RainCycle©
Standard

Rainwater Harvesting Hydraulic Simulation and Whole Life Costing Tool v2.0

User Manual

November 2005

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1.0 Introduction

1.1 System Requirements

Minimum	Recommended
IBM Compatible PC	Intel PII 233Mhz CPU or higher + CD ROM
64Mb RAM	256Mb RAM or greater
6Mb disk space per saved file	6Mb disk space per saved file
Monitor/graphics card capable of displaying 8-bit (256) colours in 800x600 resolution	Monitor/graphics card capable of displaying 16-bit colours in 1024x768 resolution
Windows 98, ME, NT, 2000, XP	Windows 2000, XP
Excel 2000 or above	Excel 2000 or above

1.2 An Overview of Rainwater Harvesting Systems

Rainwater harvesting (RWH) systems are not new. For centuries people have collected and stored rainwater close to where it falls and used it for a number of purposes such as drinking, irrigation, watering livestock and general household use. In most developed countries the wide-spread introduction of centralised water supply systems has meant that rainwater harvesting has largely fallen out of vogue. However, in recent years there has been a renewed enthusiasm for the technique in many countries. Reasons for this renewed interest include:

- The escalating environmental and economic costs of providing water via centralised water supply systems.
- Potential cost savings associated with using rainwater in place of metered mains water.
- Benefits of rainwater over mains water for certain end uses e.g. rainwater is better than mains water for garden irrigation purposes due to its chemical composition.
- The implied sustainability benefits of using rainwater in place of mains water gives it an added attraction for environmentally-conscious citizens.

However, there are still a number of issues surrounding the use of RWH systems that act as barriers to their wider implementation. The main areas of concern are:

- <u>Uncertainty about future costs</u>. Whilst capital (installation) costs can be predicted with a fair degree of accuracy, long-term costs (such as the potential reduction in water bills and future maintenance costs) are harder to forecast.
- <u>Climate variability</u>. The weather is notoriously hard to predict with any degree of accuracy and so likely rainfall patterns, and therefore the amount of water available from the RWH system at any given time, can be difficult to determine.
- <u>Uncertainty over water demand patterns</u>. Water usage within any given building is likely to vary from day to day and predictions of water demand may have a large margin of error.

These three issues often combine and act as a deterrent to installing a RWH system.

1.3 About RainCycle Standard©

RainCycle Standard is a state-of-the-art RWH system assessment tool and is the result of several years of active research in the field of sustainable water management. The function of the application is the hydraulic simulation and whole life costing (construction, operation/maintenance and decommissioning costs) of RWH systems for residential, commercial, industrial and public buildings. It is intended as an aid to decision making and can help to remove some of the uncertainty regarding the water supply/demand fluxes and cost issues surrounding systems as highlighted in section 1.2. The Whole Life Cost (WLC) of a RWH system can also be modelled alongside the WLC of an equivalent mains-only supply system, enabling the performance and costs of the two options to be compared.

RainCycle Standard is a spreadsheet-based application written for Microsoft Excel™ and requires Excel 2000 (or above) to run.

Within the UK/EU region, the licensed version of the application comes with a CD containing, amongst other things, two Excel files. The file called *RainCycle Standard v2.0.xls* is the main application file and it is recommended that this be copied to your hard drive. When modelling your own systems, this file can be used as a template and new models should be saved under a different file name. The file called *RainCycle Standard Tutorial.xls* is a fully working version of the application that contains data relating to the RainCycle tutorial (see chapter 3).

Assumptions

The application was written primarily for RWH systems that collect, filter and store rainwater runoff from the surface of a catchment (such as a roof) for subsequent non-potable uses (such as toilet flushing, washing machines, garden irrigation and car washing). It is intended for use within the UK although it is sufficiently generic enough to be used in other countries that have comparable water supply systems. The model assumes that a metered mains water supply is available to act as a backup if the rainwater harvesting tank is empty.

Application Scope

Simulations run for a user-definable period of between 2 and 100 years, for both the modelled rainwater harvesting system and an equivalent mains-only system so that a cost comparison can be made between the two options. Any possible system can be modelled as long as the configuration is the same as that in the application. Catchment size, rainfall patterns, storage tank volume, water demand patterns etc are all user-definable and for all intents and purposes have no upper limits set on their values. Some parameters have a maximum upper value of 9,999,999 but this is large enough to accommodate any feasible system e.g. the maximum storage tank volume that can be simulated is 9,999,999m^3, far larger than any tank would need to be in reality. RainCycle Standard can be used for both new-build and retro-fit assessment purposes.

Main Features

- Storage tank size optimisation routine, which allows for the range of viable tank sizes to be identified early on in the design process.
- Cost savings optimisation routine, which allows the whole life cost and hydraulic performance of a range of tank sizes to be compared.
- Simulation of the proposed rainwater harvesting system for up to 100 years. Main results are output as: WLC comparison between the modelled rainwater harvesting system and an equivalent mains only system, percentage of water demand that the proposed system can meet and the pay-back period (in years). Average per-year hydraulic and financial results are also available.
- Ability to take into account all associated costs, such as capital (to-build), maintenance/operating and decommissioning costs.
- Detailed hydraulic and financial simulation results are also available, if required.
- Automatic report generation for the system under study. No need to copy or export results to another workbook or word processor.
- Comprehensive error-checking routines keep a track of all user-inputs. Any erroneous data entries or changes to key data will be flagged and brought to the user's attention.
- Select from three default currency types ($, € or £) or specify a user-defined currency type.

Limitations

The application is a hydraulic (mass-balance) and whole life costing simulation tool and does not model water quality. However, it does allow for the inclusion of a UV unit and will take into account the associated operating and maintenance costs. It should be noted that for most well-built and well-maintained non-potable RWH systems, the provision of adequate particle filtration prior to harvested water use is considered to be sufficient protection against water-borne infections. In rare cases where there is deemed to be an elevated risk of infection, or just for peace of mind, the use of a UV unit in addition to particle filtration is considered sufficient to virtually eliminate any risk of infection.

The application is not designed to explicitly model greywater systems (that is, systems that collect and reuse lightly contaminated water from appliances such as baths and showers, wash basins etc but *not* 'black' water, such as water from toilets or dishwashers). However, the Additional Inputs module can be used to represent the daily input of greywater, or any other source of additional water, into the storage tank. It should be noted that greywater systems are technically more complex than rainwater harvesting systems and there are also further safety concerns e.g. potential increase in risk of infection compared to purely rainwater collection systems. The application does not model any greywater specific parameters, such as chemical dosing or micro-filtration, and so the Additional Inputs feature should be used with caution.

In all cases where water quality is an important consideration, users should perform their own risk assessment and ensure that steps are taken to reduce the risk of infection to an acceptable level. In the UK, risk assessments should be performed in accordance with *WRAS Information and Guidance Note 9-02-04 (1999)*.

Inputting Data

Cells that can accept user inputs are coloured white. It is not possible to enter data into any other cells, or to alter any of the formulas in the application. Most cells requiring user input have also been data validated and will only accept values within a given range or that meet certain criteria e.g. within the range 0-9,999,999 or whole numbers only.

1.4 Data Requirements

Tables 1.1 and 1.2 show the information that is required in order to carry out a full RWH system assessment. Note that in the User Manual all financial costs are denoted in £ (pound sterling) but that the application has the option of using different currency types.

Table 1.1 - Hydraulic data required for an assessment

Parameter	Units	Comments
Rainfall data	mm/day	Daily rainfall depths for one whole year. Use actual rainfall statistics or generate a rainfall profile using the Rainfall Data Wizard
Catchment surface area	m^2	Plan area of catchment surface
Catchment surface runoff coefficient	-	Advice on selecting a suitable value is provided in chapter 2
First-flush volume	litres	Some RWH systems divert the initial 'first-flush' of effective runoff away from the storage tank. This is in order to prevent any surface contaminants (e.g. dust, leafs and twigs) from washing into the tank.
Rainwater filter coefficient	-	Advice on selecting a suitable value is provided in chapter 2
Additional water inputs	l/day	Additional daily inputs for one whole year i.e. water entering the storage tank in addition to runoff from the catchment surface, such as greywater
Storage tank volume	m^3	Storage capacity available in the modelled tank
Drain-down intervals	days	Estimation of the frequency and date of tank drain-downs e.g. to facilitate maintenance/repair work
Power rating of pump	kW	None
Pumping capacity of pump	l/min	None
UV unit power rating	W	None
Water demand	m^3/day	Daily water demand for one whole year. Use actual statistics or generate a demand pattern using the Water Demand Wizard (see also appendix 2 for additional information)

Table 1.2 - Financial data required for an assessment

Parameter	Units	Comments
Total capital cost	£	Total ‘to-build’ cost of the modelled system inc. purchase and installation of all components + VAT
Maintenance/operation schedules and associated costs	£	Estimated maintenance costs and required frequency of maintenance activities
Decommission cost	£	Total costs to remove and dispose/recycle system components
Discount rate	%	Enter a discount rate to relate future costs back to their Present Value (PV). This feature is optional
Electricity costs	p/kWhr	None
Mains water costs	£/m^3	Combined cost of supply and sewerage charges
Disposal costs	£/m^3	*Note that this is in addition to any sewerage costs* e.g. trade effluent charges. In most cases these will not apply and so there will be zero disposal cost

Advice on where parameter data can be obtained is given in chapter 2 along with some generic values in case site-specific information is not available.

The amount of data required for an assessment will depend largely on how thorough the assessment is intended to be. A basic study may require less detailed information than shown in tables 1.1 and 1.2. For example an average daily water demand could be used instead of volumes that are specific to each day.

1.5 Main Components of the RainCycle Standard© Application

1.5.1 Navigating Around RainCycle Standard

To access a module from the main System Map screen, simply click the relevant module box (see section 1.5.2 for more details). When viewing an actual module, navigation buttons will be displayed in the top right-hand corner of the screen. There will always be at least one button which will be labelled “System Map”. Click this to return to the System Map screen. Other buttons will be available if a particular module has further sub-modules. Figure 1.1 shows the navigation buttons in the Water Demand module.

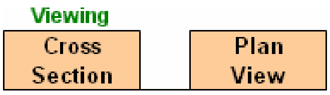
Figure 1.1 – Navigation buttons located in the Water Demand module

Some modules also have sub-modules e.g. in figure 1.1, clicking the button labelled “Demand Calculator” would open the demand calculator sub-module. All sub-modules contain at least two buttons. One labelled “System Map” and one labelled “Back”. The latter returns the user to the main module from which the sub-module is accessed.

Navigation Tabs

A number of modules contain “Navigation Tabs” (see figure 1.2). These are used to select different sections of the module. To select the required section, click on the relevant navigation tab. The word ‘Viewing’ will appear in green text over the last tab clicked, indicating which section is currently selected.

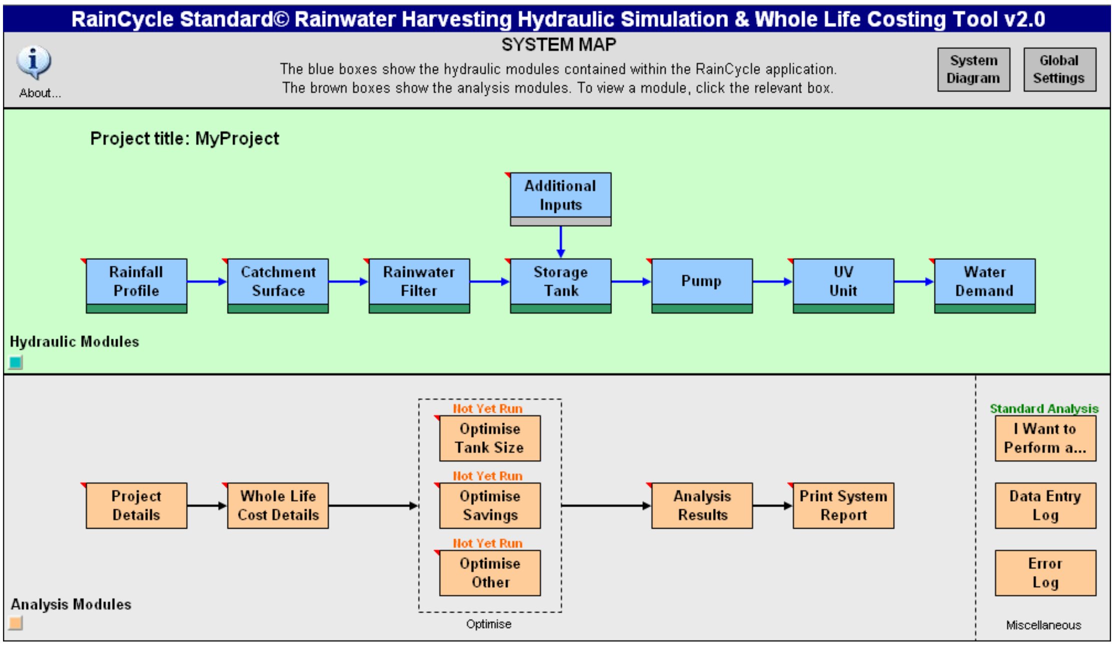
Figure 1.2 – System Diagram navigation tabs



1.5.2 System Map

The *System Map* is the main navigation screen from which the rest of the application can be accessed. The System Map is divided into three sections (see figure 1.3). The top section is the title bar and also contains buttons on the right-hand side that access the System Diagram and Global Settings modules. The middle section shows a flow diagram of RainCycle’s hydraulic modules and these represent the stages that are involved in the collection, storage and use of the harvested rainwater. The bottom section shows the analysis modules. To select a module, click the corresponding box.

Figure 1.3 – System Map screen



Located beneath each of the hydraulic module boxes is a grey rectangle. These are the module Status Boxes and they indicate the current level of information within each module by changing colour. Grey means that the key data fields in a given module are either blank or contain only zero values. Green means that the key data fields contain an entry other than zero. Red would indicate an input error e.g. text has been inadvertently entered into a numerical field. The Status Boxes allow the user to see at a glance which hydraulic modules contain data and which do not.

The Status Boxes can be turned off if required (see section 1.5.4, Global Settings module).

On the left-hand side of the screen are two small toggle buttons (one blue in the hydraulic modules section, one brown in the analysis modules section). Toggling these on/off hides or shows the sub-module boxes. When shown, these can be clicked on to open the various sub-modules. The toggle buttons are de-selected by default in order to simplify the appearance of the System Map screen.

1.5.3 System Diagram

The System Diagram consists of a series of diagrammatic sketches that show the various components found in a typical RWH system, with the components that RainCycle Standard explicitly models shown in blue (see figure 1.4). Cross section and plan view diagrams are available. If the "Show volumes" checkbox is ticked then a number of text boxes will appear showing the water volumes per year associated with each hydraulic component. All volumes are reported in m^3/yr.

Each blue-coloured component has a corresponding module which can be selected by clicking on the relevant component in the diagram.

1.5.4 Global Settings

Use this module to configure a range of global (application-wide) settings. The following parameters can be configured:

<u>Enable Status Boxes</u>

On the System Map, turns the Status Boxes on/off (see section 1.5.2 for more details).

<u>Set Analysis Runtime</u>

Set the number of years the analysis is to run for. Range: 2-100 years.

Select RWH System Cost Items

Allows the user to include/remove any of the financial items associated with the RWH system. If an item is removed, all costs incurred by that item will be given a value of zero throughout the analysis. By default, all the items are included.

