildup of sediments. Ideally, the low maintenance required for wastewater treatment plants would beneficial, but have to be weighed against the very high capital costs.

2.8 Education

The development of BMP and LID can have immediate benefits once implemented. However, the question is “are contractors and engineers up to speed with the details required for successful use?”

The USA have this concern and acknowledge that new policies, procedures and details have to be conveyed to those involved and also alter fixed attitudes, so that the industry does not feel like it is forced change, but rather become improved and evolutionary.

Santa Monica, USA incorporated public art relating to stormwater management and reuse through exterior design of the SMURRF, and along with public information sessions and flyers have encouraged more stormwater reuse initiatives to be implemented. A similar method of education had been undertaken in Sutton, UK, where a program to change community attitude towards sustainability was implemented. This consisted of door knock surveys and awareness campaigns worth millions of dollars.

The education and awareness is required to be successful before these stormwater initiatives can be implemented and accepted as the modern management strategy.

3. Climate Change and Stormwater

3.1 What is happening?

As mentioned in the introduction, one of many symptoms of Climate Change is that temperatures will increase in the future. Victoria, Australia is expected to have increased two degrees by 2030 and six degrees by 2070 (Victorian Government, 2004). This will no doubt put more pressure on water supply infrastructure and storages.

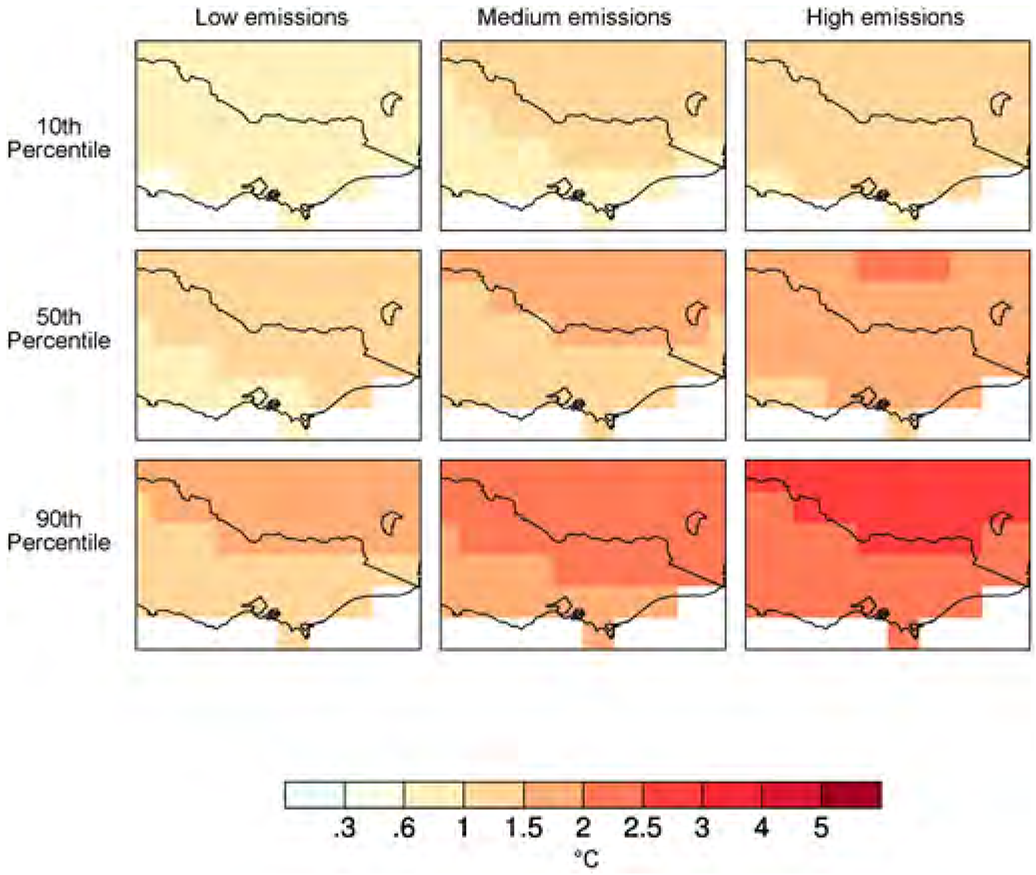


Figure 22: Predictions of Victoria's Temperature Change (CSIRO; Bureau of Meteorology; Australian Greenhouse Office, 2007)

Climate Change is effected by the CO_2 in the atmosphere, with a half life of approximately 50 to 60 years and is expected to stabilise overtime, as will rising temperatures. Any efforts to reduce the onset of Climate Change today will not have actual results for many decades. This brings about some uncertainty as to the long term forecast to deliver and maintain infrastructure (Stack, 2008).

