How to Achieve 80 per cent Water Savings in Mainstream Homes

Final report

August 2009

Project Number: 32R-3001

Smart Water Fund

Smart Water Project Research Team

Associate Prof. K. Baskaran (Project Leader)

Dr. Shobha Muthukumaran

Dr. Warren Davies

Ms. Leanne Farago

School of Engineering

Deakin University,

Geelong, Australia.

August 2009

Project Contact Details

Associate Professor Bas Baskaran

School of Engineering

Deakin University

Pigdons Road

Waurn Ponds, VIC 3217

Tel (03) 5227 2827

Fax (03) 5227 2167

Email: bas.baskaran@deakin.edu.au

Table of contents

1 Executive Summary

This report presents the results from a study of water use and conservation in an ecologically sustainably designed home in Geelong, named Sharland Oasis. Important outcomes from the study show:

1. ***Significant savings in overall water usage was made by putting into place water conservation design and measures as demonstrated in Sharland Oasis.***

Overall water consumption in Sharland Oasis was at least 26 per cent less than the resident's previous homes, 23 per cent less indoors when compared to Melbourne homes and on a capita basis 57 per cent less than Victorian households. These savings can be attributed to installing water saving devices and appliances and especially drought tolerant garden design.

2. ***Potable water demand to the residents of Sharland Oasis was significantly reduced by installing rainwater tanks that supplied rainwater to many areas of Sharland Oasis.***

By supplementing rainwater to areas such as the toilet, laundry and kitchen, Sharland Oasis reduced potable water consumption by 44 per cent. When compared to the resident's previous properties, up to 64 per cent reduction in potable water consumption was noted. The use of tank water for outside purposes (i.e. garden watering) also provided water savings, but the significance of these savings was low due to the water efficiency of the garden design and plant selection.

3. ***Water quality assessment in rainwater tanks suggests they are highly suitable as an alternative water supply for many non-drinking purposes.***

Rainwater collected and stored in tanks (made from differing materials) at Sharland Oasis was generally of high quality for non - drinking purposes. Results show little microbial contamination and generally good water chemistry measures. Concrete constructed tanks showed higher levels of pH and salts, whilst polyethylene tanks showed higher microbial presence.

4. ***The use of treated greywater could make significant savings in potable water usage in residential homes or even estates, although acceptance in using treatment systems for greywater appears low at present.***

Sharland Oasis installed a greywater treatment system which produced an average 292 L of greywater a day to a high quality. This greywater was sourced from select areas in the house and represented around 50 per cent of Sharland Oasis's daily overall water consumption. Although this presented a potentially substantial amount of recyclable water, the tenants decided not to use the treatment system and treated greywater was not utilised. A follow up survey in the Sharland Park estate showed the acceptance in using simple greywater diversion systems for garden watering, but treatment of greywater for this use was considered unnecessary.

2 Introduction

Australians are currently facing major challenges to secure a sustainable supply of fresh water. Scarcity of such a vital resource is a combination of many complex issues, including climate change, increased human demand and environmental degradation. Federal, state and local governments have all set forth initiatives to secure rural and urban water supplies. The Australian federal government has developed a national water strategy called "Water for the Future" that aims to secure long term water supply for all Australians. A number of important programs are imbedded into this framework that align closely to State policies and include a "National Water Security Plan for Cities and Towns" and the "National Rainwater and Greywater Initiative". The Victorian governments' long term water plan, "Our Water Our Future" (DSE, 2004) focuses on providing a sustainable water supply over the next 50 years. It specifically sets a water reduction target of 15 per cent for Melbourne by 2010 as well as increasing water recycling measures to 20 per cent for the same period.

In 2006, the Central Region Sustainable Water Strategy (DSE, 2006) instigated a series of plans to secure water for a designated area around Melbourne including the city of Geelong. The strategy set targets to reduce water in the region by at least 25 percent by 2015 and 30 percent by 2020 (relative to 1990's average water use). To meet this target Barwon Water (the water authority for the Geelong region) would have to reduce every residential persons daily water use from 255 to 179 litres by 2020. The Victorian state government urged all urban water authorities to work with the residential sector to meet the target and assess opportunities to recycle water and utilise alternative water supplies. The Central Region Sustainable Water Strategy also highlighted the Victorian state governments' financial commitment to innovative water conservation and recycling projects through Smart Water funding (DSE, 2006).

The Sharland Oasis project is one such Smart Water project aimed at researching potential water savings from an Ecologically Sustainable Designed (ESD) residential home (Sharland Oasis) compared to that of standard designed homes. Water efficiency, reuse and saving technologies were built into the house design and their effectiveness in residential water conservation was closely monitored by the School of Engineering at Deakin University.

The aim of this project was to encourage homebuilders and renovators to take-up water efficiency measures within their own residential setting. To achieve this Deakin University was funded to study water use and conservation on an Ecologically Sustainable Designed (ESD) home in Geelong, called Sharland Oasis. This home had been built with the latest water conservation measures and design practices and could demonstrate to the building / renovating industry the benefits of implementing such measures.

Specific tasks to meet these objectives were:

- Monitoring water usage in specific areas around Sharland Oasis to enable assessment and comparison of overall water consumption and usage relating to specific areas of the home

- Monitoring rainwater, greywater and potable water usage to measure savings in potable water demand to both consumer and supplier

- Assessment of water quality when using tank water in residential homes

- Assessment of acceptance and reliability in using greywater treatment systems and their success in water conservation in residential homes.

This report presents the results and findings from the Sharland Oasis monitoring program and provides valuable new information for home builders and renovators towards greater water efficient homes.

3 Sharland Oasis

Figure 1 Sharland Oasis in Hamlyn Heights, Geelong

Sharland Oasis is Geelong's first Ecologically Sustainable Design (ESD) home, located in the Sharland Park Estate at 7 Lomandra Drive, Hamlyn Heights (Figure 1). The house was built in 2005 by Barwon Water and industry partners and incorporated the latest technology in water and energy saving measures. From April 2005 till August 2006 the house was open to the public to showcase this technology. Upon closure Barwon Water rented the property out to a family that consisted of 6 people (2 adults and 4 children).

The house was designed with the following water conservation measures in mind:

Water efficient plumbing fixtures and appliances

Sharland Oasis was designed with AAA taps and showerheads throughout the house. It also incorporates AAAA dual flush toilets that are flushed using rainwater. Washing machines and dishwashers are also AAAA rated and supplied by rainwater.

Rainwater tanks

An extensive rainwater collection system was designed for Sharland Oasis and includes the installation of four rainwater tanks, two above and two below ground (Figure 2). The two above ground tanks were a polyethylene tank with a capacity of 2100 litres and a steel tank with a capacity of 2710 litres. Both water tanks supply the garden and other intermittent activities, such as car washing.

The two underground rainwater tanks were concrete with a capacity of 4500 litres each and supplied rainwater to internal appliances (washing machine, dishwasher and toilets) and outside garden taps (Figure 2). A pump supplied water from the underground tanks to the internal plumbing. A Rain bank connection automatically switched to mains water supply when necessary.

Greywater treatment system

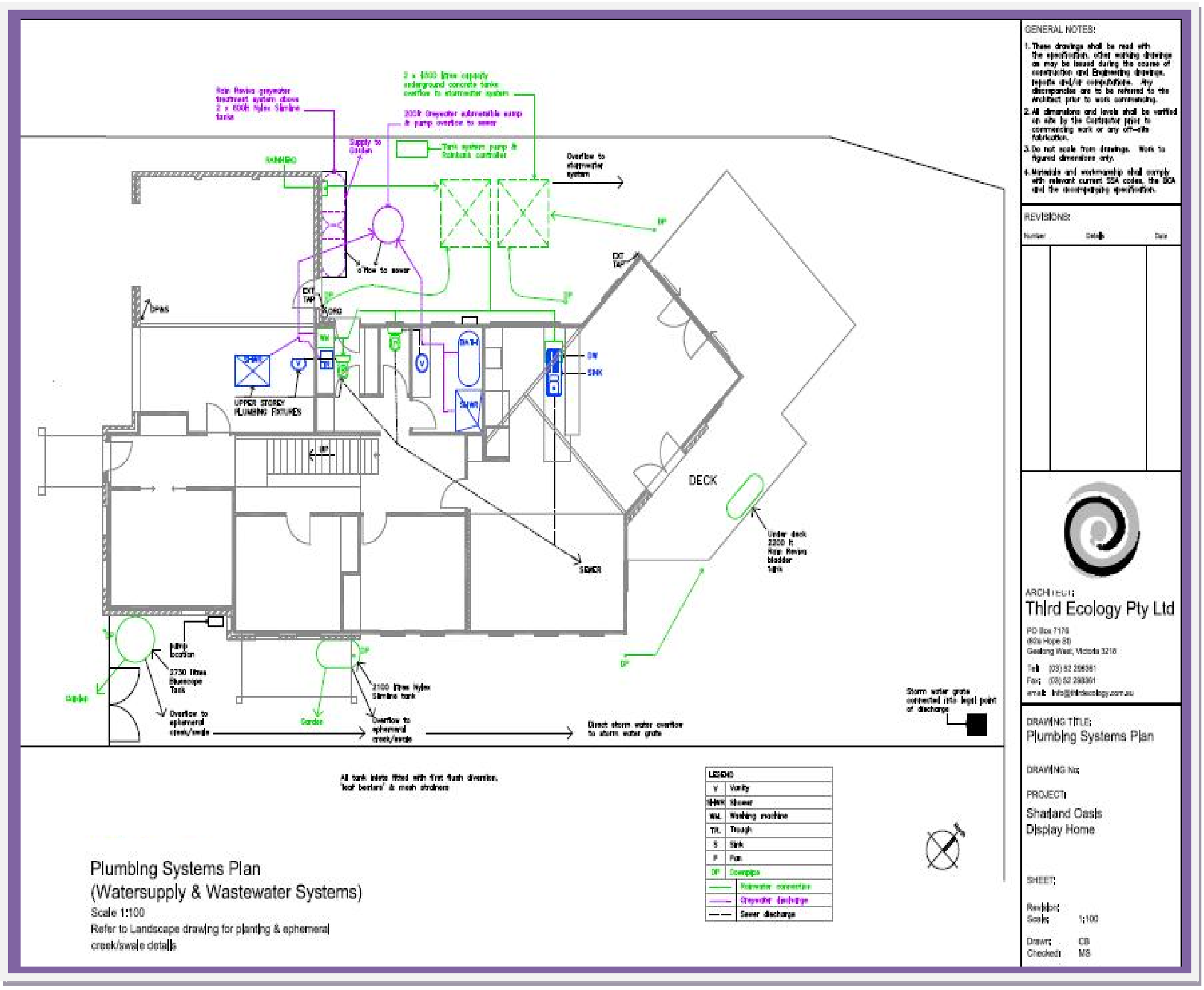
Greywater generated from bathrooms (bath and shower) and laundries (washing machine and basins) was collected and treated using a biological peat filtration unit (Figure 2). The peat technology was developed and trialled from previous Victorian state funding (Pearce, 2005). The system was installed outside the house and commissioned in early May 2007, but due to technical issues was not fully commissioned until November 2007. By January 2008, the unit appeared to be performing well.

The unit was designed to completely self contained. The biological peat filtration unit comprised of a collection cell of 700 litre capacity, hair and lint trap, peat treatment cell (with a treatment capacity of 426 litres per day) and two 600 litres storage tanks(Figure 3).

A three-stage greywater treatment process involved pumping greywater into a collection cell via a 12V pump. The collection cell helped balance any substantial variation in greywater flow and composition throughout a day. Any overflow from the collection cell was connected to sewer. The greywater was then pumped to a hair and lint trap and then directed to the treatment cell.

During the second stage, the greywater was treated in the treatment cell. Three peat cartridges (each with different media) biologically treated and physical removed contaminants from the greywater. The treated effluent was then chemical disinfected with a mild bromine disinfection process.

The final stage saw the treated water stored in two 600 litre tanks and made available for garden irrigation. The tanks had an overflow to the sewer in case they reach full capacity.



Water Supply Sources		
Potable Water	**Rainwater**	**Greywater**
- **Kitchen Sink**	- **Dishwasher**	- **Garden**
- **Showers**	- **Toilets**	
- **Bath**	- **Garden**	
- **Laundry Trough**		
- **Vanities**		

Figure 2: Sharland Oasis plumbing plan showing source water and point of use

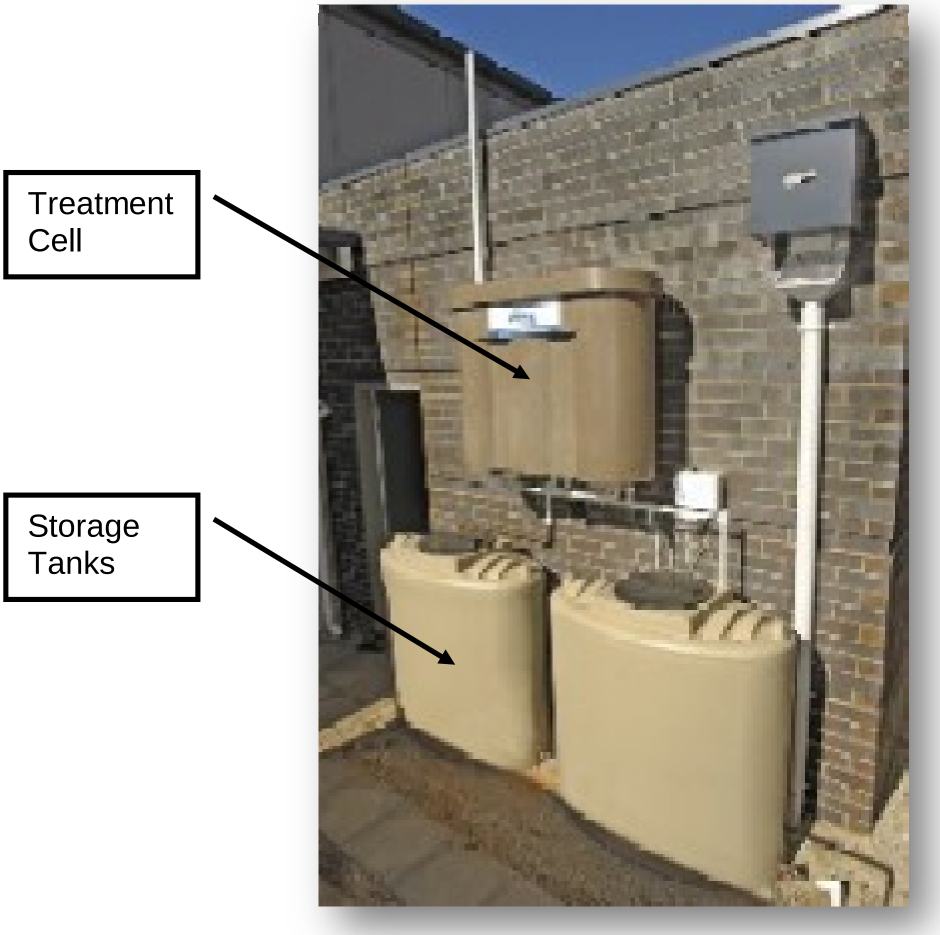


Figure 3: Peat based greywater treatment system

Drought tolerant garden

Sharland Oasis has incorporated a water efficient garden design. Plants were selected on their efficiency to conserve water. These plants were hardy, drought tolerant species that displayed a variety of colour. Placement of plants during garden design was also important with hardy species being placed at the front of the garden, while species requiring greater watering needs were located at the rear to take advantage of the grey water and rainwater irrigation systems.

4 Methodology

4.1 Potable and rainwater measurements

Water meters were installed at 18 indoor and 2 outdoor locations throughout Sharland Oasis to capture household water usage (Table 1). An additional water meter was placed on the above ground rain water tanks late in 2007 to monitor outdoor water usage.

Microbial and water quality indicators were measured in all rainwater tanks. *E.coli* and total coliforms analysis was undertaken by Ecowise Environmental (VIC) Pty Ltd. Analysis of rainwater pH, Electrical Conductivity (EC), Total Dissolved Solids, (TDS), Turbidity, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Nitrogen (TN), Total Phosphorous (TP) and Suspended Solids (SS) were also carried out by Deakin University laboratories.

