

SIA NSW Award for Excellence in Stormwater Measure / Device

Exfiltration Stormwater Treatment Systems

This nomination is for Exfiltration Stormwater Treatment Systems which:

- Enhance the performance of a stormwater quality treatment train within a catchment; and
- Reduce unsustainable impacts on supporting ecosystems through specific attention to the incorporation and operation of appropriate design boundary criteria and objectives within the catchment.

Note that this nomination is applicable to six (6) specific Exfiltration Stormwater Treatment Systems (STSs) that are operational in NSW, including: Asquith Tennis Centre; Kiama CBD; Elambra Estate, Gerringong, Kinross Industrial Park, Heatherbrae, Grasmere subdivision, West Camden, Ashgrove subdivision, Regents Park.

This measure demonstrates:

- awareness of the impact of the development on the total water cycle including benefits to water conservation, stormwater quality and flood mitigation
Exfiltration STSs are ideal measures in treatment trains that provide total water cycle outcomes. They have been constructed and are operating in two stormwater harvesting projects, i.e. Kiama CBD and Ashgrove residential subdivision in Regents Park Sydney. In both examples, the systems reduce peak flows and stormwater runoff volumes, improve water quality and make water available at a quality suitable for non-potable reuse.
- simplicity in application, cost effectiveness and retrofitting
Exfiltration STSs are designed by employing locally manufactured and supplied materials. They can be designed by any stormwater engineer and they are versatile in respect of their shape and size, whether or not they infiltrate, the extent to which they surcharge, and their ability to have media tailored to treat certain pollutant types, e.g. heavy metals. They cost no more than other comparable treatment systems such as wetlands, and they have higher treatment rates meaning that they have a lower land-take which makes them very cost-effective. Retrofitting of the devices is practical by changing the pre-filtering arrangement, and by replacing the filter matrix with performance enhancing additives such as zeolite.
- benefits to community cohesion, aesthetics and quality of urban living
When adopted and used as part of total water cycle treatment trains, Exfiltration STSs are the perfect inclusion. This has been demonstrated in the Ashgrove subdivision where three Exfiltration STSs were as multi-objective systems with the primary aim of allowing treatment and detention within and under community recreational parkland. When combined with new urbanism design approaches, they tick all the boxes of aesthetics, security/safety, recreational amenity, community control and management of water infrastructure.
- low impacts on greenhouse gases and enhanced local and regional eco-systems.
Like any STM, Exfiltration STS's have embodied energy relating to concrete manufacture and transport in the delivery to site, as well as construction. However, they contain no moving parts and they require only gravity (as opposed to a power source) to operate them. In this respect they have no ongoing greenhouse implications apart from that associated with routine maintenance. In this respect, they can be considered to be greenhouse friendly systems. On their own, they confer distinct ecosystem benefits in relation to water quality improvement and flood detention. However, when combined into a treatment train for stormwater harvesting and reuse, they provide significant benefits in relation to reducing a development's ecological footprint.

Descriptions of Exfiltration STSs and their major performance objectives

Exfiltration stormwater treatment systems (STSs) offer the stormwater industry a versatile and effective method of **combined stormwater treatment, detention and retention**. They are in themselves **self-contained treatment trains** with the following components and functions:

- GPT or pit baskets – for pre-filtering.
- Inlet sump – for maintenance and education.
- HydroCon permeable pipes – promotes sediment retention within the pipe, chemical precipitation as water exfiltrates through the pipe wall and mainly is a maintainable method to deliver water into the filter media.
- Filtering media matrix – promotes filtering, adsorption and microbial digestion and transformation of pollutants.
- Surface surcharge (where required) – for detention.

As the systems **rely on simple materials such as pipes, pits and filter media, they can be designed into any shape or size**. In the Kiama CBD, Grasmere and Ashgrove residential subdivisions in Western Sydney, Exfiltration STSs are designed as **basins with surcharge**. In the Elambra residential estate in Gerringong, the sand filter is a **linear device that lies adjacent to a perimeter road** within the road easement. **This flexibility in shape and size confers excellent versatility**.