A symptom of this is the heat being trapped by the excessive CO_2 levels in the atmosphere, where the warmer atmosphere can hold more moisture which can result in more intense rainfall events.

Projections for rainfall confirm current observed trends of longer dry spells interrupted by heavier precipitation events. It is expected that there will be increases in frequency of extreme daily rainfall in most wet tropical areas with decreases in frequency, although significant increases in intensity are expected. A map provided for one of the lower emission scenarios confirms the scenario for Victoria for moderate increases in extreme daily rainfall intensity, but does not give sufficient detail to confirm the quantitative estimate of a 70 per cent increase in daily intensity (Australian Academy of Technological Sciences and Engineering, 2008).

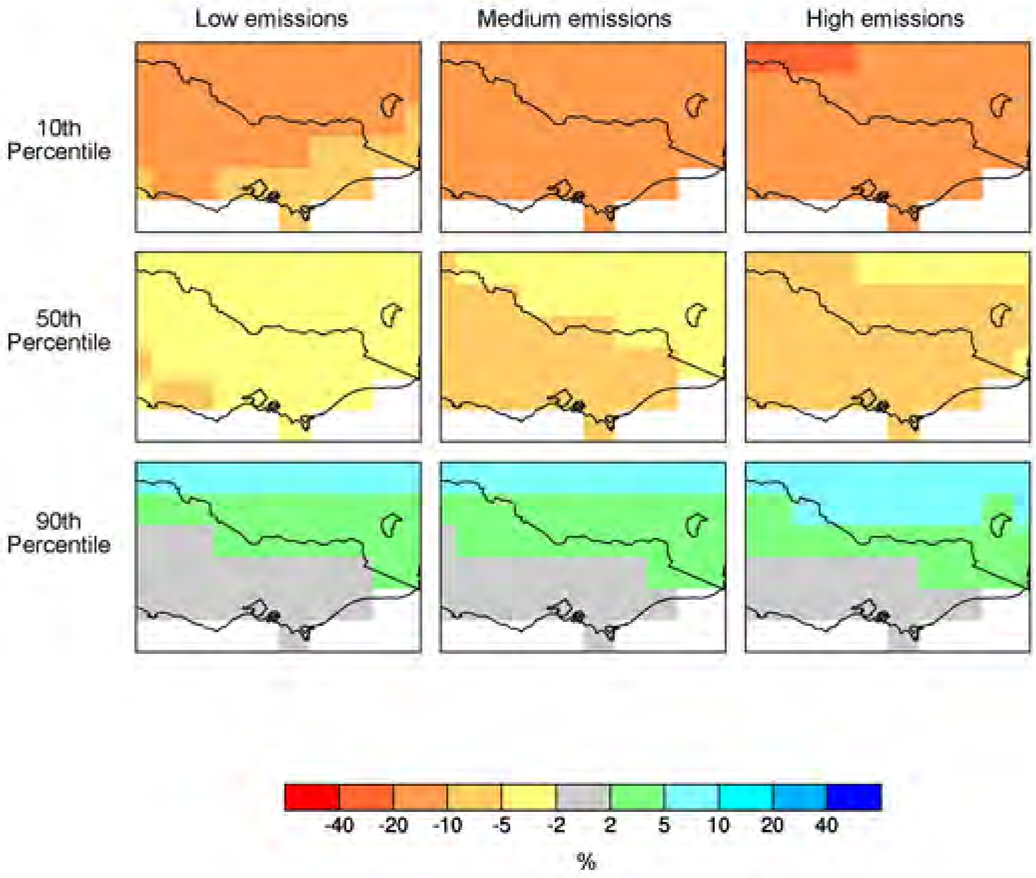


Figure 23: Predictions of Victoria's Rainfall Change (CSIRO; Bureau of Meteorology; Australian Greenhouse Office, 2007)

Many understand the implications of extreme weather patterns predicted by the International Panel of Climate Change (IPCC). The 100 year storm could be the new

10 year storm and the 20 year drought could become a common situation. If the past can no longer be relied upon to predict the future, using a design storm model with 50 year old rainfall data is thrown into question (Funkhouser, 2007).

The next level of action is to improve our long term management of infrastructure and adapt. Climate Change impacts will not be a quick, single event, but a change over a long period of time with more significant effects as more CO_2 builds up in the atmosphere.

