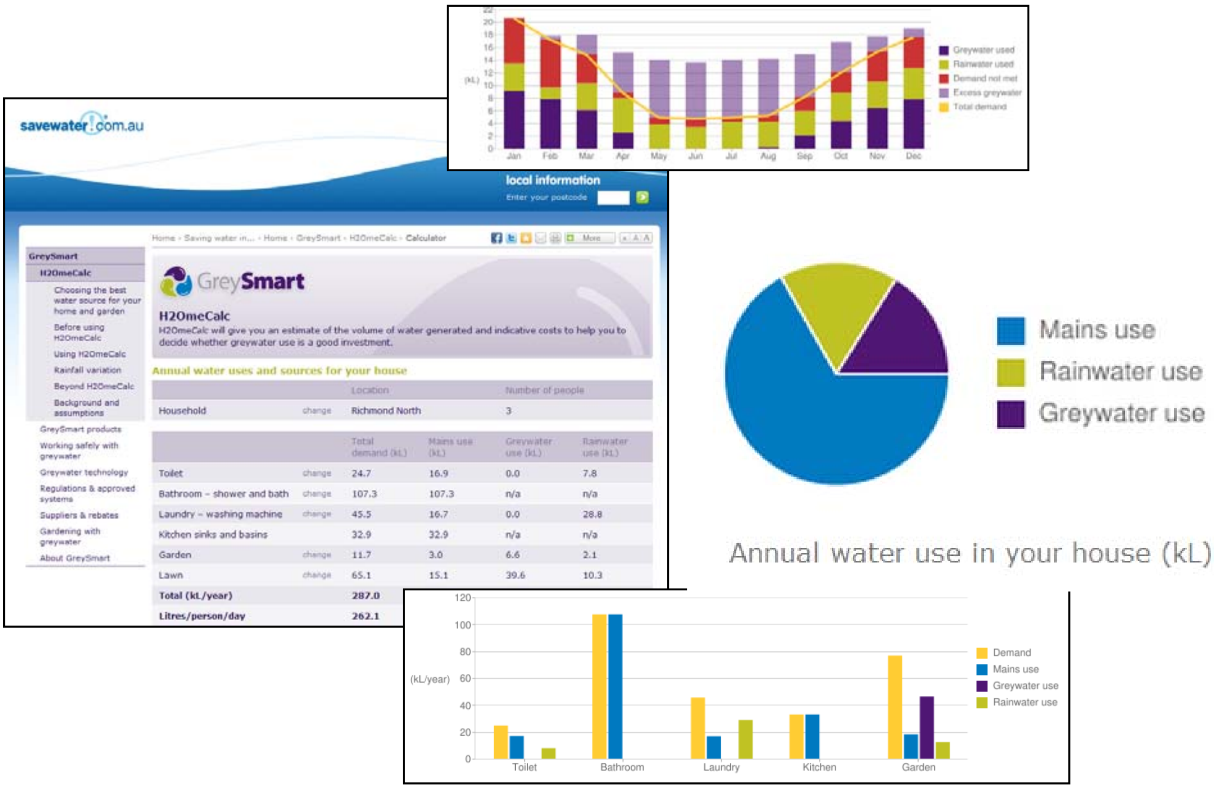
H$_2$OMECALC: LOGIC & RATIONALE

A MODEL TO ASSIST HOUSEHOLDERS TO INTEGRATE GREYWATER AND RAINWATER WITH THEIR TRADITIONAL MAINS WATER SUPPLIES.



BY

DARYL STEVENS, SIMON WILSON AND CLARE DIAPER

NOVEMBER 2010

FUNDED BY SMART WATER FUND.

Client, Organisation	Smart Water Fund
Project, Project No.	H05d
Atura Project leader	Daryl Stevens
File location	C:\Documents and Settings\Jodie\My Documents\Current work\ATURA\Greysmart phase 2\Summary of H2OmeCalc v1.6.docx

Created by:

Atura Pty Ltd.
Suite 204,
198 Harbour Esplanade
DOCKLANDS,
Victoria 3008

t 03 9602 4001
m 0418 802 621
info@atura.com.au
ABN 77 808 046 073

Document control table

Version	Type	Author	Reviewer	Issued to	Date	Approved
Draft	Report	DPS CD	JH	DPS	5/11/2010	
Darft to SMF	Report	DPS, CD	SWF	Tanya Rattry	8/11/2010	

*This table should be removed after final approval from client.

Table of Contents

1 Executive Summary

The focal point of the GreySmart project is a website incorporating interactive web calculators and a focused knowledge bank for greywater use in Victoria and across Australia (www.greysmart.com.au). The GreySmart project adopts an innovative approach allowing providers, installers and users of greywater to access this information in an easy to understand practical format. H_2Ome*Calc* is a vital component of this website and it provides an Australia wide tool for householders to assess the potential water saving benefits of various rainwater and greywater alternatives. This will potentially increase the number of households utilising alternatives to mains water lowering demand on infrastructure upgrades. H_2Ome*Calc* also provides an indication of financial costs to the householder.

Rainfall and climate data for H_2Ome*Calc* was sourced from the Bureau of Meteorology whereas household water use and generation volume data was sourced from a combination of sources; state government guidelines, water company reports, Australian and New Zealand Standards and the Master Plumbers and Mechanical Services Association of Australia.

A novel pseudo-daily time step approach was developed for modelling rainwater yield from tanks, providing signicant accuracy in collection and spill volumes, while minimised data requirements and model calculation times making it appropriate for use on a website. Daily rainfall profiles for four rainfall climate zones in Australia were selected and tested then combined with average monthly rainfall data for 18,500 postcode locations in Australia. The rainfall and irrigation modelling used accepted approaches of efficiency factors and landscape factors.

The outputs of H_2Ome*Calc* provide the householder with simple to interpret data and graphs illustrating water use and cost data for the selected option and configuration for a property. The user is given easy access to input varying data allowing them to quickly determine the specific impact of changes to a single variable (i.e. will a bigger tank help?). H_2Ome*Calc* is a valuable tool for householders to better understand their water use and possible alternative options, and for plumbers to determine the best option for householders' specific circumstances.

2 Introduction

2.1 H_2Ome*Calc* overview

H_2Ome*Calc* is a tool to assist householders to better manage available water supplies by:

- Reducing the amount of potable (mains) water used (saving money and water).
- Enhancing security of the households water supply through periods of water restrictions (protecting the garden from costly plant deaths)
- Living more sustainably by using water more efficiently
- Improving the home asset value and quality of life at home by maintaining green spaces around the house

H_2Ome*Calc* recognises that there are a wide range of water sources available to the householder. The challenge is to find the optimum mix of sources. Often people make this investment decision without fully assessing the costs and benefits. H_2Ome*Calc* provides some rational for the more appropriate investment for a householder helping weigh up the costs and benefits from a variety of options. For example:

- How much mains water will you save?
- Plumbing rainwater to the toilet provides a useful all year round demand for water, but introduces an additional cost. Is it best for you?
- What are the costs and benefits of a bigger rainwater tank or more roof area to collect the rainwater form?
- Would a greywater system be better than a rainwater tank, as it does not rely on rainfall?
- What type of greywater systems would be best for your house and garden?

At the household level there are two possible additional sources of water available to the householder; greywater and rainwater; both of which are represented in H_2Ome*Calc*. Greywater systems available in Australia can be either:

- GDT - greywater diversion temporary
- GDP - greywater diversion permanent; (usually with a coarse filter of some nature)
- GTS - greywater treatment systems

These systems nearly always use some type of greywater irrigation system (GIRS). With temporary and permanent diversion devices, greywater should not be stored for periods longer than 24 hours. The advantage of a treatment system is that greywater can be stored and used in the house.

Rainwater tanks rely on rainfall to supply water from the roof. Tanks now come in a large range of colours, sizes and shapes. Rainwater has the advantage of being better quality than untreated greywater but tanks require space in the garden and supply is rainfall reliant.

In addition to modelling greywater and rainwater supplies and uses, H_2Ome*Calc* also provides a simple financial model with a number of assumptions about the future price of water, the cost of rainwater tanks and greywater systems and the installation cost. These costs (particularly the installation cost) depend on your individual circumstances. H_2Ome*Calc* provides an indicative cost based general data entered by users to help with the decision process. These estimates are ONLY A GUIDE, a quotation for your specific house and garden is required to confirm all costs!

Remember...It is Your Water, Your Future and Your Decision.

2.2 Fundamental logic behind H_2Ome*Calc*

H_2Ome*Calc* is a tool for householders to assist them to better manage their available water supplies. There are many different reasons someone might want to manage available water supplied, these include:

- Reduced cost in comparison to potable water supply costs which are increasing with the introduction of more expensive water sources into Melbourne;
- Enhanced security of the household supply water through periods of water restrictions and ensuring garden survival; and
- Contributing to a more sustainable society where local water reuse reduces the demand for potable water and associated infrastructure.