At the Ashgrove subdivision, **treated stormwater is harvested in a centralised 800 kL tank and distributed to each residence for toilet flushing and irrigation**. At Kiama the water is used **for surface irrigation**.

With the exception of trees and deep rooting shrubs, **Exfiltration STSs can be landscaped to match with surrounding areas**. In this respect, they can be designed as rain gardens or biofiltration systems.

In the Ashgrove residential subdivision, **the basin filters are combined with public open space such that the community is encouraged to utilise the surcharge area of the basin for passive recreation in scenically landscaped surrounds**.

In this respect **they are true multi-objective systems**. Table 1 shows the location and key features of a range of Exfiltration STSs.

Table 1. System Characteristics by location

System Location	Mills Park Tennis Centre, Asquith*	Hindmarsh Park, Kiama*	Elambra Estate Subdivision	Kinross Business Park, Heatherbrae*	Grasmere Subdivision, SW Camden	Ashgrove Subdivision, Regents Park
Land Use	Car Park	Commercial, Residential and Parkland	Residential	Industrial/ Commercial	Residential	Residential
Catchment Area (m ²)	1,600	65,000	10,000	2,185	70,000	80,000
Filtration Media	Gravel / Sand	Sand	Sand	Gravel / Sand / GAC and Sand	Sand	Gravel / sand
Infiltration or Filtration System	Infiltration	Filtration	Filtration	Infiltration	Infiltration	Filtration
Iron Oxide Injection of Porous Concrete Pipe	Yes	No	No	No	No	No
Water Sampling Arrangement	Inlet: Automatic sampler Outlet: Half-pipe collection system	Inlet: Automatic sampler Outlet: Automatic sampler		Inlet: Automatic sampler Outlet: Half-pipe collection system		
Pre-Filtering	Litter basket and precast sump pits	Litter baskets, screen and sump (surcharge) pits	Litter baskets	Litter baskets and a filter pit	Litter baskets	CDS units
Receiving Location of Treated Stormwater	Discharge to Ku-ring-gai Chase National Park	Stormwater re-use for park irrigation Kiama Harbour	Union Creek	Tomago Sand Beds (drinking water aquifer)	Local creek	Duck River

*subject of research by the ARC Linkage project

Description of the design concepts and innovations

There has been a rapid expansion in the availability of proprietary products that assist with the development of WSUD. These originate from both Australia and overseas. For example, **products have been developed in Germany where discharge water quality criteria are more stringent** in comparison with Australia due to the need to protect drinking water aquifers. These products tend to be used for traditional metal clad roofs and larger transport depots or car parks, where heavy metals, which can be toxic to both macroinvertebrates and humans, are of primary concern.

The new products that are available provide an effective method for pre-filtering runoff to such an extent that land areas required for delivery of “equivalent” water quality have been significantly reduced. Such systems often incorporate enhanced filtration through filter media.

This effectively creates more usable space on a development. The reduction in area required is attributable to the use of pre-filtering products that can be easily maintained and which prevent clogging of the filter media.

The introduction of the **HydroCon porous concrete pipes** in Australia has provided an **opportunity for industry innovators and they are fundamental to the enhanced performance of Exfiltration STSs.**

The components of the exfiltration stormwater treatment system are summarised in Figures 1 and 2. The steps shown in Figure 1 correspond to the boxed numbers in Figure 2.