Select Currency

Select the required currency type from the drop-down list. Three pre-defined currencies are available: dollars ($), euros (€) and pound sterling (£). There is also a fourth option labelled "Other". This allows for the use of currencies other than the three pre-defined ones. If "Other" is selected, further on-screen instructions telling the user how to proceed will appear (it requires the number formatting of a cell to be edited, but this is a very simple procedure).

The selected currency will be applied throughout the application (all hydraulic and analysis modules, as well as the system report)

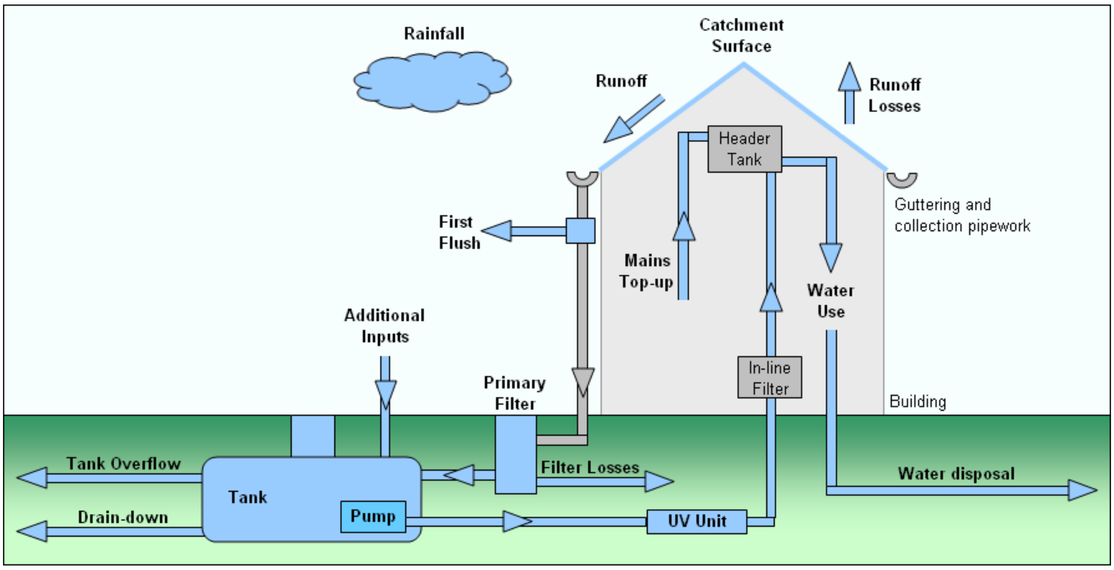
Select 1st Jan Day

Allows the user to select what day of the week the 1st of January should correspond to (the default is Monday). This feature can be useful when determining water demand patterns and it is necessary to assume that the 1st of January falls on a specific day.

1.5.5 Overview of Hydraulic Modules

A diagrammatic sketch of RainCycle's hydraulic model is shown in figure 1.4 (note that this is the same as the cross sectional diagram found on the System Diagram screen). On the diagram, each component coloured blue has a corresponding hydraulic module.

Figure 1.4 – Diagrammatic sketch showing RainCycle's hydraulic model components
(components explicitly modelled by RainCycle are coloured blue)



Rainfall Profiles

Input daily rainfall depths in mm/day for one year. Either select a monthly average rainfall profile from the data sets provided, manually input data cell-by-cell, import (copy/paste) data from another source or use the Rainfall Wizard to create a rainfall profile.

Catchment Surface

Records details of the catchment surface (the area that will be used to collect rainwater for the proposed system). Input the catchment *plan* area, runoff coefficient and first-flush volume (if any).

Rainwater Filter

Input the rainwater filter coefficient.

Storage Tank

Records details of the rainwater storage tank. Input tank *storage* volume, specify the mains top-up location (storage tank or in-building header tank) and set drain-down intervals (if any).

Additional Inputs

This module allows any water inputs other than rainwater to be taken into account. Either manually input data cell-by-cell, import (copy/paste) data from another source or use the Input Wizard. *Please note: if you intend to input greywater (e.g. water from baths/sinks) into the storage tank then there are added safety concerns that need to be taken into account. Refer back to section 1.3 (Limitations) for further details*.

Pump

Record details of the water pump. Input power rating and pumping capacity.

UV Unit

Record details of the UV unit. Input UV unit power rating and daily operating time.

Water Demand

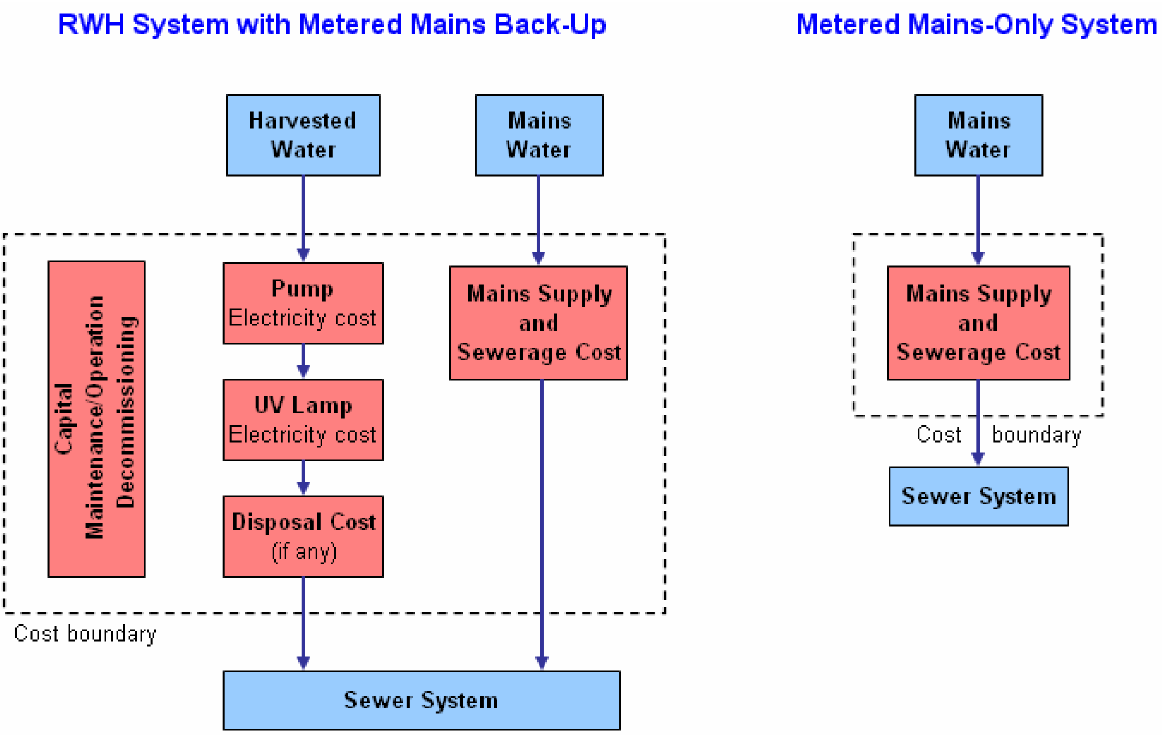
Input daily water demand data in m^3/day for one year. Either manually input data cell-by-cell, import (copy/paste) data from another source or use the Water Demand Wizard.

Note that this module also has two sub-modules. The Demand Calculator is there to help estimate the water demand for a range of building types and associated water uses. The Data Sets sub-module relates to the Water Demand Wizard and allows it to be customised to some extent.

1.5.6 Overview of Analysis Modules

A diagrammatic sketch of RainCycle's financial model is shown in figure 1.5. On the diagram, the components explicitly modelled by RainCycle are coloured red.

Figure 1.5 – Diagrammatic sketch showing RainCycle's financial model components



The cost boundary in both flow charts indicates the limit of RainCycle's financial analysis. Anything outside this boundary (shown in blue) is not modelled whilst everything inside the boundary (shown in red) is, or more precisely there is the *option* to model these items. Cost items that are not required can be deselected in the Global Settings module. Alternatively, it is always possible to input zero costs for any of the red items, effectively removing them from the analysis e.g. if there is no UV unit it can be eliminated from the assessment by entering zero values for the UV parameters, thereby giving zero running costs.

Note that the diagram for the RWH system shows that the cost of any mains top-up required is an integral part of the financial analysis. By default, RainCycle does not look at the cost of the RWH system in isolation. This is because the key factor in the financial analysis is the *overall* costs/savings presented by the RWH system and it is important to include the cost of any mains top-up required during times of short-fall. If this is not done then it would appear as though any mains water was being supplied for free and this would lead to some very strange results, such as the RWH system performing better financially the less water it delivered (since any short-fall would be made up by mains water with zero supply costs).

Project Details

Enter company and client details relating to the system under study. A number of fields are available:

- Date (default is the current Windows date. Can be overwritten if required)
- Company Details (i.e. your company details)
- Client Details
- Project Details (project title and project stage)
- Project Description

The above items are replicated in the system report. There is another field below these labelled "Project Notes". Any text entered here is for user information only and will not be replicated in the project report. (It may be necessary to scroll down to see this section, depending on the screen resolution setting).

Whole Life Cost Details

The Whole Life Cost (WLC) Details module is where the life-cycle cost data for the system under study is stored. Information relating to capital, maintenance/operating and decommissioning costs is recorded here.

Optimise Tank Size

Before an in-depth analysis is conducted, the Optimise Tank Size module can be used to give an estimate of the percentage of demand that a range of tank sizes can meet, for the catchment under study. This will help to narrow down the range of tank sizes that can provide a good balance between tank size (i.e. cost) and system performance (i.e. the amount of harvested rainwater supplied).

The Optimise Tank Size feature also contains a sub-module called “Alternative Tank Sizing Methods”, which can be accessed by clicking the corresponding navigation button located in the top right-hand corner of the screen. This sub-module contains a number of routines which are equivalent to the more common ‘rule-of-thumb’ techniques for storage tank sizing. These can be used in place of RainCycle’s own tank sizing method, although this is not recommended for larger commercial/industrial systems as they are likely to give inaccurate results.

Optimise Savings

Once a suitable range of tank sizes has been determined, obtain capital and operating costs for each and then use the Optimise Savings module to determine which tank size will give the best long-term performance.

Optimise Other

Optimise a number of other parameters for the system under study. In version 2.0, only Catchment Size Optimisation is available. Additional routines are planned for future upgrades.

Note that when performing an analysis the use of the optimise modules is optional (but recommended).

Analysis Results

Shows the analysis results for the system under study, based on the data entered in the hydraulic and analysis modules. Results are presented in two ways: 1) long-term results show how the system performs over the whole selected analysis period (in years) as compared to a mains-only system; 2) short-term results show how the system performs on a yearly basis as compared to a mains-only system.

The Analysis Results screen contains a number of sub-modules which can be accessed by clicking the navigation buttons located in the top right-hand corner of the screen.

- Per-Year Results: shows the *average* per year financial results for the system under study. For both the RWH and equivalent mains-only systems, all long-term costs are added together and then divided by the analysis runtime (in years). This gives the average running cost per year for both systems. From this the average yearly savings for the RWH system are calculated.
- Detailed Results: detailed hydraulic and financial information is available in this sub-module.

Print System Report

Once an analysis has been completed, a system report is automatically generated. The report can be printed by using Excel's built-in print function. This saves the user the time and effort of having to copy/paste the results to another workbook or application and creating their own report, although this can also be done if required.

I Want to Perform a…

Opens a dialog box which allows the appearance of the application to be changed to suit the type of analysis being performed. For the selected option, any modules that are not required are greyed out on the System Map screen. For modules that are essential but contain sections that are not required the relevant fields are greyed out.

Data Entry Log

This module provides a summary of the key parameters and associated values.

Error Log

The Error Log keeps track of potential data input errors. Most of the application has been protected and the majority of the cells that can accept user-inputs have been data validated so that erroneous entries cannot be made. However, there are a number of data ranges where this was not feasible and so an error log has been provided to track the data in these cells and to report any possible data entry errors. Table 1.3 shows the tracked ranges and highlights the circumstances in which errors will be reported.

Table 1.3 – Error Log details and possible reasons for errors

Item	Possible Reasons for Error
Rainfall Profiles module: daily rainfall depths (mm/day)	Negative number and/or text entry in rainfall depth column
Additional Inputs module: daily additional inputs (litres/day)	Negative number and/or text entry in input column
Water Demand module: daily water demand profiles (m^3/day)	Negative number and/or text entry in demand column
Whole Life Cost Details module: maintenance activities and associated costs table	Maintenance frequency of active item(s) contains an error

If any errors are detected then the Error Log box on the System Map screen will turn red. Also on the System Map, if the Status Boxes are enabled (see section 1.5.2) then the corresponding box will turn red.

Data Tracking

The application also keeps track of certain data ranges and informs the user if changes have been made to them. This is important for the Optimise Tank Size, Optimise Savings and Optimise Other modules as the current results in these depend on what data was in the application when the corresponding analysis was last run. If entries that these routines use as part of their calculations are changed and they are not re-run to take into account these changes, then the results being displayed will not represent the current data. If these changes are intended to be permanent, then the corresponding analysis should be re-run to ensure the results reflect the data in the spreadsheet.

If changes are detected, they are reported in two ways.

- On the System Map screen, the word “Changes” will appear in red text above the analysis modules that are affected (not necessarily where the change is located)
- In the analysis modules that are affected by the changes, a warning message will appear (white text on a red background) informing the user that changes have occurred and recommending that the analysis be re-run.

It should be noted that genuine data entry *errors* (not just changes to data *values*) can also trigger this response. If the Optimise Tank Size, Optimise Savings and/or Optimise Other modules are reporting changes *and* the Error Log module box has turned red (indicating that a problem has been detected), then the errors should be corrected before any analysis is re-run as this may solve the problem without the need to take any further action.

Getting Help

Most of the modules have helpful comments inserted in appropriate cells. These are denoted by a small red triangle located in the upper right-hand corner of the cell and can be viewed by hovering the mouse pointer over the appropriate cell for a few seconds. Information boxes are also provided in several modules (denoted by the Windows information icon, an ‘i’ in a speech bubble). If the information icon appears in the top left-hand corner of the screen and has the words ‘More info’ next to it, this means that the icon is clickable and will produce a pop-up dialog box which contains further information.

1.6 Learning to Use RainCycle Standard©

RainCycle Standard is a fairly large and detailed application and as such it may take some time to learn how to use all of the features properly. To help users get to grips with the software, the instruction manual contains a tutorial (see chapter 3) that goes through a full analysis of a rainwater harvesting system, utilising all of the features that RainCycle Standard offers. The tutorial is based on an actual RWH system case study and shows how to apply the software to a real-life situation.

The recommended ‘learning process’ is as follows:

1. Read chapters 1 and 2 of the manual.
2. Go through the tutorial (chapter 3) to get a feel for the software (highly recommended – you will learn more by *doing* than you will simply by *reading*)
3. Read the rest of the manual (chapter 4 and appendices 1-5)

4. Carry out a basic analysis of your own (can be based on an actual system or a fictitious one)
5. When you feel confident using the main features, begin to perform more detailed analyses. Aim to get to the stage where you can confidently use all of the available features quickly and efficiently (e.g. the optimisation modules)
6. If you get stuck, refer back to the manual or use the Information dialog boxes/comments scattered throughout the application. See also appendix 3: Trouble Shooting and Frequently Asked Questions

RainCycle Standard© is a simplified version of the full RainCycle application (also supplied as part of the software license agreement and called RainCycle Advanced©). The full application contains more sophisticated features than the Standard version and has a steeper learning curve. It may be advisable to become confident in using RainCycle Standard© before moving on to the full application.