3.2 Adapting Infrastructures

The Wimmera Region in Victoria, like many others, is going through a dry drought period. Investigating the implementation of stormwater reuse seems a little contradictive. Where is the water going to coming from to fill storages?

The main concern of introducing stormwater harvesting systems is that the cost of implementation may not be of benefit, if long term forecast for Climate Change predicts less stormwater able to be harvested and therefore create an unreliable water resource.

In lieu of the expected changes to climatic conditions, not harvesting stormwater because of its unreliability may have consequences on its own. As demand on water increases, alternatives regardless of sources will become invaluable.

The Stormwater Design Manual 1967 is the current design guideline for stormwater infrastructure in the USA, but is based on climate data from a relative short term un-industrial period that is expected not to be replicated in the next century. A storm event of 1 in 50 ARI for North West United State is currently modelled to be an intensity increase of up to 50%.

This indicates that current stormwater infrastructure is likely to be undersize in the future, if it is not already affected. Some initial studies in 2001 for the USA have shown that approximately 20% of underground stormwater infrastructure is inadequate.

Therefore it is important to take into account the increased need in capacity of stormwater systems required for the future. As it is not feasible to increase “grey” stormwater infrastructure in most cases and stormwater management will rely on the development and implementation of “green” stormwater infrastructure to alleviate the concern.

There are not only physical components that are likely to be impacted upon. Higher intensity events can cause changes in water turbidity, algae cycles and sedimentation deposits. Any long term changes in stormwater quality will likely be addressed through guidelines and legislation, however, current “green” infrastructure treatments provides a high quality end product, which should be able to be reused for many years.

Stormwater being the unpredictable resource that it is, maybe free, but difficult to estimate cost against for the significant infrastructure required for reuse.

3.3 Preparing for the future

Given the current lack of impact readiness by the USA, they are looking to other leading countries such as the Netherlands, Sweden and other European countries for methods and initiatives. The USA EPA has even been to Australia (Grumbles, 2008) to learn from stormwater management and reuse initiatives with great admiration for what has been already accomplished.

The IPCC has developed several Climate Change scenarios and countries need to look to these when re-assessing stormwater design guidelines or predicting future demands. By being able to anticipate the infrastructure with higher risk to the system’s functions, upgrading can occur with more cost effective results.

Guidelines and technologies will most certainly evolve as Climate Change models are created and knowledge is gained. It is not expected that a solution can be made today, but an effort is still required to make some sort of prediction.

4. Australian Developments

4.1 Government Action

A report by the Australian Greenhouse Office (AGO – now the Department of Climate Change) explores the risks to Australia from impacts of climate change over the next 30 to 50 years. A risk management approach is used to identify sectors and regions that have the highest priority for adaptation planning (Australian Academy of Technological Sciences and Engineering, 2008).

The Victorian Government also has an action plan to secure its water for the next 50 years and focuses more on treatment of wastewater and reducing water demand, but a section of this plan looks at urban stormwater reuse. It is recognised that stormwater is currently managed from the drainage perspective rather than as an alternative water resource and will need to provide funding for stormwater reuse initiative projects in the future (Victorian Government, 2004).

It is encouraged that Stormwater Management Plans and Sustainable Water Use Plans be implemented with Local Government, and would expect to include any reference to alterative water resources such as stormwater (Victorian Government, 2005).

4.2 Research & Guidelines

Australia is reasonably advanced in development of guidelines for the reuse of stormwater with regular educational forums on sustainable urban stormwater design, industry reports such as the Guidelines for the use of Non Potable Water for Local Government and Civil Construction Activities. This is perhaps because of Australia’s need to find solutions to water resource limitations.

Monash University have been doing some extensive research on this type of initiative and have research that strengthens arguments for implementation of “green” stormwater infrastructure, capture, filtration, storage, reuse systems.

There continues to be an increasing amount of research data and development of guidelines as a result in Australia, which perhaps is placing Australia as a leader in this field.

5. Conclusions

5.1 Stormwater Management

Stormwater reuse and implementation is part of a larger sustainability requirement, where many components are required to come together for reducing any impact of Climate Change.

Climate Change will affect the use, design and construction of stormwater infrastructure, as to accommodate less annual rainfall of a more irregular and more intensive nature. Ways to negotiate these challenges are incorporated into “green” infrastructure Best Management Practices for stormwater management.