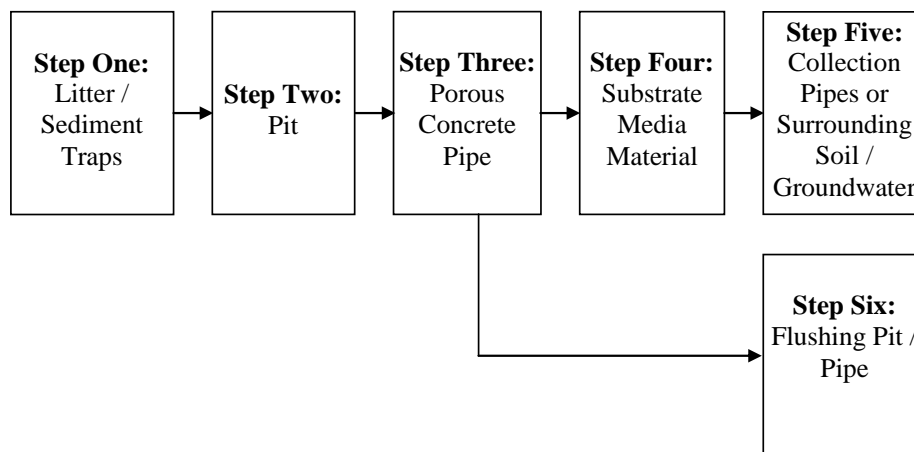


Figure 1. The Exfiltration Stormwater Treatment Process

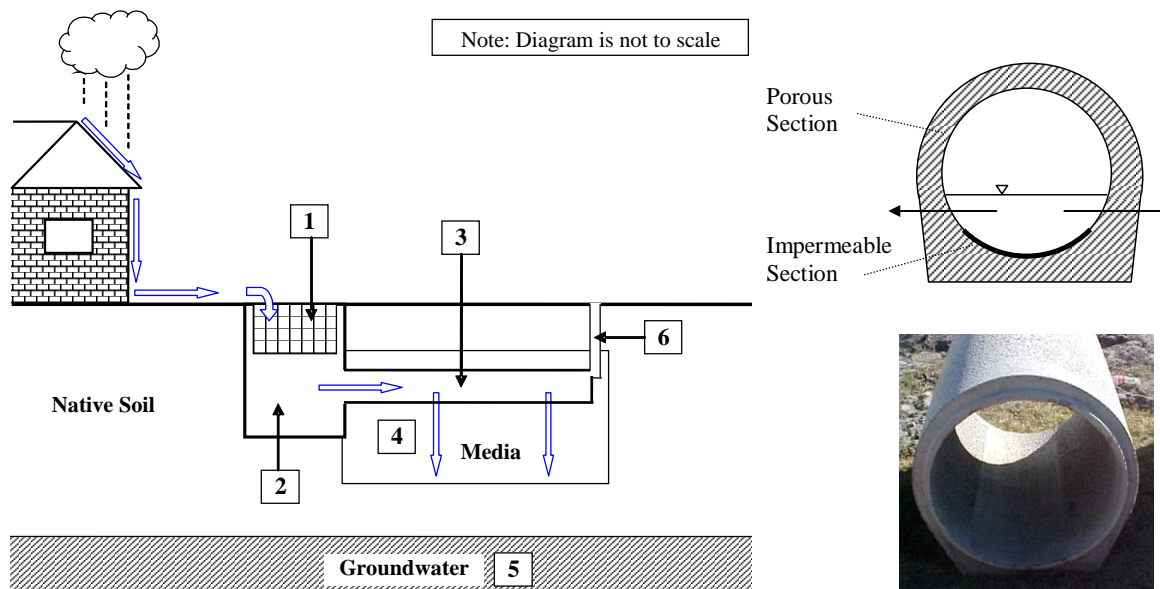


Figure 2. The Exfiltration Stormwater Treatment System and Porous Pipe

A series of **pre-filtering devices** are located at the upstream end of the system (**Step 1**). Examples of these devices include litter baskets and screens.

After passing through these devices, **stormwater enters a pit where sedimentation is promoted (Step 2)**. A regular stormwater pit or a more sophisticated HydroCon filter pit may be used. If a

HydroCon filter pit is used, the conical base of the filter pit induces a vortex action on stormwater which enhances sedimentation.

The **stormwater then enters into the porous concrete pipe (Step 3)**. The pipes are porous, except for along their invert where they are impermeable. The terminal nature of the permeable pipe reduces the water velocity and enables sediment to settle out of the water and build-up on the impermeable pipe invert. The pipes may be injected with iron oxides during their manufacture to enhance pollutant removal, due to the process of chemical precipitation.

The **stormwater then exfiltrates through the walls of the porous concrete pipe** and this exfiltration allows for mechanical filtration processes to take place. The concrete pipe will also have a neutralising effect on the typically acidic stormwater.

