What makes a sustainable stormwater harvesting project?

D. Knights[1] and A. McAuley[1]

[1] Equatica

The last five years has seen a period of rapid change in stormwater harvesting. The industry has seen a wide range of stormwater harvesting projects designed and implemented. Today, the most common stormwater harvesting schemes are council projects to extract water from the underground stormwater drainage network, to supply water for park and sportsfield irrigation. Typically these are multi-objective projects, with a strong driver being the maintenance or improvement of public open space. Contemporary stormwater harvesting projects are not particularly cost effective from a water conservation perspective, with costs per kilolitre much higher than other water conservation methods, such as water efficiency or large scale industrial recycling schemes. Furthermore the water that is being replaced is really 'virtual water', as water restrictions limit the use of potable water in public open space. While water treatment is often a component of stormwater harvesting projects, water quality outcomes also compare poorly to other stormwater treatment options. In terms of hydrologic impacts these projects also are not necessarily the most cost effective, as they do not typically retain large volumes from catchments. This paper provides a realistic assessment of the benefits of current stormwater harvesting projects, and based on this critical assessment explores the future for stormwater harvesting.

1 Stormwater Harvesting State of Play

Stormwater harvesting schemes have become increasingly popular in parts of Australia and particularly in Sydney over the last decade. In Sydney the overwhelming majority of schemes are operated by councils for irrigation of sporting facilities such as ovals, bowling greens, golf courses and public open space. Analysis of the proceedings of the 2008 Stormwater Conference showed that 11 stormwater harvesting projects were discussed in 6 papers (Crocetti (2008), Butler (2008), Dahlenburg (2008), Jonasson (2008), Wiese (2008), Swil (2008)). Of the eleven schemes that were presented nine of these schemes were for irrigation only, one of the schemes was for irrigation and toilet flushing and one scheme was for reuse in cooling towers. The Department of Environment and Climate Change (DECC) has provided funding for a range of stormwater harvesting and reuse schemes in Sydney (see http://www.environment.nsw.gov.au/grants/harvestingprojects.htm). DECC has funded 36 different projects of which 30 are for harvesting stormwater for irrigation only.

Furthermore the authors of this paper have developed designs for 19 stormwater harvesting and reuse projects, 14 of which have been for irrigation only, three have been for irrigation and internal uses such as toilet flushing and two have been for internal uses including toilet flushing.

The general focus of stormwater harvesting schemes is on harvesting frequent low flows or baseflows. Typically the storage sizes are relatively small in relation to the volume of runoff generated from the catchment. Similar to the operation of household rainwater tanks, these schemes benefit from the generation of frequent runoff from impervious areas. The theory of diverting flows is succinctly summarised for example by Hauber-Davidson (2008). In Hauber-Davidson's case study diversion rates of 0.3 to 0.8 L/s were found to be sufficient to capture flows from 1000 square metres of impervious catchment. This study found that increasing diversion rates above this value had negligible impact on the reliability of supply.

A range of stormwater harvesting schemes have also involved harvesting constant dry weather baseflows such as schemes at Meadowbank Park (McAuley 2008), Green Square (James, McAuley and Wong, 2008), Edenborough Oval (Jonasson, 2008), Bronte Park (Wiese, 2008) and North Sydney (Wilson, 2008). These schemes typically harvest from larger stormwater catchments that have constant dry weather flows due to a combination of groundwater seepage and potable water leaks.

There are a number of key institutional factors driving the popularity of stormwater harvesting schemes for irrigation. Water restrictions are a key driving force in creating demand for alternative water sources for irrigation, particularly at sports fields which have recently been on strict rationing of potable water. These restrictions are now permanent and the NSW Government has developed 'Long Term Water Saving Rules' to restrict the volume of water used for irrigation.

The availability of various government funding sources for stormwater harvesting and reuse schemes is another key institutional driver. The funding sources vary from local council stormwater levies to State government sustainability initiatives and water saving programs and Federal government programs ranging from the previous Federal Government's National Water Initiative scheme to the new Stormwater Harvesting fund. A key element of these funds is that they are typically presented with a sustainability or water conservation focus, as evidenced by the names of each fund and the funding sources (State and Federal Environment departments).

In terms of stormwater harvesting at the household scale there has also been significant uptake of roofwater harvesting using rainwater tanks. The key drivers for rainwater tanks are similar to stormwater harvesting: the availability of funding and water restrictions on outdoor water use. Most of the rainwater tanks that have been installed are for irrigation only. This is related to the drivers for the adoption of rainwater tanks but also to the nature of the funding in NSW, which has only recently been changed to promote the adoption of rainwater tanks for indoor use. Over 5 years from 2002 to 2007 Sydney Water provided rebates to more than 36,000 households to install rainwater tanks (approximately 3.5% of Sydney households). While the important role of rainwater tanks in sustainable stormwater harvesting will be referred to again at the end of this paper, the focus of this paper is on precinct or regional scale stormwater harvesting schemes.