4.2 Greywater measurements

Greywater usage was measured by connecting a meter to the greywater system. Samples of post-treated greywater were collected and analysed for microbial presence (*E. coli* and total coliforms) and water quality (pH, EC, TDS, BOD, COD, TN and TP). Ecowise Environmental (VIC) Pty Ltd. conducted microbial analyses and Deakin University measured the physical and chemical properties of the greywater.

Table 1: Meter locations at Sharland Oasis

Areas
Kitchen Sink - COLD
Kitchen Sink - HOT
Dishwasher
Downstairs Bathroom Sink - HOT
Downstairs Bathroom Sink - COLD
Downstairs Toilet - COLD
Laundry Sink - HOT
Washing Machine - HOT
Washing Machine - COLD
Upstairs Bathroom Toilet - COLD
Upstairs Bathroom Sink - COLD
Upstairs Bathroom Sink - HOT
Outside Pump - Rain Water Tank FLOW
Outside Pump - Grey water System FLOW
Downstairs Bathroom Shower - COLD
Downstairs Bathroom Shower - HOT
Downstairs Bathroom Bath - COLD
Downstairs Bathroom Bath - HOT
Upstairs Bathroom Shower - COLD
Upstairs Bathroom Shower - HOT

5 Results and Discussion

5.1 Overall water consumption at Sharland Oasis

5.1.1 Results

A total of 208,085 L of water was used from December 2006 to December 2007 by the six occupants at Sharland oasis. This translates to a daily average of 570 L or 95 L per person per day.

During the 12 month study no seasonal trend in overall water usage was observed, although water usage appeared lowest in April and highest in September (Figure 4). The lack of seasonal trend is likely to be reflected by the small percentage of water being used for outdoor purposes (Section 5.3.1) and a relatively steady use of indoor water all year round. Gardens requiring high water demands for maintenance may show seasonal spikes in water usage, especially during summer months.

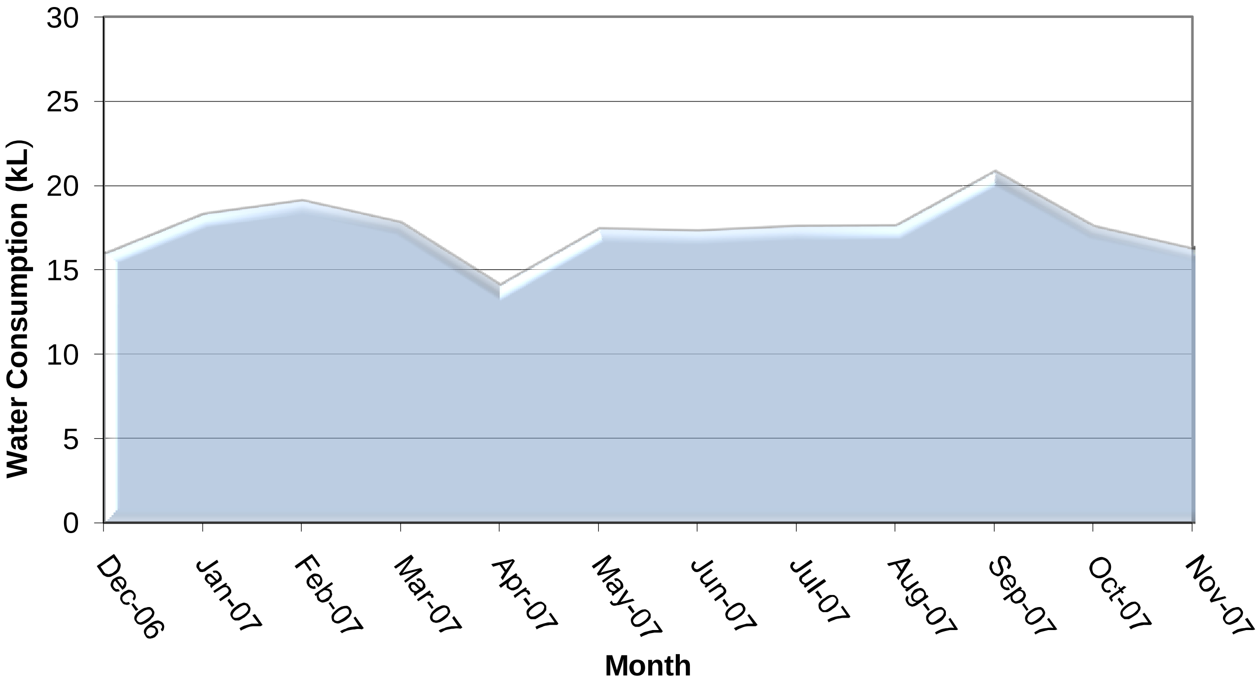


Figure 4: Sharland Oasis monthly water consumption from all sources

5.1.2 Comparisons of overall water consumption with properties in Geelong

The occupants of Sharland Oasis lived in at least three other properties in Geelong. Comparing water consumption at each property indicated whether Sharland Oasis benefited from water conservation measures, assuming the occupant's behaviour and number residing did not change dramatically. Results showed Sharland Oasis had the lowest water consumption of all properties (measured as monthly averages) (Figure 5). On average the previous three homes used 23.3 KL of water per month. Sharland Oasis used only 17.3 KL, resulting in a 26 percent reduction. Interviews with the occupants suggested no concerted behavioural change in water use was made while living at Sharland Oasis and suggested that the decrease in water usage was through a number of water conservation measures.

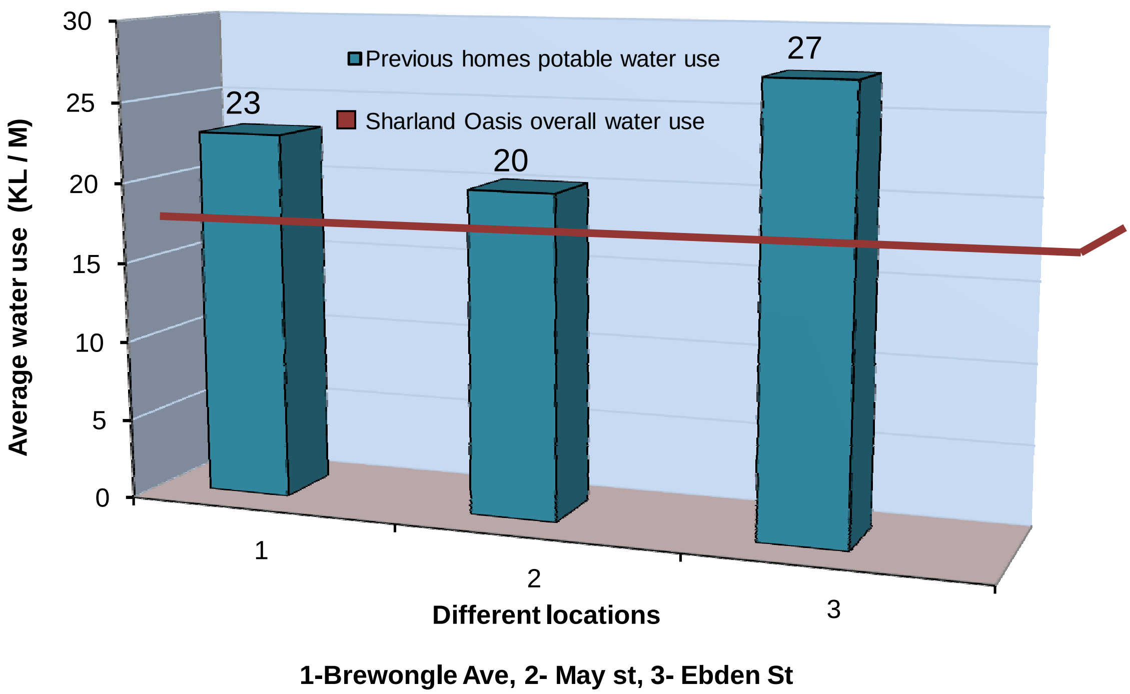


Figure 5: Previously homes potable water use and Sharland Oasis water use

Sharland Oasis is located in Sharland Park estate. This award winning eco-friendly subdivision has 38 housing allotments, and building is still continuing in 2009. The estate has been promoted and designed to embody water conservation, by recycling urban stormwater, the inclusion of swale drains, bio-filtration ponds and infiltration trenches. It might be expected that residents in the estate also have an ethos for water conservation and therefore comparison with Sharland Oasis may show differences in water usage within the local neighbourhood. Average monthly water consumption at Sharland Oasis was compared with 10 nearby homes in Sharland Park (Figure 6). Results show that Sharland Oasis consumed less water than most homes in the estate, although at least 4 homes had similar or lower monthly water consumption. It might be expected that many of these new homes were fitted with similar water saving devices found in Sharland Oasis and that some residents had excellent water conservation practices in place. The comparison does not consider the number of people occupying each home, their gardening practices, or their life style. Further research into the surrounding estate of Sharland Park might be useful to further understand water conservation in new estates.

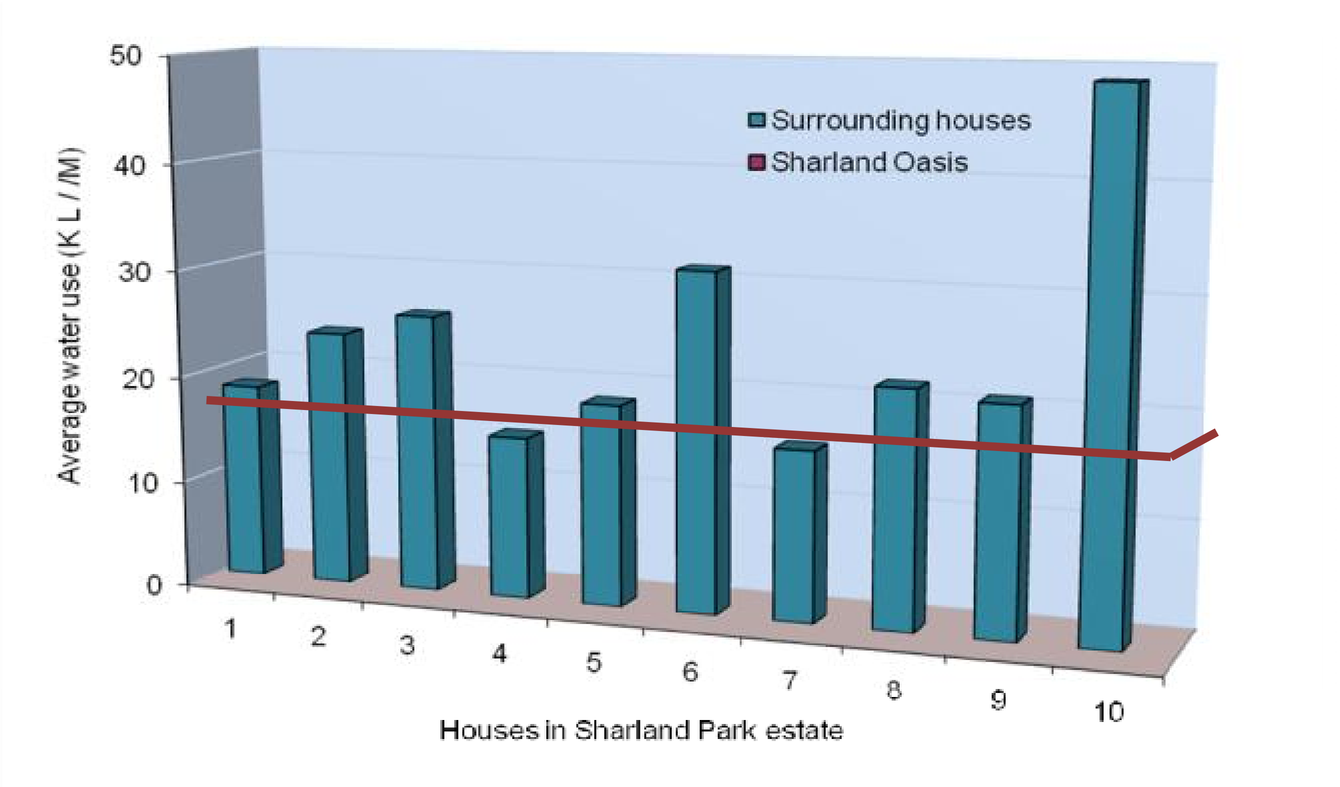


Figure 6: Comparison of overall water usage between Sharland Oasis and metered usage at neighbouring properties in Sharland Park

5.1.3 Comparisons of overall water consumption with properties in Greater Melbourne

The average Melbourne household uses about 270 KL of water a year (Frankston City, cited 2007). Overall water consumption at Sharland Oasis was 23 percent less at 208 KL. Melbourne's average daily water consumption per person from the 30th December 2008 to 25 June 2009 was 158.8 L which is 60 percent higher than the 95 L calculated for Sharland Oasis (http://www.ourwater.vic.gov.au/target155/calculating-consumption).

5.1.4 Comparisons of overall water consumption with properties in the Victorian region

In 2004 – 05, Victorian homes consumed 209 KL of water or 573 L water per day (ABS, 2006). Sharland Oasis uses a comparable amount of 570 L water per day. Although overall consumption is similar, the number of people living in the household needs to be considered, as more people may use more water.

Table 2 shows the Victorian annual water consumption per capita and per household for 2000-01 and 2004-05 (ABS, 2006) which can be used to calculate the average number of Victorian residents per house as 2.58 for both years.

Table 2: Victorian annual water use per household and per capita (adapted from ABS, 2006).

	Water use per household (KL)	Water use per capita (KL)
2000 - 01	251	97
2004 - 05	209	81

With an average of 2.58 Victorians living in each Victorian house it is now useful to compare individual daily water use in Victoria to that of Sharland Oasis:

Sharland Oasis daily water use per person = 95 (L / d / person)

Victorian daily water use per person ⇨ 573 (L / day) / 2.58 = 222 (L / d / person)

On a per person basis, Sharland Oasis uses 57 percent less water than the average Victorian home, although this comparison needs to consider changes in Victorians water behaviour since 2004 – 05 and house size.

5.2 Indoor Water Consumption

5.2.1 Results

The majority of water, totalling 198, 600 L or 544 L per day was used for indoor purposes. A breakdown of areas in the house showed the highest daily water consumption came from the bathroom, laundry, kitchen and toilet (Figure 7).

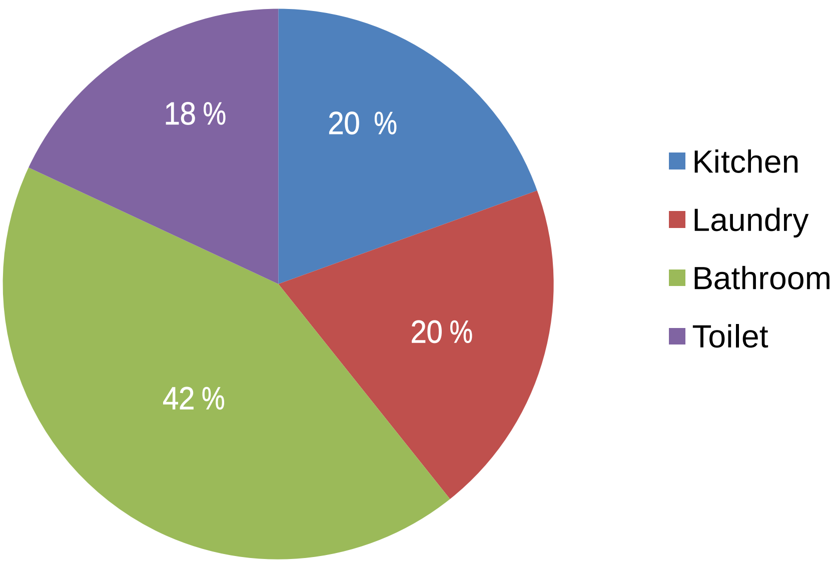


Figure 7 Water consumption in diferent indoor areas of Sharland Oasis.

5.2.2 Overall indoor water consumption compared to Greater Melbourne homes

Melbourne households (with more than 5 occupants) consume 708 L per day indoors (Coombes and Kuczera, 2003). Indoor water consumption at Sharland Oasis was calculated as 544 L per day, indicating 23 percent less water consumed than the average Melbourne household. Water consumption at Sharland Oasis was consistently lower throughout the year compared to Melbourne households (Figure 8).