The **stormwater then passes through the surrounding substrate media (Step 4)**. Some examples of readily available media may include sand, gravel, perlite, zeolite and granulated activated carbon (GAC). Alternatively, other types of media including those regularly used by the wastewater industry may be appropriate for use. Pollutants may adsorb to or may be filtered by the media material. Biofilms may develop within the media substrate and they may assist with the retention and biodegradation of pollutants, particularly dissolved organic carbon and oils (hydrocarbons). Some media types are able to remove particular pollutant types and these materials should be used when a particular pollutant is recognised as being of significant concern.

If the system is lined with an impermeable membrane it is classified as a filtration system and stormwater can not move directly to the surrounding native soil and groundwater. The stormwater is collected and transported from the system (Step 5). Alternatively, **if the system is not lined with an impermeable membrane it is an infiltration system**. Therefore stormwater can move directly to the surrounding native soil and toward groundwater (Step Five).

The system may be designed with a pit at each end of the length of porous concrete pipe, or it may be designed with a pit at one end and a flushing pipe at the other (as indicated in Figure 2).

The sediments and pollutants that accumulate within the pits and on the pipe invert are removed by **back flushing the system and extracting the material from an upstream pit (Step 6)**.

Key performance data on flows and water qualities relevant to the objectives

The University of Technology Sydney (UTS) through Professor Simon Beecham together with STORM_CONSULTING saw merit in researching the performance of these systems. Professor Beecham secured an **Australian Research Council (ARC) grant** for this purpose. This research was undertaken by Alison Dunphy, a PhD candidate at UTS.

The research involved assessing the performance of three field systems that were located at Asquith, Kiama and Heatherbrae. A rigorous stormwater sampling and testing program was implemented at the three study STSs (Kiama, Asquith and Heatherbrae). Stormwater samples were collected from the inlet and outlet of each system over a three year period.

The results obtained from the collection of stormwater samples from the inlet and outlet of the system at Kiama are presented in Figure 3. For each analyte an average inlet and outlet value is presented. These averages are based on 11 sample collections. To simplify the presentation of the results, these values have been normalised to the highest concentration, which is therefore represented as 1. A reading of 0.4 therefore represents 40% of the highest concentration.

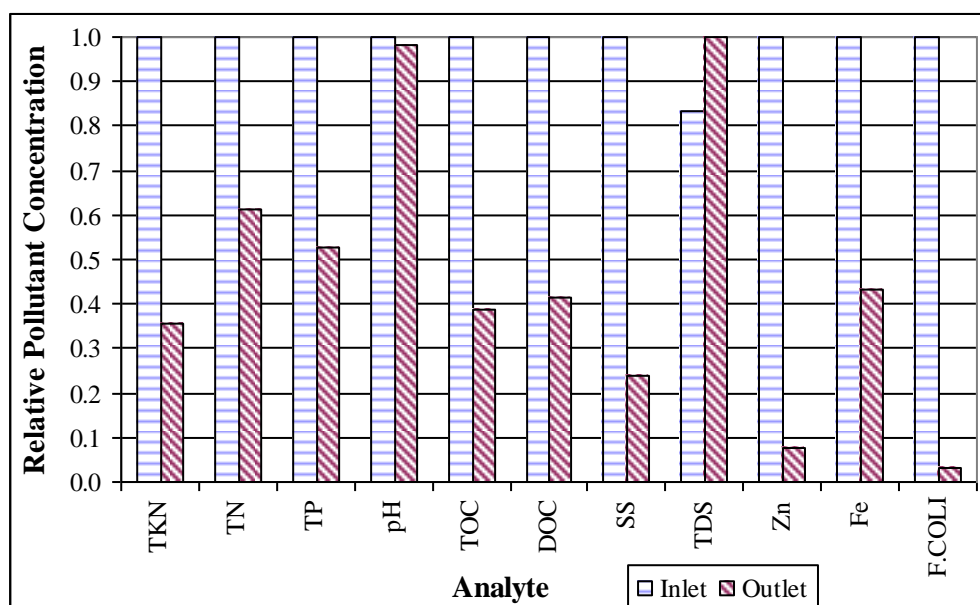


Figure 3. Hindmarsh Park, Kiama – Water Quality Results (Dunphy, 2005b)

Overall a reduction in the pollutant concentration is evident for the majority of analytes.