The water sources that can be investigated using H_2Ome*Calc* are (Figure 2-1):

- mains water supply (also called potable water or drinking quality water);
- rainwater; and
- greywater (e.g. bathroom and laundry drainage water).

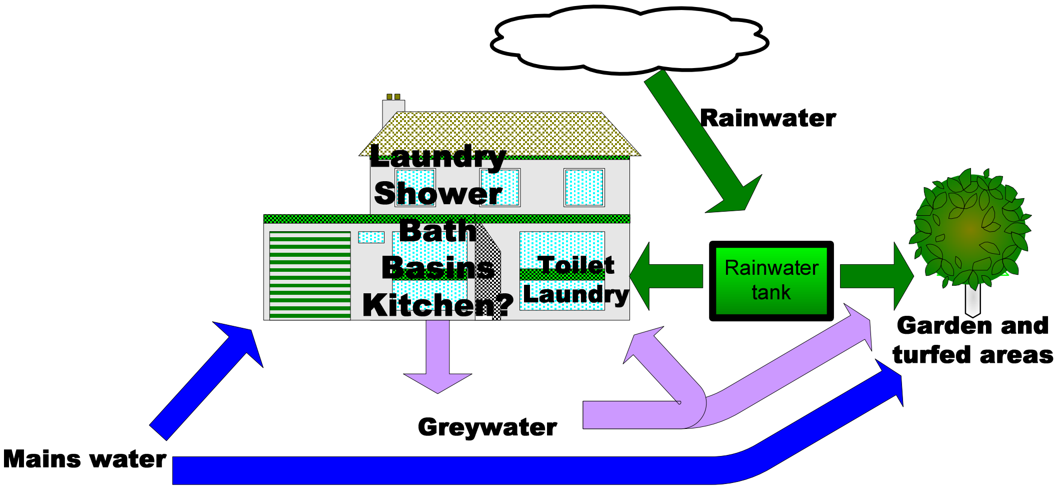


Figure 2-1 Households supply and demands represented in H_2Ome*Calc*

The water demands that can be investigated using H_2Ome*Calc* consist of both indoor and outdoor water uses. Laundry and toilet flushing indoors and gardens and turfed (lawn) areas outdoors. Water for showers, baths and kitchen use can only be sourced from mains water as recommended by health and regulatory organisations.

When sourcing water for garden irrigation in H_2Ome*Calc*, different source waters can be used for different garden areas, depending on the homeowners' specifications. The challenge for the householder is to find the optimum mix of sources that best utilise greywater and rainwater at acceptable costs.

Sourcing water from blackwater (water from toilet flushing) is not examined in H_2Ome*Calc* although the water demand for toilet flushing is included in calculations.

The philosophy of H_2Ome*Calc* is that if householders make water savings throughout the year (i.e. below Target 155 L/person/day averaged over the year) they should then be allowed to access this 'banked' water to ensure garden survival during extreme conditions (i.e. use the mains water as a backup). This means mains water remains as an irrigation option throughout the year, allowing householders assurance that their water saving efforts will mean their garden survives during extreme conditions. Trying to protect your garden from extreme weather conditions utilising a rainwater tank will usually come at very high cost, as large tanks will be required to ensure supply reliability for a short period of time.

This approach is different to the current government policy where water banking is not recognised. We recommend that target 155 campaign (155 L/day/person) should more openly acknowledge that there are extreme weather situations where mains water should be utilised to ensure garden survival and not doubling up by having expensive storage infrastructure at the household level in addition to reservoir storage capacity.

There are factors other than water savings that need to be considered when installing alternative water systems in the home. For example, retrofitting a permanent greywater diversion system into a house with a concrete slab may be too expensive, or people renting may enjoy the garden but not want to invest in water. H_2Ome*Calc* is a simple decision tool to assist the householder better understand their water resource options and to grow and maintain the garden that they want. All estimates for costs should be verified by the householder for their specific house and garden.

2.3 Components of H_2Ome*Calc*

There are four main components of calculation in H_2Ome*Calc*:

1. Rainfall as a water source (Section 3) ,
2. Greywater as a water source (Section 4) ,
3. Internal uses of water (Section 5) and
4. External uses of water (Section 6).

The next sections of the report provide details of the research, logic and assumptions which form the basis of these four components of H_2Ome*Calc*.

3 Rainwater supply and yield

H_2Ome*Calc* utilises daily rainfall profiles for different rainfall climate zones around Australia, in combination with average monthly rainfall data for over 18,500 postcodes across Australia. All rainfall data was sourced from the Bureau of Meteorology (BOM) and Datadrill (SILO, 2009) . This approach allowed the model to be kept simple with minimum calculation time and data requirements, and provided acceptable accuracy in water use, overflow, availability and water saving calculations. The selection of rainfall climate zones and rainfall profiles was undertaken using data and information from the BOM and by comparing H_2Ome*Calc* outputs for different rainfall profiles and postcodes. A further reduction in data requirements was achieved by reducing the rainfall profile data to a five year period, rather than the accepted 30 years for climate normal data. In addition, data on dry and wet years was also analysed to provide the householder with an indication of the potential reduction or increase in rainfall during extreme conditions.

3.1 Rainfall data

The research groups at Monash University (Mitchell et al., 2008) and Newcastle University (Lucas et al., 2006; Coombes and Kuczera, 2001) have undertaken significant work in Australia to enable the accurate simulation of the performance of urban rainwater tanks. One focus of this previous work has been to demonstrate that accurate tank simulation (particularly for small urban tanks) requires small time steps between mass balance calculations, and an assessment of whether the mass balance calculation should be performed before or after spillage. Coombes' model simulator PURRS uses six minute times steps to address the over prediction of yield that can occur with large time steps. The argument is that longer time steps can lead to significant overestimates of rainwater tank yield, as small tanks spill frequently if there a short, intense and less frequent rainfall events. However, using such small time steps requires a large amount of data and processing time and is a level of detail not consistent with the aims of H_2Ome*Calc*.

The approach adopted in H_2Ome*Calc* helps homeowners to understand the inter-relationships between water sources and enables an estimate of rainwater yield to assist the householder to make decisions as to which supply is most appropriate to harvest and how to optimise use of different sources. This is not a tool for urban planners and water authorities looking to compare options and develop policy and rebate levels nor is it a research tool for precise prediction of tank performance.

The most appropriate time step for H_2Ome*Calc* was selected as a pseudo daily time-step, providing the level of detail required for householders, but not requiring excessive data or processing time. Monthly time steps were investigated by comparing the outputs from H_2Ome*Calc* to those of the Rainwater Tank model, another daily time-step model developed by other researchers (Viertiz et al., 2007). The aim was to assess errors in the calculations, when H_2Ome*Calc* utilises monthly rainfall and demand data for typical urban scenarios. The comparison indicated that the estimate of the potential rainfall capture from the roof was similar using real daily rainfall data and monthly data, also the demand for water on the garden was similar between the two models. However using monthly time steps were not adequate for the tank mass balance. Thus the pseudo daily approach was adopted in H_2Ome*Calc* with a Yield Before Spillage mass balance model. This approach assumes that there are four main rainfall climate zones (See section below); wet winter, wet summer, uniform and arid and that the patterns of rainfall in these regions are similar but the actual amount of rain is a significant function of location.

The daily rainfall patterns for the rainfall climate zones are then scaled with monthly average postcode based rainfall data to achieve the same monthly or annual rainfall that is calculated for surrounding sites. For example, the daily rainfall pattern for central Melbourne is scaled and adjusted to equal the actual monthly annual historic rainfall levels in specific postcodes or suburbs/towns (Section 3.1.1). This pseudo-daily rainfall is combined with a daily demand (derived as an average demand for garden irrigation and internal demand) to enable a rainwater tank balance.

This approach best achieves the aims of H_2Ome*Calc* and whilst a more detailed model is possible, there is not significant additional value to householders if complexity was increased. Especially as variation in actual rainfall is a much more critical component.

Monthly average rainfall data for over 18,500 Australian postcodes was sourced from the Australian Bureau of Meteorology (http://www.bom.gov.au/climate/averages/climatology/gridded-data-info/metadata/md_ave_rain_1961-90.shtml). These data averages are calculated from the current 30 year climate normal period, 1 January 1961 to 31 December 1990. Climate normals are generally used as reference values for comparative purposes and the 30 year period is long enough to include the majority of typical year to year variations in the climate, but not so long that it is significantly influenced by longer-term changes in climate. This monthly data was combined with daily rainfall data from the nearest zone to calculate a scaled daily rainfall profile to be used in the model.

In developing the four rainfall climate zones the rainfall profiles of ten Australian cities were analysed (Appendix Table 9-1), for the period 01/09/1980 to 31/08/2010.