Sharland Oasis was fitted out with a number of water saving devices and appliances that may explain the reduced water usage. The Victorian state government also recognizes the importance of introducing a range of indoor water saving measures (DSE, 2004) and current results reaffirm government policy. Results can be further broken down to select areas of the home and compared. Overall water usage in the bathroom, laundry and toilet of Sharland Oasis was significantly less than other Melbourne households by 40, 51 and 65 percent respectively (Figure 9) and could be attributed to the water savings devices installed at Sharland Oasis.

Interestingly, Sharland Oasis used more water in the kitchen than other Melbourne homes (Frankston City, cited 2007) (Figure 9). Water saving education programs play an important role in reducing consumption and should be further promoted to maximise other water efficient measures such as AAA taps and the AAAA rated dishwasher. Companies supplying water saving appliances should be encouraged to promote information on the best practices in conserving water when using their products.

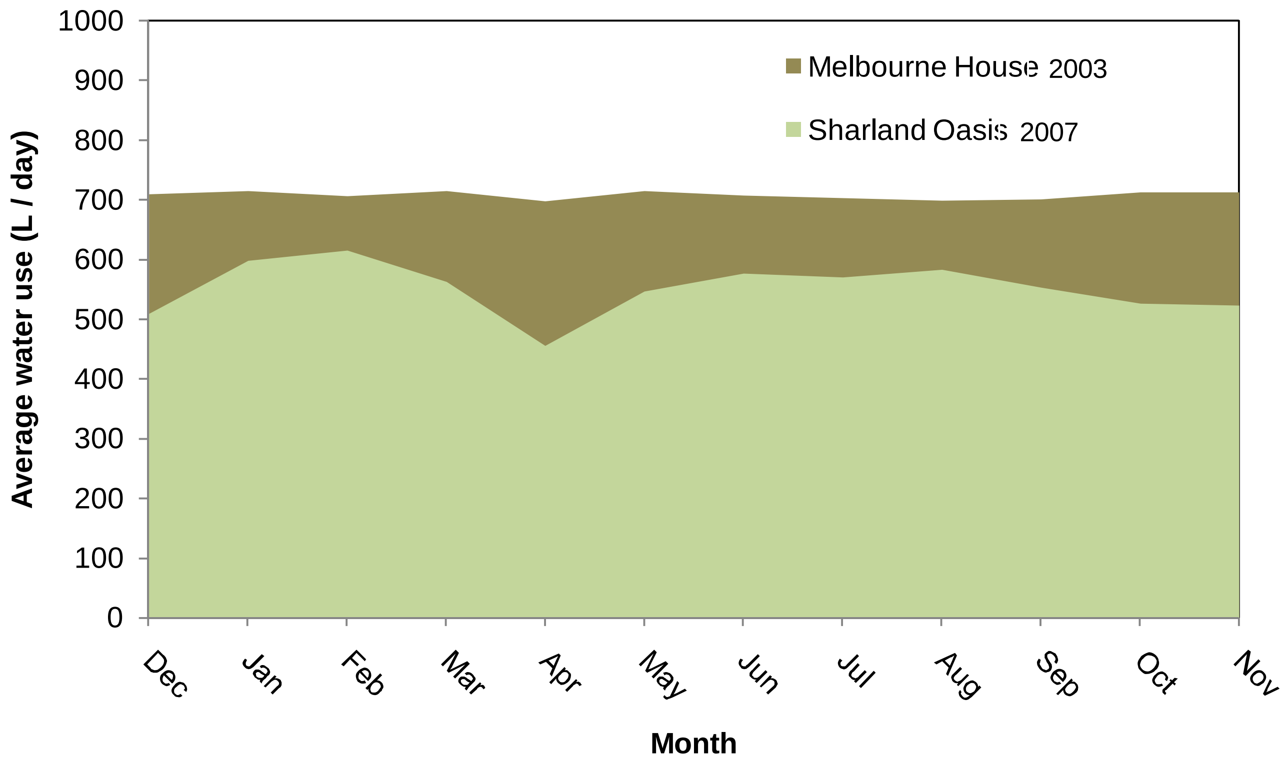


Figure 8: Comparison of average daily indoor water use between Sharland Oasis and Melbourne homes (Coombes and Kuczera, 2003).

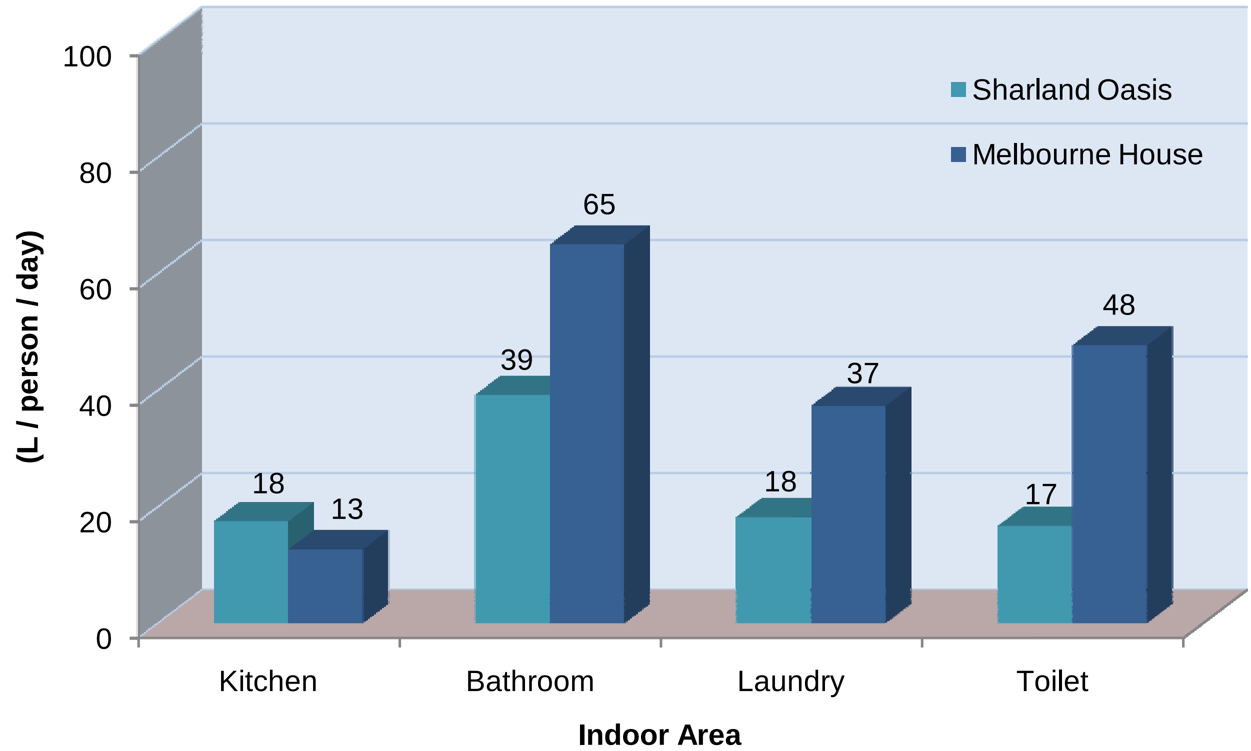


Figure 9: Comparison of average daily water use per person between Sharland Oasis and Melbourne homes (Frankston City, cited 2007) in select areas of the house.

5.3 Outdoor Water Consumption

5.3.1 Results

From December 2006 to December 2007 only 9,485 L of water was used for outdoor purposes. This represents 5 percent of overall water consumed and on average only 26 L per day.

5.3.2 Overall outdoor water consumption compared to Greater Melbourne homes

Melbourne households used 222 L of water per day on outdoor activities (Coombes and Kuczera, 2003). Sharland Oasis showed a 88 percent reduction with only 26 L per day. This low outdoor water consumption was consistent over a 12 month period (Figure 10). The drought tolerant garden and water efficient design probably contributed to the low outdoor water consumption. It is also possible that the rental tenants may have been less inclined to maintain the garden compared to an owner occupier, resulting in less watering. When comparing the data from Melbourne and Sharland Oasis it should be noted that Melbourne's water behaviour has likely changed since 2003. Also not considered was the Melbourne household outdoor area compared to Sharland Oasis and the occupants' attitude towards garden maintenance.

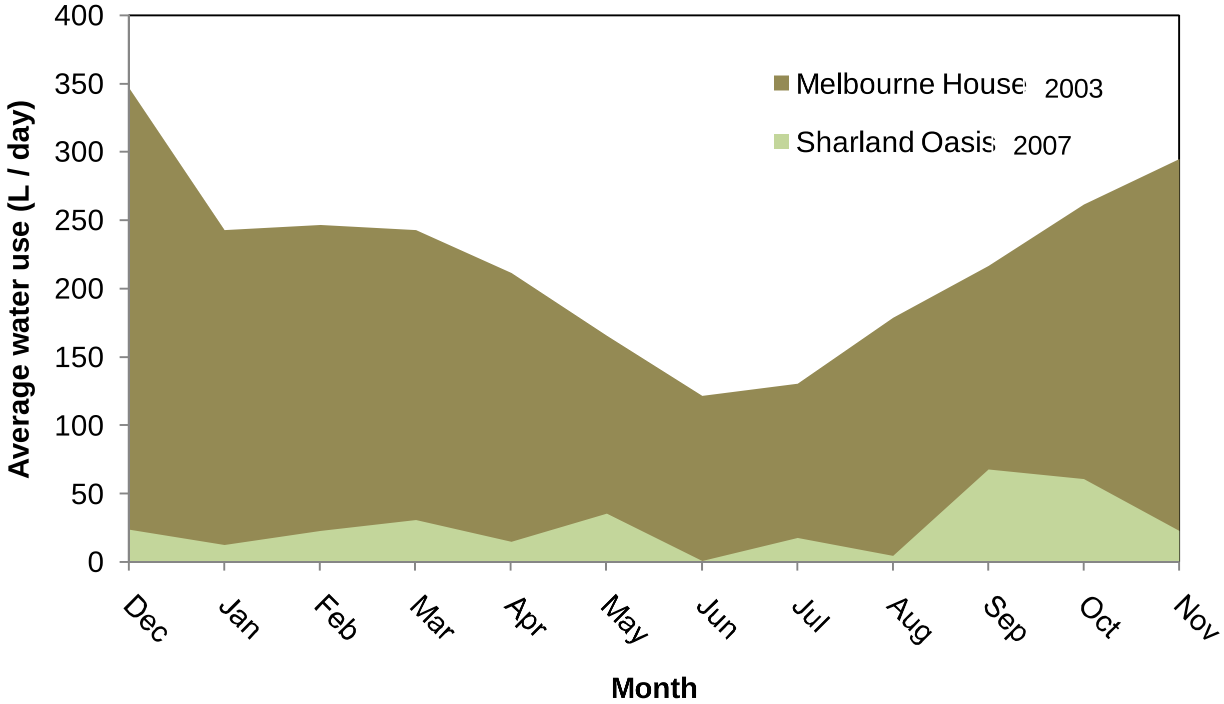


Figure 10: Comparison of average daily outdoor water consumption between Sharland Oasis and Melbourne homes (Coombes and Kuczera, 2003) over a 12 month period

5.4 Water consumption by source

5.4.1 Potable

Potable water consumption at Sharland Oasis for the 12 month period was 56 percent of overall water consumption at 117,295 L. The summer months of January and February showed the highest potable water demand (Figure 11). The daily potable water consumption was 321 L or a remarkable 54 L per person per day.

Barwon Water aspires to reduce daily water usage to 191 L per person by 2015 for Geelong residential customers (Barwon Water, 2007). Potable water results show Sharland Oasis is well within Barwon Waters's future target. Homes adopting these measures should help achieve these future targets.

5.4.2 Rainwater

Rainwater supplied the dishwasher, washing machine, toilets and outdoor garden tap. Consumption for the 12 months was 90,790 L or 44 percent of overall water consumption. The daily average was calculated as 249 L.

Rainwater supply to certain areas provided evidence of reduced potable demand when compared with the tenant's previous properties. Potable water consumption was reduced to 9.8 KL per month at Sharland Oasis, which was up to 64 percent less potable water consumed compared to previous residences (Figure 12).

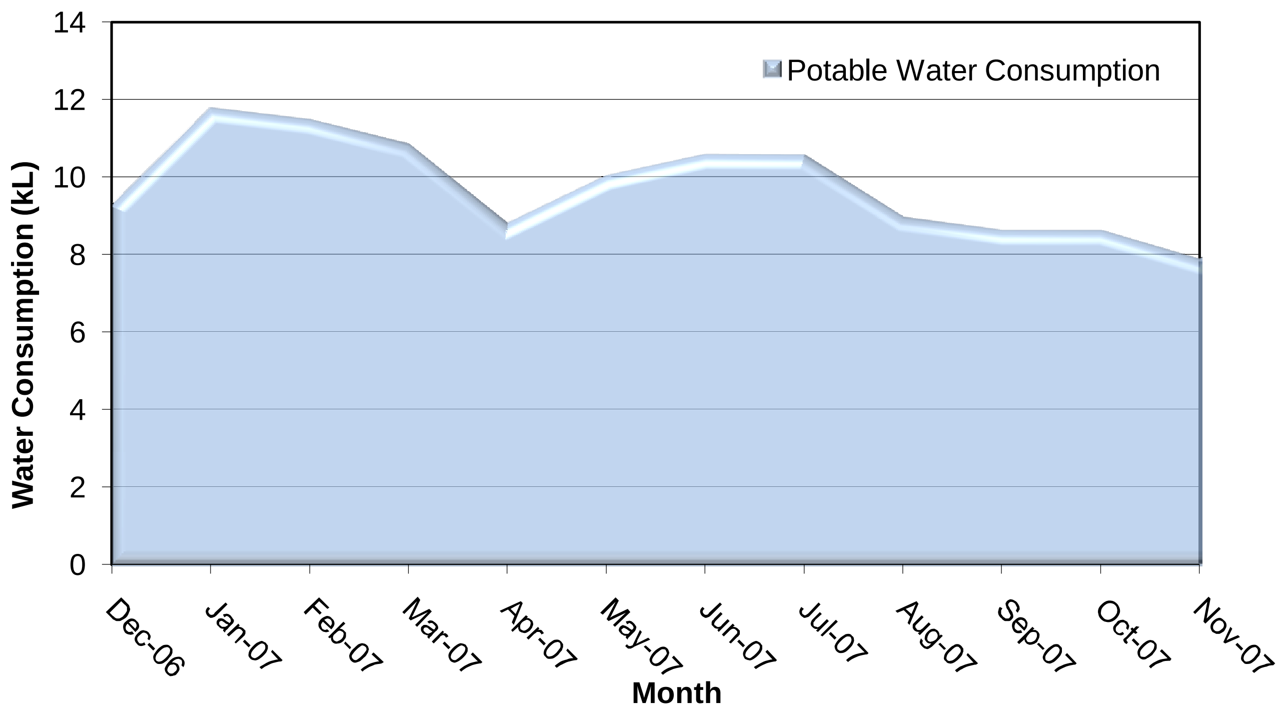


Figure 11: Monthly potable water consumption at Sharland Oasis

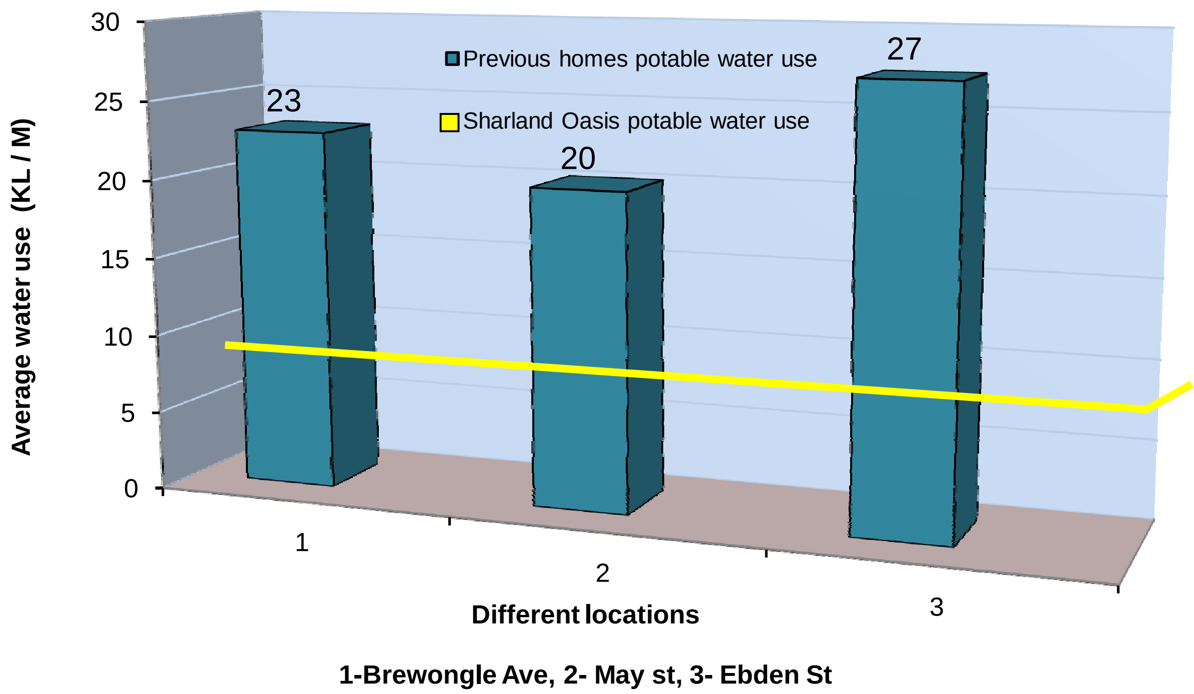


Figure 12: Previous homes potable water consumption compared to Sharland Oasis potable water consumption

Although the use of rainwater amounted to a significant reduction in potable water consumption for Sharland Oasis, areas not supported by rainwater (i.e. the kitchen sinks and bathroom) continued to use large amounts of potable water. These areas should be considered for future rainwater supplementation. In the case of Sharland Oasis, using rainwater in the bathroom could reduce potable water by 232 L per day. Acceptance of rainwater for bathroom purposes depends on public perception of rainwater, water quality, tank capacity, and space and rainfall patterns.