2 Stormwater Harvesting State of Play – Analysis

Stormwater harvesting schemes in Sydney are clearly driven by a focus on Council assets. Stormwater assets and local and regional park assets are predominantly owned by local governments in Sydney. Parks are typically the largest consumers of water for local governments in Sydney. For example in the Auburn local government area (LGA), eight of the top ten consumers of water are parks which require irrigation and in Strathfield LGA, the top six water users are parks (Strathfield Council, 2006). Furthermore the average annual volumes of stormwater that are available in close proximity to these parks typically significantly exceed the average annual irrigation demands. This overlap of both physical and asset ownership has encouraged Councils to develop stormwater harvesting and reuse schemes. One of the key implications of this is that the strong emphasis for stormwater harvesting schemes has been on the provision of water for *Council* assets rather than broader *community* assets. This is important because, similar to the use of rainwater tanks, as illustrated elsewhere (Knights 2008, Coombes 2007), the most cost effective and optimal stormwater harvesting schemes are delivered by placing regular daily demands, such as internal household demands, on the scheme, rather than highly seasonal irrigation or cooling tower demands.

A second reason that stormwater harvesting schemes have become popular in their current form is that they are perceived as achieving multi-purpose objectives. A significant objective of councils is to provide a higher level of service to the community, including sporting groups. In particular, councils often place an emphasis on providing an increased level of service to this community. The perception is that through stormwater harvesting, sporting fields will be open more frequently, provide an increased level of amenity through more even and wider turf cover as well as grounds that are not as hard and have an improved soil structure. The condition of sports fields is also linked to the frequency of severity of injuries during sporting activities. There is also a perception that stormwater harvesting schemes will reduce maintenance burdens, both human resources and costs, caused by a lack of sufficient water. In particular there may be reduced maintenance due to reduced need to re-lay turf, manage weeds, apply fertilisers and water by hand. The range of multi-purpose objectives for stormwater harvesting schemes are discussed in detail in a paper at the 2009 Ozwater Conference (Milne, 2009).

The technical status of stormwater harvesting schemes is currently mixed. There is a distinct lack of *technical* regulation and guidelines for stormwater harvesting schemes:

- There are no standards for stormwater harvesting schemes.
- There are no technical design guidelines available for proponents or designers to assist in the development of schemes.
- There are no specific water quality guidelines.
- There are a distinct lack of standard tools, which has resulted in the use of a range of tools which are only partially suited to the development of stormwater harvesting schemes and require a fair degree of expertise in their correct use. This has led to the development of a range of in-house models by local and state government and the private sector which have little or no external validation or transparency.
- The estimation of irrigation demands is not well understood and irrigation demand estimates vary widely depending on the method adopted. Irrigation estimation methods typically used by irrigation consultants such as crop factor methods are not robust. Other irrigation demand models such as Sydney Water’s Water Right Tool do provide a more robust approach by including a range of microclimate factors but in its current form Sydney Water’s tool is a black box and is not transparent in its estimation of irrigation demand.
- The role of reduced irrigation scheduling to preserve supplies during dry weather is not well understood nor included in the analysis of most irrigation schemes.
- There is no training or training materials in Sydney for stormwater harvesting and reuse schemes.
- There is a major gap in knowledge about the requirements for upstream treatment as well as appropriate post-storage treatment. For example Findlay (2009) suggests that UV disinfection may not be required in some cases.

The lack of technical regulations has resulted in the development of some inappropriate stormwater harvesting schemes. In particular the focus of stormwater harvesting schemes on *irrigation* reuse has led to the development of schemes by *irrigation* consultants. In a number of the worst schemes reviewed by the authors these schemes have been developed without any analysis or understanding of the upstream catchments or the stormwater flow rates and volumes that they would deliver. Furthermore, storage sizes were based *solely* on irrigation demands, ignoring the stormwater catchment altogether.

The water conservation status of stormwater harvesting projects is also mixed at best. In particular one of the key findings that has arisen from water restrictions is that many sports ovals have historically been overwatered and irrigated on inappropriate irrigation regimes (for example at inappropriate frequencies of irrigation, at inappropriate times of the day and/or during inappropriate weather). Furthermore during times of drought in the water supply catchment, restrictions are very cost-effective and reliable forms of reducing water consumption. Thus stormwater reuse schemes implemented in a regime of long term water restrictions are only saving "virtual water". This is because the significant water savings are already occurring through restrictions on potable water use. Stormwater harvesting and reuse *does* provide an alternate supply, but it *does not,* strictly speaking, conserve significant volumes of water under long term water savings rules.

Furthermore in terms of overall water savings there is extremely limited long term potential for stormwater harvesting and reuse for council *irrigation* schemes. The overwhelming majority of water consumption in Sydney is for residential, commercial and industrial uses (91%). Thus even if all ovals were to adopt stormwater harvesting and reuse as an alternate supply the total potential savings are small for Sydney as a whole.

3 Indicators to assess sustainable stormwater harvesting schemes

The most obvious way in which to assess the effectiveness of a stormwater harvesting project is in terms of its effectiveness in meeting water demands. Due to the intermittent nature of stormwater flows, most stormwater harvesting schemes won't meet 100% of water demands, but in temperate climates it may be reasonable to aim for an outcome where stormwater will meet 70-80% of demands.