3.1.1 Rainfall climate zones

In order to minimise H_2Ome*Calc* data requirements and calculation times, the potential for grouping of cities and their associated rainfall patterns into climatic zones was investigated. Utilising Bureau of Meteorology information on major seasonal rainfall zones in Australia (Figure 3-1) a number of cross comparisons were made, comparing H_2Ome*Calc* outputs when using different rainfall profiles for major cities i.e. using the Melbourne rainfall profile with a Sydney scaled postcode based monthly average. Graphical representation of results provided an indication of whether an alternative rainfall profile was appropriate to use. The results of using a Perth rainfall profile with Melbourne average monthly post code related rainfall data and vice versa show that a Perth profile could be used in Melbourne and vice versa (Appendix Figure 9-1). The data for Sydney and Adelaide shows that a Sydney rainfall pattern is not appropriate for Adelaide and vice versa (Appendix Figure 9-2Figure 9-2). From a number of cross comparisons (Table 9-2 Appendix I) four rainfall climate zones were identified for which a single rainfall profile, scaled with post code based monthly averages provided adequate model accuracy. These zones are given in Table 3-1 with the recommended 'standard rainfall pattern' to be used for the entire zone, highlighted in bold. These zones compare to winter dominant rainfall, summer dominant rainfall, uniform rainfall and arid zones identified by the BOM (Figure 3-1).

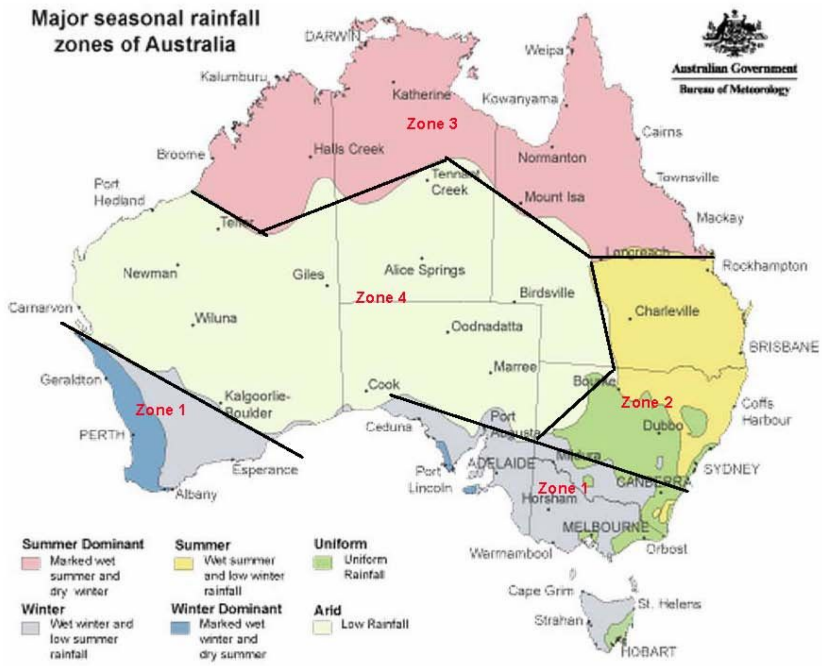


Figure 3-1 Major seasonal rainfall zones in Australia (Source: Bureau of Meteorology http://reg.bom.gov.au/lam/climate/levelthree/ausclim/zones.htm)

Table 3-1 Recommended rainfall climate zones and standard profiles

Zone	Rainfall profiles	BOM description
1	Darwin Cairns	Summer dominant rainfall
2	Brisbane Sydney	Uniform rainfall
3	Melbourne Perth, Adelaide, Hobart, Canberra	Winter dominant rainfall
4	Alice Springs	Arid

Note: Towns highlighted in bold are the recommended rainfall profiles to use for each zone

It should be noted that the BOM rainfall zones are based on normal climate data (from the years 1961 to 1990) whereas calculation undertaken in H_2Ome*Calc* are for the years 1980 to present day. For this reason there are likely to be some anomalies for some towns situated on the borders of climate zones, as the borders are likely to have shifted in the last 20 years.

Using the Melbourne rainfall fingerprint as a basis, cross checks of H_2Ome*Calc* outputs for various locations in one rainfall climate zone were undertaken on the cities of Shepparton, Mildura, Warrnambool, Sunshine and Wantirna (Figure 3-2). Outputs for all towns were comparable (and within the expected variation due to the variability in weather patterns within a single location).

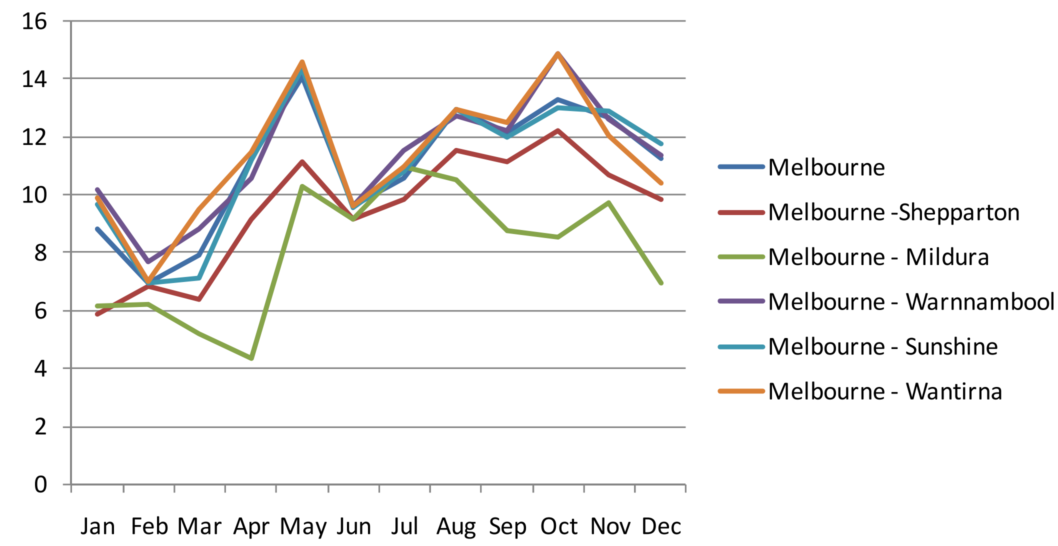


Figure 3-2: Variability in H_2Ome*Calc* Total Monthly inflow calculation for Victorian towns

3.1.2 Rainfall averages

To further reduce the amount of data required for H_2Ome*Calc* and to reduce calculation time for a web-based calculator a standard rainfall pattern was developed from the 30 years of daily rainfall data. This was done by comparing monthly H_2Ome*Calc* outputs (Total Monthly Inflow, Tank Yield, Overflow lost from tank, Mains Top-up required) calculated from different 5 year periods to the same outputs calculated from the entire 30 year period. The least square of the differences was used to identify the best fit five year time period to be used in all calculations (Appendix II). The results of the five year periods of daily rainfall data selected for the ten Australian cities are provided in Table 3-2.

Table 3-2 Five year rainfall data ranges for use in H_2Ome*Calc*

City	Five year profile to be used in H_2Ome*Calc*
Darwin	1984 - 1989
Cairns	2004 - 2009
Brisbane	1994 - 1999
Sydney	2004 – 2009
Melbourne	1994 - 1999
Perth	1999 - 2004
Adelaide	1984 - 1989
Hobart	1989 - 1994
Alice Springs	1984 - 1989
Canberra	1999 - 2004

Note: Towns highlighted in bold are the recommended rainfall profiles to use for each rainfall zone

3.1.3 Dry and wet years

With an ever varying climate there are fluctuations in rainfall, and year to year and month to month excess or shortage of rainfall will occur. To examine the effects of dry and wet years and dry and wet months H_2Ome*Calc* allows the user to vary the yearly rainfall to examine the effects of extreme weather conditions. In order to provide reasonable estimations for these values in different climate zones, 5^{th} (extreme dry conditions) and 95^{th} %ile (extreme wet conditions) monthly average rainfall data were compared to average monthly data. This comparison provided an average % value of potential reduction or increase in rainfall during wet and dry months. These monthly values are much more extreme than those often quoted for annual reduction in rainfall, as within the shorter time period zero rainfall for example is much more likely (than zero rainfall for a year). For example, in Melbourne in an extreme month there will only be 29% of the normal average rainfall, whereas in Alice Springs this could be as extreme at 0% (Table 3-3). The majority of extreme wet events are 2 to 3 times the average rainfall in one month (200 to 300%). The exception is in Alice Springs where nearly 5 times the average rainfall can be observed in extreme wet conditions.