Sharland Oasis could have further reduced potable water use in the kitchen if appliances supplied by rainwater were more frequently used. For example, the dishwasher (supplied be rainwater) was generally regarded as underutilised, while the sink (on mains water) was often used to wash a few dishes. Appropriate conservation measures for using the dishwasher (i.e. using the dishwasher when full) should also help minimise demand rainwater supply.

5.4.3 Greywater

Greywater was collected and treated at Sharland Oasis for the sole purpose of outdoor use. Drains in the bathroom and laundry (including the washing machine) sent greywater to the treatment system. Not all greywater from the bathrooms was treated as vanity wastewater went to drain. On average around 290 L per day was available for greywater treatment (Table 3) and represented 50 percent of total daily water consumption. However, the residents of Sharland Oasis decided not to use the greywater treatment system and as such greywater usage was zero. Once the two 600 litres storage tanks filled, further treated greywater was diverted to sewer.

Table 3: Available greywater for treatment at Sharland Oasis

Greywater source	Available grey water (L)
Laundry	114
Bathroom	178*
Total	292

*(bath and shower only)

Interviews with the residents suggested a number of reasons why the greywater treatment system was not utilised and included:

- The system being complicated to operate and program the irrigation controller
- Ongoing inspections were required

- Watering of the garden could be undertaken using rainwater
- The garden design and drought tolerant plant selection meant watering was only needed minimally and often rainfall events sufficed.

Future consideration of installing and using a greywater treatment systems should take into account the user's needs, their willingness to operate and maintain the system and the use of other alternative water supplies. Rainwater use seemed an easier alternative for the residents. Owner – occupiers who have gone to some expense to purchase a greywater treatment system would probably have greater incentive to learn, operate and maintain such a system than the rental tenants at Sharland Oasis.

Treated greywater benefits cannot be assessed because of the lack of use. Potentially, 50 percent of daily water could have been reused and could have amounted to significant savings in potable or rainwater stores. The benefits of using greywater to replace potable water are already well recognised (EPA, 2008) and should be continued to be encouraged.

5.5 Assessment of water quality in various types of rainwater tanks

Rainwater quality was measured in concrete, steel and polyethylene tanks. Rainwater systems can become contaminated from a variety of sources leading to changes in water quality to levels beyond acceptable health guidelines. Water quality can be measured as numbers of microorganisms and change in the physical and chemical condition of the water.

Rainwater samples were collected between May 2007 and April 2008. Measures of water pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Turbidity, Dissolved Oxygen (DO), Total Nitrogen (TN) and Total Phosphate (P) were collected monthly (Figure 13). Acceptable water quality ranges for drinking or recreational water are also represented as shaded regions for each measure. The exception is phosphate which does not have a reported guideline value. (NRMMC, 2000; NH&MRC, 2004).

Water quality differed between tanks, with the concrete tanks showing elevated levels of EC, TDS and pH compared to others (Figure 13). Changes in the chemical and physical properties could be attributed to lime leaching from the concrete walls (enHealth, 2004). Levels of pH up to 9.2 can be tolerated in new tanks (NH&MRC, 2004). Turbidity increases were noted in the polyethylene tank and may be caused by algal growth or dirt washed from the roof. The pH observed in the concrete tanks were occasionally outside the range of drinking water guidelines (NH&MRC, 2004), although water was not used for drinking. Whether the occasional changes in pH or salts affected indoor appliances using the rainwater from concrete tanks would require further investigation. Measures of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were taken as a measure of organic contamination (data not shown). Only low levels (between 0 and 10) were detected in all rainwater tanks, suggesting little contamination.

Microbial presence in all rainwater tanks was measured as total coliforms. Species that indicate faecal contamination (e.g. from bird droppings), such as *Escherichia coli* were found not to be present. The polyethylene rainwater tank had the highest coliform counts (Table 4). Further microbial analysis carried out in the polyethylene tank showed no pathogenic organisms such as *Campylobacter* and *Salmonella* present. Elevated total coliforms in the polyethylene tank indicated this particular tank appeared more susceptible to microbial contamination than other tanks. Windborne algal spores, soil washed from the roof or biofilm build-up in the piping may have contributed to total coliform numbers. Water quality results also suggested higher nutrients and turbidity entering the polyethylene tank, which possibly helped promote bacterial growth (Figure 13).

It is not entirely clear why the polyethylene tank had higher microbial contamination than other tanks, although it had been noted that a fitted level gauge allowed a small amount of light to enter the tank and showed evidence of algae growth. This, plus the sighting of the tank to sunlight, its smaller size (that may influence temperature change) and the material it was constructed may all have contributed to higher bacterial growth. It is recommended that rainwater tanks should be fitted with a level gauge that minimises light entering the tank.

Table 4: Total coliforms in Sharland Oasis's rainwater tanks

	Total Coliform (MPN/100 ml)													
Date	07-Jul-07	21-Aug-07	03-Sep-07	30-Oct-07	20-Nov-07	06-Dec-07	14-Dec-07	20-Dec-07	29-Jan-08	20-Feb-08	05-Mar-08	02-Apr-08	16-Apr-08	28-Apr-08
Steel tank	2	1	0	-	-	-	-	-	6	240	24	220	84	0
Polyethylene tank	11	96	65	51	-	18	12	21	71	520	43	190	79	73
Concrete tank	0	0	0	-	16	0	0	4	0	0	0	0	0	0

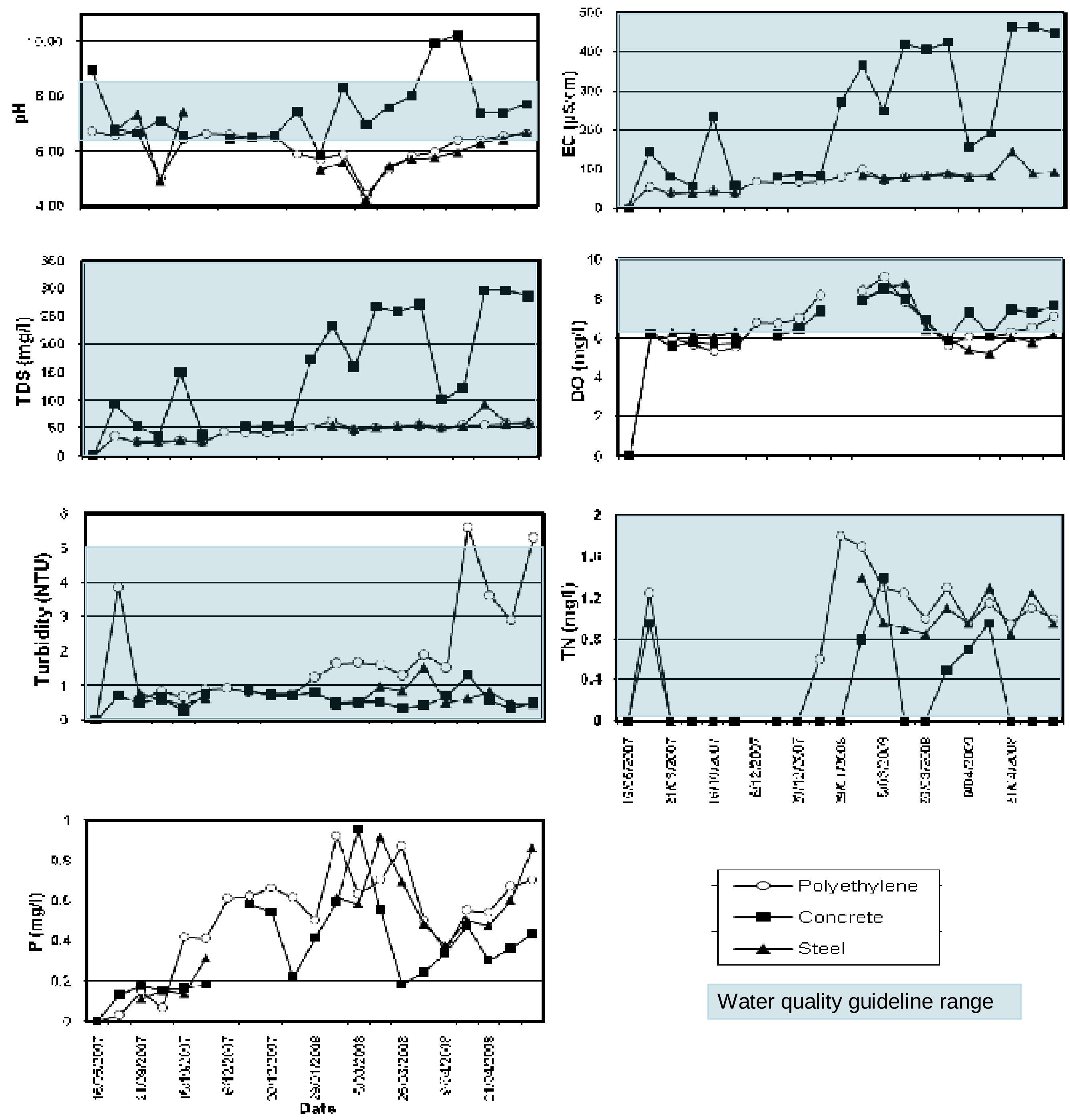


Figure 13: Water quality in Sharland Oasis's rainwater tanks compared (exception phosphate) with acceptable Australian water quality guidelines (shaded areas) (NRMMC, 2000; NHMRC, 2004).

5.6 Assessment of water quality in greywater system

Although greywater was not used, the greywater treatment system was assessed for water quality and compared to Victorian EPA guidelines for reuse. Household greywater entered an underground collection cell, preventing access for sampling. However, indication of untreated greywater quality can be derived from Pearce (2005) and Australian guidelines for water recycling (NRMMC, 2006) (Figure 14).

Treated greywater from the Sharland Oasis greywater treatment system was collected and analysed from January to April 2008. Physical and chemical measures included pH, EC, TDS, Turbidity, DO, TN, P, BOD and COD, although not all measures are shown in Figure 14. Microbial contamination was assessed by enumerating *E.coli* and Total Coliforms in the greywater storage tanks.

Comparing the treated greywater at Sharland Oasis with typical untreated greywater suggests the treatment system worked effectively at improving water quality by reducing COD, BOD and bacteria (Figure 14). Results also suggest that TN and P were not removed by greywater treatment system. Caution should be taken in drawing TN and P comparison between Sharland Oasis and other sites as influent greywater may differ in composition. Treated greywater high in nutrients maybe beneficial for plant growth, but environmental risks need to be considered such as plant nutrient imbalance and direct toxicity. Greywater may also cause groundwater contamination or enter water bodies as runoff causing algal growth (NRMMC, 2006).

At the household level, the Victorian EPA have specified guidelines for the reuse of treated effluent and treated greywater (EPA, 2008). Treated effluent would have met the 10/10/10 standard (≤ 10 mg/L BOD_5, ≤ 10 mg/L suspended solids and *E. coli* ≤ 10 cfu/100 ml) for use indoors (suspended solids was not measured).

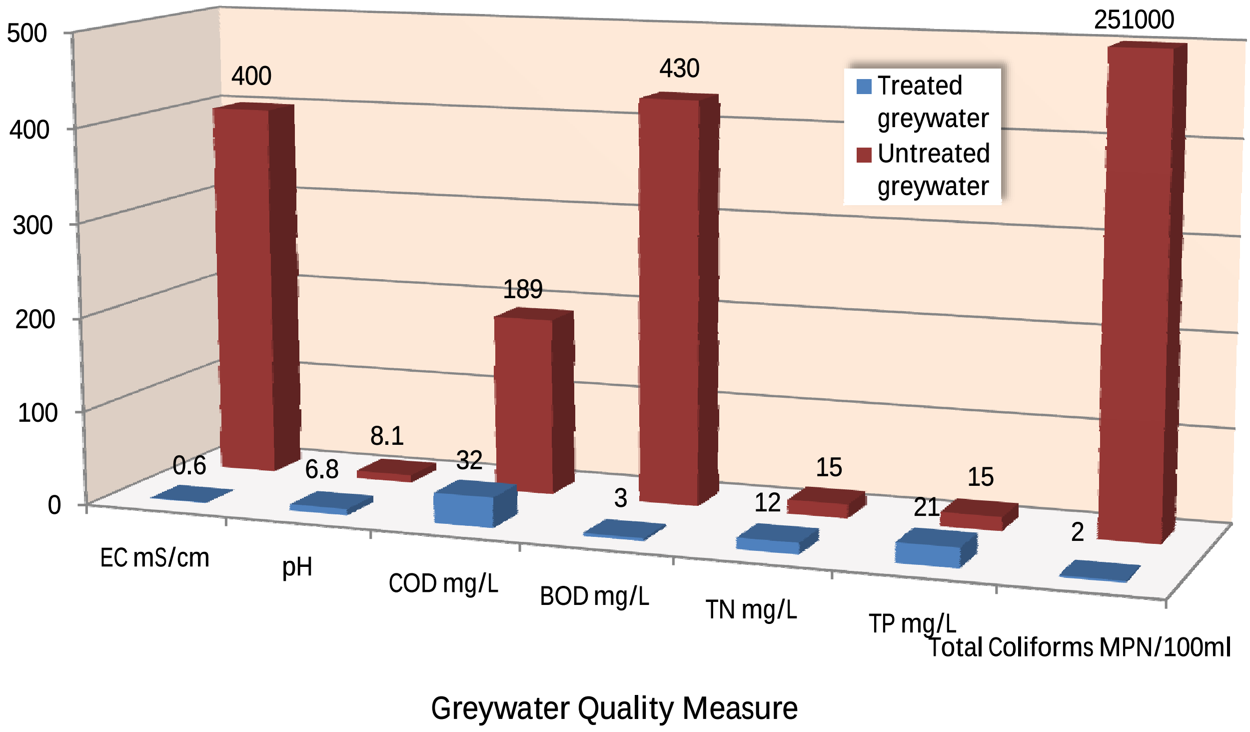


Figure 14: Treated greywater quality at Sharland Oasis compared to untreated greywater (Pearce, 2005; NRMMC, 2006)

5.7 Greywater survey results

A survey was prepared and distributed to 23 householders in Sharland Park Estate. The purpose of the survey was to better understand the water saving measures and behaviour of surrounding residents. Within the estate, 11 households responded to the survey and results show that nearly three quarters (73 percent) used greywater as a conservation measure for mainly garden usage (Figure 14a- d). Those using greywater did so via a bucket and simple diversion system from predominately the laundry and did not consider the need for a commercial greywater treatment system. As greywater can contain pathogens that can be a risk to human health (EPA, 2008) it may be important consider further education programs in the safe usage of greywater.