1.7 License Details and Software Upgrades

When the application first loads, you will be presented with the License Details dialog box. You may only use the application if you are the named licensee or are an employee of the company/organisation that the license pertains to. To view the license details at any other time, go to the System Map screen and click the information icon located in the top left-hand corner of the screen.

Licenses are sold in batches. One license entitles the license holder to install RainCycle on one machine e.g. if 5 licenses are purchased then RainCycle can be installed on 5 machines in total. If further licenses are required then SUD Solutions should be contacted to discuss specific requirements.

Purchasing a software license also entitles the license holder to free after-sales support which includes upgrades and patches of RainCycle version 2 for life. Customers will be informed by email when updates/patches are available for download.

1.8 Contacting Us

For free information/advice regarding any of our products, to report bugs or to suggest improvements, please direct your emails to:

support@sudsolutions.com

Alternatively write to us at the following address:

SUD Solutions
PO Box 104
LEEDS
LS13 9AA
West Yorkshire
United Kingdom
We will endeavour to deal with any enquiries as quickly as possible.

Note: if your query is regarding the use of one of our products then we strongly advise you to refer to the instruction manual before contacting us. We are happy to answer any questions that you may have but reading the relevant part of the instruction manual can often provide the information you seek in less time than contacting our support team would.

1.9 Copyright Notice

You may only use RainCycle Standard© v2 if you are the registered license holder, or you are an employee of the registered license holder. Licences can be obtained from SUD Solutions. Visit: www.SUDSolutions.com for further details.

Windows and Excel are registered trademarks of the Microsoft Corporation.

1.10 Legal Information

SUD Solutions accept no responsibility and exclude all liability whatsoever in respect of any person's use and/or reliance upon any data generated by the RainCycle application.

1.11 Further Reading

Users who are not familiar with rainwater harvesting systems and who wish to know more are advised to consult the following documents:

CIRIA C539 (2001). *Rainwater and Greywater Use in Buildings – Best Practice Guide*. CIRIA. London, UK.

CIRIA Report 80 (2001). *Project Report 80. Rainwater and Greywater Use in Buildings – Decision Making for Water Conservation*. CIRIA. London, UK.

CIRIA Report C626 (2004). *Model Agreements for Rainwater and Greywater Use Systems*. CIRIA. London, UK.

WRAS [Water Regulations Advisory Scheme] (1999). *Information and Guidance Note. Reclaimed Water Systems: Information about Installing, Modifying or Maintaining Reclaimed Water Systems*. August 1999. No 9-02-04. Issue 1.

Note that the above resources relate to the use of rainwater harvesting systems within the UK. For countries outside the UK, refer to the relevant best practice guidance and legislation regarding the use of harvested rainwater for that specific country.

Internet Resources

An overview of rainwater harvesting systems and some freely downloadable files are available from the UK Environment Agency's website:

http://www.environment-agency.gov.uk/subjects/waterres/286587/511050/?lang=_e

2.0 Performing an Analysis with RainCycle Standard©

2.1 Detailed Design of Rainwater Harvesting Systems

Whilst it is possible to design a complete RWH system from scratch and to construct it from separately purchased components, a more common approach is to employ the services of a company that specialises in the supply of complete off-the-shelf systems. There are a number of such companies currently operating in the UK and some of these can be found in the Members Section of the UK Rainwater Harvesting Association's (UKRHA) website: http://www.ukrha.org. (Please note this link is provided for information only. SUD Solutions does not endorse any of the content this website contains).

Unless you have the necessary technical expertise to design and construct a RWH system then asking for expert advice from a specialist company is a sensible approach. Many of them offer free advice and can supply much of the basic information needed to carry out an analysis using RainCycle Standard© e.g. technical data, up-to-date capital and maintenance costs, engineering drawings and specifications and so on.

2.2 Information and Advice on Performing an Analysis

The recommended approach is as follows:

- Read through the rest of this chapter in order to gain a better understanding of the information required in order to carry out your own analysis.
- Collect as much of the required information as possible. This chapter also provides some generic data for a number of parameters which can be used in the absence of site-specific information.
- If not all the required data can be found, or if what can be acquired is not satisfactory, then a RWH company/supplier should be contacted. Most will ask for some basic information about the intended system and in return should be able to supply capital cost data, maintenance requirements/schedules, water demand estimates, technical advice, engineering drawings etc.
- Enter the details into RainCycle Standard and analyse the proposed system. Note that the level of complexity of the analysis is entirely up to the user.
- Assess the results. If the results are not acceptable, then either reject the proposed system or redesign it (e.g. increase catchment area, increase water usage). If the results are acceptable, implement the proposed system.
- If the system is to be implemented, a RWH company/supplier should again be contacted and arrangements made for delivery of the components. Installation should always be performed by a competent person, such as a qualified engineer/plumber.

2.3 The RainCycle Standard© Analysis Process

There is no universally agreed 'right' way to design and analyse a rainwater harvesting system but there are a sequence of logical steps that, if followed, will increase the likelihood of creating a successful design. This section contains a number of flow-charts which lead the user through these steps (see figures 2.1 - 2.3) and divides the design and analysis process into 3 distinct steps:

1. Step 1: determine range of suitable tank sizes
2. Step 2: determine cost savings of tanks from (1) and choose optimum size
3. Step 3: examine analysis results of selected tank from (2) and assess performance. Accept/reject/amend proposed system as appropriate.

Note that in practice there is no strict requirement to carry out steps 1 and 2, although doing so is likely to lead to a more robust design. It is entirely possible to analyse a system in which the tank size and associated costs have already been determined before an analysis is conducted.

As well as the flow-charts, advice is given on how to generate/obtain the required data. General figures are also provided for a number of parameters; these can be used in the absence of more site-specific information.

Pre-Analysis Assessment

Before any analysis is conducted, it is advisable to make explicit the aims and objectives of the proposed system. Important issues to address could include:

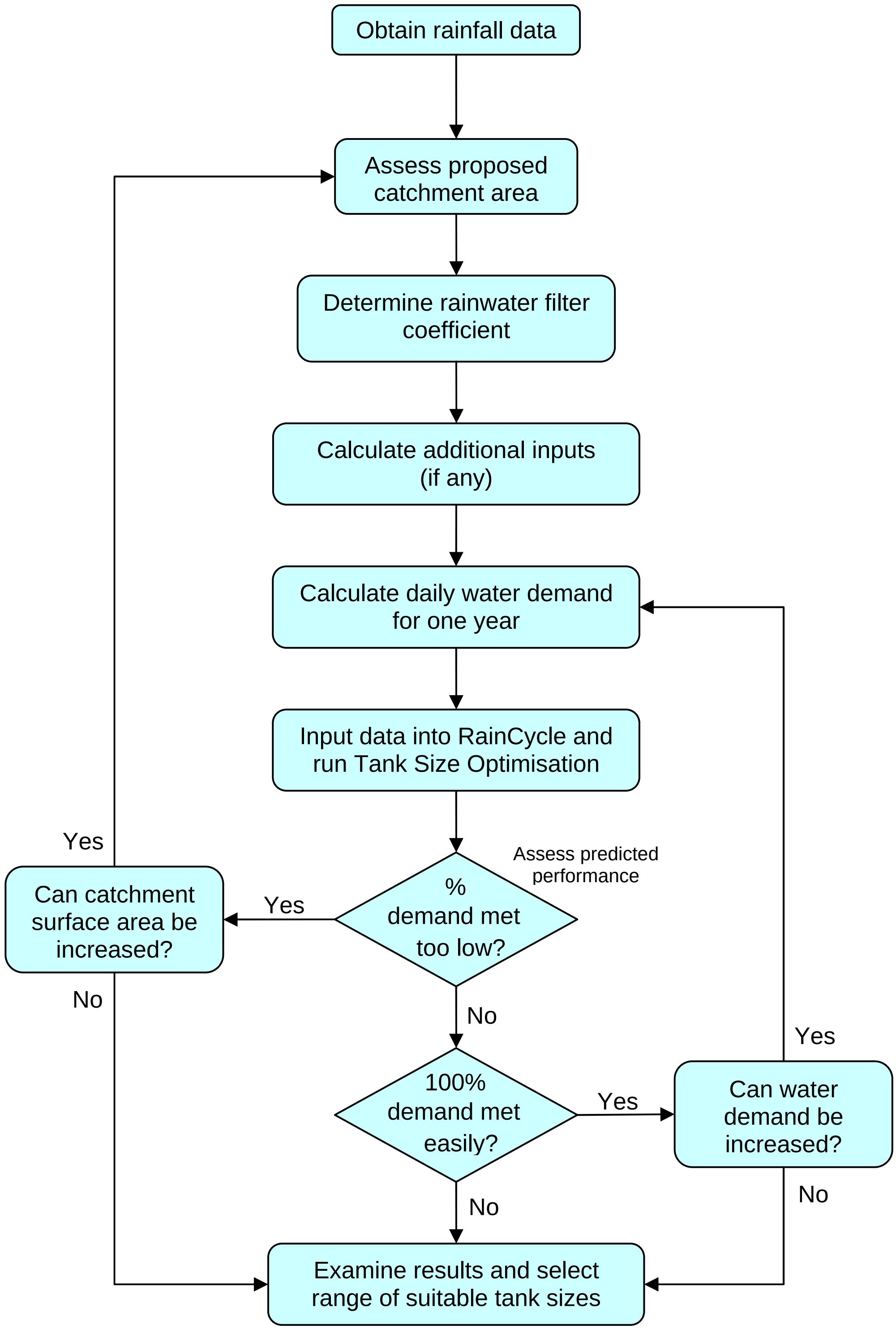
- What are the intended uses for the harvested rainwater? Will they be non-potable only or does the water require treatment to potable standards?
- Does the system require a UV treatment unit?
- What level of risk/responsibility is likely to be acceptable?
- What are the reasons for wanting a RWH system? Are they purely financial (potential water bill savings) or is there an environmental element? E.g. conservation of water resources.
- Is a short pay-back time important, or is a longer period acceptable?

Essentially it is important to have a clear idea in mind as to what the rainwater harvesting system is intended to do, the minimum level of performance that will be deemed satisfactory and what level of risk is likely to be acceptable (e.g. financial risk).

The hydraulic and financial criteria that any RWH system will have to meet are entirely up to the individual or organisation considering the system. RainCycle Standard© is ideally suited to determining whether or not these criteria can be met, and under what circumstances.

2.3.1 Step 1: Determine range of suitable tank sizes

Figure 2.1 - Step 1 flowchart



2.3.2 Obtain Rainfall Data

The amount of rainfall available for collection is one of the key factors in the success (or otherwise) of any rainwater harvesting system. It is therefore important that the rainfall data used is as accurate as possible. Since rainfall patterns vary from region to region, the rainfall data should relate to the catchment area under study.

Generally speaking there are 3 types of rainfall data available. In terms of decreasing accuracy, they are:

1. Daily rainfall statistics (mm/day)
2. Monthly rainfall statistics (mm/month)
3. Yearly total rainfall (mm/year)

Daily rainfall statistics are not always available for every location in the UK and even if they are they can be difficult to locate. Monthly rainfall statistics are easier to obtain and data sets for average monthly rainfall depths in 10 UK regions have been included with RainCycle. More data is available from the UK Met. Office (see: http://www.met-office.gov.uk).

Finally, in the absence of more accurate information, a single yearly average figure can be used. Note that this is not recommended since it does not take into account seasonal variations in rainfall patterns.

2.3.3 Assess Proposed Catchment Area

Determine Catchment Plan Area

The catchment area is the surface (usually a roof) that will collect and channel rainwater to the storage tank. It is necessary to calculate the plan area of the catchment surface i.e. the length multiplied by the width if one were looking down on the catchment from directly above. Roof areas for domestic dwellings vary from building to building but they generally fall somewhere between 50 and $100m^2$. Catchment areas for other building types (e.g. commercial or industrial) are likely to be site-specific and so will have to be determined on a case-by-case basis.

Determine Runoff Coefficient

The runoff coefficient determines how much water will flow from the catchment surface when it rains and how much is lost. Not all of the rain landing on a roof (or other surfaces) will end up in the pipe collection system. Surface wetting (the small fraction of rainfall that ‘sticks’ to a surface when it starts to rain), evaporation, ponding in depressions and the type of surface material all effect the level of effective runoff. Table 2.1 shows typical runoff coefficients for various roof types as well as some other common surfaces.

Table 2.1 – Typical runoff coefficients for various surface types

	Coefficients		
Surface Type	**High**	**Expected**	**Low**
Pitched roof tiles	0.90	0.85	0.75
Flat roof with smooth surface	0.60	0.55	0.50
Flat roof with gravel or thin turf (<150mm)	0.50	0.45	0.40
Asphalt or similar surface	0.90	0.85	0.80
Block pavements with wide joints	0.70	0.60	0.50
Gravel roads and driveways	0.30	0.20	0.15

Note: a coefficient of 0 = 0% runoff, a coefficient of 1 = 100% runoff

2.3.4 Determine Rainwater Filter Coefficient

Filter coefficients are best obtained from manufacturers or suppliers of rainwater harvesting components. In the absence of more specific data, a coefficient of 0.90 can be used.

2.3.5 Calculate Additional Inputs (if any)

Refers to storage tank inputs other than rainwater, such as greywater from baths and showers. Note that this would imply the use of a dedicated greywater system, which should be designed by a qualified engineer. It is not recommended that greywater be stored in a system that is intended for rainwater only. If the system under investigation is designed to only accept rainwater then greywater should *not* be input into the storage tank.

2.3.6 Calculate Daily Water Demand for One Year

If recorded water usage data for the building under study exists then it should be possible to calculate the daily water demand from this (appendix 3 contains further information which will be of assistance). RainCycle comes with a Demand Calculator sub-module that can be used to create a daily demand estimate. Alternatively, estimates can usually be obtained from RWH system suppliers.

It is strongly recommended that a site-specific water demand profile be determined. This is especially true for commercial, industrial and public premises since water usage here can vary widely from building to building. It is not advisable to use ‘average’ figures or data obtained from a different building. This is less of an issue for domestic dwellings since water usage per person tends to be more consistent, although site-specific data should still be obtained if possible. The Demand Calculator sub-module, which is accessible from the Water Demand screen, can be used to calculate demand values for domestic dwellings as well as commercial/industrial premises

<u>***Important Note*** The water demand estimate should *only* refer to that which is intended to be met by the rainwater harvesting system e.g. toilet flushing and washing machine supply. Do *not* include demand which is to be met by other means such as drinking water which is to be supplied only from the mains.</u>

2.3.7 Input Data into RainCycle and Run Tank Size Optimisation Analysis

Input the catchment surface area and first-flush volume (if any) as well as values for the rainfall, runoff coefficient, filter coefficient, additional inputs and water demand. Once the data has been input correctly, go to the 'Optimise Tank Size' module, enter a sensible figure in the *Max. Tank Size to Simulate* field (e.g. 20m^3 for a domestic system) and click the Analyse button.