However where a project has multiple objectives, it is important to assess its performance against the full range of objectives. For example:

- Where real water savings are an objective, mains water demands should be assessed with and without the stormwater harvesting scheme. These days it is most realistic to estimate demands in terms of a water restrictions scenario, instead of considering a hypothetical "ideal" irrigation demand.
- All stormwater harvesting projects which involve open storage ponds should be assessed in terms of the risk of algal blooms. Algal blooms can pose a significant risk to stormwater reuse systems, public health, ecological health of waterways and amenity. Several quantitative methods are available to assess the risk of algal blooms, ranging from simple methods to estimate residence times, to more sophisticated pond modelling tools.
- Where water quality improvement is an objective for the catchment, a stormwater harvesting project can easily be evaluated in terms of best practice targets for load reductions in total suspended solids, total phosphorus and total nitrogen. MUSIC can be used to quantify pollutant load reductions associated with the stormwater harvesting scheme.
- Where environmental flows are important in the waterways downstream of a stormwater harvesting project, these projects can be evaluated in terms of

their impact on flow hydrology. Several quantitative indicators exist, such as effective impervious fraction, stream-forming flows and low flow frequency curves. These are discussed further below.
- Where there are other objectives (such as capital/operational costs, greenhouse gas emissions, public/occupational health and safety, aesthetic outcomes, etc), quantitative or qualitative assessment may be appropriate, depending on the type of objectives.

Environmental flows are a key point of interest, as they are often poorly understood, and assessment methods are not as well established as those for water quality or other objectives. Stormwater harvesting projects have the potential to help restore certain aspects of the hydrological regime downstream of urban catchments, but only if designed appropriately.

Urbanisation generally increases the frequency, duration and quantity of stormwater runoff. A stormwater harvesting scheme can potentially remove a significant proportion of the excess flows, returning the catchment to conditions more closely resembling its natural hydrological regime. Key indicators include:
- Effective impervious: Effective impervious is defined as the impervious area that is directly connected via stormwater pipes or channels to receiving waters. Empirical research has shown that stream health declines sharply with increases in effective impervious. It may be possible to use effective impervious indicators such as those developed by Wong, Knights and Lloyd (2008) to demonstrate the impact of stormwater harvesting schemes.
- Stream-forming flows: these are the flows which cause the most erosion in waterways, sometimes defined as "bank-full" flows, and often equated to the 1.5 year ARI peak flow or 50% of the 2 year ARI peak flow. The duration of flows above the stream-forming flow may be compared for different scenarios, including pre-development and post-development with and without the stormwater harvesting scheme.
- Low flow duration frequency curve: the duration of low flow periods that are likely to be experienced annually. The low flow duration frequency curve is based on the average daily flow over a given number of consecutive days (e.g. 1, 7, 14, 30 or 60 days). For each period of interest (e.g. seasonally or annually), the lowest average flow is identified and these are plotted against exceedance probability. Low flow duration frequency curves can be compared for different scenarios.
- Low flow spells frequency curve: the frequency of low flow spells that are likely to be experienced annually. The low flow spells frequency curve is a measure of the number of consecutive days that flows are below a daily flow threshold. The value of the low flow threshold is normally based on the 50th percentile daily flow rate from the low flow duration frequency curve.

An example of low flow duration and low flow spells frequency curves produced for a stormwater harvesting project are shown in Figure 1 and Figure 2 respectively. These show the following scenarios:
- "Pre Dev" – undeveloped catchment
- "Developed (No Harvesting)" – existing situation, prior to implementation of the stormwater harvesting scheme
- Options 1-4 – four alternative stormwater harvesting scenarios, each involving alternative subcatchments and storage options

Figure 1 and Figure 2 show that the stormwater harvesting options 1-4 progressively bring the low flow duration and low flow spells frequency curves closer to the pre-development conditions.

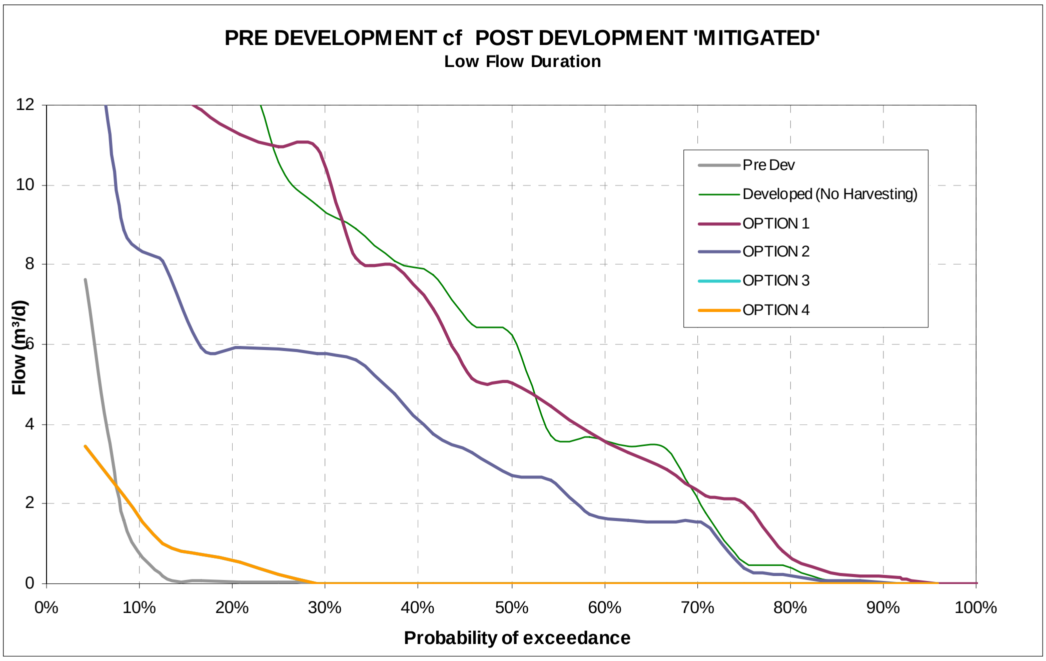

Figure 1 Low flow duration frequency curves for example stormwater harvesting project