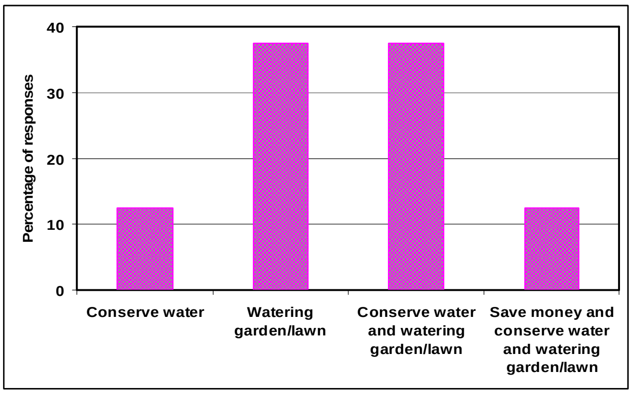


Figure 14a: Motivations to use greywater

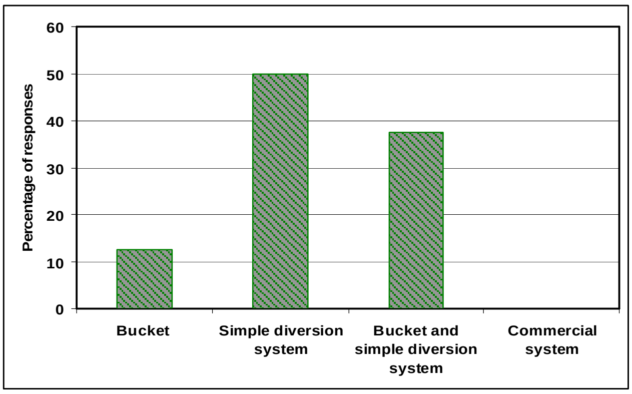


Figure 14b: Type of Greywater system used

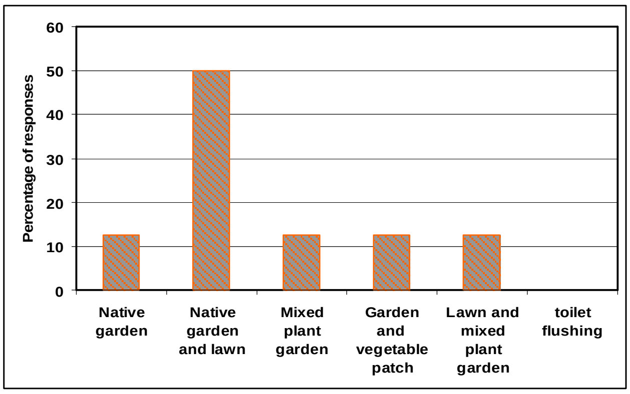


Figure 14c: Greywater uses

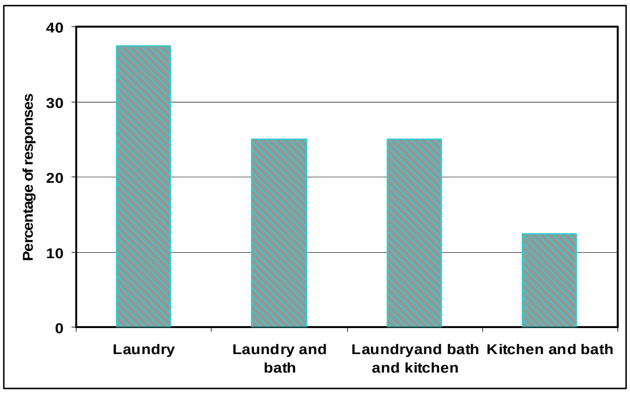


Figure 14d: Willingness to use greywater

6 Conclusions

The outcomes of this study show that:

- Sharland Oasis achieved a significant reduction in household water use, both potable and overall, when compared to the tenant's consumption at previous homes and consumption in average Melbourne and Victorian households. This was achieved by installing water saving devices and appliances, constructing drought tolerant outdoor landscapes and by incorporating a rainwater system to supply areas in the house.
- Overall water use at Sharland Oasis was 26 percent less than the tenant's previous homes. Overall indoor use was 23 percent less when compared to Melbourne homes and 57 percent less when compared to Victorian homes on a per person basis. Overall outdoor use was 88 percent less compared to an equivalent household in Melbourne. The overall water consumption was calculated as 95 L per person per day.
- The use of rainwater as an alternative to potable water in the toilet, laundry, kitchen and outdoors provided significant savings in potable water consumption. Rainwater supplied 44 percent of the total annual water use at Sharland Oasis.
- Sharland Oasis used up to 64 percent less potable water than the tenant's previous homes. Potable water consumption was calculated as 54 L per person per day, well within Barwon Water's future target of 191 L per person per day by 2015 for Geelong residential customers.
- Rainwater quality generally met Australian Drinking Water Guidelines for the indicators measured. The water chemistry varied depending on the rainwater tank material, with higher pH and salts in concrete tanks and higher microbial growth in polyethylene tanks.
- Sharland Oasis's greywater treatment system treated an average 292 L per day of wastewater. Greywater was treated to a quality that met the Victorian EPA standard for onsite use of greywater for toilet flushing and washing machines. The quantity of greywater produced represented around 50 percent of Sharland Oasis's overall water consumption and potentially was a valuable alternative water resource. Unfortunately, the benefits of reusing treated greywater could not be assessed as the tenants decided not to utilise this resource.
- A survey of the surrounding houses in Sharland Park estate suggested that simple greywater diversion systems were well accepted. Respondents used greywater for garden watering only, not for indoor use. Treatment of greywater for this purpose was seen to be unnecessary by those surveyed.

7 Recommendations

From the results of this research it can be recommended that:

- Water efficient fittings and appliances should be installed in homes to reduce overall water consumption.

- Rainwater systems that supply rainwater for indoor use should be planned and installed in homes to reduce potable water usage.

- Gardens should be designed to maximise water efficiency.

- Rainwater tank material and placement should be considered with regard to their effect on water quality, to ensure stored water is fit for use.

- The operation and maintenance of greywater treatment systems should be simplified to improve ease of use for consumers.

- All greywater users need to be aware of the possible health implications when using untreated greywater for domestic purposes. Information on the risk and appropriate management should be easily accessible.

8 References

Australian Bureau of Statistics, (2006) *Water account Australia 2004-2005*, Australian Government. pp. 151

Barwon Water, (2007). Water Supply Demand. pp. 162

Coombes and Kuczera., (2003), Analysis of the Performance of Rainwater Tanks in Australian Capital Cities, *The Institution of Engineers, Australia 28th International Hydrology and Water Resources Symposium* 10 – 14 November Wollongong, NSW.

Department of Sustainability and Environment, (2004). *Securing our water future together – Victorian Government White paper*, Victorian State Government. pp. 172.

Department of Sustainability and Environment, (2006). *Sustainable water strategy central region. Action to 2055*, Victorian State Government. pp. 135.

EnHealth, (2004). *Guidance on use of rainwater tanks*, Australian government department of health and aging, publication 3432. pp 72.

EPA Victoria, (2008). *Guidelines for Environmental Management, Code of Practice- Onsite Wastewater Management,* Publication 891.2. Victorian State Government. pp. 37.

Frankston City (cited 2007). The benefits of a rainwater tank, Environment fact sheet. Frankston City. pp 2

National Health and Medical Research Council, (2004). Australian drinking water guidelines, Australian Government. pp. 615

National Resource Management Ministerial Council, (2000). Australian and New Zealand guidelines for fresh and marine water quality. Australian Government. pp. 615

National Resource Management Ministerial Council, (2006). Australian guidelines for water recycling: Managing health and environmental risk (Phase 1). Australian Government. pp. 415

Pearce, (2005). *Peat based greywater system*. Final Report to Smart Water Fund by Bio-Flo Pty Ltd, Victorian State Government. pp 42.

9 Acknowledgements

The project team would like to thank Smart Water Fund for providing financial support to this project. The support from Barwon Water and in particular, Nicole Paterson who is a member of the project steering committee, for her contributions and assistance towards this project is gratefully acknowledged. The project team would also like to acknowledge Third Ecology, Daran Constructions, Gordon TAFE and the Plumbing Industry Commission, for their contribution and support on several aspects of this project. The tenants of Sharland Oasis and Sharland park residents for their participation in this study as well as Kemi Seriki, from Wageningen University for her involvement in the grey water survey at the Waterwise expo are gratefully acknowledged.

10 Appendix 1

Outcomes from the Waterwise Gardening Expo, October 14-15 2006, including the greywater system survey

Forty people were interviewed during the Waterwise gardening expo. Of these 13 were recycling greywater, the remaining 27 were not.

10.1 People recycling greywater

Among all interviewees, 13 of them were recycling greywater by simply diverting washing machine wastewater with a hose or by bucketing (9 people), with a diversion system (2 people) or by constructing their own greywater recycling system (2 people). Most people acknowledge that their main reason to recycle greywater was to irrigate their garden all year round and to conserve water with 7 responses respectively; water restrictions came last with only 3 responses.

All people were using greywater for garden watering (most of which was surface irrigation). Most people were satisfied by their greywater recycling system and express no problems using them. Those that were not satisfied mentioned that were sometimes experiencing pipe and/or outlet clogging. However, these people admitted that human/animal hair was entering the system occasionally, which could have caused pipe clogging. A respondent mentioned that he was not always satisfied by his diverting system as it demanded too much maintenance. Smells from a greywater tank was also noticed by another owner, but he was able to relate the reason to long greywater retention in the tank and the warm water. The fact that people were able to explain problems of recycling greywater is encouraging as it proves that people are truly interested in making their greywater system work.

People's main source of greywater can be seen in figure 1. As it can be seen most people used greywater from the laundry and bathrooms. Overall, people had good knowledge on greywater sources to use for recycling. The fact that 3 households were using kitchen water on an occasional or regular basis emphasis that information on greywater recycling for each source should be given for owners to understand failures that could occur by using different greywater sources. Most people used surface irrigation (people using bucketing and hose) which has possible health and environmental risks, this proves that emphasis on proper ways to reuse greywater should be distributed to those that reuse their greywater.

As it can be seen on figure 2, most people learnt about greywater recycling through the media and family and friends. Some respondents mentioned that many of their relatives had already been using greywater, so recycling felt normal for them. The media sources mentioned Bunning's, TV shows and newspaper most of the time. These sources have apparently been useful in providing people with basic information but not thorough enough. Which is illustrated by the fact that most of them did not seem to see surface irrigation with greywater as a health risk. Most people thought that finding information on greywater recycling was easy but a little less than half thought that information was not detailed enough.

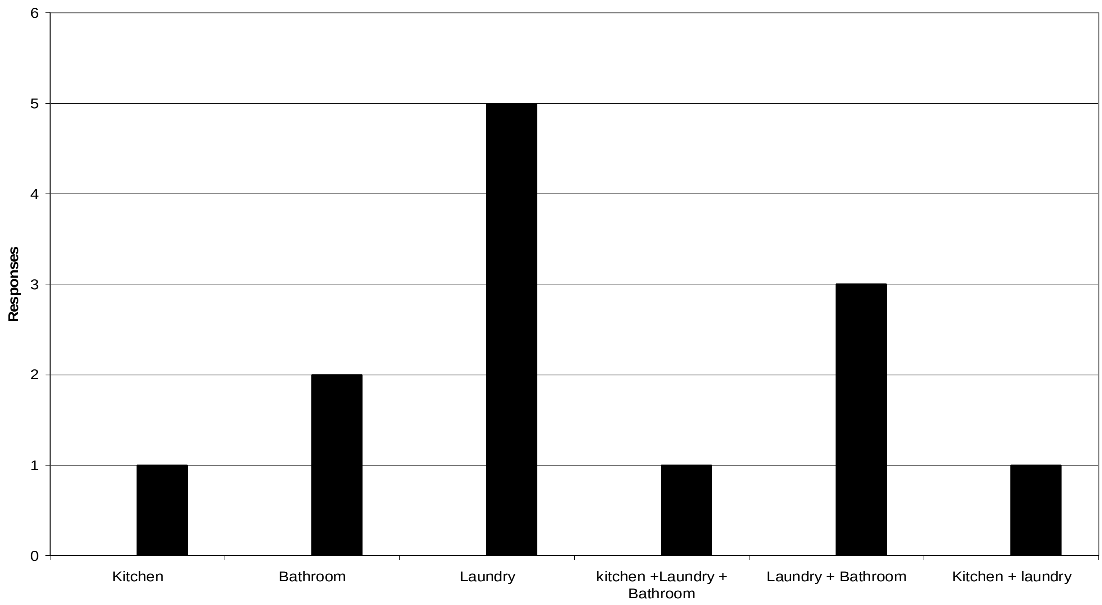


Figure 1: Greywater household sources

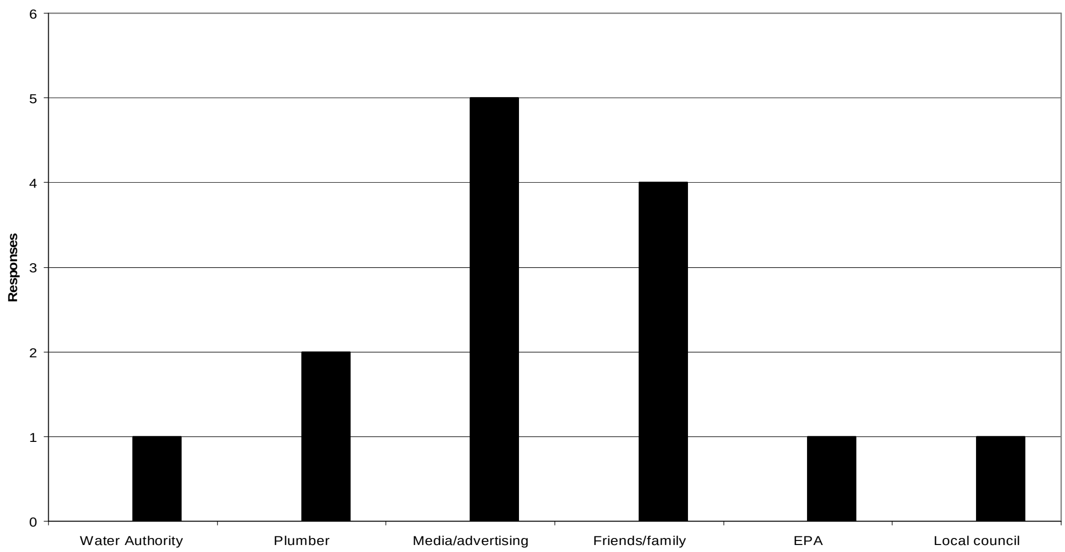


Figure 2: Ways people were exposed to greywater recycling

All people that had a greywater recycling system owned their house (with the exception of one person) and all were connected to main water and sewer. This indicates that people made the decision and were not constrained to make the choice of recycling greywater. This is positive as it indicates that people are willing to make changes in their lifestyle, which is an important asset when considering water recycling as a secondary water source. However, only 1 person thought about contacting the local council before using greywater on their property and none of the people had a permit to use greywater (including people with a diverting system). This shows that important work is needed by the local council to inform people on their responsibility towards neighbouring houses and the environment (water filtration in soils to groundwater, water running in neighbours' back yard).

When asked what their main source of information was prior to using greywater onsite, households responded that family and friends were their main source of information shown in Figure 3. Practically no information was taken from water authorities or local council. This suggests that information published by both agencies was either not accessed by the public (so better ways of communication should be identified to spread information) or that more involvement of both parties was required as they appeared to be the most qualified to provide information on water recycling according to the respondents as shown in figure 4. Possible partnership between both would enable the council and water authority to educate each community in a more personalized way. This would possibly show that their involvement in greywater recycling is of great importance. By showing people their importance in a recycling scheme, this would raise their interest in knowing more about it (increase exchange between authorities and the public, communication and knowledge) and possibly motivate them to use greywater.