Table 3-3 Variation in monthly and yearly dry and wet years compared to the average values data used in H_2Ome*Calc*

City	Monthly percentiles		Yearly percentiles	
	Dry month	**Wet month**	**Dry year**	**Wet year**
Melbourne	29%	232%	73%	141%
Sydney	11%	288%	62%	147%
Canberra	15%	272%	66%	148%
Perth	22%	250%	64%	117%
Darwin	16%	258%	68%	141%
Adelaide	22%	274%	89%	179%
Brisbane	10%	244%	48%	136%
Hobart	30%	245%	78%	151%
Cairns	14%	223%	59%	136%
Alice Springs	0%	496%	28%	181%

Calculated using data from BoM 2010, dry is the 5^{th}%ile and wet the 95^{th}%ile.

The percentages above can be used as guide to enter into the Rainwater supplies section (Rainwater menu) question – What is your estimated rainfall variation? (This is set a 100% to give average rainfall as a default). If the percentages in Monthly data (Table 3-3) are used monthly extremes that could be experienced will be calculated for every month. Although this is not typical of what might happen over a year this will provide the householder an indication of times when extreme weather events may require mains water back up. An alternative is for the householder to use the yearly data (Table 3-3), which will not provide outputs for extreme short duration weather events but will give an indication of longer term changes in weather patterns on the water supply and demands in the home.

3.2 Rainwater supplies

Rainwater supplies are calculated by estimating rainfall events and flow using the rainfall profiles (Appendix 9.1) and monthly rainfall data. The rainfall calculator uses this data with a number of assumptions to calculate inflow to a rain tank, the amount of water used from a tank (yield), the overflow lost from tank, the mains top-up required and the average volume in the tank. An efficiency factor of 0.8 for rainfall collection was used for all rainfall collection calculations to account for loss of water due to evaporation and minor infiltration from the roof surface (Khastagir and Jayasuriya, 2010).

Daily calculation of rainfall yield and use assumed:

- A tank is installed and allowed to fill before use.
- Inflow from the area specified taken from the rainfall finger print that is adjusted daily for the postcode monthly averages relative to the fingerprint monthly averages (Rainfall finger prints used were specifically selected five year periods that best described each rainfall zone).
- Internal demand for the house (Washing machine and toilets) was first priority for use and if there was any more rainwater available it was used externally (Garden and Lawn)
- Internal and external uses were calculated separately for the daily time step and rainfall use figures were calculated on a proportional demand bases of internal or external total use.
- Rainwater overflow was estimated on a daily time step considering tank inflow less daily demands relative to the effective volume of the tank (i.e. less air gap at top and dead volume at bottom)
- Average overflows for the month are summed from daily estimates.

These calculations were similar to the Tank model developed by Viertiz et al., (2007) and were validating using this software (Our thanks to Ted Gardner for his assistance).

The size and height of the tank is also required to allow calculation of the dead space within a tank. These calculations assume an air gap of 0.1 m at the top of the tank where the overflow is located and 0.1 m dead space below the outlet of the tank were water is not access (Viertiz et al., 2007). These values allow the calculation of the effective working volume of a tank if the user provides the tank volume and height.

4 Greywater supply and yield

One major benefit of a greywater is that the supply is available the entire year (except when householders are on vacation) and represents a significant opportunity to use greywater to substitute for potable water.

One of the key questions with greywater use is understanding the likely amount of water collected (yield) or 'How much water will end up on your garden?' In order to answer this question there are two factors that need to be considered, the volume of greywater generated and the harvest efficiency. In H_2Ome*Calc* it is assumed that all water produced from household appliances is collected and that the harvest efficiency is 100%. However, not all water from all appliances can always be harvested and users should be aware that estimations of greywater produced are maximum values.

In H_2Ome*Calc* the following sources of greywater are available:

- Buckets from washing machine, shower or bath
- Front and top loading washing machines
- Shower water
- Bath water
- Hand basin water
- Kitchen (for greywater treatment systems only)

4.1 Greywater supply

4.1.1 Buckets

Bucket use assumes 8L/bucket and that this water reduces the supply of greywater for any supply it is taken from **Error! Reference source not found.**. Bucket water can be sourced from:

- Shower;
- Washing machine;
- Bath; or
- All of the above

4.1.2 Washing machine

See Section 5.2

4.1.3 Shower

See Section 5.3

4.1.4 Baths

See Section 5.4

4.1.5 Kitchen

See Section 5.5

4.1.6 Hand basins

Hand basin volumes were assumed to be 13L/Person/day (MPMSAA et al., 2008).

4.1.7 Volumes Available

The volume of greywater available can be calculated based on the number of people living in the house, and the types of appliances used.

In H_2Ome*Calc* the householder can examine a number of options for greywater use including ad hoc use involving buckets of water from the shower and laundry, temporary and permanent greywater diversion devices and greywater treatment systems, the latter for indoor uses only.

There are issues with greywater use that need to be considered and these are provided in more detail in the 'Working safely with greywater - Basic greywater do's and don'ts for working safely with greywater' section of the GreySmart website.

Data required for H_2Ome*Calc* includes the number of people using showers that supply greywater, bath water generated, washing machine water utilised or captured for reuse and the number of buckets collected from the washing machine, bath or shower.

4.2 Greywater uses

4.2.1 Connection type

The connection type (Table 4-1) allows the user to select the type of greywater system that might be used in their household. This selection will provide an estimate of the cost of the greywater system to be installed and indicates where the greywater could be sourced from.

Table 4-1: Types of greywater connections represented in H_2Ome*Calc*

Connection type	Description
GW Ready house	The house has been designed and plumbed to allow easy access to greywater (GW) from the house when built to lower the cost of permanent diversion or treatment systems
Laundry Only	Connection of laundry to a permanent greywater system
New	There are no existing greywater or rainwater connection that can be used for a permanent diversion or treatment system
Temporary	Buckets, hose from washing machine or sump pump in bath
None	No greywater connection required

If householders select to utilise the greywater within the home for toilet flushing or washing machine use, a greywater treatment system is automatically added to the installation costs as this will be required where greywater is to be used indoors.

4.2.2 Garden demand

The irrigation demand can be determined based on – Garden Area, Garden Type and Location (and associated Evapo-transpiration and Rainfall, irrigation practice, Survival or Lush, Extreme conditions and the Demand profile or frequency of irrigation (This is relevant for tank storage)

The issue of extreme conditions are summarised in Section 3.1.3. More detail of the algorithms describing the irrigation demands are given in Section 6.1.1.

There is significant scope to reduce the volume of water required for the garden through the selection of drought tolerant plants and also urban garden design. These opportunities are significant and can initially be explored using H_2Ome*Calc*. The determined to be appropriate additional information from landscape designer and nurseries should be sort.

5 Demands in the house (Internal demands)

H_2Ome*Calc* estimates water demands in the house using logic from several sources and data input by the householder. This logic and user required information are provided in the following sections.

5.1 Toilets

There are a number of possible toilet appliance options in the home, from old style single flush to new low volume dual flush models. The volumes used in H_2Ome*Calc* for these various toilet flushing options are given in Table 5-1 (Roberts, 2005).

Table 5-1 : Assumptions of water use in toilet flushing in the home

TOILET FLUSHING	Low or single flush	Full flush	Daily volume
	L/flush	L/flush	L/person/day
Old single flush only	12	12	48
New single flush	9	9	36
Dual flush (6L/11L)	6	9	27
Dual flush (4.5L/9L)	4.5	9	22.5
Dual flush (3L/6L)	3	6	15
Dual flush (3L/4.5L)	3	4.5	13.5

5.2 Washing machines

With washing machines there is the potential for variation in wash sizes due to householder adjustment of cycles and wash types. To allow for this variability H_2Ome*Calc* utilises data on small, medium and large wash sizes for both front loading and top loading machines and washes per week depending on the number of people (Table 5-2) (DEUS, 2007).

Table 5-2: Assumptions for washing machine wash volumes in the home.

Number of people	Number of Washes per week	Water required or greywater Generation – Washing Machine (L/Week)					
		Front Loading Washing Machine			Top Loading Washing Machine		
		Small (<5.5 kg)	Medium (6 – 7 kg)	Large (>7.5 kg)	Small (<5.5 kg)	Medium (6 – 7 kg)	Large (>7.5 kg)
0	0	0	0	0	0	0	0
1	2	103	133	164	210	273	336
2	3	154	200	246	315	410	504
3	4	205	267	328	420	546	672
4	6	308	400	492	630	819	1008
5	7	359	466	574	735	956	1176
6	8	410	533	656	840	1092	1344
7	9	461	600	738	945	1229	1512

Source: DEUS (2007)

5.3 Shower

The shower in the home is another appliance for which water use will vary depending on the setting selected by the householder. In H_2Ome*Calc* it is assumed that households have knowledge of the Star rating for their shower and these ratings are used to specify water flow rates used for calculating shower volumes (Table 5-3) (AS/NZS, 2006). If householders do not know the Star rating for their shower a simple estimation of flow rate can be made with a stop watch and a bucket and the appropriate Star rating selected.