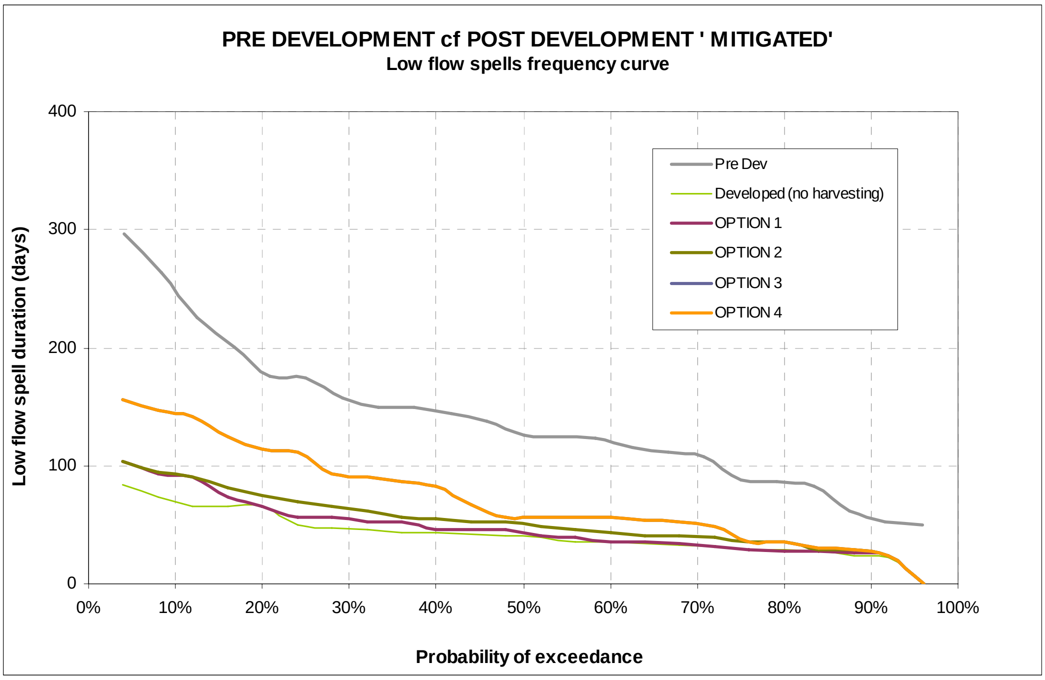

Figure 2 Low flow spells frequency curves for example stormwater harvesting project

4 What would a sustainable stormwater harvesting project look like?

There are some good examples of sustainable stormwater harvesting projects in Australia. Some good examples from New South Wales are Wyong Council's Porters Creek stormwater harvesting strategy, Orange's stormwater harvesting scheme and the City of Sydney's proposed Sydney Park stormwater harvesting scheme.

In Wyong, Porters Creek wetland is NSW's largest freshwater wetland. Within its catchment, urban development is occurring at a rapid rate, and poses a significant risk to the survival of key vegetation communities within the wetland. A key issue for Porters Creek wetland is the impact of urban development on hydrology. Each vegetation community within the wetland has evolved in response to a particular inundation regime, and urbanisation of the catchment is increasing the occurrence of high flows, reducing the occurrence of low flows and reducing the length of low flow spells. Stormwater harvesting has the potential to reduce these impacts, by removing excess flows from urbanised catchments. Wyong Council is developing the infrastructure and institutional arrangements to facilitate large-scale regional stormwater harvesting in the Porters Creek catchment. Hydrological modelling has shown that it will not be sufficient to reuse stormwater within a typical subcatchment, and therefore the Porters Creek stormwater harvesting scheme involves regional pipelines to transfer stormwater out of the urban area and into the Wyong River, either upstream of the Wyong weir (to supplement potable supplies) or downstream of the weir (to supplement environmental flow requirements).

Figure 3 and Figure 4 show the impact of implementing the overall harvesting scheme on a key indicator for the ecosystem protection of Porters Creek wetland, low flow hydrology indicators. Figure 3 shows the low flow duration frequency curve before and after development, showing the significant impact on low flows. For example the 50^{th} percentile 30-day low flow increases from approximately 2 m^3/day before development to approximately 35 m^3/day after development. Figure 4 shows the low flow duration frequency curve after the application of the Porters Creek stormwater harvesting scheme to the developed catchment (this scenario is labelled "WSUD"). The scheme includes stormwater treatment to meet current best practice management objectives through a wetland and storage at the downstream end of the catchment, with a rapid pump-out facility. This scenario is able to return the low flow frequency curve very close to pre-development conditions.