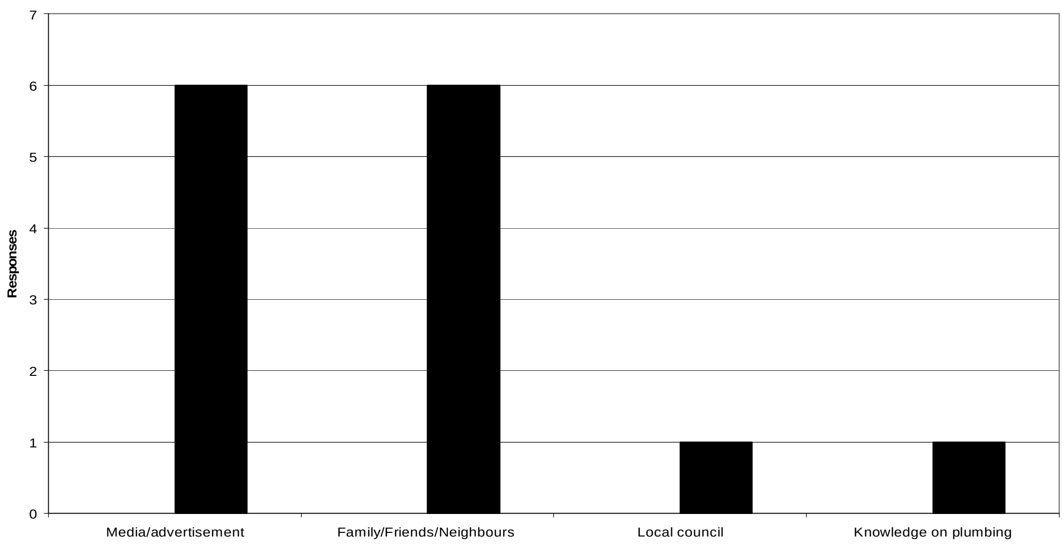


Figure 3: Greywater source of information

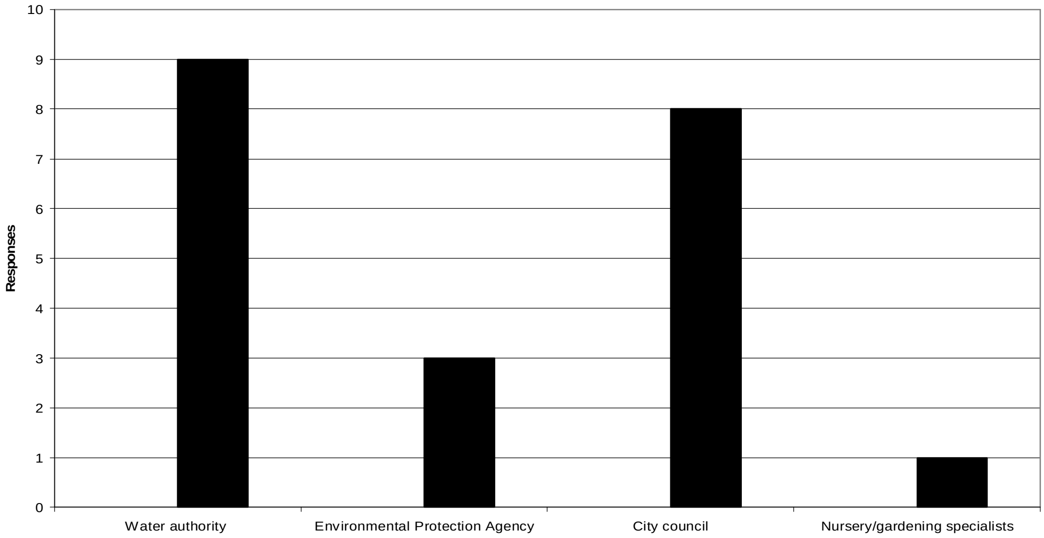


Figure 4: Trusted authorities to provide information on greywater recycling

When asked what type of information they would like to know before recycling greywater the following subjects were raised:

- How the system works
- How water is saved
- Advantages and disadvantages
- Cost effectiveness of individual home
- The dos and don'ts
- Product to use and to avoid
- Make a greywater policy
- What type of sources to use
- Safety aspects (for humans, soil, plants)

It was found that 10 people were ready to use greywater for toilet flushing, 10 for car washing while 9 approved its use for laundry washing. People seem quite willing to use greywater for uses other than irrigation, however, hesitation existed especially for car washing and for laundry use. Some people mentioned the fear of spoiling car paints with chemicals that may be present in greywater. Other people mentioned their fear to stain their white clothes so mentioned not wanting to use greywater for washing whites.

People were later asked what would motivate then to recycle more greywater and the 3 top responses were to conserve water, water restrictions and all year round irrigation and governmental rebates (see figure 5). People seemed very open to the idea of recycling greywater for other activities, however, more needs to be done by water authorities (by completing more research on greywater recycling, looking into different systems and assessing risks linked to its reuse).

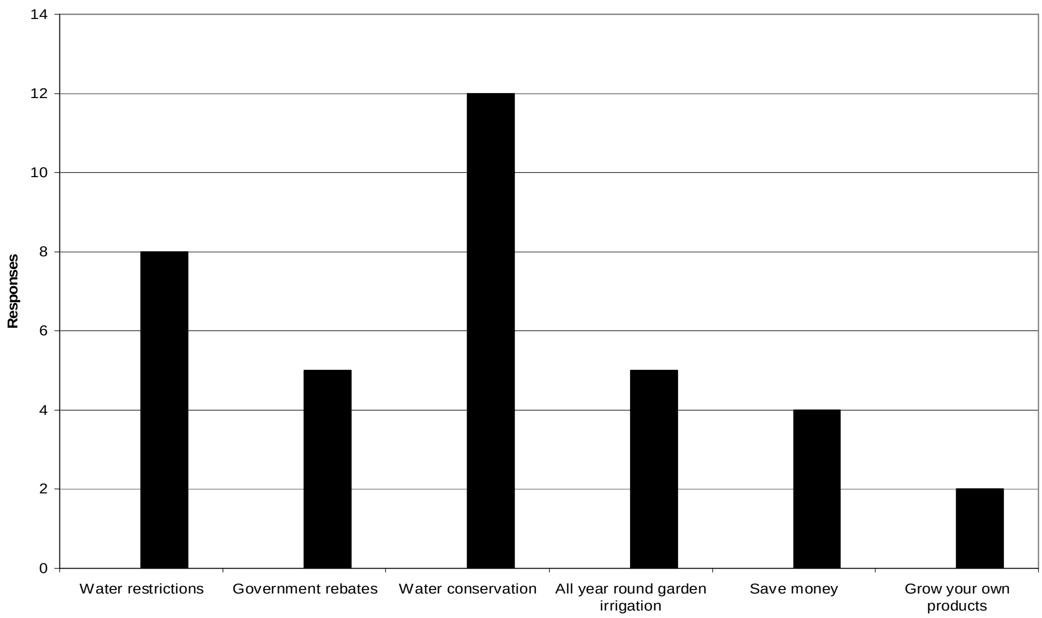


Figure 5: Motivation to continue recycling greywater

10.2 People not recycling greywater

Among the people not recycling greywater only 4 did not know what it was and 24 were interested in acquiring a greywater recycling system. People's willingness to recycle greywater is quite encouraging but also proves that people are aware that water recycling is becoming a necessary option to conserve water. When asked what would be their motivation to recycle greywater people responded similarly to the other group with water conservation first with 23 responses, water restrictions with 16 responses and all year round irrigation with 14 responses. People were concerned about knowing the following information before considering greywater recycling:

- Type of recycling systems
- Advantages and disadvantages
- Risks
- Costs
- Technical aspects of the system
- Water quality
- Explain recycling process
- Uses of greywater for activities
- Safety aspects
- Maintenance
- Products that can be used
- Health issues
- Greywater sources to use
- Best system to buy for new houses (most adapted)
- Dos and don’ts
- Plumbing changes to make
- Life expectancy of system
- Feasibility
- Reliability of the system

People also showed willingness to reuse the greywater for other activities. As it can be seen in figure 6 willingness to use greywater decreased with body contact. This is mainly attributed to the fact that people did not have much knowledge on greywater recycling and therefore needed more information to decide on greywater use for diverse activities. It was also noticed that people were in general more inclined to pay up to a $1000 for greywater recycling. This amount corresponds to the price range of diversion systems which does not allow for uses other than irrigation. However, as people still need to be convinced to use greywater, starting with a diversion system was of interest. When convinced on the advantages of using greywater, people may then focus on having a system that recycles water to a higher level.

No significant correlation was evident between age, and educational background suggesting that it did not affect in any ways people’s willingness to take up greywater recycling. It appeared that the 18 – 30 years age group was not present in the study probably because most rented and did not see any use in investing in a greywater recycling system, as they do not own a house. Assessing the interest in greywater recycling of this age group is not evident; however providing constant information to this age group is important as they would be tomorrow's owners. Making people receptive to greywater recycling at an early stage and continually updating them on progress made may convince them on the usefulness of acquiring a greywater system by the time the buy a house of their own.

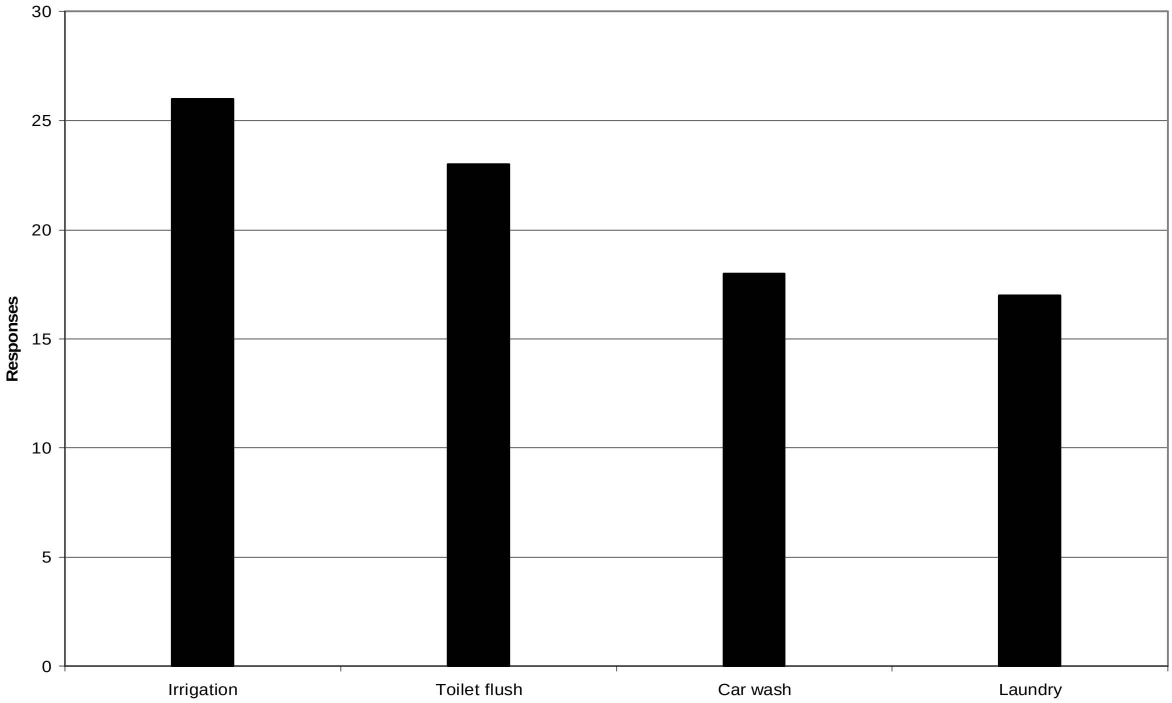


Figure 6: Willingness to use greywater for different activities

10.3 Water expo

All interviewees enjoyed the expo and wished that it would happen on yearly basis around the same time of the year. However, interviewees emphasized that presenting changes and progresses made in different areas given at the expo would justify making it an annual event.

In general, people were satisfied by the expo but thought that it could have been bigger; the most popular feature was the stallholders. People mentioned they really appreciated the numerous choice of water saving plants and the fact that a lot of information was available at one place. Some mentioned that were not always attractive and focussing on more attractive plants next time would be better. A criticism that was mentioned was the lack of connection between stall holders and guest speakers. Some people felt that it would have been of interest to have all stall holders talk. Maybe having themed presentations would enable all stall holders to be represented. This would however mean that stall holders of the same theme would have to prepare presentations together.

Other people were disappointed by the greywater recycling stand as there was only one and they seemed to have come mainly for that. Next time, offering a wider choice in greywater recycling system as well as people working in that areas (other than retailers) as guest speakers would be of interest. Having a wider choice of stallholders on the same theme would enable to cover a wider area. Some parents were disappointed by the kids' activities, especially in the morning as some stands were left unattended or in the afternoon, during which there weren't enough people to cope with the activities.

People also mentioned that the advertising was not well done as the website for the expo had not been taken care of. People mentioned going on a website, then calling for information on the website and were sent to another website that referred to the first one they had went on. It seemed that people were not really sure who was in charge of the website which next time should be clearly assessed to avoid mix ups.

Interviewees mentioned that sending a flyer with water bills would be a good way to advertise but also by putting reminders in the local newspaper each day the week before the event. When asked which program would be of interest to decrease water consumption at a household level, rain water tanks for existing homes was the most popular followed by greywater recycling and an outdoor program for water efficient gardening. This suggests that people are actually ready to recycle water but that additional information should be given to people to encourage them to take up greywater recycling. When asked which sector should benefit from water saving programs, industry came first, followed by big business and then tourism.

Appendix 2

10.4 Greywater and Greywater Treatment systems

The Brundtland report 1987 was the first internationally written report that showed how developed countries unsustainable consumption and developing countries' population increases and poverty would lead to irremediable environmental damages (WCED, 1987). The report emphasized that sustainable development could only be achieved if all countries worked together in protecting and preserving environmental resources while replacing unsustainable technologies by sustainable ones (WCED, 1987). The main message brought by the report was the need of "development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). From that point it had become clear that all nations were responsible of global environmental depletion and the only way to cope with these problems was to start international cooperation.

The Brundtland report was a first step in acknowledging each nation's responsibility in environmental degradation while underlining the necessity of changing institutional, economical and social conduct (WCED, 1987). The report was a call for global actions to be taken before irremediably damaging our environment. As a result, the first Earth Summit held in Rio de Janeiro in 1992, gathered more than a hundred countries to discuss on environmental problems and ways to solve them (UN, 1993). Among the numerous environmental problems on the agenda, freshwater protection and conservation was discussed (UN, 1993). This topic had over the past years become a hot topic given that freshwater consumption and pollution had increased over the last century at an alarming speed (UNEP, 1999).

Nations were to rethink on ways to preserve water resources and to consider alternative sources. Some countries turned to seawater desalinization process; yet this technique did not promote sustainable development because not only was the process expensive but it also released pollutants in the atmosphere (Friedler, 2005). Other countries like Japan turned to waste water stream reuse as an alternative water resource after experiencing severe droughts in 1964 (Yutaka, 2002). The Japanese example inspired countries like The Netherlands, Germany and Sweden to develop ecological sanitation (or DESAR). The idea is to encourage waste water stream separation, treatment and reuse onsite or off site instead of discarding the waste water to conventional treatment plants.

Unlike the conventional waste water treatment, Decentralized Sanitation and Reuse (DESAR) enabled to create a closed loop philosophy. Waste water is no longer viewed as a waste but rather as a possible resource that can be used to profit humans and the environment. The four common waste water streams found in literature are the following (Buuren, 2005):

The yellow stream composed of urine and flushing water

The brown stream composed of excrements and flushing water

The blue stream composed of rain water

The grey stream composed of shower, bath, sink, laundry water

In the conventional treatment plant scenario, a significant amount of freshwater is used to transport pollutants on the treatment site (Lens, 2001). By applying the DESAR concept, not only can freshwater consumption be minimized but treatment cost can also be decreased (Langergraber, 2005). Another advantage of DESAR is that each separate stream can be treated according to its level of pollution and thus facilitate the recovery and reuse of each stream's end product. For example, the yellow stream can be reused as source of fertilizer, the brown stream as a soil conditioning, the blue stream as a ground water recharge and the grey stream for irrigation.