The average concentration of nutrients, represented by total nitrogen (TN) and total phosphorus (TP), reduces by approximately 45%. Organic carbon (TOC (total) and DOC (dissolved)) average concentrations are lowered by approximately 60%. The average concentration of suspended solids (SS) is reduced by approximately 75% as the stormwater passes through the system. The average heavy metal concentrations have reduced and there has been a significant reduction (approximately 90%) in the zinc (Zn) concentration. The average faecal coliform levels have reduced by approximately 95%.

Results of the research has shown that Exfiltration STSs with pre-filtering devices provide exceptional water quality treatment. The resultant water is of a quality that is suitable for subsurface irrigation without further treatment, or surface irrigation when combined with disinfection.

The performance of the Kiama CBD system shown in this paper is, however, not a representation of the full treatment train effectiveness in place at Kiama as it only measures performance of the Exfiltration sand filter itself and not the effect of the litter baskets. **If the contribution of the upstream litter baskets was included in the assessment of pollutant reduction the actual performance would be higher.** In particular the retention of suspended solids, attached heavy metals and total phosphorus is likely to be greater than that shown in Figure 3.

Key data or projections on performance related to other aspects of sustainability

The ability of the Exfiltration STSs to be confined and to trap the treated stormwater makes them **highly suitable for stormwater harvesting projects** and at least two new major projects are now under construction or complete.

Compliance with the NSW Department of Environment & Climate Change guidelines for water reuse requires that the treated **stormwater is to have a turbidity of no greater than 2 NTU so that UV disinfection can be effective.** It is highly unlikely that stormwater treated only with a pre-filtering device would achieve this criterion. However, a good pre-filtering system combined with **the use of Exfiltration STSs is a reliable way of achieving compliance with the guideline.**

Exfiltration STSs alone will not provide reuse quality water (despite a log reduction in pathogens). Then again, once disinfected with a UV system, the resultant water should comply with Australian guidelines for the reuse of water for non-potable purposes.

How to optimise system operation and performance

Design considerations

Overall the three study systems (Kiama, Asquith and Weathertex) are performing well. Because the systems have been extensively researched, it is possible to recommend design optimisation that will confer even greater benefits of these systems.

Some of the key findings in relation to **design development and system optimisation** include:

- Associated with a filtration system is a longer stormwater residence time, and therefore there is greater opportunity for pollutant removal because of the increased contact time.
- The concrete (of the porous concrete pipe) neutralises stormwater acidity.
- Iron oxides are recognised for their ability to remove heavy metals from stormwater, due to the process of chemical precipitation. It was found that there was a significantly greater reduction in the average zinc and copper concentrations, and significantly smaller average outlet zinc and copper concentrations, associated with the Asquith system where iron oxides were present in the porous pipe.
- The filtration media should be chosen based on the pollutants of primary concern and therefore on the pollutant removal ability of the media. The residence time of stormwater within the system should also be considered when choosing the media (due to the amount of pore space) as typically the longer the residence time, the greater the level of treatment provided by the system.
- The system effectively removes sediment and colloidal matter from stormwater, due to the process of sedimentation within the pits and porous concrete pipe, and as a result of the process of mechanical filtration as stormwater exfiltrates through the walls of the pipe.

The Exfiltration system does have limits to its application. It is not suited to areas where the groundwater is high and where subsurface storage is therefore limited. It is **recommended that at least 1m separation to the groundwater table** needs to be present for infiltration to be effective and also to enable wetting and drying of the filter media to occur – this in turn permits both anaerobic and aerobic conditions to develop which can assist with nitrogen removal.

Exfiltration STSs do **require a hydraulic gradient to drive the flow** and there is a head loss across the system. Because of this requirement, wetlands may be preferable in very flat landscapes.