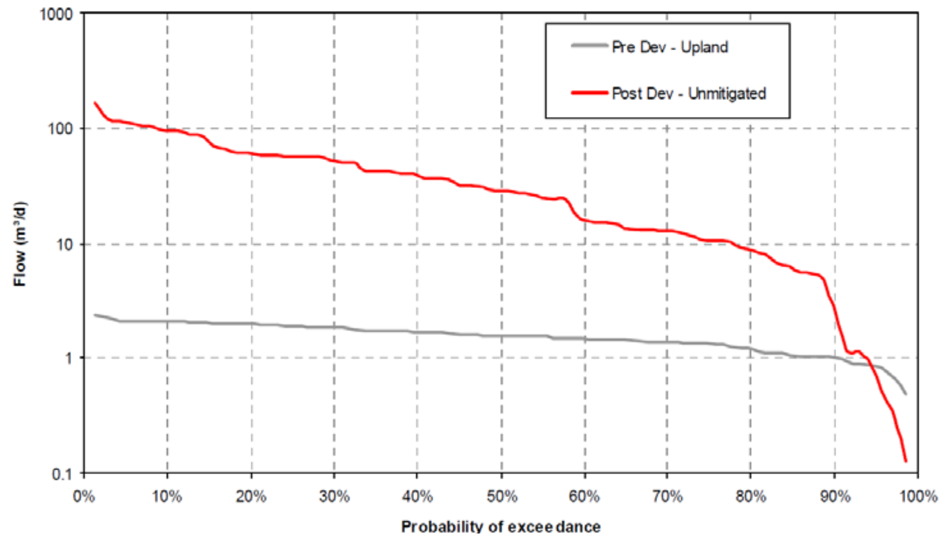

Figure 3: Example low flow duration frequency curve for a typical Wyong catchment before and after development

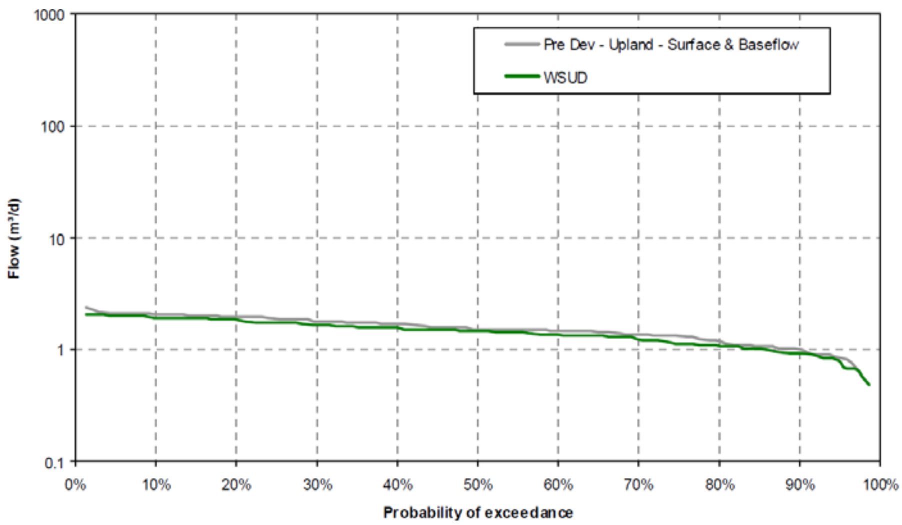

Figure 4: Low flow frequency duration curve for the same typical Wyong catchment with implementation of the Porters Creek stormwater harvesting scheme

A large scale stormwater harvesting and reuse project has been proposed at Sydney Park, a regional scale park, in the inner western suburbs of Sydney. Sydney Park is adjacent to an industrial area with a number of high water using industries including laundry washing, metal recyclers and textile manufacturers. Furthermore Sydney Park has a significant existing asset in the form of four ponds in series with a total of more than 30 ML of storage within the ponds. These ponds are currently only receiving runoff from a small catchment which is more than 90% pervious. The ponds do not receive sufficient inflows from the catchment. A medium to high density 200 hectare catchment drains through the park in a concrete lined open channel. A multi-objective study was undertaken to analyse the potential for reuse, stormwater quality improvement to a degraded urban waterway and to improve the sustainability of the ponds within Sydney Park.

The study found that significant sustainability outcomes could be achieved by:

- Diverting water from the concrete channel into the existing ponds, using a diversion rate of approximately 0.5-1 m^3/s
- Providing upstream treatment prior to storage utilising bioretention systems which will be integrated into the landscape of the ponds and the park
- Undertaking minor modifications to two of the four ponds to provide a suitable storage volume for reuse (nominally 5 ML but significantly more than this due to the nature of buffering and recirculation of water within the storage ponds)
- Constructing a post storage treatment and reuse system connected to a reuse pipeline to supply non-potable water to local industry and for irrigation at Sydney Park

The environmental outcomes are summarised in Table 1. This analysis shows that even with a scheme optimised for a large adjacent industrial demand (roughly equivalent to supplying 50 ovals) the harvesting scheme is able to remove approximately 25 to 30% of pollutant loads and 15% of flows from a 200 hectare catchment. The scheme, adopted in its entirety has significant potential sustainability outcomes. Currently Stage 1 of the project, involving harvesting and treating approximately 15% of the total final diversion, is in the final stages of detailed design and construction will begin this financial year.