2.3.8 Examine Results and Select Range of Suitable Tank Sizes

Once the optimisation analysis is complete, examine the results table and corresponding graph, both of which are located in the bottom half of the screen. If the system performance is satisfactory then select an appropriate range of tank sizes. Aim to select tank sizes that meet a respectable amount of the water demand but that aren't excessively large, in order to keep capital costs to a minimum. For domestic systems, tanks are usually available in sizes of 1-6m^3 so try and choose sizes that fall within this range. There is a wider range of sizes available for commercial and industrial systems and the most appropriate ones need to be selected with some care. For instance, if a 30m^3 tank can meet 85% of demand and a 15m^3 tank can meet 80% then the best choice would be the 15m^3 tank. The extra 5% that the 30m^3 tank could supply is unlikely to compensate for its increased cost over the smaller tank.

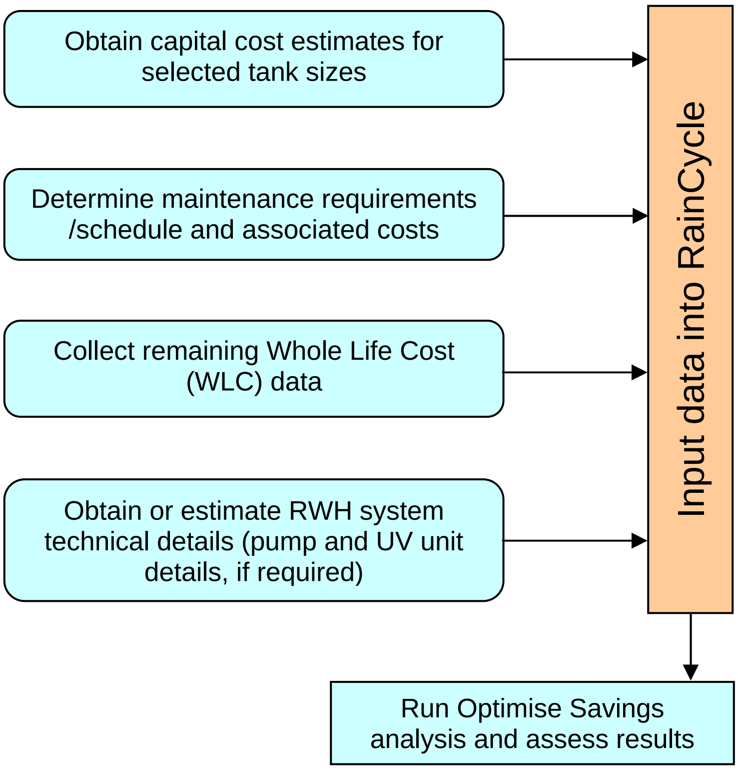
All in all, try and choose the smallest tank sizes that can meet an acceptable amount of the water demand. Any commercial/industrial RWH system that can supply 70-100% of the required volume is generally considered to provide a good level of service. Domestic systems tend to perform less well than this because of their inherent small catchment sizes (usually a house roof) and in general they can satisfy between 20-50% of non-potable demand.

Alternative Methods for Sizing Rainwater Tanks

The Optimise Tank Size module also contains a sub-module called Alternative Tank Sizing Methods, which can be accessed by clicking the corresponding navigation button located in the top right-hand corner of the screen. This sub-module contains a number of routines which are equivalent to the more common 'rule-of-thumb' techniques for storage tank sizing. These can be used in place of RainCycle's own tank sizing method, although this is not recommended for larger commercial/industrial systems as they are likely to give inaccurate results.

2.3.9 Step 2: Determine cost savings of selected tank sizes from Step 1 and choose optimum size

Figure 2.2 - Step 2 Flowchart



2.3.10 Obtain Capital Cost Estimates for Selected Tank Sizes

Capital/Installation Costs

Capital costs are best obtained from RWH system suppliers. In the absence of more accurate data, the figures in tables 2.2 and 2.3 can be used as a rough guide for capital costs (prices are for the UK, 2005). Costs for commercial/industrial systems tend to be highly site-specific; there tends to be less variation with domestic systems, although accurate up-to-date figures should still be sought. See also appendix 5 for a Bill of Quantities for a typical storage tank.

Table 2.2 – Typical capital costs for commercial/industrial RWH systems

Description	Component Costs (£)	Installation Costs (£)	Total Capital Cost (£)
10m^3 tank , no pump (gravity driven), up to 1000m^2 catchment area	3,300	3,000	6,300
10m^3 tank with pump, up to 1000m^2 catchment area	4,000	4,000	8,000
20m^3 tank , no pump, up to 3000m^2 catchment area	6,000	6,000	12,000
20m^3 tank with pump, up to 3000m^2 catchment area	6,500	6,000	12,500
30m^3 tank, no pump, up to 10,000m^2 catchment area	10,000	10,000	20,000
30m^3 tank with pump, up to 10,000m^2 catchment area	11,000	10,000	21,000

UK prices, 2005

Table 2.3 – Typical capital costs for domestic RHW systems

Tank size (m^3)	Component Costs (£)	Installation Costs (£)	Total Capital Cost (£)
1.5	1,600	1,000	2,600
2.4	1,700	1,000	2,700
3.0	1,800	1,000	2,800
4.0	1,900	1,000	2,900
5.0	2,000	1,000	3,000
6.0	2,300	1,000	3,300
6.5	2,700	1,000	3,700

UK prices, 2005

UV disinfection units cost in the region of £1200. Generally speaking, installation costs for domestic systems are approximately £1000.

2.3.11 Determine Maintenance Requirements/Schedule and Associated Costs

Maintenance schedules for commercial/industrial systems tend to be site-specific and requirements are best discussed with suppliers. Maintenance of domestic systems is normally straightforward and modern systems are designed with ease of maintenance in mind. It should be possible for the homeowner to carry out basic maintenance tasks by themselves e.g. cleaning the leaf filter. More complicated tasks, such as checking or replacing the pump, should only be carried out by a qualified individual. Table 2.4 shows a typical maintenance schedule for a domestic set-up.

Table 2.4 – Typical maintenance schedule for domestic RWH systems

Item	Activity	Frequency	Comments
Self-cleaning and/or coarse (i.e. leaf) filters	Check and clean	Every 3-6 months	Check during autumn/spring seasons
Roofs and gutters	Check and clean	1-2 times per year	Ensure adequate safety precautions are taken when cleaning roofs and gutters
Pump	Check operation and wiring	Once per year	Should only be carried out by a qualified electrician
UV unit	Check operation and replace lamp	1-2 times per year	Should only be carried out by a qualified electrician

Maintenance Costs

Maintenance costs will vary depending on whether the owner is able/willing to perform some of the activities themselves (in which case the labour cost is essentially zero), the type of maintenance required, cost of replacement items and the frequency of activities. Again, RWH system suppliers are able to provide an accurate description of the type of maintenance that a specific system requires. Some offer their own maintenance service and this is often a good way to reduce future uncertainty over costs since many just charge a flat fee to carry out the agreed works.

Approximate costs for typical maintenance activities are presented in table 2.5.

Table 2 .5 – Approximate costs for typical maintenance activities

Item	Activity	Frequency	Cost per Activity (£)
External maintenance contract	Typically consists of one visit per year to check system performance, repair/replace pump and clean filters	As agreed with contractor (usually once per year)	£250
Clean roofs and gutters	Sweep/wash roof surface to clear any debris. Unblock and clean guttering	1-2 times per year	£100
Clean filters	Check and clean all filters	2-4 times per year	£50
Pump	Check operation and wiring. Repair/replace as necessary	1 per year. Typical replacement frequency is 5-7 years	£500 to replace
UV lamp	Replace UV lamp	1-2 times per year (once is typical)	£60

2.3.12 Collect Remaining Whole Life Cost (WLC) Data

Operating Costs

Operating costs in RainCycle consist of the following items:

- Discount rate. Effects the relative cost of future financial expenditures.
- Electricity costs (to run the pump and UV unit, if applicable).
- Mains water costs
- Water disposal cost (if any).
- Cost of consumables.

Discount Rate

Future costs are heavily dependent on the selected discount rate. The discount rate is explained in appendix 1. However, the concept is not always easy to grasp and the term itself is not widely known outside of accounting circles. It should be noted that in order to use RainCycle it is not strictly necessary to take the discount rate into account. It is likely to be most applicable to businesses or large organisations that need to undertake proper financial accounting of future cash flows. It may not be particularly useful to people simply wanting a small domestic system. If this is the case, the discount rate field can be set to zero, resulting in all future costs simply being reported back at their *equivalent current price*s i.e. what those items would cost if they had to be paid for right now.

The UK Treasury currently recommends a discount rate of 3.5%. Unless this advice changes, the Expected Discount Rate should be entered as 3.5%.

Electricity Costs

Electricity prices can be obtained by contacting the local utility or from a recent electricity bill. The average price of electricity in the UK is currently about 7 pence per kilowatt hour (7p/kWhr).

Mains Water Costs

Mains supply and sewerage costs for all primary UK Water Authorities have been included in the application. Alternatively, prices can be obtained by contacting the local water utility or from a recent water bill. Note that, in the UK, the future cost of mains water is likely to increase significantly faster than the rate of inflation. Prices in some areas are predicted to rise by as much as 18% over the next five years. This is partly due to increasing water scarcity (especially in the south and southeast), increasing energy costs and more stringent environmental legislation, such as the EU Water Framework Directive (WFD).

Water Disposal Cost

Most water utilities do not charge to dispose of used rainwater to their sewer system, although this may change in the future if RWH systems become more widespread. Some large commercial/industrial sites may be subject to trade effluent charges which need to be taken into account. In most cases there will be no disposal charge and so a value of zero can be entered for the water disposal cost parameter.

Cost of Consumables

Some rainwater harvesting systems employ items that need regular replacement, such as filter cartridges or disinfectant modules. These can be taken into account by using the maintenance schedule planner located in the Whole Life Cost Details module.

2.3.13 Decommissioning Costs

Decommissioning a RWH system consists of removing/excavating the component parts and disposing of them, most likely to a landfill site. The Decommissioning Cost has its own field in the WLC Details module. Decommissioning is assumed to occur at the end of the analysis runtime period (as specified in the Global Settings module).

Decommissioning is unlikely to be an issue for domestic systems since the major components (e.g. tank, pipework) are likely to last as long as the building itself. Commercial/industrial systems may need decommissioning if the site undergoes a change of usage and the building needs to be demolished. In this case, the system is likely to be removed as part of a larger contract to clear the site and this should be taken into account when estimating the decommissioning cost. The cost of removal may be negligible when compared to the overall cost of site clearance. In this case it may be acceptable to assume a zero decommissioning cost.

2.3.14 Obtain or Estimate RWH System Technical Details

Obtain or Estimate Pump Details

Pump details are best obtained from suppliers/manufactures. In the absence of case-specific details, use the figures in table 2.6 that most closely match the proposed pump.

Table 2.6 – Generic pump data

Pump power rating (kW)	Pumping capacity (l/min at given height)		
	10m	20m	30m
0.8	60	50	30
1.0	63	55	45
1.2	65	58	52
1.4	67	60	55

Note: if power rating is in horse power, to convert to kW multiply by 0.746

Obtain or Estimate UV Unit Details

UV unit details are best obtained from suppliers/manufactures. In the absence of case-specific details, use the figures in table 2.7 that most closely match the proposed UV unit. Note that the unit must be capable of processing the maximum anticipated flow of water passing through the device (in most cases given by the pump's capacity).

Table 2.7 – Generic UV unit data

Max. flow rate (l/min)	20	45	80	140	220
Power rating (W)	35	50	60	90	100

Run Optimise Savings Routine and Assess Results

The Optimise Savings routine works by running a separate analysis for all the tank sizes input into the Tank Sizes to Analyse table. The values shown in the Summary of Required Parameters table will be applied to each tank size.

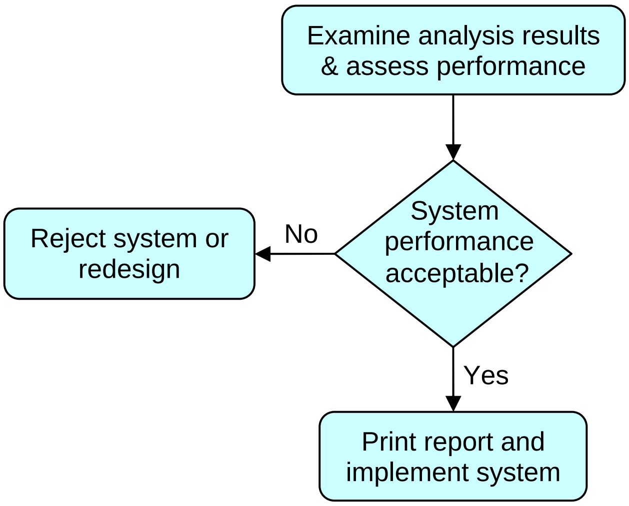
To run the analysis, click the green Analyse button. The analysis will only take a few seconds to run and the results will be displayed in the Latest Simulation Results table. Results can be sorted by using the Results Sort Criteria. Simply select the required option from the drop-down list.

Assess Results

How the results are interpreted will depend on the purpose of the RWH system. If the main goal is financial savings then the tank size with the greatest long-term savings is likely to be the best choice. Or perhaps the system with the quickest pay-back period may be more desirable, or the one that can meet the highest percentage of demand. Alternatively the tank size that has the best overall performance may be preferable – one that gives good results for long-term savings, pay-back period and percentage of demand met. Ultimately some human judgement needs to be applied when deciding which tank size to take forward to stage 3.

2.3.15 Step 3: Examine analysis results and assess performance

Figure 2.3 - Step 3 flowchart



2.3.16 Assess Performance

Whether or not performance is acceptable will depend on the criteria used to judge the system and these will vary from case to case. Potential monetary savings are obviously an important consideration but there are also the implied environmental benefits to take into account and so, even if the system has a long pay-back time or even runs at a loss, it may still be worth implementing from an environmental perspective.

Whilst there is no universal set of criteria with which to judge whether or not a RWH system should be implemented, some common assessment criteria could include:

- Does the system pay for itself within a reasonable timeframe?
- Are the long-term savings significant enough?
- Does it meet an acceptable amount of the expected water demand?

RainCycle can help to answer the above questions. It assesses both the long- and short-term performance of the proposed RWH system, determines the optimum tank size, reduces the level of uncertainty and reduces the large amount of data produced by the analysis to smaller, more manageable chunks that are easier to understand. However, the decision to implement the system or not ultimately requires a degree of human judgement.

If System Performance is not Deemed Acceptable

In this case, then there are two options to consider:

1. Reject the system outright.
2. Redesign the system so that performance becomes acceptable.

In the second case, there are a number of approaches that may be worth attempting:

- Increase water demand e.g. increase the number of proposed uses.
- Increase the catchment surface area e.g. consider collecting water from areas other than roof surfaces, such as paved areas or car parks. The Optimise Other module can be used to determine what level of demand can be met by a range of catchment sizes.
- Try and reduce costs e.g. cheaper systems may be available elsewhere, or perhaps installation/maintenance costs can be reduced through better design. Is it possible to obtain a grant or to raise more money to fund the system?
- Re-evaluate the performance criteria e.g. the system may perform poorly from a monetary point of view but have the environmental benefits also been taken into account?