Table 5-3: Flow rates for different shower ratings used in H_2Ome*Calc*

Rating	(L/min)
0 Stars	18
1 Star	14
2 Star	10
3 Star	8
3 Star +	6

5.4 Bath

In the Yarra Valley Water study (Roberts, 2005) an average volume of water used for a bath was 123 litres which translated to an average across all logged days of only 46 L/ bath if household/day were considered. H_2Ome*Calc* allows the user to define how many baths are taken per a week in the household and assumes this in addition to showers defined.

5.5 Kitchen

The usage in the kitchen was calculated from the difference between an average household water use per week and the known uses for all other appliances (MPMSAA et al., 2008). This was calculated at 17 L/person/day and hand basins was caculated and 13 L/person/day. This option was grouped as usually this would be if people collect all greywater and use a Greywater Treatment Systems.

6 Garden demands (External demands)

For calculation of garden and lawn water demand the Landscape Coefficient methodology was used (UCCE and CDWR, 2000; Tanji et al., 2007). This methodology is well accepted and described in detail in the following two sections.

6.1.1 Irrigation requirement

Irrigation requirements (IR) can be calculated from pan evaporations or reference evapotranspiration (ET_O) and a crop factor (CF) or landscape coefficient (K_L). Rainfall calculations should also consider:

- Leaching through the root zone of the soil causing deeper percolation
- Rainfall that does reach the soil or plant.
- Evaporation before being used by the plant (i.e. lands on leaf area and evaporates).

The rainfall efficiency factor (E_{RF}) is used to allow for evaporation from and/or adsorption into surfaces before entering the soil as plant available water. In H_2Ome*Calc* an E_{RF} of 0.8 was used. Leaching can also be accounted for by use of a leaching requirement (LR) factor and the efficiency of the irrigation system using the irrigation efficiency factor (E_{IR}). This can vary considerably depending on the irrigation system and management (Table 6-1). An E_{IR} of 0.8 was used in H_2Ome*Calc*.

The efficiency of applying water when irrigating (E_{IR}) can be calculated using Equation 1 (Asano *et al.* 2007).

Equation 1 Irrigation efficiency factor

$$E_{IR} = \frac{I_{ben}(mm)}{I_{app}(mm)}$$

Where:

E_{IR} = Irrigation efficiency

I_{ben} = Water used beneficially (e.g. not lost in wind drift, runoff, or excess application leading to deep percolation in excess of *LF due to low distribution uniformity*, but accessible to the crop for evapotranspiration, plant cooling and leaching of salts)

I_{app} = Water applied to field (e.g. irrigation water applied)

Table 6-1 Comparison of irrigation systems and their attainable efficiencies

Type of System	Attainable Efficiencies
Surface Irrigation	
Basin	80 - 90%
Border	70 - 85%
Furrow	60 - 75%
Sprinkler Irrigation	
Hand Move or Portable	65 - 75%
Travelling Gun	60 - 70%
Centre Pivot & Linear Move	75 - 90%
Solid Set or Permanent	70 - 80%
Trickle Irrigation (Drippers and micro sprays)	
With Point Source Emitters	75 - 90%
With Line Source Products	70 - 85%

Source: Raine (1999)

For sprinkler systems losses of water are due to evaporation of spray droplets before impact, spray drift, surface run-off from the application point, soil surface evaporation, evaporation from the plant canopy and deep percolation. Evaporative and spray drift losses are probably the most significant of these factors. As irrigation droplet diameter decreases evaporation, losses increase dramatically with 20% evaporation occurring in droplets less than 0.2 mm in size (Raine, 1999), Decreasing droplet size also substantially increases the potential for drift loss beyond the target area. Sprinkler droplet size distribution is also important in determining water loss due to drift of small droplets, evaporation of spray and wind distortion, the three ways in which the water application varies (Raine, 1999).

Calder (1998 cited by Raine 1999) found evaporative losses from sprinkler systems as high as 40-50% of the discharge volume when the pan evaporation was greater than 13 mm/day and daily wind runs were approximately 300 km. Therefore, one strategy to reduce evaporative losses with spray irrigation is to irrigate during the night when temperature and wind conditions are usually lower. Another strategy to reduce evaporation is by applying the spray below the crop canopy or as close to the crop canopy as possible. This typically involves using longer drop lines on lateral moving and pivot boom irrigation systems. Low energy precision application (LEPA) systems are a good adaptation of centre pivot and lateral systems to overcome nozzle drift effects (Raine, 1999).

For **dripper systems**, deep drainage losses are often the major source of volumetric inefficiencies in drip irrigation systems (Raine, 1999). Deep drainage losses occur due to the use of excessive irrigation periods arising from either inadequate knowledge regarding the volume of water required to be applied to recharge the root zone or poor dripper irrigation design leading to over watering to improve lateral movement and water delivery in-between drippers. The potential efficiency of micro-irrigation systems is often quoted as greater than 90% (Raine, 1999). However, as with all irrigation systems, the ability to achieve high levels of efficiency is a function of both the design and management practices.

Drainage losses may also be associated with management of the system as maintaining the root zone at field capacity will ensure that any infiltrated rainfall will be lost directly to deep drainage. However, drippers also give the operator the capability to irrigate to a field capacity deficit, allowing more effective use of rainfall and minimising deep drainage (Raine, 1999).

The irrigation requirement for H_2Ome*Calc* was calculated using Equation 2.

Equation 2 Irrigation Requirement

$$IR = \frac{(ET_O \times K_L) - (RF \times E_{RF}) + LR}{E_{IR}}$$

Where units are:

IR (Irrigation requirement) = mm
E_{IR} (Irrigation efficiency factor) = unitless
ET_O (reference evapotranspiration) = mm
K_L (landscape coefficient). = unitless
RF (Rainfall) = mm
E_{RF} (Rainfall efficiency factor) = unitless
LR (Leaching requirement) = mm

6.1.2 Crop factors

The crop factors can be considered the percentage of pan evaporation (PE) used by the plant and lost from the soil via evaporation (Evapotranspiration). Crops factors (CF) vary considerably depending on the type of plants grown, the density of the plants and the visual appearance desired (Table 6-2). Crop factors also vary depending on the plant's stage of development. The crop factors in Table 6-2 give good indications of typical average crop factors for a range of amenity horticultural plants. More detailed crop factors and method for calculation of crop factors are available online[1] (UCCE and CDWR 2000). However, CFs were not used in H_2Ome*Calc* as Landscape factors were considered more appropriate (See Section that follows).

Table 6-2 Summary of crop factors (CF) for turf and ornamental plants

Plant type	**Desired look of plant**					**Error est.**
	Excellent (Premium)	**Great (Strong)**	**OK (Medium)**	**Just OK (Low)**	**Surviving (minimal)**	
	Crops factor[A]					
Turf – warm season	0.625	0.5	0.325			0.08
Turf – Cool season	0.825	0.725	0.675			0.10
Ornamentals	0.775	0.65	0.4	0.3	0.1	0.05
Vegetables	0.85	0.7				
Comments	Vigorous lush growing broad leaf	Strong growth	Some drought tolerance required.	Moderate drought tolerance required	Desert plants	

Source: Handreck and Black 2001

[A]Crops factors × Class A pan Evaporation = plant water requirement (mm). These factors apply when at least 70% of the surface soil is shaded by the plant, if less they can be reduced by 0.1-0.3.

Note: These numbers are rough guides only, measures should be made on-site. As plants become larger in containers their crop factor can increase to as high as 4.

[1] www.cimis.water.ca.gov/cimis/infoEtoCropCo.jsp

6.1.3 Landscape factors

Reference evapotranspiration (ET_O) is also used to estimate irrigation requirement, similar to the crop factor and pan evaporation (Section 6.1.2). This term describes the rate of evapotranspiration from a healthy grass, completely covering the ground to a uniform height of 75 to 125 mm, and having an adequate supply of water with no microclimate factors influencing it. A crop coefficient (K_C) is used to determine other specific crops evapotranspiration (ET_C) from the ET_O ($ET_C = K_C \times ET_O$). As a rough guide crop factors are 80% of crop coefficients values (e.g. if $K_C = 0.6$ then CF = 0.48). For calculation in H_2Ome*Calc* the Pan Evaporation data sourced from the BOM for postcodes across Australia (Section 3) was multiplied by a factor of 0.8 as an estimate of ET_O as indicated by Table 6-2 where the crop factor for healthy grass (cool season) ranges from 0.725 to 0.825.

For landscapes the crop coefficient (K_C) is replaced with a K_L (landscape coefficient). The K_L is calculated from three factors:

- K_S = Species factor.
  - Low = succulent, cactus or native plants with low water requirements
  - Mod = a mix of native and English garden plants surviving
  - High= More traditional English gardens with a lush feel
  - (Consult your landscape garden or nursery for more details or see reference at www.greysmart.com.au)
- K_D = Density
  - Low = Immature and sparsely planted landscapes.
  - Mod = Full planting of one species type.
  - High = Plantings with mixtures of vegetation types (trees, shrubs, and groundcovers)
- K_{MC} =Microclimate
  - Low = Plantings that are shaded for a substantial part of the day or are protected from winds typical to the area.
  - Mod = open-garden setting without extraordinary winds or heat inputs not typical for the location
  - High = Plantings surrounded by heat-absorbing surfaces, reflective surfaces, or exposed to particularly windy conditions. E.g. next to northwest-facing walls of a building, or in "wind tunnel" areas.