Table 1 Predicted Environmental Outcomes for Sydney Park Harvesting and Reuse Project

Parameter	Munni Catchment kg/yr	Estimated Load Removed or Reused kg/yr	% of Munni Catchment Removed or Reused
Flow	1490 ML/yr	267 ML/yr	15
TSS	307,000	98,700	32
TP	624	180	29
TN	4,310	1055	25

To illustrate the inherent difficulty in achieving multiple environmental objectives from a stormwater harvesting scheme, a conceptual example was prepared, based on a typical 10 ha urban catchment in Sydney. The catchment was assumed to be 50% impervious and Observatory Hill rainfall data was assumed to be relevant. Several different stormwater harvesting scenarios were modelled:

- Water demands ranging from 5-25 ML/year, approximately equivalent to irrigated areas of 1-5 ha (assuming an irrigation demand of 5 $kL/m^2/year$).
- Storage sizes ranging from 10-1,000 kL.

A simple analysis of the effectiveness of each scenario in meeting irrigation demands is shown in Figure 5. On the basis of this assessment, one could conclude that the stormwater harvesting project is only suitable for meeting irrigation demands for 1-2 ha of irrigated area, and the most efficient storage size is approximately 200 kL.

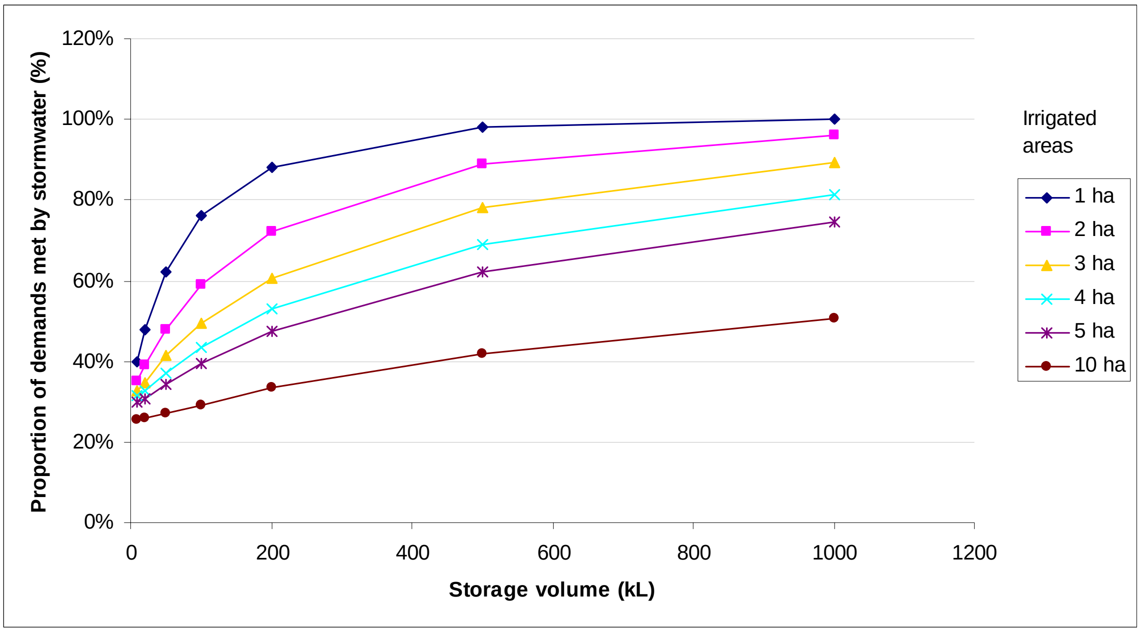

Figure 5: Hypothetical stormwater harvesting scenarios – effectiveness in meeting demands

If other objectives are considered as well, then the preferred stormwater harvesting scheme may take on a substantially different form. To illustrate this point, four different reuse scenarios were considered, all involving the 10 ha catchment and a 200 kL storage, but with the irrigated area ranging from 1-10 ha. These scenarios were analysed in terms of pollutant load reductions, peak flows and total flow volumes. This analysis was performed using MUSIC, using 6-minute rainfall data.

First, a suitable low flow diversion/high flow bypass rate was selected for each scenario. It is common for stormwater harvesting to pick up low flows, up to a certain flow rate, then allow higher flows to bypass the harvesting system. This is particularly important where stormwater needs to be pumped out of a pipe/channel. Suitable low flow diversion rates were selected by modelling a range of options in MUSIC. The results are plotted in Figure 6. The results show that for each scenario, a diversion rate can be selected beyond which there are diminishing benefits of capturing higher flows. Suitable diversion rates were estimated for each scenario based on the point at which the scheme would capture at least 80% of the flows of an equivalent scheme with no high flow bypass:

- 5 L/s where 1 ha is irrigated
- 10 L/s where 2 ha is irrigated
- 15 L/s where 5 ha is irrigated
- 20 L/s where 10 ha is irrigated