Pre-filtration is absolutely critical to the success of Exfiltration STSs. Lessons learnt here include the need for more sophisticated gross pollutant traps. The litter baskets used in this study were generally inadequate. This statement does not imply that litter baskets are not effective. However, where exceptionally good pre-filtering is required to prevent clogging, the performance of more sophisticated devices such as cyclonic or vortex separating units is preferred. The reason being they offer a fail-safe mechanism that prevents flow from reaching the device if the unit is blocked. The performance of litter baskets is very much contingent on being able to capture sediment and debris from every pit in the catchment. Generally litter baskets are better suited to installations where protection of a sensitive downstream stormwater treatment device is not required.

Not all Exfiltration STSs are designed to promote surface storage. However, the ones that do will obviously function with two distinct regimes – one below the surface which is described as exfiltration and one above the surface with vertical flow down through the filter media. Described as bioretention this operates once the exfiltration capacity of the pipe has been exceeded. Even exfiltration systems with surface storage will rarely surcharge because the majority of flow is

delivered into the media *via* underground pipe systems. This causes the surface vegetation to have a greater rooting depth as the vegetation searches for water below the ground.

Construction considerations

It is important during the construction of an Exfiltration STSs that appropriate sediment controls are implemented until the system is completely stable. A better approach yet may be to construct the STSs device sometime after the development construction is substantially complete and with vegetation established and soils stable. Alternatively one may accept that the device will be inundated with high sediment loads during construction and to factor in the need for maintenance sooner than would otherwise be required. These are factors that need to be considered when installing WSUD systems in general.

Maintenance Considerations

To optimise the performance of the system and to prolong its life it is imperative that a series of pre-filtering devices be positioned at the most upstream end of the system and within the drainage catchment. These devices must be regularly maintained.

The sediment and pollutants that build up in the pits and on the invert of the porous concrete pipe are removed from the system by back flushing and extracting the material from an upstream pit (flush and educt). Photographs of the cleaning of the Heatherbrae system, and of the porous concrete pipe before and after cleaning are shown in Figures 4 and 5 respectively. The ARC Linkage study found that system cleaning is required on a yearly basis though cleaning of Kiama has taken place every two years without any apparent loss of performance. Clearly cleaning frequency will depend on the loading rate of the treatment system.



Figure 4. Cleaning of the Heatherbrae System



Figure 5. Porous Concrete Pipe – Before (Left) and After (Right) Cleaning

The majority of gross pollutants captured within the pre-filtering devices of the Kiama and Asquith systems were leaf matter. It is worth noting that at Kiama there were also litter baskets installed in almost every pit upstream and the leaf litter shown Figure 6 (right) has either bypassed the litter baskets or entered the system from a pit that does not have a litter basket. A selection of low leaf yield street trees would help to reduce the maintenance burden on treatment systems. However, such an approach may not be fully consistent with the principles of water sensitive urban design. The screen shown in the right of Figure 6 was placed as a final gross pollutant barrier and it is clearly required. As noted above, one of the key lessons learnt here would be to use a more sophisticated GPT device such as a cyclonic or vortex separating unit upstream of Exfiltration systems.



Figure 6. Leaf Accumulation in Pre-Filtering Devices (Left: Asquith; Right: Kiama)

Other WSUD components such as bioretention systems utilise vegetation as part of the treatment process and are influenced by the permeability of the surface of the system. It is therefore important that the surface landscape and surface permeability are maintained accordingly. For vegetated Exfiltration STSs (such as the Kiama system), similar maintenance regimes may be required. Such systems function both as an exfiltration device and also as a bioretention device.

On detailed examination of the Kiama sand filter after two years of operation, the rooting depth of the grass was found to be close to 1 metre. A feature of the Kiama filter media was that it used river sand from the Shoalhaven River. Despite its alluvial origin it was likely to be relatively nutrient poor (typical of coarse sand) and this encouraged the grass above to root deeply into the media in search of both water and nutrients. Bioretention media is often specified to be a loamy organic material which will easily support plant life. On the other hand, it is suggested that stressing the vegetation by depriving it of water and nutrients (between storm events) will maximise rooting depth. This in turn maximises the penetration of flow pathways down into the media, which in turn helps keep open the infiltration pathways through the filter media.