If system performance is deemed acceptable, print the report and then implement the project. It may still be possible to make further improvements and so the points highlighted above are worth considering even if the scheme successfully passes the feasibility stage.

2.4 Summary of Parameter Data Sources

Table 2.8 shows a summary of the parameters that are required for an analysis and some possible sources of information.

Table 2.8 – System parameters and some possible sources of information

Parameter/Item	**Sources of Information (in order of preference)***
Rainfall Profiles	Actual site-specific rainfall profiles, obtainable from: The Met. Office; Water Authority; local Environmental Agency office (UK). Monthly average rainfall statistics (UK regional data supplied with RainCycle)
Catchment Surface	*Plan Area*: design/engineering plans of the building; physical measurement; estimate from site inspection
	Runoff Coefficient: design/engineering plans of the buildings combined with guidance in table 2.1; site investigation/observation combined with guidance in table 2.1
Rainwater Filter Coefficient	Manufacturers own technical Standardrature; use 'average' value of 0.90
Additional Inputs (if any)	Actual recorded water usage data from building under study; estimate of water usage for building under study
Daily Water Demand	Actual recorded water demand data from building under study; estimate of water demand for building under study (own estimate or contact RWH supplier)
Capital Costs	Supplier's quote for required system components and quantity surveyor's estimate of installation costs; data from previous similar schemes; average data e.g. from tables 2.2 and 2.3
Maintenance Requirement /Schedules and Associated Costs	Site-specific requirements to be discussed with system supplier and site owner/management company; review latest best practice guidance (e.g. CIRIA manuals, table 2.4); use information from previous schemes with similar characteristics

Continued on next page…

Table 2.8 (continued) – Parameters and some possible sources of information

Operating Costs	*Cost of Electricity*: Local electricity utility; recent electric bill; historic data
	Discount Rate: Determine case-specific discount rate; use latest UK Treasury recommendation (currently 3.5%)
	Cost of Mains Water: Local water utility; recent water bill; historic data. Supply and sewerage costs for primary UK Water Authorities are supplied with RainCycle
	Water Disposal Cost: Local sewerage undertaker; recent water bill/trade effluent charges agreement; historic data
	Cost of Consumables: Suppliers of required items; information from previous schemes with similar requirements
Decommissioning Costs	Quantity surveyors estimate of removal/disposal cost; information from previous schemes with similar characteristics
Obtain or Estimate RWH System Technical Details	*Pump Details*: supplier/manufacturer of pump; generic data from table 2.6
	UV Unit Details: supplier/manufacture of UV equipment; generic data from table 2.7

**In order of preference* relates to the likely accuracy of data from the listed sources i.e. the earlier a source is listed, the more accurate data from that source is likely to be compared to those listed later

2.5 Practicalities of Data Gathering

Whilst in an ideal world it would be easy to obtain all the site-specific information that RainCycle Standard requires for an analysis, the reality is that this is not always possible. Some information may not be as detailed or as accurate as is desirable, and some may not be available at all. Alternatively, information may exist but is proving difficult to track down. Given that most people have deadlines to meet and numerous responsibilities to attend to, spending large amounts of time gathering data may not be feasible.

However, this does not mean that the RWH assessment process should be abandoned altogether if accurate, site-specific information for all parameters cannot be found. Quite often, average or typical data is available that will suffice in place of more accurate information (this chapter presented a lot of generic figures that can be used in place of site-specific information). In many cases a useful analysis can still be conducted using only average or generic data. In conclusion, one should aim to get the best data that is available but there is no need to become obsessive about obtaining figures that are accurate to 10 decimal places!

3.0 A Tutorial Guide to Using RainCycle Standard©

3.1 Modelling a Rainwater Harvesting System: a Tutorial

This chapter takes the user through a tutorial which explains in detail how to conduct a full hydraulic and financial analysis of a proposed rainwater harvesting system. See the supplied Excel file called *RainCycle Standard Tutorial.xls* for a completed version. It is suggested that you go through the tutorial using the template version of RainCycle Standard i.e. the Excel file called *RainCycle Standard v2.0*. If you save the tutorial at any point, do not save it over the original *RainCycle Standard v2.0* file. Instead save it under a different file name.

The tutorial is based on an actual RWH system for a new junior school in the UK that was installed in early 2005. Note that the name of the school has been changed and the exact location of the school and name of the involved parties (a Local Authority and a design consultancy) withheld for reasons of confidentially.

3.2 High View Junior School: RWH System Assessment

A Local Authority (LA) has been given the responsibility of designing and constructing a new junior school in their region. The school has a term-time occupancy of 680 pupils and staff, consisting of 340 males and 340 females. In the interests of sustainability, the LA want to include a rainwater harvesting system within the project. However, before a decision is made as to whether or not to include one, they require an analysis to be conducted to ensure that the system will be cost effective in the long-term.

The collected rainwater will be for non-potable use, namely W.C. and urinal flushing. The risk of infection is considered to be very low and therefore no UV treatment is required.

Global Settings

The first thing to do is configure the global (application-wide) parameters. From the System Map, select the Global Settings module (click the button located in the upper right-hand corner of the screen labelled “Global Settings”).

For the purposes of the tutorial, the default settings for the *System Map Options* (all enabled), *Select RWH System Cost Items* (all included), *Select Currency* (£) and *Select 1st Jan Day* (Monday) will suffice. All that needs changing is the current value for the analysis runtime. The school building under investigation has a design life of at least 65 years, so we will use this as the length of time for the RWH system analysis. In the Analysis Runtime (yrs) field, enter 65 and press the return key (all such data entries need to be confirmed by pressing the return key once the required value has been input).

Project Details

Next, enter the project details. From the System Map, select the Project Details module and enter the information shown below:

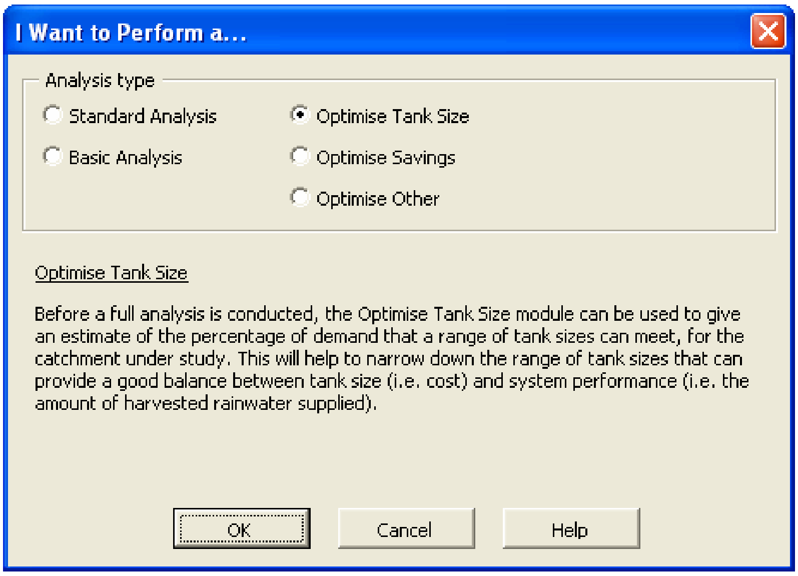
Category	**Field**	**Information to Enter**
-	Date	*Automatically completed*
-	Project Reference	HVJS-001
Company Details	Name & Address	SUD Solutions PO Box 104 Leeds West Yorkshire LS13 9AA
	Contact	Richard Smith
	Phone	(0113) 234 567
	Fax	(0113) 246 789
	Email	support@sudsolutions.com
Client Details*	Name & Address	Local Authority Education Dept. The High Street Leeds LS1 5AB
	Contact	Tony Johnson
	Phone	(0113) 283 746
	Fax	(0113) 232 435
	Email	tony.johnson@local_authority.gov
Project Details	Project Title	High View Junior School
	Project Stage	Feasibility
Project Description	-	High View Junior School is a design-and-build project with a Local Authority acting as the design agency. A rainwater harvesting system has been proposed for toilet and urinal flushing. The purpose of this report is to investigate the whole life costs of the proposed system as compared to relying solely on mains-only water and to investigate the likely long-term financial savings

*Note: client details are fictitious

3.2.1 Step 1: Determine range of suitable tank sizes

At this stage it is prudent to make use of the "I Want to Perform a…" feature in order to simplify the appearance of the program's interface. This will make it easier to follow the rest of the tutorial. Click the relevant box on the System Map screen (located on the right-hand side in the *Miscellaneous* section) to open the dialog box shown in figure 3.1.

Figure 3.1 – The "I Want to Perform a…" dialog box



This feature works by allowing the user to choose from a range of analysis types and then customising the application's interface to suit the selected option. On the System Map screen, any modules that are not required as part of the selected analysis type will be greyed out (although they can still be clicked on) to indicate that they are not needed.

The "I Want to Perform a…" feature can be very useful when learning to use RainCycle since it helps prevent information overload and focuses attention on where it is needed. For example, selecting the Optimise Tank Size option greys out all non-essential hydraulic modules (storage tank, pump and UV unit) and analysis modules (all except the Optimise Tank Size and Miscellaneous modules). For the required modules, it greys out any unnecessary elements to show they are not required for the selected analysis type.

There are 5 types of analysis to choose from. Activating an option button brings up a brief description of that option in the bottom half of the dialog box. The best way to understand how this feature works is to experiment with it i.e. work through the options one at a time and see what changes each of them makes to the user interface.

For now, select the Optimise Tank Size option and click the "OK" button. It is time to start gathering the data needed for this tutorial.

Obtain Rainfall Data

Daily rainfall statistics for the catchment area under study were not available and so predefined average monthly rainfall depths (mm/month) from the Rainfall Profiles module will be used instead. The figures shown in table 3.1 are the average monthly rainfall depths for the England E & NE region as found in the Monthly Average Rainfall Data Sets sub-module.

Table 3.1 – Average monthly rainfall depths for study catchment

Month	Rainfall Depth (mm/month)	Month	Rainfall Depth (mm/month)
January	61	July	58
February	59	August	81
March	54	September	92
April	68	October	109
May	57	November	91
June	67	December	88

Total yearly rainfall = 885 mm per annum

Assess Proposed Catchment Area

The catchment plan area was measured from design drawings of the school. The roof area available for rainwater collection was found to be 1,845m^2.

The roof material consists of pitched roof tiles and so an expected runoff coefficient of 0.85 will be used (refer to table 2.1).

Determine Rainwater Filter Coefficient

A standard coarse debris filter is to be located before the main storage tank. These typically have a filter coefficient of 0.90 and so this is an acceptable value for the system under investigation.

Calculate Additional Inputs (if any)

The system is intended to collect and store rainwater only and so there are no additional inputs to take into account.

Calculate Daily Demand for One Year

It is anticipated that demand will only occur Monday-Friday during term times and that any collected rainwater will be used for toilet (W.C.) and urinal flushing. Any shortfall in supply will be compensated for by mains top-up water.

The following information about the school's toilet facilities was obtained from design plans:

Appliance	Number	Flush volume (litres)
W.C.'s	28	6.0
Urinal ranges	10	7.5

On the System Map screen, select the Water Demand module and from there select the Demand Calculator sub-module. This module has two demand calculators available: one for domestic systems and the other for school/commercial (or similar) systems. We want the School/Commercial calculator so click the corresponding navigation tab at the top of the screen. The word 'Viewing' will appear over the School/Commercial tab, indicating that this section of the module is currently active.

Tip: If any of the features in this module are unclear then refer to the comments which have been inserted in cells throughout the worksheet (denoted by a small red triangle in the top right-hand corner of a cell). To view a comment, hover the mouse pointer over the corresponding cell for a few seconds.

Enter the following information into the Demand Calculator module:

Heading	Item	Value
Occupancy Details	Number of males	340
	Number of females	340
W.C. (Toilet) Flushing	Volume per flush (litres)	6.0
	% of males who visit W.C. per day	30%
	Number of visits per day for above	1
	% of females who visit W.C. per day	100%
	Number of visits per day for above	3
Urinal Flushing	Volume per flush (litres)	7.5
	Number of urinal ranges	10
	Operating time (hrs/day)	8.0
	Number of hours between flushes	0.5

If the figures have been entered as shown then the combined total will be given as **7.932m^3/day**. This is the figure that we will use for the term-time period, Mondays to Fridays. It is assumed that no water demand occurs during weekends or school holidays.

Input Data Into RainCycle Standard

We now have all the data required to run the Optimise Tank Size analysis. Table 3.2 shows a summary of the data collected so far.

Table 3.2 – Summary of data collected for Step 1

Parameter	Value
Annual rainfall data	*See table 3.1*
Catchment surface area	1,845m^2
Catchment runoff coefficient	0.85
Rainwater filter coefficient	0.90
Additional inputs	0m^3/day
Daily water demand	7.932m^3/day*

*During term-times, Monday-Friday only.

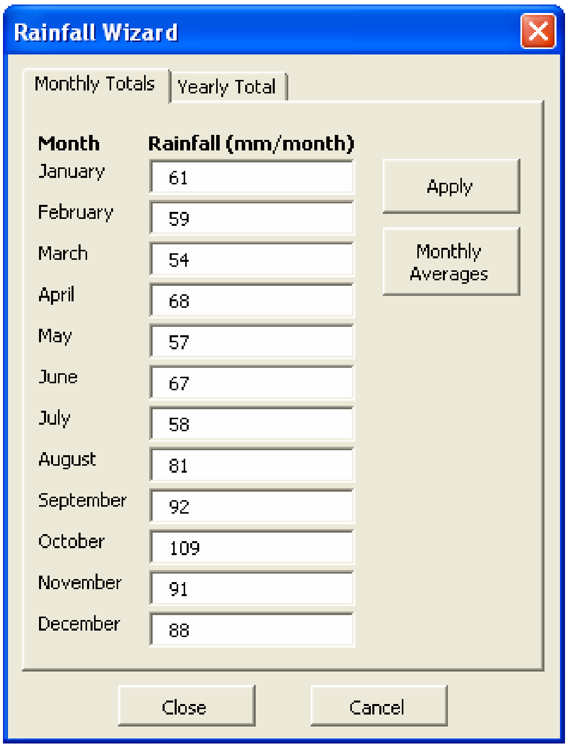
It is now time to input the above data into RainCycle Standard.

Input Average Rainfall Data

On the System Map screen, select the Rainfall Profiles hydraulic module. We are going to use one of the rainfall data sets provided with RainCycle Standard and for this it is necessary to select the Monthly Average Rainfall Data Sets sub-module. There are two ways in which to do this 1) click the button located in the top right-hand corner of the Rainfall Profiles screen labelled “Rainfall Data Sets” 2) open the Rainfall Wizard, select the tab labelled Monthly Totals and then click the button labelled “Monthly Averages” (as shown in figure 3.2).

Note that in the Rainfall Data Wizard it is also possible to input a single rainfall figure (in mm/yr) using the Yearly Total tab. In this case, when the Apply button is clicked the single figure will be disaggregated into daily averages for one whole year, with all days assumed to have the same amount of rainfall. Note that this method is likely to be inaccurate as it does not take into account seasonal variations in rainfall patterns. Alternatively, actual daily rainfall statistics can be copied/pasted directly into the relevant cells, assuming these figures are available.