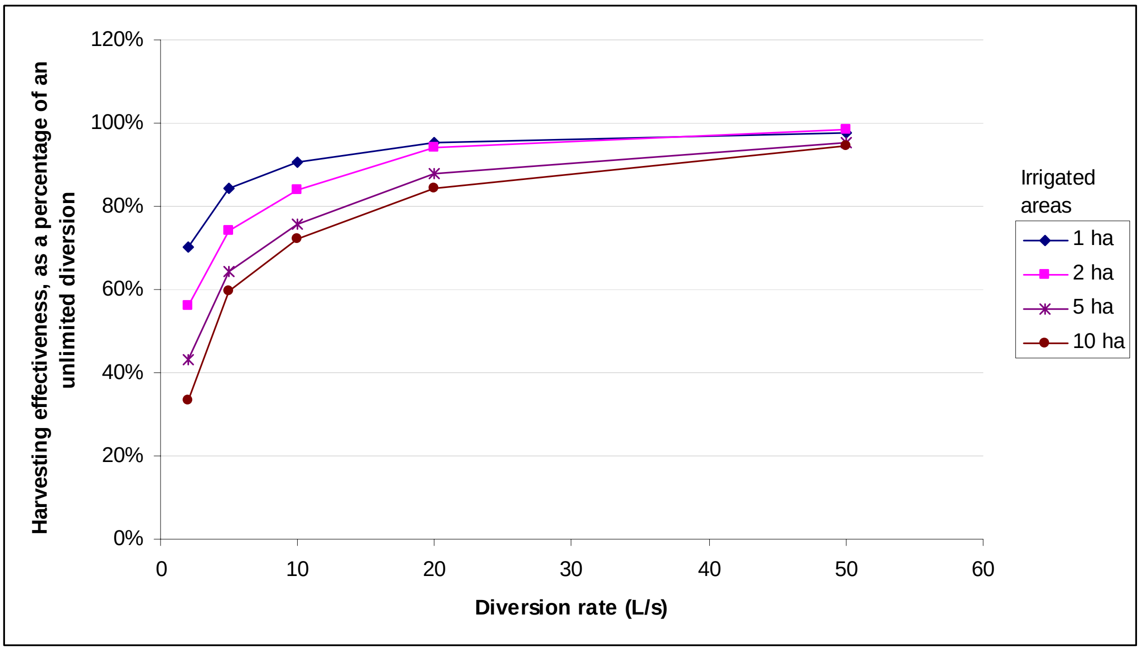

Figure 6: Hypothetical stormwater harvesting scenarios – diversion rates

Each stormwater harvesting scenario was assessed in terms of the pollutant load reductions associated with the harvesting scheme. It was assumed that the stormwater harvesting scheme did not include any treatment prior to the storage (other than basic screening for gross pollutants). This is a common scenario, especially where an enclosed storage tank is used to store stormwater prior to reuse. Therefore pollutant load reductions are those associated with water use.

Results are shown in Table 2. These show that as the demands on the harvesting scheme increase, there are increasing benefits in terms of pollutant load reductions. However none of these schemes comes close to best practice pollutant load reduction targets.

Each stormwater harvesting scenario was also assessed in terms of peak flows and flow mean annual flow volumes, as simple indicators of the effects on hydrology. These results are also shown in Table 2. These results show that there is very little difference between different harvesting scenarios. As the demands on the harvesting scheme increase, there are slight decreases in peak flows (in the 1 year and 6 month ARI events) and a small decrease in the mean annual runoff. However none of these schemes would be sufficient to offset the impacts of urban development.

Table 2: Hypothetical stormwater harvesting scenarios – pollutant load, peak flow and mean annual runoff results

Indicators	Base case (no harvesting)	Stormwater harvesting for an irrigated area			
		1 ha	2 ha	5 ha	10 ha
TSS load reduction	0	6%	8%	12%	16%
TP load reduction	0	5%	8%	11%	15%

Indicators	Base case (no harvesting)	Stormwater harvesting for an irrigated area			
		1 ha	2 ha	5 ha	10 ha
TN load reduction	0	4%	7%	11%	15%
Peak flows (m^3/s): 1 year ARI	1.48	1.47	1.47	1.46	1.46
Peak flows (m^3/s): 6 month ARI	1.26	1.26	1.25	1.25	1.24
Mean annual runoff (ML/year)	59.9	56.3	54.1	51	48

5 Stormwater Harvesting or Rainwater Tanks?

An interesting question arises as to whether rainwater tanks are any more effective than stormwater harvesting at meeting multiple environmental objectives. To illustrate this a case study is presented which compares a strategy which uses stormwater harvesting for oval irrigation with a strategy that utilises rainwater tanks for household use. Lofberg Quarry Creek catchment is a typical northern Sydney residential catchment. The total catchment is 120 hectares comprising approximately 700 single detached dwellings with two sporting ovals located within the catchment. The two ovals are downstream of a 40 hectare catchment and a 20 hectare catchment respectively. Using relatively low diversion rates in the order of 20 L/s with moderate underground storage tanks in the order of 500 kL, a stormwater harvesting scheme can supply approximately 70 to 80% of the irrigation demands at the ovals, saving up to 15 ML/yr of “virtual water” based on *ideal* irrigation demands and about 3 to 4 ML/yr of *actual* water consumption during restrictions.

An analysis was undertaken to understand what the outcome would be if rainwater tanks were adopted in the same catchment. A simple scenario was modelled assuming that all houses had adopted rainwater tanks, harvesting from 75% of the roof area for a range of different external and internal uses. The results of this analysis are shown in Figure 7. Option 1 shows that with 2 kL rainwater tanks plumbed into hot water systems or laundries and irrigation, water savings would be 40 ML/yr. Option 2 involves 5 kL rainwater tanks plumbed into hot water, laundry, toilets and irrigation, saving on average 70 ML/yr. This is two to three times more than the virtual water saved by the oval schemes and 10 to 20 times more than the actual water saved by the oval schemes.