In summary, with intelligent design and no moving parts, Exfiltration STSs can be easy to maintain. Sumps and the Hydrocon pipes are simply backflushed and educted while pre-filtering devices need to be routinely cleaned.

Capital and operating costs and benefits to occupants, developer and owners

Using the example of the Ashgrove residential subdivision, the Exfiltration STS used comprised three bioretention basins in series to satisfy flood mitigation, recreational open space and water

quality objectives. The resultant water is harvested on a communal basis and reused for all non-potable uses in the development.

Mirvac undertook a detailed analysis of the costs of constructing a communal scale stormwater system such as this which supplied 115 houses with toilet flushing water plus enough water to irrigate 2.55 hectares of open space versus the use of rainwater tanks on each lot.

Table 1 Approximate Costs per dwelling of a Communal harvesting scheme versus rainwater tanks on each lot.

COSTS PER DWELLING	Capital Cost	Ongoing Maintenance	Usage Charges ⁽¹⁾
Stormwater Harvesting Scheme Construction (based on actual construction costs)	\$6,200	\$260 PA	
Typical Household Rainwater Tank ⁽¹⁾ based on actual construction costs from other developments	\$5,500	\$300 PA	
Household Use (Saving) ⁽¹⁾			\$79 PA
Landscape Irrigation (Saving) ⁽²⁾			\$58 PA
Stormwater Harvesting Savings	(\$700)	\$40 PA	\$137 PA
Break Even	Approx. 4yrs		

Notes:

(1) Based on a typical new dwelling with above ground 3,100L tank excluding internal plumbing costs using 172 L/day harvested of 425 L/day total @ \$1.264/kL.

(2) Irrigation volumes have been applied at 77.28 kL per week at \$1.634/kL.

Table 1 shows that while the capital costs of constructing a communal system (based on Exfiltration STSs) is marginally more expensive (a cost differential of \$700 per dwelling), lower operating costs and avoided water bills soon come into to play to deliver a system with a much lower life cycle cost.

To Mirvac, equally there is value in selling a “serviced” development, i.e. the ultimate homeowner will not have the direct responsibility for maintaining his or her own rainwater tank and pump. The communal approach also enables maintenance to be carefully programmed and undertaken with minimum effort.

Harvesting of stormwater is not something that could be readily undertaken by an individual homeowner. However, harvesting of stormwater provides a significant benefit to harvesting of roofwater alone. Roads and paving can make up 30% of the surfaces in a dense urban environment. This just about doubles the effective catchment area that can be harvested with a consequent increase in water yields.

Harvesting of roofwater is certainly less risky than harvesting of stormwater, however, using the Exfiltration STS technology and methods developed by STORM, it was considered possible to filter water to such an extent that it would be fit for its non-potable end use.

Benefits to occupants in terms of health, safety, convenience, costs, land uptake

The adoption of Exfiltration STSs as a combined treatment and detention measure has made development in two severely constrained sites feasible, providing an example of WSUD driving true ESD.

When compared with other WSUD systems, for example wetlands, Exfiltration STSs take **much less land space. This releases more land and can provide a greater yield for the developer.**

There two reasons why the Exfiltration STSs take up less space:

1. They provide advanced pre-filtration of sediment which enables clogging factors to be reduced, which in turn enables the size of the device to be reduced.
2. If contact time and exposure to a pollutant reducing bacteria (such as *Nitrosomonas* for example, which is known to transform Nitrogen) drives good water quality outcomes, then filtration through a fine media will maximise the contact surface area available. Generally the finer the media the greater the contact surface. In contrast, for a constructed wetland the contact surface area is only in the water column and may only occur on the stems of reeds. Yet a delicate balance needs to be achieved between maximising contact time (which reduces the treatable flow rate) and maximising the treatable flow rate (which reduces the contact time). In essence, a good design is one which will maximise the amount of pollutant retention achieved by the filter. This process can be more easily controlled in an Exfiltration STS than within a constructed wetland. The vertical flow process that occurs in an Exfiltration system is one which is analogous to a “plug flow” model (often used as the basis of wetland design) and it is suggested that this aids in achieving better design control and smaller, more effective designs.