Equation 3 Landscape Coefficient

$$K_L = K_S \times K_D \times K_{MC}$$

When K_L and ET_O were known the evapotranspiration of the landscape (ET_L) was calculated from:

Equation 4 Evapotranspiration of the landscape

$$ET_L = K_L \times ET_O$$

The range of values for the factors that make of K_L are described in detail by UCCE and CDWR (2000) and summarised below (Table 6-3). The values used in H_2Ome*Calc* for high, moderate and low species factor (water demand), density (planting density) and microclimate (sun/wind exposure) are also summarised in Table 6-3.

Table 6-3 Values for Landscape Coefficient Factors

Factor	Ranges specified in UCCE and CDWR (2000)				
	Abbreviation	**High**	**Moderate**	**Low**	**Very low**
Species factor	K_s	0.7-0.9	0.4-0.6	0.1-0.3	<0.1
Density	K_d	1.1-1.3	1	0.5-0.9	
Microclimate	K_{mc}	1.1-1.4	1	0.5-0.9	
Factors used in H_2Ome*Calc*		**Options in H_2Ome*Calc***			
Factor	**Abbreviation**	**High**	**Moderate**	**Low**	
Species factor	K_s	0.8	0.5	0.2	
Density	K_d	1.2	1	0.7	
Microclimate	K_{mc}	1.25	1	0.7	

Note: Density was not used for lawn as it was assumed to be moderate.

6.1.4 Mulch or ground cover

Most gardens have a little mulch or organic layer (5mm). This can be increased with mulch material to improve water retention. The main atmospheric parameters that influence evaporation from the soil surface are wind speed, air temperature and relative humidity, and the parameters of the soil are porosity and thickness (Jalota, 1993). Gardeners can minimise evaporation of water from the soil by increasing the thickness of cover between the moist soil and the atmosphere, adding more mulch. H_2Ome*Calc* calculates the improvement in water retentions by assuming the garden will have some mulch (5mm) and any difference from this (25 50 or 75 mm thickness of mulch) will lead to a reduction in vapour flux or reduction in water loss from the soil surface (Figure 6-1Figure 6-1).

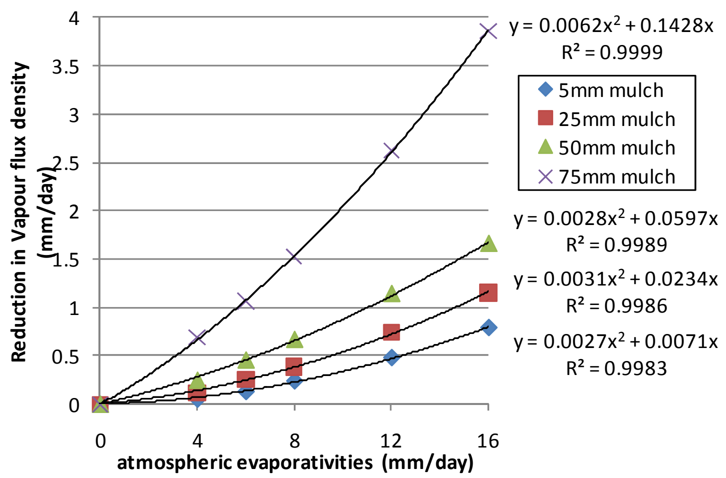


Figure 6-1 Estimates of the change in vapour loss at given atmospheric evaporativities for 5 different thicknesses of mulch (Drawn using data from Jalota, 1993).

7 Outputs

7.1 Water supply use and summary

The outputs of H_2Ome*Calc* provide the householder a summary of their water savings, listing:

- Potable water you have replaced with grey or rain water kL
- Percentage reduction in your household's water demand %
- Approximate savings for the year in $
- Cost (in infrastructure) to replace over a 10 year period $/kL
- Annual water use in your house (kL)

A summary of estimated costs and payback time is also provided, based on the householder selections.

Please note: All cost estimates are indicative only. All sites should be individually costed considering all site specific components.

There are also a number of graphical outputs from H_2Ome*Calc* which provide the householder with simple representations of:

- Water uses and sources
- Water demand, use and excess
- House – Water demand and use
- Garden – Water demand and use
- Demand and use of water (average L/person/day)

The water uses and sources graph indicates the total demand for water in the house and garden for the year (yellow bars) for toilets, bathroom, laundry, kitchen and the garden. Comparisons of volume of water supplied from mains or potable source (green bars) and how much was supplied from greywater and rainwater (purple bars) can be made.

The water demand, use and excess graph indicates monthly demands for water in both the house and garden (yellow line) and then how greywater and rainwater meet these demands. If the total demand is not met (red part of bar) and there is excess greywater or rainwater, prompting the householder to change some mains water uses to rainwater or greywater. Demand not met by greywater or rainwater will require potable or mains water.

The household and Garden water demand and use figures show the demand in the house and garden where greywater or rainwater could be used. The graphs are similar to the overall water demand graph but are split for indoor and outdoor uses.

The demand and use of water figure shows the total monthly water demand (L/person/day) for house and garden (yellow bar) and compares these monthly totals to the volumes of potable or greywater and rainwater potentially used.

7.2 Financial estimator

H_2Ome*Calc* encourages householder to take an extra step and make an informed decision and understand the costs and benefits of different options and configurations. This includes a tool to estimate the dollar savings associated with reduced mains water consumption, and required investment in a greywater system or rainwater tank. For example, plumbing rainwater to the toilet provides a useful all year round demand for water, but introduces an additional cost. Is it best for you? Or what are the costs and benefits of a bigger tank or more roof area connected to the tank?

It is important to note that this simple financial model contains a number of assumptions about the future price of water, the cost of rainwater tanks and greywater systems and the installation cost. These costs (particularly the installation cost) depend very heavily on your individual circumstances. A written quotation should always be obtained for final costings specific to a particular scenario. The aim of the financial estimator was to provide an indicative cost based on available industry data to assist the decision making process.

There are a number of greywater and rainwater use combinations that can be examined using H_2Ome*Calc* Table 7-1. The costs for these combinations of options provide the householder with an estimate of installation costs and were approximated from discussions with plumbers and assessment of previous research (MJA, 2007) (Table 7-2).

Table 7-1 Greywater and rainwater options that can be costed in $_2$Ome*Calc*

Combinations considered in H_2Ome*Calc*
Greywater Diversion
Greywater Treatment System (GTS)
Rainwater Internal and Garden
Rainwater Garden Only
Greywater Diversion and Rainwater Garden
GTS and Rainwater Internal and Garden
Greywater Diversion and Rainwater Internal and Garden
GTS and Rainwater Garden
Temporary greywater use

Table 7-2 Summary of values used to estimate cost of greywater and rainwater systems

Case	Greywater diversion systems (permanent)	Greywater treatment systems (permanent)	Rainwater tank and internal plumbing (Permanent)	Rainwater tank (Permanent)	Temporary
System (Tank or greywater system)	700	7000	1207	1207	100
Installation cost	0 to 1500[B]	1500	550	550	0
Pump Cost	200	650	650	650	0
Internal Plumbing Cost	0	730	730		0
Irrigation system cost (supply and installation)	500 [A]	50	100	100	0
O&M cost annual	50	500	20	20	0
Totals	1450	10430	3257	2527	100

[A] Irrigation area calculated as area irrigated with dripper (m^2) × \$5/ m^2 (i.e. example above is irrigation of 100 m^2 of garden or lawn.
Greywater cost from discussions with plumbers in Melbourne. Costs in other cities and town could vary significantly.
Rainwater costs estimated from MJA (2007) The cost-effectiveness of rainwater tanks in urban Australia. Canberra: Marsden Jacob Associates for the National Water Commission.
Intial plumbing costs for permanent greywater divsersion systems were dependent on the type of connection: Greywater ready houses $250; Laundry only $500; New connection to existing house $1500.

Discounted payback calculations assume:

- A new pump (where relevant) is required after 10 years.
- Increase in prices of water annually was 7.5% annually
- The initial water cost in 2010 was $2.50/KL
- Operational costs increase by 2.5% annually
- Net present value was discounted at 5.5%

Rainfall tank costs were estimated from MJA (2007):

Tank cost ($) = (117.8*P7)+490

Note: Pump operating and cost may not be required for rainwater use, gravity may be an option.

There are a number of rebates for rainwater tanks and greywater systems. More information on rebates available for installation of greywater and rainwater systems can be found on the GreySmart website.