Figure 3.2 – Rainfall Wizard



Select the Monthly Averages sub-module using either of the two previously mentioned methods. This sub-module has several features which are explained in more detail below.

UK Regional Rainfall Map

Shows a map of the UK divided into 10 rainfall regions.

Select UK Region from List

RainCycle Standard already contains monthly average rainfall data for each of the areas shown on the UK regional rainfall map. To select a data set, choose the required region from the drop-down list. The data for the chosen region will appear in the Currently Selected

Rainfall Statistics tables. To edit the existing UK data sets, click the text that says Edit which is located next to the drop-down list.

Select User Defined from List

There are 20 user definable data sets that can be selected from the drop down list. Each of these can be edited to suit specific requirements. Click the text that says Edit which is located next to the drop-down list to view the user definable data sets. Each data set has a number of editable fields:

- Rainfall Name: the name of a given rainfall profile e.g. its location
- Type: the type of rainfall e.g. regional, local
- Area: the name of the area that the rainfall data relates to
- Monthly Rainfall Depths: enter the actual rainfall data under the relevant month

Currently Selected Rainfall Statistics

This is where the currently selected rainfall data is displayed, along with the Type of rainfall data (regional or user-defined) and the Area that the rainfall data relates to. The button at the bottom labelled "Transfer Current Data" copies the monthly data currently in the table to the Rainfall Profiles module. Monthly rainfall depths are disaggregated into equivalent daily rainfall depths and placed in the rainfall column. If data is present in the table that has not been transferred, a message will appear underneath the table that states "current data has yet to be transferred" in order to remind the user that the data is not yet in use.

The area under study is located in Yorkshire which falls within the boundary of the England E & NE region. From the Select UK Region from List drop-down menu, select England E & NE. Rainfall data for this region will appear in the Currently Selected Rainfall Statistics tables. Click the transfer button to copy this data to the Rainfall Profiles module.

Once the data has been copied, a message box will appear stating "Transfer complete". Close this and go back to the System Map screen (click the button in the top-right hand corner of the screen labelled System Map) and then select the Catchment Surface module. Enter the catchment surface area and runoff coefficient values as shown in figure 3.3.

Figure 3.3 – Catchment surface parameters

Catchment Area		
Surface area	1,845	m^2

Runoff Coefficient	
Range 0-1	0.85

First-Flush		
First-flush volume	0	litres

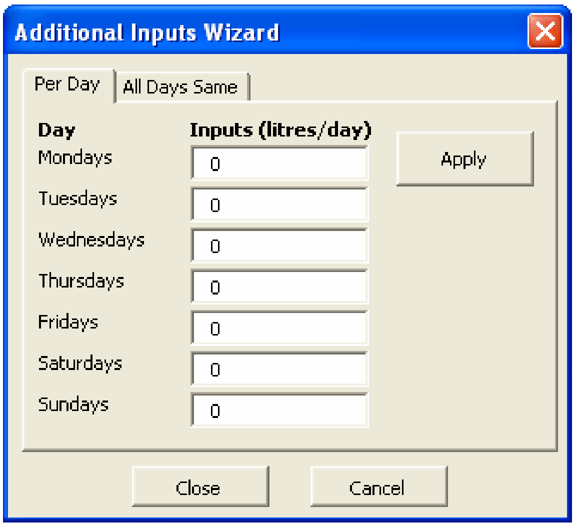
Next select the Rainwater Filter module from the System Map and enter the rainwater filter coefficient as shown in figure 3.4.

Figure 3.4 – Rainwater filter parameters

	Filter Coefficient
Range 0-1	0.90

Now select the Additional Inputs module. This module allows for the inclusion of any water entering the tank in addition to rainwater, e.g. greywater. In this example there are no additional inputs but if there were then this module would be used to represent them, in litres per day. Data can be entered manually into the appropriate cell ranges or the input wizard can be used to enter information in a similar fashion to the rainfall wizard (see figure 3.5).

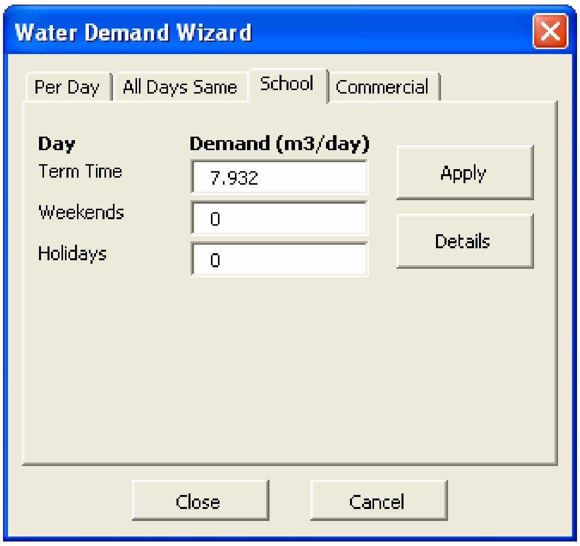
Figure 3.5 – Additional Inputs Wizard



Return to the System Map and select the Water Demand module. This is where the anticipated water demand profiles and volumes are input. Note that there is a sub-module called “Water Demand Wizard: Data Sets” which can be accessed by clicking the button labelled “Data Sets” (located in the top right-hand corner of the screen) or from the water demand wizard by clicking the button labelled “Details” (when shown). The function of this sub-module will be explained shortly, so don’t click the button just yet – just be aware that it exists.

The water demand wizard has a number of tabs that allow a variety of different demand patterns and associated water volumes to be quickly input into the module (see figure 3.6).

Figure 3.6 – Water Demand Wizard



The available options are as follows:

Per Day

Input water demand on a weekday basis (Monday-Sunday inclusive).

All Days Same

Allows only one entry which is applied to every day of the year.

School

Allows different water demand profiles to be input for Term-times, Holidays and Weekends. To view or edit the demand profiles, click the Details button to see the Water Demand Wizard Data Sets sub-module (click the button now). This allows the user to specify which days of the year should be classified as term times, holidays or weekends (although it can be assumed weekends will always mean Saturday and Sunday). The default settings correspond to typical term dates for UK schools. The contents of each cell can be changed to whatever is required by selecting a cell and choosing an entry from the drop-down list that appears. The cells are also colour-coded to show what type of day is being represented. Blue indicates a term-day, purple indicates weekends and grey represents holidays.

Commercial

Allows different demand profiles to be input for Workdays, Saturdays, Sundays and Holidays. The principle is the same as for the school demand profile and can be edited in a similar fashion. The default settings are for a typical UK business with working days being Monday-Friday inclusive, Saturdays and Sundays are self-explanatory and holiday periods are UK bank holiday dates. Again, the contents of the cells can be changed to represent a different demand profile and the cells are colour-coded to show what type of day is being represented. Blue for workdays, purple for Saturdays & Sundays and grey for holidays.

The commercial profile can be used to represent any number of building-types, such as offices, shopping centres, industrial buildings, universities, hospitals, warehouses and so on.

The default settings in the school profile are acceptable for the tutorial so go back to the Water Demand module by clicking the button in the top right-hand corner labelled “Back”.

Open the Water Demand Wizard, select the School tab and input the following:

Term-times:	7.932
Weekends:	0
Holidays:	0

The term-time demand was calculated earlier in this section. It is assumed that there will be no demand during weekends or holiday periods. Once the figures have been input, click the Apply button. The spreadsheet will then update using the school demand profile and associated water volumes, giving a total yearly demand volume of 1,546m^3/yr. Once the spreadsheet has finished inputting the figures, a message box will appear that states “Data successfully applied”. Click the OK button to close this box.

All the data that is required to run the tank size optimisation analysis has now been entered. On the System Map screen click the Optimise Tank Size box. This will take you to the storage tank optimisation screen. This module has a number of features:

Summary of Required Parameters

Displays a summary of the values entered earlier for the parameters that are used by the optimisation routine. If changes have been made since the last analysis was run then the corresponding cell in the Value column will turn yellow. Also, the simulation cannot be run if there are errors present. If all the data in the tutorial up to this point has been entered correctly then the figures in the table will match those shown below:

Rainfall Profile	885 mm/yr
Catchment Surface: catchment area	1,845 m^2
Catchment Surface: runoff coefficient	0.85
First Flush Volume	0 litres
Rainwater Filter: filter coefficient	0.90
Additional Inputs profile	0.00 m^3/yr
Water Demand profile	1,546 m^3/yr

Analysis Criteria

Max. tank size to simulate (m^3) specifies the maximum tank size that the computer should simulate before it stops the analysis. The maximum tank size that can be simulated is $1000m^3$ whilst the lowest is $2m^3$. The computer will *always* attempt to analyse the first two tank sizes ($1m^3$ and $2m^3$) since it needs at least two data points to create the corresponding results graph.

Analysis Status

Reports the current condition of the analysis.

Simulating Tank Size (m^3)

When the simulation is running this reports the size of the tank currently being modelled.

% Demand Met

The percentage of demand that can be met by the current tank size being simulated.

The following features are found in the Results section in the bottom half of the screen.

Table of Results

Stores all the results from the last analysis (tank size vs. % of demand met). Use the scroll bar on the right-hand side of the table to look through the results.

Tank Size vs. % of Demand Met Graph

Shows a graph of the percentage of water demand that each tank size simulated is predicted to meet (see figure 3.7). The graph shows all tank sizes from $1m^3$ up to the last tank size that was simulated.

Figure 3.7 – Graph of tank size vs. % demand Met

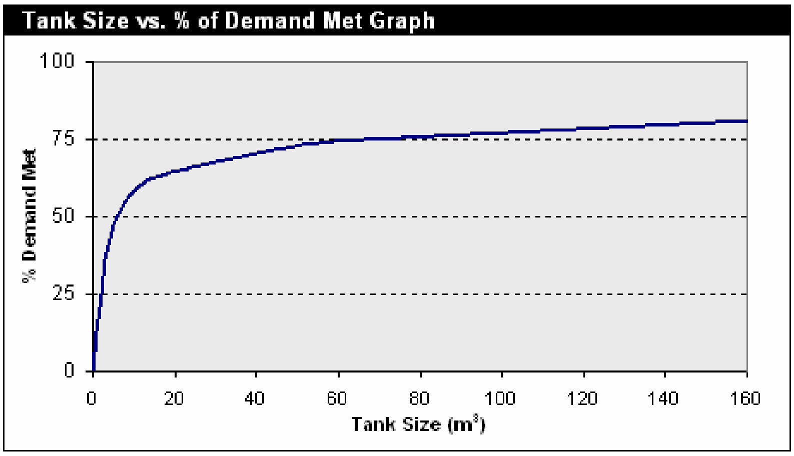


Figure 3.7 shows the graph that will be produced when the tutorial analysis is run. The graph shows a typical *tank size vs. percentage of demand met* profile and other studies concerning RWH system performance have found similar results. The percentage demand met rises quickly at first but then levels off somewhat and only small gains are seen for increasing tank sizes beyond this point. From a cost savings point of view, tank sizes far beyond the 'knee' of the graph should be avoided as they often produce only small increases in water savings but can increase capital costs significantly. Likewise, tank sizes corresponding to the steeply rising leg should be avoided *if possible* as the performance of these tanks is likely to be highly variable in practice. In the previous graph, a good range of sizes to consider would be between 15m^3 and 50m^3 as tanks within this range are likely to give a good compromise between the percentage of demand that can be met and capital costs.

Analyse the System

For the purposes of the tutorial, a maximum tank size of 200m^3 will be sufficient so enter 200 in the *Max. tank size to simulate* cell and press the green Analyse button. Simulations will run until one of three conditions are met:

1. The maximum tank size to simulate as specified by the user has been reached.
2. 100% of demand has been met.
3. Percentage of demand met has peaked i.e. it does not increase with increasing tank size.

The last two criteria were included as there is no need to simulate beyond these points since no additional water savings will be observed.

In this case the simulation will run until it reaches a tank size of 160m^3, at which point the computer will detect that the % of demand met has peaked at 80.8% and will stop the simulation.

Once the analysis is complete, examine the graph (figure 3.7). It can be seen that the % of demand met rises steeply until a tank size of about 15m^3 is reached and then it gradually tails of until little improvement is seen for all tank sizes above about 50m^3. Therefore the tank sizes we are going to investigate further should fall within the 15-50m^3 range. Note that the range of tank sizes chosen for further study is a somewhat arbitrary decision, but the results from the analysis will help to provide a clearer picture of the range of sizes that are likely to provide an acceptable level of performance.

Assess Predicted Performance

The Table of Results shows that a tank size of 15m^3 could meet 62.6% of the expected demand and a tank size of 50m^3 could meet 72.9% of demand. Whilst these figures represent a good performance for a RWH system such as this, it would still be worthwhile trying to improve the system. Two approaches are worth consideration:

1. Increase water demand – in this case not likely to result in any significant improvement since demand already exceeds supply.
2. Increase catchment surface area – will nearly always result in some improvement. However, in this case this was not possible since the entire roof area was already contributing to the RWH system and so could not be increased. The possibility of connecting other surface areas (e.g. pavements, car parking areas) was discussed but was considered to be too costly in this instance. However, these approaches may be feasible on other projects and so they are worth considering on a case-by-case basis.

This concludes Step 1 of the analysis. Step 2 will examine the range of selected tank sizes (15-50m^3) in more detail and determine which tank size will give the best financial and hydraulic performance.

3.2.2 Step 2: Determine Cost Savings of Selected Tank Sizes from Step 1 and Choose Optimum Size

From Step 1 it was determined that the tank sizes deemed suitable for further investigation are in the range of 15-50m^3. The next step was to acquire capital and running costs for a number of tank sizes that fall within this range. It should be noted that, in reality, it is highly unlikely that any supplier will have a range of tanks that cover the whole 15-50m^3 range inclusively. Tanks are normally available in distinct sizes e.g. 5, 10, 15, 27, 35m^3 and so on.

A rainwater harvesting company was contacted and asked to supply capital cost data for a number of tank sizes in the 15-50m^3 range. RainCycle's Optimise Savings routine can analyse up to 10 tank sizes at once and the company were able to supply cost data for 6 tanks within this range (one was 54m^3, slightly greater than the specified 50m^3 but close enough to be acceptable). This left some spare slots available and so costs for two smaller tank sizes were also obtained. Although tank sizes below 15m^3 are unlikely to perform well, there is no harm in including them in the cost analysis. The information supplied by the company is shown in table 3.3.

Table 3.3 – Tank sizes and associated capital costs

Tank Size (m^3)	Capital Cost (£)
4.700	5,000
6.500	5,500
10.000	8,000
15.000	10,000
20.000	11,000
27.500	13,000
30.000	13,500
36.000	16,550
45.000	18,700
54.000	20,800

Note: all systems include a pump unit

Note that this information is replicated in the Cost Examples sub-module

From the System Map screen, open the "I Want to Perform a…" dialog box and select the Optimise Savings option. Click OK and then open the Optimise Savings module and enter the figures shown in table 3.3 into the Tank Sizes to Analyse table. *Don't press the Analyse button just yet*. We still need to obtain and input maintenance/operation costs and schedules, as well as some technical details about the system. (Refer back to chapter 2, figure 2.2 for further details).