The cost for the oval harvesting schemes is in the order of $1 million. If the equivalent amount of money was spent on rainwater tank harvesting, Option 1 would allow installation of 2 kL rainwater tanks on 400 properties and save 24 ML/yr and Option 2 would allow installation of 5 kL rainwater tanks on 285 properties and save 29 ML/yr. Both these options save significantly more water than the oval harvesting scheme.

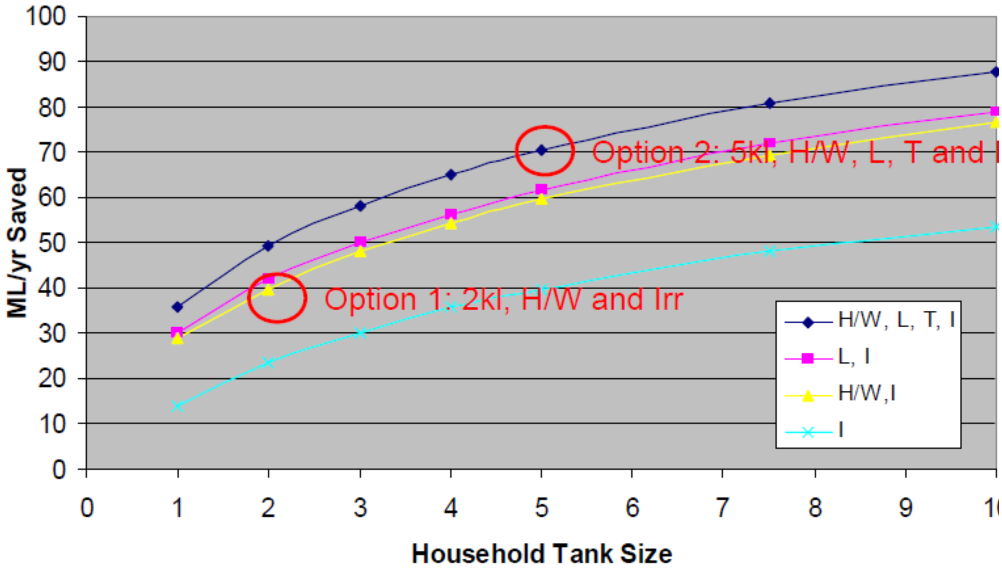

Figure 7: Rainwater tank savings in Lofberg Quarry Creek Catchment

6 Is Stormwater Harvesting Sustainable?

Stormwater harvesting is an industry that is in its infancy. In Sydney stormwater harvesting has focussed on the development of schemes for irrigation of sporting ovals. These schemes typically have low organisational complexity and have been partially driven by the desire to provide an alternate water supply due to the current water restrictions. Typically these schemes are being funded by grants with an emphasis on sustainability and water conservation. However as this paper has shown through a range of case studies and technical analysis these schemes are:

- Saving “virtual water” rather than actual water
- Achieving little additional benefit with regard to a range of sustainability criteria developed in this paper. This is because optimally designed stormwater harvesting schemes focus on harvesting low flows. Furthermore those schemes that harvest baseflows achieve little *if any* additional benefits as defined by the sustainability criteria.
- Limited in the extent that they can achieve significant water savings in Sydney. Irrigation for ovals is only a small fraction of the total demand for water in Sydney.

Hence it is argued that these schemes are not particularly environmentally sustainable (they save little potable water and do not achieve significant environmental outcomes) nor are they particularly environmentally unsustainable (they do not increase potable demands or have significant detrimental environmental outcomes). In fact some of the most significant benefits of stormwater harvesting schemes are the improvement in the level of service that is able to be offered to sporting groups through the increase in the level of service that is provided by well watered turf sporting facilities.

Thus a significant issue that arises is the question of who benefits from stormwater harvesting schemes and who is paying in the community. Currently stormwater harvesting schemes have been seen as a broader environmental initiative. However in reality the largest benefits accrue to the community rather than the environment, and to sports groups in particular. This suggests two key things:

- That there is a potential case for user pays stormwater harvesting schemes and that the industry would benefit from a willingness to pay analysis of sporting associations.
- That schemes in their current format should not be funded by environmental or water conservation levies particularly where they do not achieve significant *actual* water savings and/or environmental benefits

This paper has also suggested two approaches to go beyond stormwater harvesting for park irrigation. These two approaches are a significant challenge to the industry but need to be understood if stormwater harvesting is to have more than limited application and currency as a tool in sustainable urban water management. This paper suggests two key findings:

- Rainwater tanks are likely to be the most valid form of stormwater harvesting in existing developments except where significant stormwater assets (particularly storage) already exist in close proximity to high demands, such as those found at Sydney Park
- In new developments there may be significantly more opportunities for expanded stormwater harvesting schemes to progress beyond harvesting for sporting ovals. These schemes need to understand the catchment and site characteristics (such as at Porters Creek). Furthermore in new developments stormwater harvesting schemes should be assessed in comparison to the sustainability criteria developed in this paper.

This paper also has significant consequences for research programs such as Cities as Water Supply Catchments which focus on stormwater harvesting. These research programs need to clearly articulate how local and regional stormwater harvesting will address residential and commercial water consumption which comprises more than 80% of water demand in Sydney. Furthermore these research programs need to clearly articulate how in a city such as Sydney stormwater harvesting provides greater benefits than rainwater tanks which offer significant advantages in technical simplicity, ownership arrangements, institutional arrangements, staggered infrastructure spending as well as higher water quality capture at source and direct relation between who pays and who benefits.

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