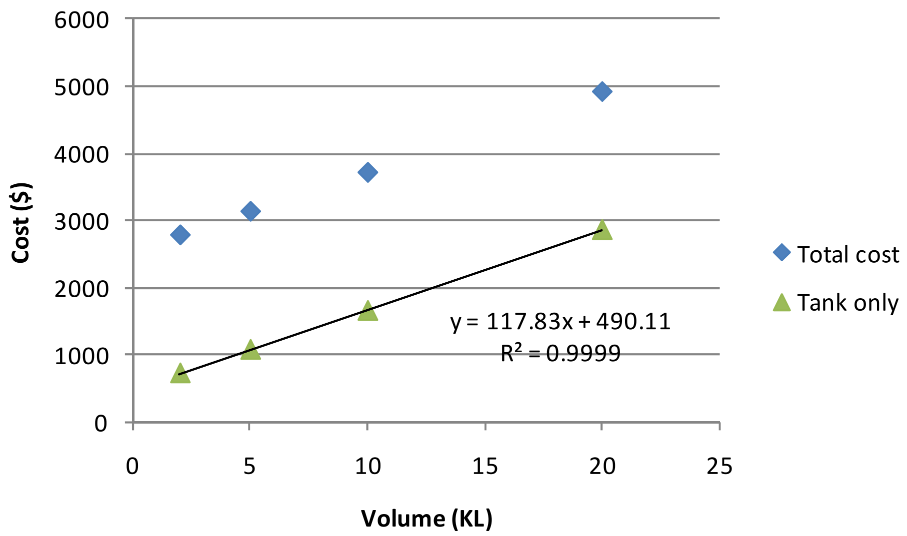


Figure 2 Estimation of rainwater tank costs (Total cost include installation, plumbing and pump (MJA, 2007).

8 References

AS/NZS (2006) AS/NZS 6400:2005 Water efficient products—Rating and labelling. Standards Australia/Standards New Zealand, Sydney and Wellington: Standards Australia/Standards New Zealand.

Coombes PJ, Kuczera G (2001) Rainwater tank design for water supply and stormwater management:Probabilistic Urban Rainfall and Wastewater Reuse Simulator (PURRS) In Port Stephens, NSW.

DEUS (2007) NSW Guidelines for Greywater Reuse in Sewered, Single Household Residential Premises. Sydney, NSW, Australia.: Department of Energy, Utilities and Sustainability. NSW Government. Available at: http://www.deus.nsw.gov.au/Publications/NSW%20Guidelines%20for%20Greywater%20Reuse%20in%20Sewered,%20Single%20Household%20Residential%20Premises.pdf.

Jalota S (1993) Evaporation through a Soil Mulch in Relation to Mulch characteristics and Evaporativity. Aust. J. Soil Res. 31:131-136

Khastagir A, Jayasuriya N (2010) Optimal sizing of rain water tanks for domestic water conservation. Journal of Hydrology 381:181-188

Lucas S, Coombes P, Hardy M, Geary P (2006) Rainwater harvesting: revelaing the detail. Water 33:89-94

Mitchell V, Siriwardene N, Duncan H, Rahilly M (2008) Investigating the Impact of Temporal and Spatial Lumping on Rainwater Tank System Modelling Available at: http://search.informit.com.au/documentSummary;dn=497046862306774;res=IELENG [Accessed December 12, 2009].

MJA (2007) The cost-effectiveness of rainwater tanks in urban Australia. Canberra: Marsden Jacob Associates for the National Water Commission.

MPMSAA, RMIT, NWC (2008) Urban greywater design and installation handbook. Melbourne, Australia: Master Plumbers and Mechanical Services Association of Australia (MPMSAA) and RMIT University for the National Water Commission.

Raine SR (1999) Research, Development and Extension in Irrigation and Water Use efficiency. A Review for the Rural Water use Efficiency Initiative. Toowoomba: National Centre for Engineering in Agriculture, University of Southern Queensland, Toowoomba in association with the Faculty of Natural and Rural Systems Management, University of Queensland, St Lucia. Available at: http://www.nrw.qld.gov.au/publications/water_management.html http://www.nrw.qld.gov.au/rwue/pdf/publications/lit_review_doc.pdf.

Roberts P (2005) Yarra Valley Water - 2004 Residential End Use Measurement Survey. Available at: http://www.manuelectronics.com.au/pdfs/YarraValleyWater2004REUMS.pdf.

SILO (2009) QNR&M Enhanced Meteorological Datasets. Available at: http://www.longpaddock.qld.gov.au/silo/ [Accessed August 28, 2009].

Tanji K, Grattan S, Grieve C, Harivandi A, Rollins L, Shaw D, Sheikh B, Wu L (2007) Salt management guide for landscape irrigation with recycled water in Coastal Southern California, a comprehensive literature review. Davis, California, USA: A peer-reviewed report to WateReuse Foundation and National Water Research Institute.

UCCE, CDWR (2000) A guide to estimating irrigation water needs of landscape plantings in California.The Landscape Coefficient Method and WUCOLS III. University of California Cooperative Extension and California Department of Water Resources. Available at: http://www.cimis.water.ca.gov/cimis/infoEtoCropCo.jsp.

Viertiz A, Gardner T, Baisden J (2007) Rainwater TANK Model Designed for Use by Urban Planners In Sydney, NSW, Australia.: Australian Water Association.

9 Appendix I

9.1 Validation Data of rainfall zones for the Rainfall Calculator

Table 9-1 Daily rainfall data used in H_2Ome*Calc*.

Location	Latitude	Longitude
Sydney	-33.65	151.20
Melbourne*	**-37.80**	**144.95**
Adelaide	-34.90	138.60
Perth	-31.95	115.85
Brisbane*	**-27.45**	**153.05**
Darwin*	**-12.45**	**130.85**
Hobart	-42.85	147.30
Canberra	-35.30	149.15
Cairns	-16.90	145.80
Alice Springs*	**-23.70**	**133.90**
Mildura	-34.20	142.15
Shepparton	-36.35	145.40
Warrnambool	-38.40	142.50
Sunshine	-37.80	144.85
Wantirna	-37.85	145.25

Source: Datadrill http://www.longpaddock.qld.gov.au/silo/datadrill/index.frames.html
*Sites selected as representative of Climate zone

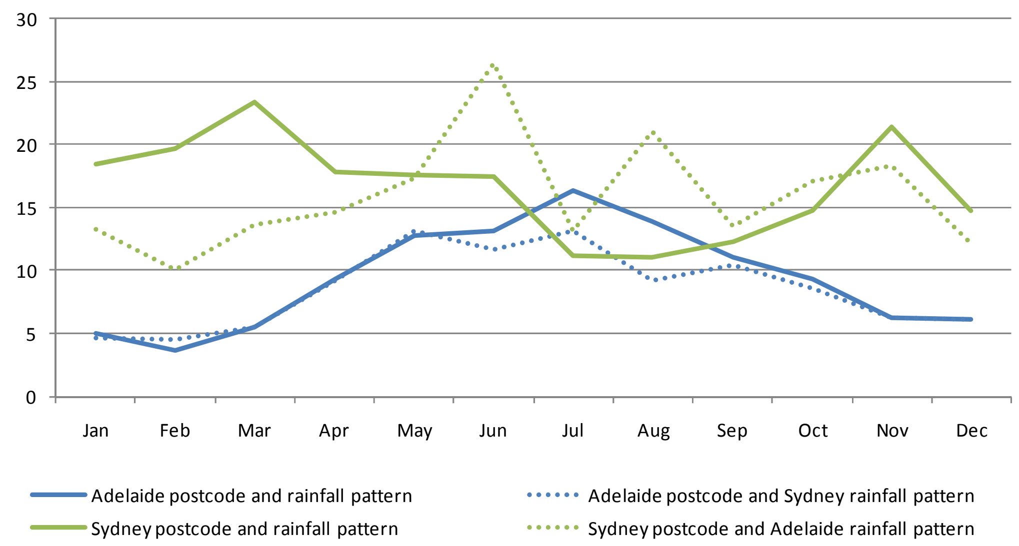


Figure 9-1 Comparison of total monthly inflow calculated in H_2Ome*Calc* for different rainfall patterns – Perth and Melbourne.