Also note the button labelled Cost Examples, which is located in the top right-hand corner of the screen. Clicking this opens a sub-module with some generic cost examples for domestic and commercial/industrial systems. The prices include all capital (purchase and installation) costs and are 'average' values for the UK, year 2005. These can be used in the absence of more accurate data. However, it is strongly recommended that, whenever possible, site-specific costs be obtained for all projects.

Determine Maintenance Requirements/Schedule and Associated Costs

The company that supplied the capital cost data also provide a maintenance service. For a flat fee of £250 a year they will send one of their engineers to site and perform the following activities:

- Check and clean all filters (leaf filter before the tank, pump filter in the tank and in-line filter in the building before the header tank).
- Check wiring and function of pump. Repair/replace pump if necessary, at no extra charge.
- Replace other components, if requested. Purchase of other components will have to be paid for independent of the maintenance contract e.g. UV lamp and filters (not relevant in this case as there is no UV unit). The engineer will fit them free of charge if they are made available.

A non-essential but recommended activity is catchment surface cleaning (i.e. clean the roof and clear gutters), which should be performed once or twice a year. Estimated costs for this are £100 per activity.

From the System Map screen, select the Whole Life Cost Details module. It is necessary to specify the planned maintenance schedule and associated costs by entering the relevant data in the Maintenance Activities and Associated Costs table.

To enter these details in the maintenance table, either edit one of the cells in the Item column or use one of the predefined settings (note that the text of any Item can be changed to suit specific requirements). Enter the required maintenance frequency (in years or months) and then input the cost of the activity *at current prices*. Also don't forget to click the tick-box in the 'Select?' column so that the program knows to take the required activities into account. The corresponding row will turn green to indicate that the item has been selected. The table should now look like figure 3.8.

Figure 3.8 – Planned maintenance schedule table

Maintenance Activities and Associated Costs					
Item	Frequency			Cost	Select?
Routine scheduled maintenance operations	**Every**	**1**	**Years**	**£250.00**	☑
Repair/replace pump	Every		Years		☐
Replace UV lamp	Every		Years		☐
Clean filters/replace filter media	Every		Years		☐
Annual cost of consumables	Every		Years		☐
Clean catchment surface	**Every**	**1**	**Years**	**£100.00**	☑
Water quality treatment items	Every		Years		☐
User Defined	Every		Years		☐
User Defined	Every		Years		☐
User Defined	Every		Years		☐

All the maintenance items in this tutorial are carried out on a yearly basis. However, there may be occasions when maintenance is required on a timescale that is measured in months, not years e.g. if a UV unit was installed then the UV filters would normally require changing at least once every six months. In this case, it would be necessary to change the frequency from the default years to months. In order to do this, select the corresponding cell that says "Years" and a drop-down list will appear. From the list, select Months (see figure 3.9).

Figure 3.9 – Set maintenance frequency timescale

User Defined	Every		Years		☐
Replace UV unit filters	**Every**	**6**	**Months**	**£60.00**	☑
User Defined	Every		Months Years		☐

(Note: figure 3.9 is an example only. Do not set the UV filter activity as part of the tutorial)

Collect Remaining Whole Life Cost Data

Operating Costs

Discount Rate

Select an appropriate value for the discount rate (for more information on discount rates see appendix 1). Enter the value 3.5 in the Discount Rate field.

Note that if you do not want to take the discount rate into account on any future projects, then simply enter zero in the Discount Rate field. This will cause all future financial costs to be reported at their equivalent current prices i.e. what those items would cost if they had to be paid for right now.

Electricity Costs

Yorkshire Electricity were contacted in order to obtain the cost of electricity for the school. A price of 5.5p/kWhr was given. Enter the value 5.5 in the Electricity Cost field.

Mains Water Costs

RainCycle Standard comes with mains supply and sewerage costs for all primary UK Water Authorities (default prices will remain current until end March 2006). Note that under the current UK pricing system, there are two components to the cost of delivering mains water: the *supply* cost and the *sewerage* cost. In most cases these two costs are simply added together to give an overall cost for supplying water and then discharging it to the sewer system, on a per cubic metre basis.

From the WLC Details module, click the button labelled “Mains Cost Data Sets” which is located in the top right-hand corner of the screen. This brings up a sub-module called “Mains Supply & Sewerage Cost Data Sets”. This sub-module is essentially the user-interface for a database of mains cost information. The user selects options from a number of drop-down lists and the spreadsheet will retrieve the cost data associated with the selected items. There are several on-screen features, which are explained in more detail below.

<u>Primary UK Water Authorities – Boundary Map</u>

Shows the operational boundaries for the 10 main Water Authorities in England and Wales.

<u>Select Building Type from List</u>

The cost database has areas for four different building types: Commercial, Office, School and Other. Note that for the default cost data sets, the mains supply and sewerage costs for all four building types are the same, but they can be edited independently if necessary e.g. when creating user-defined data sets, the costs for different building types may vary and this can be taken into account.

Select Mains Supplier from List

Select the mains water supplier from the drop-down list.

Select Sewerage Company from List

Similar to the Select Mains Supplier from List item but refers to the cost to dispose of used mains water to the sewer system. Select the sewerage company from the drop-down list.

“Edit” Button

Clicking this button opens the cost database. By default it contains mains supply and sewerage cost data for the primary UK Water Authorities as well as information for a further 22 water utilities. The majority of UK water utilities are covered by the default database. Entries in the Water Authority Name, Mains and Sewerage columns can be edited i.e. if costs need updating due to price changes.

Currently Selected Cost Data

Shows a summary of the current data:

- Mains supply cost per m^3
- Sewerage cost per m^3
- Total cost: supply + sewerage per m^3

Allow Manual Input

Clicking the associated checkbox allows the user to manually input the mains supplier, sewerage company, supply cost and sewerage cost.

For the tutorial, select “School” for the building type. Both the mains supplier and sewerage company are Yorkshire Water. Select this water authority from the drop-down lists and then click the “Transfer Current Data” button. This copies the *total* cost per cubic metre (£1.92) to the Mains Water Cost column in the WLC Details module. Once this has been done, click the button in the top right-hand corner of the screen labelled “Back”.

It is also possible to simply enter the total expected Mains Water Cost directly into the relevant cell in the WLC Details module.

Water Disposal Cost

There is no disposal cost for water originating from the RWH system, so enter 0 in the Disposal Cost field.

Cost of Consumables

There are no consumables to take into account with this system.

Capital and Decommissioning Costs

At this stage there is no need to input capital and decommissioning costs into the WLC Details module. If the Optimise Savings option was selected from the “I Want to Perform a…” dialog box then both these fields should be greyed out.

Obtain or Estimate RWH System Technical Details

Technical details for the RWH system were obtained from the same company that supplied the capital cost data for the range of tank sizes under investigation.

Pump Details

Enter the following details in the Pump module:

Power rating of pump (kW)	1.0
Pumping capacity (l/min)	60

UV Unit Details

There is no UV unit with the RWH system. In the UV Unit module, enter 0 in the Power Rating field. The words “No UV unit “ will appear, indicating that there is to be no UV treatment.

All the data that is required for the Optimise Savings analysis has now been entered. From the System Map screen, select the Optimise Savings module. If the data has been entered correctly, then the Summary of Required Parameters table will contain the following information:

Rainfall Profiles	885 mm/yr
Catchment Surface: catchment area	1,845 m^2
Catchment Surface: runoff coefficient	0.85
First-Flush Volume	0 litres
Rainwater Filter: filter coefficient	0.90
Additional Inputs profile	0.00 m^3/yr
Water Demand profile	1,546 m^3/yr
Power Rating of Pump	1.0 kW
Pumping Capacity	60 l/min
UV Unit Power Rating	0 W
Discount Rate	3.5 %
Electricity Cost	5.5 p/kWhr
Mains Water Cost	1.92 £/m^3
Water Disposal Cost	0.00 £/m^3
Number of Active Maintenance Items	2

To run the analysis, click the green Analyse button. Click the button now. The analysis will only take a few seconds to run and the results will be displayed in the Latest Simulation Results table. The results should match those presented in figure 3.10, which have been sorted according to Savings over 65yrs using the Results Sort Criteria table.

Figure 3.10 – Results from the optimise savings analysis

Use Top Rank	Latest Simulation Results (65 years)			
Tank Size (m^3)	Capital Cost	Savings over 65yrs	Pay-Back Period (yrs)	Demand Met (%)
30.000	£13,500	£30,003	9	67.8
20.000	£11,000	£29,988	8	64.6
27.500	£13,000	£29,887	9	67.0
15.000	£10,000	£29,479	7	62.6
36.000	£16,550	£28,160	12	69.3
10.000	£8,000	£27,968	6	58.1
45.000	£18,700	£27,821	13	71.7
54.000	£20,800	£27,170	14	73.5
6.500	£5,500	£25,107	5	51.2
4.700	£5,000	£21,710	5	46.2

Note: results have been sorted according to savings over 65yrs

Assess Results

From a long-term savings perspective, the results show that *all* the tank sizes simulated have the potential to save considerable sums of money. The best is the 30m^3 tank, which indicates savings of £30,003 over 65 years of operation. Note that the smaller tank sizes of 4.7m^3, 6.5m^3 and 10m^3, which are outside the range of tank sizes initially chosen, also show good results, particularly for the pay-back periods. At between 5 and 6 years, they have the shortest pay-back times of any of the tanks simulated. If a quick financial turn-around was the primary criteria, these could be a good choice of tank.

For the purposes of this tutorial, we are going to select the 30m^3 tank. It shows the best potential long-term savings, the pay-back period is not excessively long considering the type of building it is going to be installed in (the school has an expected service life of at least 65 years) and the percentage demand met value is fourth best at 67.8%. Enter the chosen tank's details into the relevant modules by clicking the button located in the top-left hand corner of the results table labelled "Use Top Rank". This transfers the details of the tank currently at the top of the results table into the relevant modules (tank size to the Storage Tank module and capital cost to the WLC Details module). Alternatively, input the details manually into the relevant modules.

This concludes Step 2 of the analysis. Step 3 will cover the performance assessment of the selected 30m^3 tank.

3.2.3 Step 3: Assess System Performance

From the System Map, open the "I Want to Perform a…" dialog box and select the Standard Analysis option in order to activate all modules and associated sections.

Then select the Analysis Results module. This will take you to the Long-Term Analysis screen. This contains a lot of information and so a more detailed explanation of this module is warranted.

Summary of Parameter Values table

Displays the values of the system parameters currently being used by the application to generate the results in the Analysis module, as shown in figure 3.11.

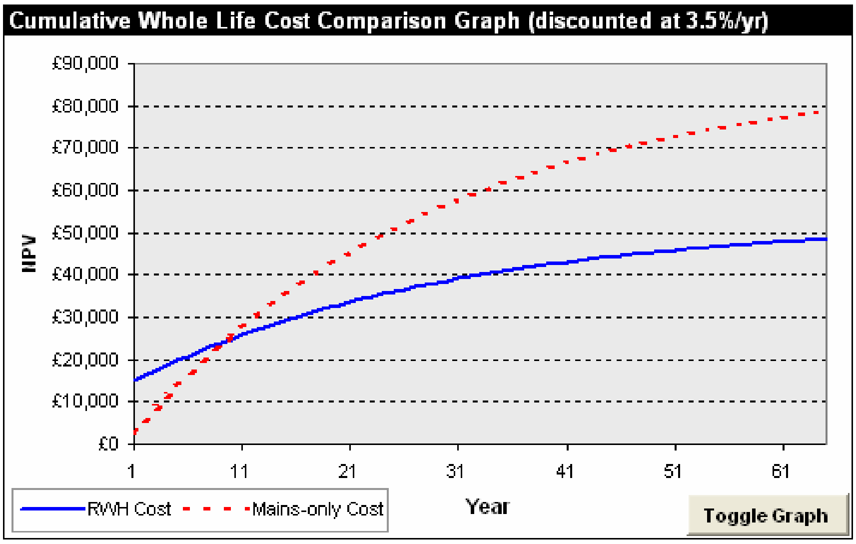
Figure 3.11 – Summary of Parameter Values table

Summary of Parameter Values		
Parameters	**Comments**	**Value**
Rainfall profile	-	885 mm/yr
Runoff coefficient	-	0.85
Filter coefficient	-	0.90
Additional inputs	-	0.0 m^3/yr
Discount rate	-	3.5 %
Electricity cost	-	5.5 p/kWhr
Mains water cost	-	1.92 £/m^3
Disposal cost	-	0.00 £/m^3
Water demand	-	1,546 m^3/yr
Capital cost	-	13,500 £
Decommissioning cost	No cost	0 £
Parameters	**Comments**	**Value**
Catchment surface area	-	1,845 m^2
First-flush volume	No first-flush	0 litres
Storage tank volume	-	30.000 m^3
Pump power rating	-	1.0 kW
Pump capacity	-	60 l/min
UV unit power rating	No UV	0 W
UV operating time	No UV	24 hrs

Cost Comparison Graphs

There are two results graphs available for the long-term analysis and these can be viewed separately by clicking the button on the graphs labelled "Toggle Graph". The *Cumulative Whole Life Cost Comparison Graph* shows the latest results in terms of the cumulative WLCs of the modelled rainwater harvesting system and an equivalent mains-only system, for the selected analysis time period. All future costs will be related back to their Present Value (PV) using the selected discount rate (see figure 3.12).

Figure 3.12 – Cumulative WLC comparison graph



The *Year-by-Year Cost Comparison Graph* shows the annual expenditure for both the RWH system and an equivalent mains-only system, for each year over the selected analysis time period. Again, all future costs will be related back to their Present Value using the selected discount rate.

Summary of Long-Term Analysis Results

This section is split into three parts: RWH system results summary, (equivalent) mains-only system results summary and comparative long-term financial summary.

The RWH System Results Summary consists of the following items:

Item	Explanation
RWH system WLC (NPV)	Rainwater harvesting system – whole life cost (at net present value)
Total water demand (m^3)	The total water *demand* from the system over the whole analysis period
Total water supplied (m^3)	The total water *supplied* by the system over the whole analysis period. Figure relates to harvested water only and does not include any mains top-up. Overall, demand met is 100% since any short-fall will be compensated for by mains supply
% demand met by harvested water	The percentage of demand that was met by the rainwater harvesting system over the whole analysis period (given by: water supplied/water demand x 100)

The Mains-Only System Results Summary consists of the following items:

Item	Explanation
Mains supply WLC (NPV)	Mains-only water supply – whole life cost (at net present value)
Total water demand (m^3)	The total water *demand* from the system over the whole analysis period
Total water supplied (m^3)	The total water *supplied* by the system over the whole analysis period
% demand met by mains water	The percentage of demand that was met by mains water. This will always be 100% for the mains-only system

The Comparative Long-Term Financial Summary consists of the following items:

Item	Explanation
RWH system savings	The whole life cost difference between the rainwater harvesting system and an equivalent mains-only system. If the rainwater system costs more in net present value terms then this region will turn red and display a negative number (effectively the net financial loss)
RWH system pay-back period (years)	The number of years it takes for the rainwater harvesting system to begin to save money i.e. the cumulative cost of supplying water from an equivalent mains-only system exceeds that of the rainwater harvesting system from this point onwards. If no savings are seen over the whole analysis period then this section will display "N/A"

Error Detection

If errors are detected in any of the modules, the message "*Warning! Errors detected. See Error Log*" will appear below the comparative long-term financial summary section and the relevant row of the Summary of Parameters Values table will turn red. It is probable that, even with errors present, the simulation will still give acceptable-looking results. In fact it may not even be apparent from the results that any erroneous data exists. However, any errors should still be tracked down via the Error Log module and corrected.