Predictions of higher intensity storm events lead to the conclusion that existing stormwater systems will become undersized and ineffective to control stormwater movement and possible further decrease stormwater quality. The option to increase stormwater capacity for “grey” infrastructure is not an economical or practical solution in most cases and therefore leads to ideas such as stormwater management through harvesting and “green” infrastructure.

Although “green” infrastructure would ideally be used from the present day onwards (Grumbles, 2008), in some cases the community is not ready for the change. Education for the community and public works engineers is required to be able to successfully implement these initiatives.

Stormwater reuse initiatives generally follow five functions, which includes:

1. Collection;
2. Filtration;
3. Storage;
4. Storage time- transferred to another use (overflow);
5. Reuse;

The use of existing Best Management Practices such as stormwater retention basins are becoming seen as a negative use of land and have little cost effective impact on the management and quality of stormwater and have other environmental issues such as mosquitoes and algae.

Current initiatives in capture, infiltration, storage and reuse provide for a more sustainable solution as well as reduce the need to renew “grey” infrastructure, which has associated risks. Initiatives currently being used internationally such as permeable pavements, rain gardens, and underground retention/reuses systems have been successful and costs effective, not to mention the long term benefits to the environment.

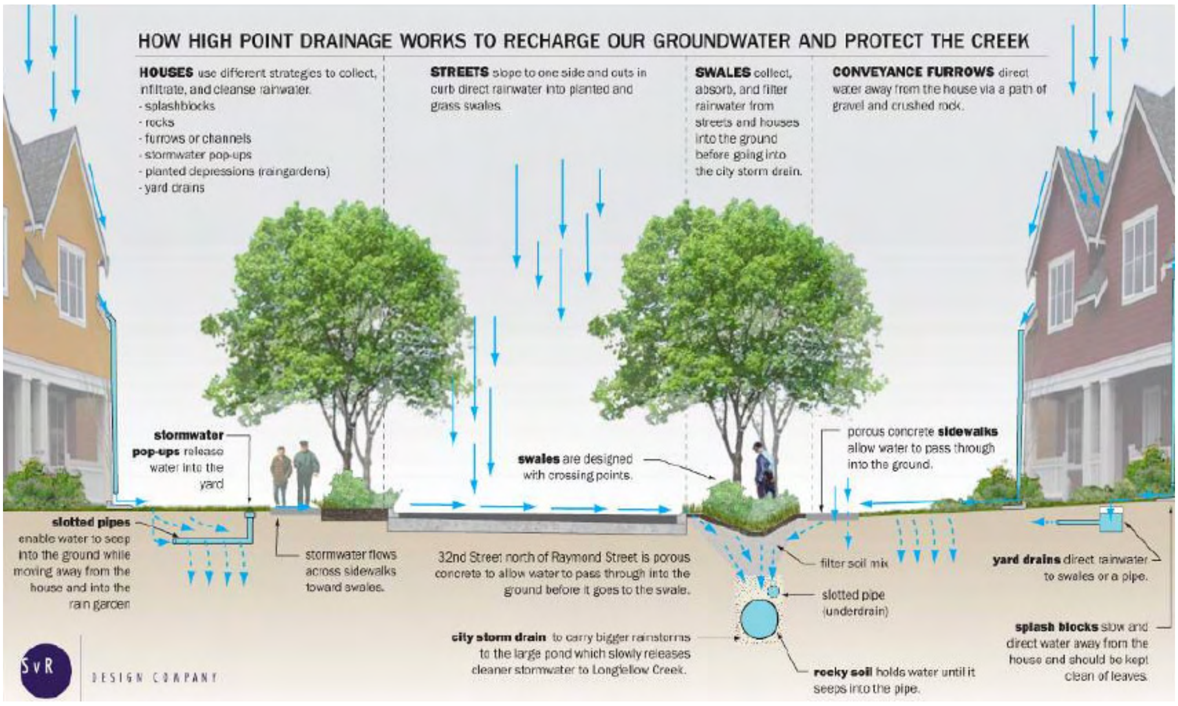


Figure 24: Capturing stormwater through green infrastructure in a roadway

Given the relative infancy of Local Government policy and plan for details and implementation of stormwater reuse initiatives, State and Federal Government guidelines and legislation are important to guide municipalities.

Because alternative sources of water are not easily and reliably available and are prohibitively costly to obtain, it makes economic sense for use of reclaimed stormwater (U.S. Environmental Protection Agency, 2004).

Stormwater runoff is a significant source of water, although perhaps unpredictable and possibly of less quantity in the future due to Climate Change, but is currently in Australia and internationally not used to its full potential.