Japan has been mastering the use of waste water streams as an alternative water resource to decrease stress on their water resource for the past 50 years (Yutaka, 2001). Serious droughts in Japan have forced the government to treat and reuse waste water to assure sufficient water in supply for human activities in cities such as Tokyo, Kobe, Fukuoka (Ogoshi, 2001). Nowadays, recycled waste water is used as toilet flushing in commercial buildings, schools and hotels, as irrigation water in parks and as environmental water for aquatic parks and water gardens (Ogoshi, 2001). The Japanese case is a good illustration on how waste water's function has shift.

Applying this model to countries that are not at the present suffering from water shortage may not succeed. A step by step approach would be safer and give the public more time to ease into waste water recycling. Water recycling should be done in sewered areas and in new building complex and a practical way to do it would be by diverting one waste water stream the entire waste water stream. This could be achieved using greywater because diversion since all households produce it on a regular basis and convincing the general public of its economical sustainability would be easier.

Greywater is understood to be water coming from bath, showers, kitchen and bathroom sinks, washing machines and from dishwashers. Variation of greywater production due to seasonal change and holiday periods may occur, but greywater production on day to day basis can be estimated to be steady. Up to 75 % of waste water generated within the household is greywater (Eriksson, 2003). Recycling greywater would enable to keep drinking water quality for personal care and food preparation and become a second water source for activities that do not need drinking water quality like gardening, toilet flushing and laundry. Figure 1 shows the typical household consumption for different activities. Recycling greywater would enable to recover a maximum of 45 % of total drinking water use. Knowing an average household consumes 657 liters of water per day, a maximum of 295 liters could be saved and used for gardening and/or for toilet flushing.

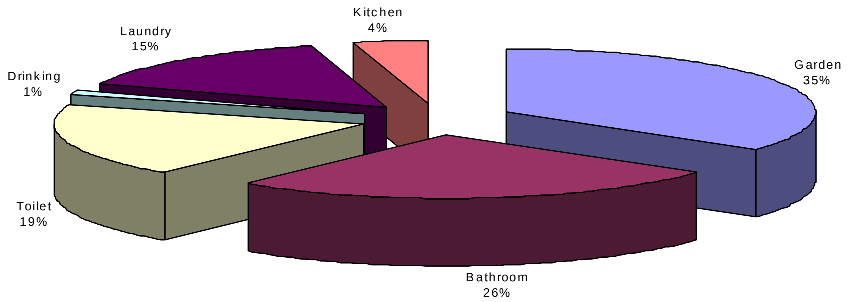


Figure 7: Domestic water use in Melbourne (Urban rain water System, 2001)

Greywater composition mainly depends on household lifestyles, personal care products and chemicals used (Ridderstolpe, 2004). Variations will occur from household to another but greywater remains less polluted than black water. As it can be seen on table 1, greywater flow is 3 times bigger than black water's but its nitrogen and phosphate concentrations are 15 and 5 times lower. Pathogens concentrations in greywater are 10 times lower than in black water. Greywater is mainly composed of easily biodegradable compounds such as oils, fats, other kitchen organic compounds, soap and detergent residuals (Ridderstolpe, 2004). The minimum requirement in Australia for greywater reuse is a secondary treatment (Agriculture and Resource Management Council of Australia and New Zealand, 2000).

The first national greywater reuse guidelines are still under study, therefore, existing state greywater quality and reuse guidelines have inspired theirs using the Guidelines for Sewerage

Systems. Most states require greywater treatment by either using simple technologies such as coarse screening or more advanced technologies such as septic tank like treatment. Not all states require greywater treatment before reuse; treatment requirements are given in section 3 where further details on guidelines and greywater reuse option in all Australian states are provided. Concerning reclaimed water use, it is a national trend to have at least a secondary treatment before use. As it will be explained in section 3, greywater quality will mainly depend upon intended reuse. A complete greywater treatment will involve the following steps:

The primary: gross and suspended particles removal

The secondary: organic compounds removal (aerobically or anaerobically),

Tertiary treatment: nutrients and pathogens removal

Table 2: Grey and black water composition (Palmquist, 2005; Ridderstolpe, 2004)

	Units	Greywater	Black water
Flow	M^3/h	0.54	0.17
PTot	mg/L	7.53	42.7
Ntot	mg/L	9.68	150
BOD_7	mg/L	418	1037
COD_{CR}	mg/L	588	2260
TS	mg/L	630	3180
VS	mg/L	330	1900
Pathogens	Unit/L	$10*10^3$	$100*10^3$
pH	-	7.5	8.94

Reclaimed water is used for several activities which may involve human contact. To avoid any environmental health incident, reclaimed water quality will vary according to the reuse. The closer human contacts are to occur with the reclaimed water the higher the treatment and standards will be. For example the EPA Victoria authorizes the reuse of greywater for diverse activities. Each activity is categorized in one of the four classes that are shown on table 2. Class A appears to be the highest quality and thus can be used for activities that may necessitate close contact with the water. However, water of class D would imply no human contact and would favour irrigation systems in the soil to minimize, as much as possible human exposure to pathogens.

Table 2: Approved uses of treated Greywater (EPA Victoria, 2008)

Treatment	Appropriate use of greywater sourced from and recycled on *single domestic premises*		Appropriate use of greywater sourced from and recycled on *multi-dwelling[2]/commercial[3] premises*	
Secondary treatment (20/30 standard) (≤5000L/day)	Subsurface irrigation	Yes	Subsurface irrigation	Yes[4]
	Surface irrigation	No	Surface irrigation	No
	Toilet flushing	No	Toilet flushing	No
	Washing machine	No	Washing machine	No
Secondary treatment and disinfection (20/30/10 standard) (≤5000L/day)	Subsurface irrigation	Yes	Subsurface irrigation	Yes[4]
	Surface irrigation	Yes	Surface irrigation	Drip only[4]
	Toilet flushing	No	Toilet flushing	No
	Washing machine	No	Washing machine	No
Advanced secondary treatment and disinfection (10/10/10 standard)[7] (≤5000L/day)	Subsurface irrigation	Yes	Subsurface irrigation	Yes[4]
	Surface irrigation	Yes	Surface irrigation	Drip only[4]
	Toilet flushing	Yes	Toilet flushing	AGWR standard only[6]
	Washing machine	Yes[5]	Washing machine	AGWR standard only[6]

10.5 Greywater treatments

Many greywater technologies are found on the market. The technology to adopt mainly depends on the greywater reuse intent. The closer the contact with humans, crops or animals, the higher the effluent quality will have to be. Greywater technologies found are divided in four categories:

- Greywater diverter
- Greywater natural treatment
- Greywater sand/media filtration treatment
- Greywater full treatment

Greywater treatments listed in the following section are onsite greywater treatment for single households.

Greywater diverter

This is the simplest technology found on the market. Greywater is filtered through a filter to remove large particles such as hair and lint then directed to leaching fields to irrigate gardens. Biological and disinfection processes are done within the soil by microorganisms present in the soil. Greywater diverters are most of the time equipped with a handle that enables to switch greywater flow to sewer system in case of overflow or sufficient water. Only subsurface irrigation is authorized for these types of systems because pathogens present in greywater could be transmitted by inhalation, contact with spray residues and surface run offs (Jeppesen, 1996).

When using such system, close attention should be paid to chemicals used within households, especially those with high sodium content. High sodium concentration damage clay soil structure and drainage (Jeppesen, 1996). Plants' ability to take water is inhibited by high sodium presence (Jeppesen, 1996). In most cases, it may be best to plant vegetation that can cope with greywater effluent.

Diverters are usually the cheapest greywater technology found on the market. The inconvenient with some of these systems is that they all use filters to remove gross particles, which means customers need to clean or at least checked filters on a regular basis to avoid any device failures. Greywater is usually not stored due to possible odours and mosquitoes infestation. Technologies found in this section varied from under hundred to few thousands of Australian dollars. Another disadvantage of this system is that salts present in greywater will be directly applied to soils. As high amounts of salts are known to cause soil structure destruction and affect plants' ability to get water, households planning to use these systems on a regular need to consider changing house care products (Jeppesen, 1996). These systems remain a good option for people that just want to test greywater reuse before investing in more complicated systems, or just need greywater in their garden on occasional basis.

Bio flo greywater. -

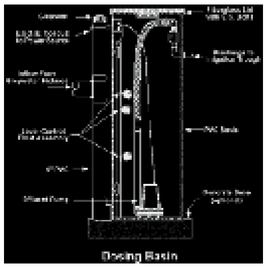
Greywater sources: Washing machine, bath/shower

Treatment process: Filter

Reuse options: Subsurface Irrigation

Cost: Not found

Clivus multrum



Greywater sources: Not mentioned

Treatment process: Settling + soil infiltration

Reuse options: Subsurface Irrigation

Cost: Not found

Ecocare

Greywater sources: Bathroom, laundry

Treatment process: Filtration

Reuse options: Subsurface Irrigation

Cost: 990 AU$ + delivery + installation

Ecocare greywater diverta valve

Greywater sources: Bathroom, laundry

Treatment process: Filtration

Reuse options: Subsurface Irrigation

Cost: 53 AU$ + delivery + installation

Envirosink

Greywater sources: Kitchen

Treatment process: Soil infiltration

Reuse options: Subsurface Irrigation

Cost: 73 AU$ + installation

Everwater greymate

Greywater sources: Not mentioned

Treatment process: Filtration

Reuse options: Subsurface Irrigation

Cost: Not found

(No longer available)

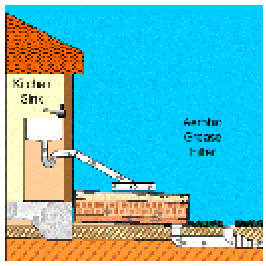
Grey to green

Greywater sources: Bathroom, laundry

Treatment process: Filtration

Reuse options: Subsurface Irrigation

Cost: ≥ 3,000 AU$ + installation



Grey recycling & irrigation systems

Greywater sources: Bathroom, kitchen, laundry

Treatment process: Filtration

Reuse options: Subsurface Irrigation

Cost: >2,050 AU$

+ delivery + installation

Greywater rainwater automated solution

Greywater sources: Bathroom, laundry

Treatment process: Filtration

Reuse options: Subsurface Irrigation

Cost: Not found

Greywater Saver

Greywater sources: Bathroom, laundry

Treatment process: Filtration

Reuse options: Subsurface Irrigation

Cost: 1,000 AU$

Marshall greywater Reuse system

Greywater sources: Not mentioned

Treatment process: Filtration

Reuse options: Subsurface Irrigation

Cost: Not found

Nature clear

Greywater sources: Bathroom, kitchen

Treatment process: Filtration

Reuse options: Subsurface Irrigation

Cost: ≥1,090 AU$

Nylex, greywater diverta

Greywater sources: Bathroom, laundry

Treatment processes: Filtration

Reuse options: Subsurface Irrigation

Cost: 199 AU$ + packaging and posting

Water Harvesting, Clearwater environmental design

Greywater sources: Not mentioned

Treatment process: Filtration

Reuse options: Subsurface Irrigation

Cost: 8,500 AU$

Water smart Gully

Greywater sources: Bathroom, laundry

Treatment process: Filtration

Reuse options: Subsurface Irrigation

Cost: Not found

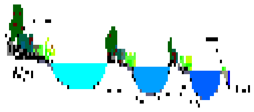
Greywater natural treatment

These treatments systems solely rely on biological breakdown of compounds present in greywater by filtrating it through soil layers. In some cases, soil is planted with specific vegetation that can cope with greywater. These systems are solely used for subsurface irrigation or ground water recharge because disinfection process is not done chemically.

These systems require a lot of land so such system would be convenient areas where land is available (rural areas, recreational park, new housing complex). Such system can be installed in a backyard or for a housing/residential complex. This type of system can become if not designed and/or managed correctly a hazard (mosquitoes and odours) (Dallas). Pricing of this installation depends on the material, volume of water, and area of the system to be installed.

The advantage of using natural system is that it does not need any chemicals or extensive piping system since reclaimed water is used to irrigate one part of the garden. The system has an aesthetic value and can be used to create for wildlife habitats (Lens, 2001). In addition, the system can achieve significant removal of BOD, TSS, nutrients, metals, trace organics and pathogens (Lens, 2001). Low maintenance is required and it a low tech technology that can be applied in developing country (Dallas).

Infiltration-wetland-pond system



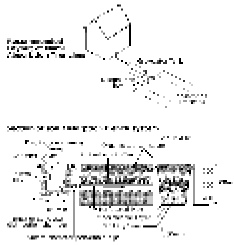
Greywater sources: Bathroom, kitchen, laundry

Treatment processes: Rootzone infiltration + soil infiltration

Reuse options: Subsurface Irrigation

Cost: 920 AU$ per person

Niimi adsorption trench and rock plant filtration



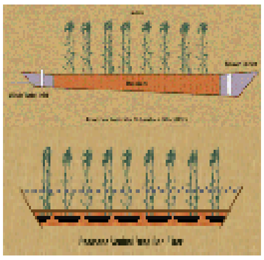
Greywater sources: Bathroom, kitchen, laundry

Treatment process: Holding tank + soil infiltration + filtration

Reuse options: Subsurface Irrigation

Cost: Depends on area and volume to be treated

Rootzone



Greywater sources: Bathroom, laundry

Treatment process: infiltration + rootzone infiltration

Reuse options: Subsurface Irrigation

Cost: 5,000 AU$

Wetland

Greywater sources: Not mentioned

Treatment process: Soil infiltration

Reuse options: Subsurface Irrigation

Cost: Depends on area, vegetation type and volume to be treated

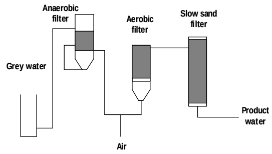
Greywater sand/media filtration treatment

Such system mostly consists of beds of sand and/or other media that trap and adsorb contaminants present in wastewater (NovaTec, 2004). Bacteria and other microorganisms do the biological treatment in sand beds by breaking organic compounds in wastewater (NovaTec, 2004). In most cases, greywater is directed into a septic tank for suspended particles to settle and then directed to the sand bed.

When dealing with sand units, removal or replacement of sand layers may be necessary after months of operation.

The advantage of using such a system is that its operation is simple and requires little maintenance (NovaTec, 2004). Contrary to diversion systems that only allow a coarse filtration, sand filtration enable biological treatment, which increase effluent stream quality and thus diversify application options especially if followed by a disinfection process (NovaTec, 2004).

Aerobic / anaerobic fixed film process



Greywater sources: Not mentioned

Treatment process: Anaerobic filtration Aerobic filtration + sand filtration

Reuse options: Subsurface Irrigation

Cost: Not found

Anaerobic/Aerobic treatment

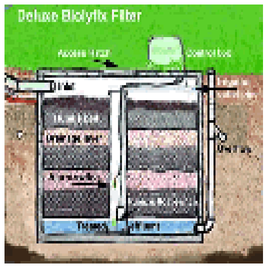
Greywater sources: Bathroom, kitchen, laundry

Treatment process: Septic tank + filtration

Reuse option: Subsurface Irrigation

Cost: Not found

Biolytix



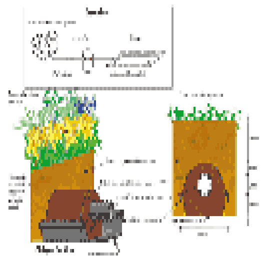
Greywater sources: Bathroom, kitchen, laundry

Treatment process: Filtration + humus filtration

Reuse option: Subsurface Irrigation

Cost: 5,300 AU$

Ecomax



Greywater sources: Bathroom, laundry,

Treatment process: Septic tank + soil infiltration

Reuse options: Subsurface Irrigation

Cost: Not found (no longer available)

Effluent irrigation

-

Greywater sources: Not mentioned

Treatment process: Septic tank + drainage field

Reuse options: Subsurface Irrigation

Cost: Not found

NuTreat -

Greywater sources: Not mentioned

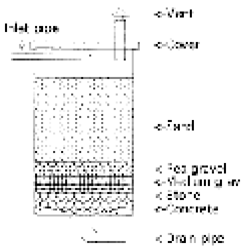
Treatment process: Aerobic sand filtration

Reuse options: Subsurface Irrigation

Cost: > 8,000 AU$

+ delivery + installation fees

Sand filter



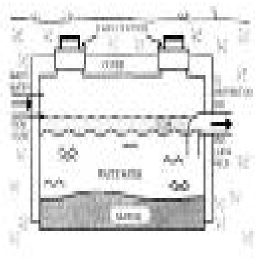
Greywater sources: Bathroom, kitchen, laundry

Treatment process: Septic tank + filtration

Reuse options: Subsurface Irrigation

Cost: Not found

Soil absorption



Greywater sources: Not mentioned

Treatment process: Septic tank + soil absorption

Reuse options : Subsurface Irrigation

Cost: Not found

Greywater full-scale treatment

Treatment units in this section provide primary, secondary and disinfection processes. Most of these treatment units involve high technology processes such as membrane filtration and/or UV disinfection.