Exfiltration STSs are largely (but not entirely) subsurface, however, **the land above can keep its amenity value and be utilised for other purposes, such as provision of parklands. The system can be easily combined and blended with the urban fabric.**

The adoption of a **new urbanist design approach** at the Ashgrove subdivision in Regents Park demonstrates how urban development can successfully manage many contemporary social and environmental issues, including the hydrological impacts of climate change. From a water cycle management perspective, new urbanism can be characterised as a response which:

- **Seeks to create a sense of community and belonging by limiting private space and maximising instead public open space.** This creates fantastic opportunities for Water Sensitive Urban Design (WSUD) because stormwater treatment trains which are a hallmark of WSUD require space. More importantly, it dictates the kind of treatment train that can be put in place. It limits the use of rainwater tanks and OSD on private space and conversely promotes the adoption of communal scale harvesting of stormwater and detention.
- **Creates open communities where passive surveillance is major feature.** This facilitates the implementation of WSUD because streets now look onto and surround parks. The parks can contain all of the water cycle infrastructure necessary to manage the water constraints present. This contrasts markedly with traditional developments which have a “combined detention basin and water quality pond” located on one lot at the bottom of the development most often out of sight and rarely maintained for that reason. At the Ashgrove Estate, however, the parkland and all the water cycle infrastructure contained within it is woven seamlessly into the fabric of the development.
- **Empowers a community** – through a body corporate - to own and maintain the public infrastructure that serves the whole estate’s community. Under such an approach, communities can begin to turn stormwater runoff - which would otherwise be a waste stream that would pollute Duck River - into a valuable resource.

The Ashgrove development demonstrates that there are sound ecological, economic and social reasons to put in place communal or cluster scale water cycle management systems based on Exfiltration STSs.

Project partners

There was a number of industry partners involved with the ARC Linkages Project Research who provided project funding and in-kind contributions. The partners were:

- HydroCon Australasia (porous concrete pipe and pit supplier)
- University of Technology, Sydney (Professor Simon Beecham and PhD candidate Alison Dunphy)
- Hornsby Shire Council
- Kiama Municipal Council
- CABP (Weathertex industrial site and the proponents of the Kinross subdivision)
- STORM_CONSULTING (consultants to Kiama Council and CABP)

Photos of Exfiltration Stormwater Treatment Systems



Figure 7: Ashgrove subdivision Basin A



Figures 8 & 9: Ashgrove's Basin A under construction showing liner, HydroCon pipes in position



Figure 10: Ashgrove's Basin A under construction showing gravel matrix



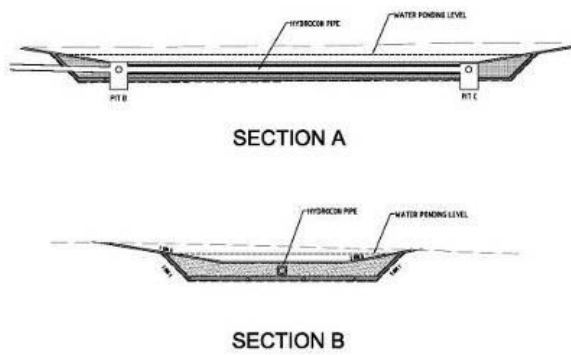
Figure 11: Ashgrove's 800kL treated stormwater storage tank under construction



Figure 12: Ashgrove subdivision under construction showing the stormwater system comprising Exfiltration STSs in series



Figure 13: Elambra Estate under construction in Gerringong. Linear Exfiltration STS at lower end of subdivision



Figures 14-17: Kiama CBD exfiltration system



Figure 18: Grasmere subdivision in West Camden showing two Exfiltration STS protecting the stream



Figures 19 & 20: Thredbo WSUD car park with linear Exfiltration STSs on the perimeter