5.2 Beyond Tomorrow

Technology and knowledge is developing quickly, since this report it is expected that new initiative may have been developed, new guidelines and policies discussed.

“Green” infrastructure is a positive initiative, but this technology needs to be successful. Continued development is required with flexibility in the applications of this technology and support from regulations and regulators can guide us forward.

Looking to reduce impacts from the effects of Climate Change, to meet with evolving legislation and regulations and to deliver quality infrastructure, the “green” infrastructure movement is going to continue to grow (Grumbles, 2008). It is evident that the continuing of existing stormwater guideline development, new programs, technology and initiative and the financial backing of government departments is to remain significant well into the future.

5.3 Australia’s Future

There has been a recent rapid increase in stormwater harvesting in Australia, although the lack of associated guidelines and design recommendations have resulted in a wide variation in design approaches (Mitchell, Hatt, Deletic, Fletcher, McCarthy, & Magyar, 2006).

As a result of needing to implement stormwater reuse programs and initiative due to the long term drought effects across the country, Australia is seen by many as leading the way in implementation and development. Countries such as Sweden are too wet to need this technology, but the USA has been working with the Australian Government and relevant companies hoping to use what has been leaned.

6. Recommendations

6.1 Recommendation 1 – Natural Treatment

In order to make better use of stormwater, provision to implement “green” infrastructure to capture, storage and reuse initiatives should be made by municipalities in their Stormwater Management Plans to replace potable water for uses as appropriate.

6.1.1 Sporting Fields

Given community demand for sporting activities, implementation of stormwater reuse infrastructure is a necessity. All new and redeveloped sporting fields should have installed underground stormwater storage with field surface overlying the storage. This will enable storm events (catchment from sports field and nearby buildings) and irrigation to filtrate and recycle back to underground storages for reuse at a high enough quality, not to pose health risks to users.

6.1.2 Parks & Gardens

Including roadway vegetation areas, smart use of stormwater infrastructure would see all stormwater catchment areas discharged over and infiltrated into vegetation areas, such as swale drains and other rain gardens, as a natural irrigation before entering any stormwater system or stormwater storage.

6.1.3 Buildings

Buildings should have both a potable water main connection and a reclaimed water connection. The reclaimed water will be used for toilet flushing, garden irrigation, and car washing. Dependant on the location and quality of stormwater it is possible to also connect these for laundry functions in a domestic environment.

Buildings in high air pollution areas, particularly metropolitan areas, should allow for extensive roof gardens to treat stormwater before being collected in rainwater tanks for non-potable reuses. This will improve the stormwater quality and lower any health risks, as well as provide an alternative water resource locally.

Building stormwater storage overflow, or discharge where no storage is apparent, should be directed into roadside swale drains for treatment and collection in municipal stormwater systems.

6.1.4 Basins

It is recommended that use of common detention basins be abandoned as there are now more sustainable and viable options for treatment and storage available. Where detention is required as a function of the stormwater systems, underground storage should be installed where both storage for local use and temporary detention can be used.

6.2 Recommendation 2 – Mechanical Treatments

Where natural capture and treatment are not able to be achieved, there are options for mechanical treatment and storage. These would be in place of natural options for reuse.

6.2.1 Stormwater Treatment Plant

In high density areas where natural or not structural stormwater treatment and collection infrastructure is not viable, funding for significant stormwater reuse infrastructure should be considered for stormwater treatment facilities to accommodate high flow, untreated stormwater. This will require high volume storage capacity, but can be distributed back to required uses through piped systems.

6.2.2 Pre-fabricated Products

There are many pre-fabricated products available already that incorporate all of the reuse functions, capture, treatment, storage and distribution. Where none of the above options are viable, this type of solution can be installed for local stormwater treatment and reuse. It should be noted that lower standards of treatment are provided and may restrict the reusability of stormwater.

6.3 Recommendation 3 – Education & Guidelines

6.3.1 Education

Municipalities should look at their existing stormwater management and water management plans and revise to include reference to stormwater reuse initiatives and use as of stormwater as a alternative water source.

Any revised outcomes should be acknowledged through public consultation, if the community is not in favour of the changes, further education on the benefits and concepts for these changes need to be conveyed. Only with public support and willingness to be involved in these changes will the implementation be successful.

6.3.2 Guidelines

Government and industry have developed guidelines and concepts for stormwater reuse and provide a strong support base for municipalities wanting to evolve their own plans, policies strategies etc into “green” infrastructure. Municipalities are encouraged to seek out these supporting documents in review of stormwater management and water management plans.

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