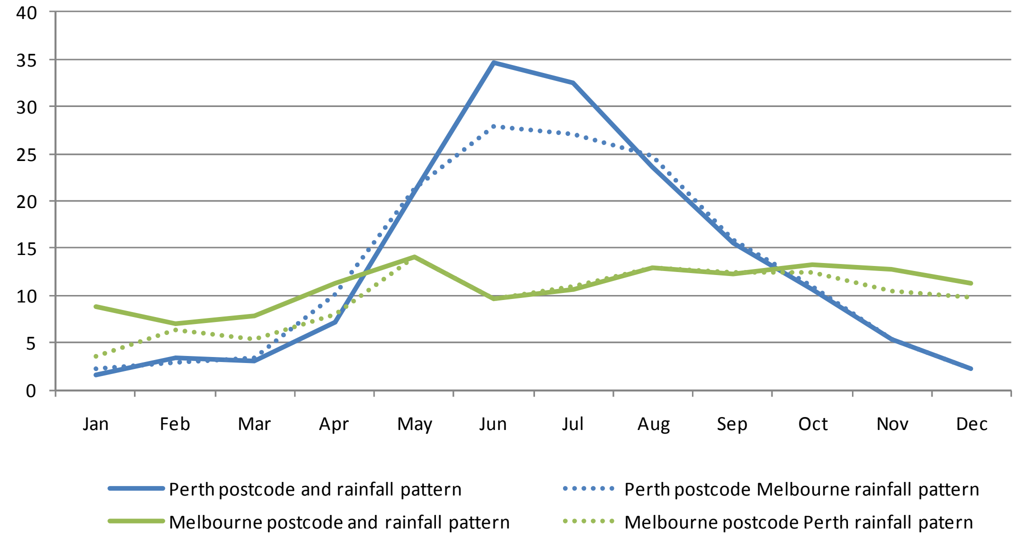


Figure 9-2 Comparison of total monthly inflow calculated in H_2Ome*Calc* for different rainfall patterns – Sydney and Adelaide.

Table 9-2 Comparisons of H_2Ome*Calc* outputs for different rainfall patterns and average monthly climate data.

Cities	**Sydney**	**Melbourne**	**Adelaide**	**Perth**	**Brisbane**	**Darwin**	**Hobart**	**Canberra**	**Cairns**	**Alice Springs**
	Comparison made and assessment if comparable (√ = yes, X = no)									
Sydney			√		√		?		X	
Melbourne			√	√		X		√		
Adelaide	X				X					
Perth		√					√	?		X
Brisbane	√		X			X		X		
Darwin		X			X				√	
Hobart	?			√						
Canberra		√			X					
Cairns	X					√				
Alice Springs				X						

10 Appendix II

Table 10-1: Sum of Squares rainfall data comparing different end year to 30 year averages

City Year End	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum of squares
Sydney													
End year													
2009	**1.3**	**2.8**	**0.2**	**4.9**	**0**	**2.7**	**0.9**	**7.4**	**3.1**	**1.2**	**0.7**	**0.4**	**25.65**
2004	3	0.2	2.3	0.6	0	19	0.2	0.7	4.7	4.3	5.6	0.8	41.03
1999	4.1	0.2	0.6	12	4.5	10	0	1.1	1.2	3.2	4.2	2.9	44.58
1994	7	6.3	4.7	0.4	0.8	9.9	0.5	0	2.8	8.7	18	0	58.66
1989	5.5	0.3	18	21	0.4	2.5	2.6	0.8	2	0.8	0.8	0.4	54.56
Melbourne													
2009	0	1.2	1.2	0.1	0.8	0.1	0.2	0	0.1	0.1	0.1	0	3.865
2004	0	1.6	1.2	0.3	0	0.1	0.1	0.1	0	0	0.2	0.3	3.834
1999	**0.1**	**0.6**	**0.1**	**0.6**	**0.1**	**0**	**0.1**	**0.4**	**0.1**	**0**	**0.2**	**0**	**2.409**
1994	0.2	0.8	0.7	0	0.2	0	1.1	0.1	0.1	2.2	0	0.4	5.773
1989	0.1	0.9	0.1	0.3	0.3	0.1	0.1	0.1	0.3	0	0.2	0.6	2.909
Perth													
2009	0.3	0.5	0	1.1	5.4	1.6	0.8	0.1	0.8	0.5	0	0	10.98
2004	**0**	**1**	**0.1**	**0.9**	**0.5**	**0.5**	**0.5**	**0**	**0.1**	**0**	**0**	**0**	**3.7**
1999	0	0	0.1	2.2	0	0.1	0.7	0.7	0	1.9	0	0	5.766
1994	0	0	0.1	0	0.1	1.3	4.3	0.1	0.7	0.8	0	0	7.565
1989	0.1	0	0.1	0	0.2	0	9.1	0	4.9	0.7	0	0	15.19
Darwin													
2009	1.7	17	11	0	0.9	0	0	0	0.3	0.5	1	26	58.64
2004	0	21	2.8	0.3	3.9	0	0	0	0	2.2	0.2	3.7	33.91
1999	0.8	1.2	7.6	0	0.2	0	0	0.1	1	0	1.9	1.2	13.99
1994	0.9	5.3	0.7	1	0.2	0.1	0	0	0.1	4	1.5	5.7	19.51
1989	**0.1**	**0.8**	**0.4**	**0.1**	**0.3**	**0.1**	**0**	**0.7**	**0.4**	**0.3**	**0**	**2.2**	**5.41**
Adelaide													
2009	0	0.5	0.1	0.4	0.3	1.8	0.1	0	0	0	0	0.1	3.488
2004	0.1	0.4	0.1	0	0	0.1	0	0	0	0.4	0.1	0	1.264
1999	0.1	0.3	0.2	0.1	0.1	0.3	0	0	0	3.2	0.3	0.3	4.92
1994	0.1	1	0.3	0	0.3	0.2	0.3	0	0	0.7	0	0	2.984
1989	**0**	**0**	**0.1**	**0.1**	**0.4**	**0**	**0.1**	**0**	**0.1**	**0.5**	**0**	**0**	**1.432**
Brisbane													
2009	3.4	7.5	4.2	2.7	7.7	4.8	1.1	0.1	0	0.8	3	1.4	36.73
2004	24	7.9	18	27	0.3	1	5.1	0	1.3	0	7.1	2.1	94.1
1999	**1.7**	**0.3**	**5**	**3.1**	**0.1**	**0.5**	**0.7**	**1.5**	**0.4**	**5.1**	**1.3**	**1.5**	**21.13**
1994	0.3	7.9	1.4	0.8	1.9	0	0.3	1.7	0.1	2.6	0.1	8.8	25.84
1989	35	4.3	11	2.6	29	0.1	0.5	0.3	0.1	4.7	0.1	0.8	87.72

City Year End	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum of squares
Hobart													
2009	4.3	0.1	0.1	1.3	0.9	0.8	1.3	0.1	1.6	0.2	0	4.3	15.05
2004	0.3	2.1	0.3	0.1	0.2	0.4	1.8	0.7	0.7	0.2	0	0.4	7.145
1999	0	0.6	0.1	0	0	0.4	0.6	1.8	1.1	0	0.6	15	19.96
1994	**0.5**	**1.8**	**0.6**	**0**	**0.7**	**0.3**	**0**	**1.4**	**1.2**	**0**	**0**	**0.1**	**6.581**
1989	0.9	0.2	1.1	0	0.2	0.4	1.1	0.1	0.7	0.3	0	4.4	9.514
Canberra													
2009	0	2.8	2.4	0.2	6.9	0	0.1	0.6	1.9	0	1.4	0	16.32
2004	**0.6**	**0.1**	**1**	**1.7**	**0.1**	**0**	**0.9**	**0**	**0.2**	**0**	**0.4**	**0**	**5.017**
1999	0.8	8.6	0.8	1.2	0	0	0.3	0.1	0	0.2	0.1	8.6	20.68
1994	0.4	6.2	0.2	2.3	0.7	0	0	0	0.2	0.4	0.1	0	10.5
1989	0.4	8.7	1.4	1.9	1.8	0	0.3	0.1	0.3	0	0.1	1.7	16.98
Cairns													
2009	**24**	**0.3**	**1.5**	**0.6**	**0.1**	**0**	**0**	**0**	**0.5**	**3.6**	**3.8**	**0.4**	**35.05**
2004	0.9	4.8	0.2	9.7	2.2	3	0	0	0	0.6	13	6.7	41.18
1999	41	3.2	3	7.4	3.1	2.3	0.2	0	0.2	0	0.5	0.2	60.58
1994	11	4.9	118	0	0.6	2.6	0	0	0.1	3.3	58	1.1	199.9
1989	32	0	111	1.6	5	0	0.1	0	1.1	0.6	0.2	0.1	151.1
Alice Springs													
2009	0.7	5	2	0.5	0.3	0.1	0.7	0	0.3	0	0	0.6	10.19
2004	0.4	4	5.5	0.2	0.2	0	0.1	0	0.3	0	0.2	0.1	11.12
1999	0.2	0	2.2	0.1	0	0.1	0.7	0	0	0	0.3	0.6	4.313
1994	2.3	0.1	0.5	0.7	0.7	0.1	0	0	0	0	0	0.4	4.88
1989	**0.5**	**0.1**	**1.1**	**0**	**0.8**	**0**	**0**	**0**	**0.2**	**0.1**	**0.2**	**0**	**3.121**