These technologies are aimed for single households of 5 to 10 people. Some of the technologies are buried so in case of a system's failure, the unit would have to be dug out. These systems require a large investment (from 5000 to 15000) cost and maintenance cost depending on the technology involved.

The advantage is that these systems are complete waste water units and can achieve water class of A and B quality. If greywater reuse involving human contact is planned these systems should be preferred. Moreover, storage is possible in this case scenario, which increases reclaimed water applicability to more activities. Unlike other treatment, consumers would not need as much involvement and, for some systems, be able to include kitchen water.

Aquacell

Greywater sources: Bathroom, laundry

Treatment process: Screening + membrane bioreactor

+ disinfection

Reuse options: Laundry + toilet flushing

Cost: 13,000 AU$

Aquareuse

Greywater sources: Bathroom, kitchen, laundry

Treatment process: Filtration + disinfection

Reuse options: Subsurface Irrigation + toilet flushing

Cost: Not found

Bio flo Pty system, Aqua reviva

Greywater sources: Bathroom, laundry

Treatment process: Biological growth + disinfection

Reuse options: Subsurface Irrigation, toilet flushing

Cost: 9,000 to 11,000 AU$

Bushwater, Waterboy HSTP-10

Greywater sources: Bathroom,, kitchen, laundry,

Treatment process: Membrane filtration + disinfection

Reuse options: Subsurface Irrigation + toilet flushing

Cost: 10,000 AU$

Ecowaste water recycling

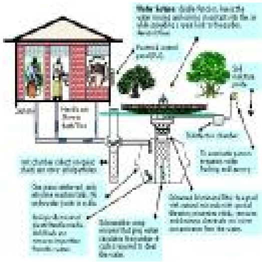
Greywater sources: Bathroom, laundry

Treatment process: Filtration + disinfection

Reuse options: Subsurface Irrigation + toilet flushing

Cost: >1804 AU$

Envirowater



Greywater sources: Bathroom, laundry, spa

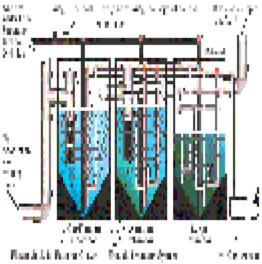
Treatment process: Septic tank + biological growth

+ biomineral filtration + disinfection

Reuse options: Subsurface Irrigation + laundry + toilet flushing

Cost: 4,000 AU$

Equaris greywater



Greywater sources: Bathroom, kitchen, laundry

Treatment process: Settling + biological growth + sedimentation

Reuse options: Subsurface Irrigation

Cost: 15,000 AU$

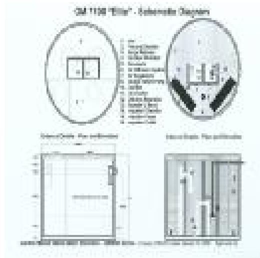
Everwater re-viver

Greywater sources: Bathroom, dishwasher, laundry

Treatment process: Filtration + disinfection

Reuse options: Subsurface Irrigation + toilet flushing

Cost: Not found



Garden master Elite

Greywater sources: Bathroom, laundry (?)

Treatment process: biological growth (Anaerobic /aerobic)

+ biological media + disinfection

Reuse options: Subsurface Irrigation

Cost: Not found

Grey 2 blue

Greywater sources: Bathroom, laundry

Treatment process: Filtration

Reuse options: Subsurface Irrigation + laundry + toilet flushing

Cost: Not found

Membrane bioreactor

Greywater sources:

Treatment process: Screening + membrane filtration

+ biological growth (aerobic)

Reuse options: Subsurface Irrigation + toilet flushing + laundry

Cost: Not found

Nubian water system

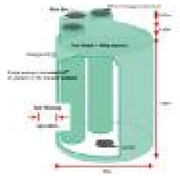
Greywater sources: Bathroom, laundry

Treatment process: Screening + biological growth + disinfection

Reuse options: Subsurface Irrigation + laundry + toilet flushing

Cost: > 5,000 AU$ + installation

Ozzikleen



Greywater sources: Bathroom, kitchen, laundry

Treatment process: Biological growth (aerobic) + sedimentation

Reuse options: Subsurface Irrigation

Cost: Not found

Perpetual water

Greywater sources: Bathroom, laundry

Treatment process: Filtration + settling + adsorption filtration

Reuse options: Subsurface Irrigation + toilet flushing

Cost: > 6,500 AU$ + installation

Pontos Aquacycle

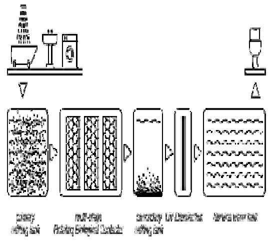
Greywater sources: Bathroom

Treatment process: Filtration + biological growth (aerobic) + disinfection

Reuse options: Subsurface Irrigation + laundry + toilet flushing

Cost: 7,522 AU$

Rotating biological contactor



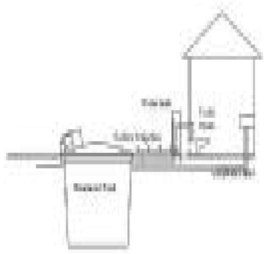
Greywater sources: Bathroom, laundry

Treatment process: Settling + Biological growth (aerobic) + settling + disinfection

Reuse options: Subsurface Irrigation + toilet flushing

Cost: Not found

Super natural greywater system



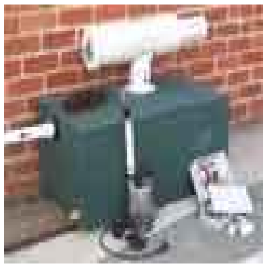
Greywater sources:

Treatment process: Membrane filtration + disinfection

Reuse options: Subsurface Irrigation + laundry + toilet flushing

Cost: Not found

Wattworks Greywater System



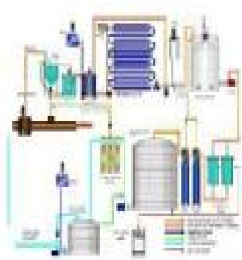
Greywater sources: Bathroom

Treatment process: Filter + disinfection

Reuse options: Toilet flushing

Cost:

Waterfresh



Greywater sources:

Treatment process: Septic tank + disinfection + filtration

Reuse options: Subsurface Irrigation + toilet flushing

Cost:

The list of technologies showed in this section is not exhaustive many other technologies similar to some of them were not listed because they were similar to those mentioned above.

11 References to appendices

Asano, T. Wastewater Reclamation and Reuse. Lancaster : Technomic, 1998.

Australian Academy of Technological Sciences and Engineering. Water Recycling in Australia. Parkville: Australian Academy of Technological Sciences and Engineering, 2004.

Baker, R. Greywater Rebate Increases to $ 500. The Age 9 May 2003.

Bixio, D. et al. “Wastewater Reuse in Europe.” Desalination 187 (2006) : 89 -101.

Brissaud, F. Wastewater Reclamation and Reuse in France. MSE dissertation. Université de Montpellier.

Buuren, J. Waste Water Management in Developing Countries. Wageningen: Sub-department of Environmental Technology, 2005.

Colls, K. et al. Australian Weather Book. Sydneay: Reed Holland Imprint, 2001.

Council of European Communities. Urban Waste Water Treatment Directive 91/271/EEC. Brussels: European Commission 1991

Commission of the European Communities. Report from The Commission : 2004 Report on PHARE, Pre-Accession and Transition Instruments. Brussels : Commission of The European Communities, 2005.

Commission of the European Communities. Enlargement and EU Budget: Commission Proposes Expenditure for the 10 New Member States. Brussels Commission of the European Communities, 2004. <http://europa.eu/rapid/pressReleasesAction.do?reference=IP/04/161&format=HTML&aged=0&language=FR&guiLanguage =en>.

CSIRO Urban Water. Greywater Technologies Review and Selection. CSIRO: 2005.

Dallas, S. Constructed Wetlands for Wastewater Treatment in Western Australia. Perth: Murdoch University.

Department of Health. Code Practice for the Reuse of Greywater in Western Australia. Department of Health 2005.

Dettrick, et al. Environmental Guidelines for the Use of Recycled Water in Tasmania.

Hobart: Department of Primary Industries water and Environment 2002.

Government of Western Australia. Securing our Water Future- A State Water Strategy for Western Australia. Government of Western Australia 2003.

Greywater Reuse. City of West Torrens. 21 Jul 2006. 31 Aug 2006 <http://www.wtcc.sa.gov.au/site/page.cfm?u=502>

EPA Victoria (2008), Guidelines for Environmental Management, Code of Practice- Onsite Wastewater Management, Publication 891.1.

Eriksson, e. et al. "Household Chemicals and Personal Care products as Sources for Xenobiotic Organic Compounds in Grey Wastewater." Water SA 29.2 (2003).

European Environment Agency. The European Environment- State and Outlook 2005. Copenhagen: European Environment Agency, 2005.

Friedler, E. et al."On-site Greywater Treatment and Reuse in Multi-storey buildings" Water Science and Technology 51.10 (2005): 187-194.

Jeppesen, B. Model Guidelines for Domestic Greywater Reuse for Australia. Brisbane: Urban Water Research Association of Australia, 1996.

Juanicó, M. et al. "Water Reuse in the Northern Mediterranean." Technical workshop: The Integration of Reclaimed water in water resource management, Lloret de Mar, Oct. 2005.

Kamizoulis, G. et al. "Wastewater Recycling and Reuse Practices in Mediterranean Region: Recommended Guidelines." MED-REUNET, Case Studies, www. Med-reunet.com

Lallana, C. et al. "Sustainable Water Use in Europe Part 2 : Demand Management." Copenhagen: European Environment Agency 2001.

Langergraber, G. et al. "Ecological Sanitation-a Way to Solve Global Sanitation Problem?" Environment International 33 (2005): 433-444.

Lens, P et. al."Decentralised Sanitation and Reuse: Concepts, Systems and Implementation." Cornwall: TJ International 2001.

Marecos de Monte, M.H. "Water Reuse in Europe." 4th World Water Forum, Mexico 2006.

Nixon, S. et al. Europe's Water: An Indicator-Based Assessment. Copenhagen: European Environment Agency,2003.

Northern Territory Government. Greywater Reuse in Single House Premises. Information bulletin 2004.

Novatec Consultant Inc. Greywater Reuse Study Report. British Columbia: Novatec Consultant Inc, 2004.

NSW Health. Greywater Reuse in Sewered Single Domestic Premises. NSW 2000.

Ogoshi, M et Al. "Water Reuse in Japan." Water Science and Technology 43.10 (2001): 17-23.

Palmquist, H. et al. "Hazardous Substances in Separately Collected Grey- and Black Water from Ordinary Swedish Households." Science of the Total Environment 348.1-3 (2005): 151-163.

Queensland Government Environment Protection Agency. Manual for Recycled Water Agreements in Queensland. Brisbane: EPA 2005.

Queensland Government Department of Local Government, Planning, Sports and Recreation. Greywater Guidelines for Councils Use of Greywater for Residential Properties in Queensland Sewered Areas. Department of Local Government, Planning, Sports and Recreation 2006.

Radcliffe, J. An Overview of Water Recycling in Australia-Results of the Recent ATSE Study.” 2nd National Conference Water Recycling Australia, Brisbane, 2003.

Raizon, D. “L’Union européenne et la Chine poursuivent leurs discussions.” *RFI Actualité* 28 Aug. 2005. <http://www.rfi.fr/actufr/articles/068/article_38197.asp>

Ridderstolpe, P. Introduction to Greywater Management. EcoSanRes. Stockholm. Jun 2004.

Schleicher, A. “Le challenge universitaire de l’Europe.” *Observateur de l’OCDE* Mar. 2006 n. 254. <http://www.observateurocde.org/news/fullstory.php/aid/

1538/Le_challenge_universitaire_de_l%92Europe.html>

UN.Report of the United Nations Conference on Environment and Development. New York: United Nations Publications, 1993.

UNEP. Global Environment Outlook-2000. London: Earthscan Publications Ltd, 1999.

World Commission of Environment and Development. Our Common Future. New York: United Nations Publication, 1987.

Domestic Water Uses. Urban Rainwater Systems. 13 Jul 2006. http://www.urbanrainwater.com/domestic.htm

Yutaka S., et al. “Large-area and on-site water reuse in Japan.” Proceedings of Sustainable Development of Water Resources Pluralizing Technology. 2002.

12 Appendix 3

The project has also focused on dissemination of the results to a broad range of stakeholders

The **objectives of the communication strategy were to:**

- raise awareness of Geelong's first eco display home, Sharland Oasis
- encourage new home builders and renovators to incorporate in their own home the ideas incorporated in the Sharland Oasis display through demonstrated waters savings
- recognise the efforts of project partners and sponsors
- raise Deakin University and Barwon Water's profile and that of the Smart Water Fund in the region and show we aiming to encourage innovation both regionally and nationally
- demonstrate that the predicted water savings as a result of the selection of particular water saving and water conservation products are actual savings.
- Provide the Smart Water Fund with an opportunity to further publicise the fund
- provide the government with an opportunity to promote the objectives of the white paper *Our Water Our Future*

12.1 Project stakeholder communication

To the community: Sharland Oasis has won the Master Builders State Awards for the best energy efficient display home, and the Housing Industry Association's Award for Best Project/Display Home.

A brochure detailing all of the innovative aspects of the home has been produced and made available to all visitors of the home during its display period. Extensive advertising was also undertaken to promote the house to the broader community, and to encourage take up of innovative aspects of the house's design and construction. Barwon Water further promoted the outcomes of this project to the community through a media release on July 25th, 2008 which went to print in the Geelong Advertiser on Monday the 28th July 2008.

Barwon Water also promoted the Sharland Oasis project during its "Waterwise Gardening" event at the Geelong Botanic Gardens on the 14 - 16 October 2006. The event informed the community of the project and also obtained community views on water efficient homes.

The project results were also promoted through articles in Barwon Water's customer newsletters (Barwon News, Volume 17, 2007 and Volume 20, 2008) and updates on Barwon Water's website (with the approval of the family living in the home).

To suppliers and trades persons: Thirty local suppliers embraced the philosophy of the Sharland Oasis project and accepted an invitation to participate in the display home project. All suppliers were committed to environmentally sustainable products, practices and manufacturing processes and were willing to make these ideas cost effective and easy to incorporate in mainstream homes. These suppliers, trades people and the architects involved in the design of the house, will be sent copies of the final report and will be encouraged to disseminate that information and to incorporate more aspects of water efficiency into their product developments and new home design and construction.

To the plumbing industry: The Plumbing Industry Commission is currently lacking information on water consumption patterns from various water sources. The Commission therefore sees value in this project as it will provide ongoing monitoring, assessment and reporting of the performance of the home. Their support is demonstrated through the provision of $10,000 to researching of the house. Results from the research will be made available to the Plumbing Industry Commission on approval of the final report, with the intention for them to disseminate that information and to incorporate the outcomes in their practices.

To education providers: The Gordon TAFE filmed innovative aspects of the home's construction, including the installation of water and energy saving products such as the photovoltaic system, solar hot water system greywater system and other water and energy saving technologies incorporated in the home. The film will be an important resource in the training of apprentice builders, plumbers and other trades people. Results will also be made available to Gordon TAFE for incorporation in their training of apprentice builders, plumbers and other trades people as well as to Deakin University architecture students.

To other water authorities: Through the SmartWater Fund and Barwon Water's network (WSAA, AWA, VicWater), outcomes of the project were disseminated to the broader water industry at a water industry event held in Benalla (AWA conference) on the 14 – 16 October, 2008. Dr. Shobha Muthukumaran made an oral presentation of the results and the research is contained in the conference proceedings.