Average Per-Year Results

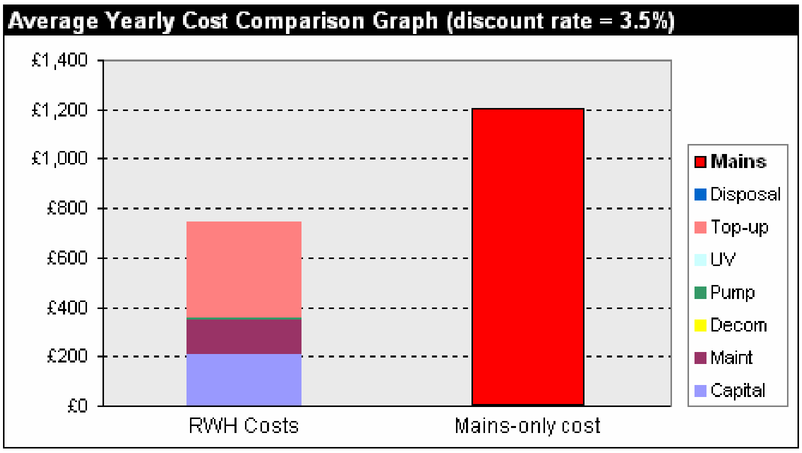
Average per-year financial and hydraulic results summaries are also available. To access this section, from the Long-Term Analysis screen, click the button located in the top right-hand corner labelled "Per-Year Results".

The financial element works by averaging the systems whole life costs over the selected analysis period and displaying the results on an equivalent per-year basis. It does this for *all* selected cost items, even those that are one-off costs (e.g. capital and decommissioning) or infrequent (e.g. long-term maintenance activities). It is possible to remove undesired cost items from the calculation by deselecting them in the Global Settings module.

The hydraulic element works by reporting the results for one year. In the hydraulic model, all years are assumed to be the same so there is no 'average' year as such.

The Summary of Average Per-Year Financial Results section highlights the yearly running cost of the RWH system and an equivalent mains-only system, as well as the annual cost savings (if any) provided by using rainwater in place of mains water. The average cost per cubic metre of water supplied from both systems is also shown, as well as various other performance-related data. A chart (see figure 3.13) shows the results graphically and breaks down the yearly RWH running cost into its component parts.

Figure 3.13 – Average Per-Year Results graph



The selected discount rate is applied to all future costs and this is reflected in the average yearly costs.

Detailed Results

Detailed hydraulic and financial information relating to the system under study is available in this sub-module (see chapter 4 of the User Manual for further details).

Examine analysis results and assess system performance

Whether the predicted performance of the rainwater harvesting system is deemed satisfactory or not will depend on the criteria used to judge the system. Criteria will vary from case to case although some, such as long-term savings, are likely to be universal. For the tutorial RWH system, the client was a Local Authority and so, whilst financial issues are important to them, they also have an obligation to take a wider range of issues into account e.g. social and environmental. Table 3.4 gives an example of the type of criteria that an institution such as a Local Authority might use to judge a RWH system.

Table 3.4 – Criteria used to judge performance of the tutorial RWH system

Criteria	Expected Value (if applicable)	Performance Acceptable?	Comments
Capital (to-build) costs	£13,500	Yes	Capital costs are significant but long-term benefits outweigh short-term costs
Expected cost savings	£30,003	Yes	Savings are over a 65 year period
Pay-back period	9 years	Yes	Operational life is at least 65 years
% Demand Met	67.8%	Yes	% demand met refers to non-potable uses only i.e. WC and urinal flushing
Health and safety: risk of infection	-	Yes	Risk of infection is deemed to be very low, even without UV treatment
Educational value: providing knowledge of sustainable practises to pupils	-	Yes	The educational value of the proposed RWH system is seen as one of the major benefits

RWH System Performance Acceptable?

In this case, all of the criteria were met and the RWH system was installed as part of the initial construction phase of the school.

Even if some of the criteria had not been met, this would not necessarily have meant that the RWH system would not have been installed. If it performed well on a number of other criteria then it may still have been worth implementing e.g. if there was a long pay-back period but over 65 years significant savings would have been seen then there would still be benefits to proceeding with the installation.

Print Report and Implement System

RainCycle Standard has an automatic report generation feature, making printing reports quick and easy. Go back to the System Map and click the Print System Report box. This will open a module which contains a preview of the report, with the screen split into two sections. On the left-hand side is the report itself and on the right-hand side is a green area which contains notes about the report, such as an explanation of each part and where the information has come from i.e. which module the data was taken from. You can access the relevant modules directly by clicking any blue underlined text e.g. clicking on the Project Details module text opens that module. Anything on the green right-hand side of the screen will not be printed.

The report consists of the following items:

- Title page
- Project details (company and customer details, project notes)
- System and whole life cost details
- Maintenance schedule and associated costs
- Analysis runtime (in years)
- Yearly and long-term hydraulic results
- Average per-year cost results
- Long-term cost results

Whenever any changes are made to the application the report will automatically update so there is no need to edit the actual report.

Have a look at the report preview now to see what information is included. There is a user-editable section denoted by a yellow rectangle located near the bottom of the title page. Any additional information can be entered here. Simply click inside the yellow rectangle and enter the required text (note that the yellow background colour will not be printed).

Printing the Report

Print formatting has already been set up and so all that is required is to tell Excel to print the report. Either click the print icon on the toolbar or go to the File menu and select print.

This concludes the tutorial, which has covered the primary functions and features of the application and demonstrated how to apply them to a real-life assessment. RainCycle Standard also contains a number of secondary features and these are discussed in chapter 4.

4.0 Other Features

4.1 Detailed Results and Graphs

More detailed analysis results are available, if required. These can be accessed by clicking the button labelled “Detailed Results”, located in the top right-hand corner of the long-term analysis screen, Analysis Results module. Clicking this button brings up a dialog box that allows the user to choose between the detailed hydraulic results and the detailed financial results. Whichever option is chosen, the user can view the various graphs and tables by clicking on the relevant navigation tabs located near the top of the screen, as shown in figure 4.1. The word ‘Viewing’ will appear above the last tab clicked, indicating which results section is currently active.

Figure 4.1 – Navigation tabs in the detailed hydraulic results sub-module

The hydraulic results are displayed in table and graph form and all data refers to one year of results (all years used in the hydraulic simulation are assumed to be the same). The financial results are displayed in tabular form only and the cost calculations are carried out independently for each year that the analysis is run for.

Some of the graphs in the hydraulic results module have two display modes: daily values or cumulative values for one year. To switch between the different modes for each set of graphs, click the button labelled “Toggle Graphs”.

It is possible to copy/paste the results tables and graphs into another Excel workbook or Windows application e.g. MS Word.

4.1.1 Detailed Hydraulic Results

The detailed hydraulic results sub-module consists of the following sections:

Parameter	Tables	Graphs
Rainfall Profiles	Summary of yearly rainfall depths	Daily and cumulative rainfall hyetographs
Catchment Surface	Summary of catchment surface data: catchment surface area, first-flush volume runoff coefficient	Daily and cumulative rainfall volume falling on catchment surface
	Summary of rainfall/runoff results: yearly volume of water falling on catchment surface, effective runoff volume and runoff losses	Daily and cumulative effective runoff volume
		Daily and cumulative runoff losses
Rainwater Filter	Rainwater filter coefficient	Daily and cumulative volume of water entering filter
	Summary of rainwater filter results: yearly volume of water passed to filter, volume of water passed to tank and volume of water lost from filter	Daily and cumulative volume of water to tank from filter
		Daily and cumulative filter losses
Additional Inputs	Summary of yearly additional inputs (if any)	Daily and cumulative additional inputs (if any)
Storage Tank	Summary of storage tank details: storage volume and number of drain-down intervals	Daily and cumulative volume of water entering tank
		Daily volume of water in tank
	Summary of storage tank simulation results: volume of water entering tank, overflow, withdrawal, total number of days per year tank is empty and longest consecutive number of days per year tank is empty	Days when drain-down occurs
		Daily and cumulative overflow from tank
Pump	Summary of pump details: power rating and pumping capacity	Daily and cumulative operating time
	Summary of pump results: operating time, total power usage and total energy usage	Daily and cumulative power usage
		Daily and cumulative energy usage
UV Unit	Power rating and daily operating time of UV unit	Daily and cumulative UV unit operating time
	Summary of UV treatment results: UV unit operating time, total power usage and total energy usage	Daily and cumulative UV unit power usage
		Daily and cumulative UV unit energy usage
Water Demand	Summary of yearly water demand	Daily and cumulative water demand
	Summary of water demand results: total yearly water demand used in simulation, average daily water demand, water supplied and shortfall	Daily and cumulative water supply from tank
		Daily and cumulative shortfall (mains top-up required)
Water Sources	Summary of water sources results: total input to tank, rainwater input to tank and additional inputs to tank (if any)	Daily and cumulative total input to tank and sources of water
		Daily and cumulative sources of water supplied to end users

4.1.2 Detailed Financial Results

The detailed financial results sub-module consists of the following sections:

Parameter	Tables
Whole Life Cost (WLC) Summary	Summary of WLC data at current prices: capital and decommissioning costs, discount rates, electricity costs, mains water costs, disposal costs and number of active maintenance items
	Summary of WLC results (at Present Value). Cost items include: capital, maintenance, decommissioning, pump operation, UV unit operation, mains top-up, total WLC of RWH system, total WLC of equivalent mains-only system and RWH system savings (if any)
	WLCs Data Table: shows detailed year-by-year results for financial calculations
Maintenance Costs	No. of maintenance items selected (active maintenance items)
	Summary of maintenance activities and associated values (at Present Value). A list of all maintenance activities, frequencies, total cumulative cost over whole analysis runtime and % of maintenance costs. Also displays the total cost (at Present Value) of all maintenance activities over the whole analysis runtime
	Maintenance costs data table: a detailed year-by-year breakdown of all maintenance activities and their yearly costs (at Present Value)
Water Costs	Summary of water cost data: mains water costs and water disposal costs (if any)
	Summary of water demand data: above average, average and below average yearly water demand figures
	Summary of long-term water supply and demand: total water demand over 'x' years; water supplied from RWH system over 'x' years and percentage of demand met by RWH system; shortfall from RWH system
	RWH system and mains-only system cost comparisons: WLC of RWH system, amount of water supplied by RWH system over 'x' years, cost of harvested water on a per m^3 basis, WLC of equivalent mains-only system and cost of mains-only water on a per m^3 basis

Note: there are no graphs with the detailed financial results. All results take into account the selected discount rate

Appendix 1

Discount Rate Explained

The *discount rate* is a financial accounting technique commonly used by businesses to discount money with time in order to help make financial decisions that span several years. Many businesses often use different discount rates depending on their aims and objectives, perceived investment risk, project timescale, current and predicted future financial criteria (e.g. interest rates) and sometimes the personal opinions and experiences of the key decision makers. To some extent the selection of an appropriate discount rate is arbitrary – there is no scientific method for selecting the “right” value.

The process of selecting the most appropriate discount rate is rather complex and thus we will not go into the details of it. Most people consider the discount rate to be related to opportunity cost of investing capital. In other words, if an investor considers receiving £100 today as equivalent to receiving £112 one year from today, then the discount rate is 12% for that investor. The discount rate is usually much higher than the interest rate that you would get from the bank since it includes risk, cost of capital, government policies, and other business factors.

It should be noted that in order to use RainCycle it is not strictly necessary to take the discount rate into account. It is likely to be most applicable to businesses or large organisations that need to undertake proper financial accounting of future cash flows. It may not be particularly useful to people simply wanting a small domestic system. If this is the case, all discount rate fields can be set to zero, resulting in all future costs simply being reported back at their *equivalent current price*s i.e. what those items would cost right now.

Whole Life Costing, Net Present Value and Discount Rates

Whole Life Costing is about identifying future costs and referring them back to present day costs using standard accounting techniques such as Present Value (PV). Different methodologies for discounting future costs exist, but PV is the simplest and most commonly used discounting method available and is appropriate for application to rainwater harvesting (RWH) systems which may have different time patterns of expenditure e.g. irregular maintenance items. It should be noted that discounting costs to a PV has limitations and is sensitive to discount rates and assumptions of future costs and the timing of these costs.

Present Value (PV) is defined by MAFF (1999) as: *"The value of a stream of benefits or costs when discounted back to the present time"*. It can be thought of as the sum of money that needs to be spent *today* in order to meet all future costs as and when they arise throughout a system's lifetime. The formula for calculating the *Net* PV is:

$$NPV = \sum_{t=0}^{t=N} Ct \, / \, (1+r/100)^{t}$$

Where: NPV = Net Present Value
N = time horizon in years
C_t = total monetary costs in year t
r = discount rate in %

The higher the discount rate, the less impact future costs will have on the Net Present Value (NPV) – see figure A1 for an example. If the discount rate is set to zero then all future costs will be returned at their equivalent current prices. Currently the UK Treasury is recommending that a discount rate of 3.5% be used (2005).

Figure A1 – graph showing effect of discount rate on Net Present Value

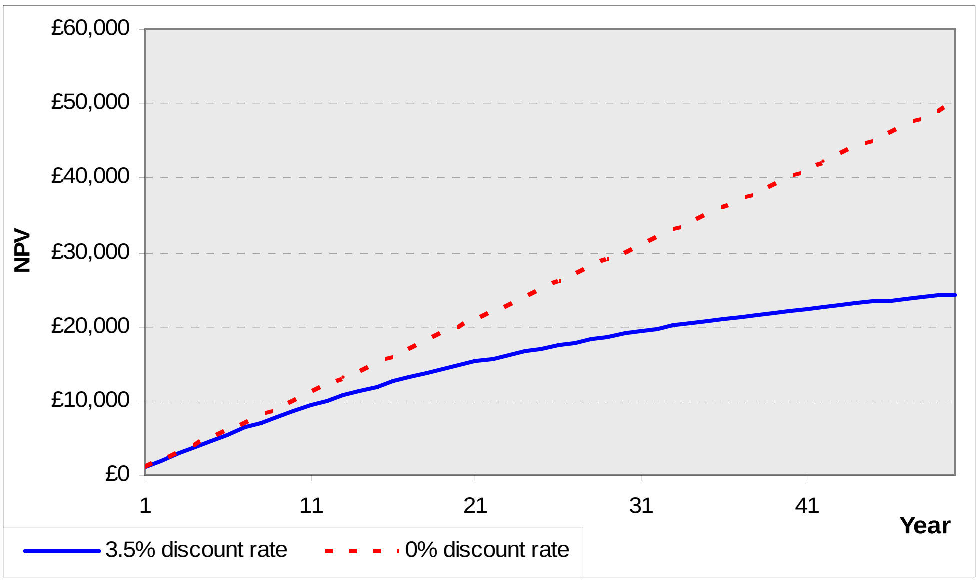


Figure A1 shows the effect of applying a discount rate of 3.5% per year for 50 years to a system that costs £1000/yr to run. The cumulative cost of the 0% discount rate scenario was calculated simply by summing the running costs for 50 years i.e. 50 x £1000/yr = £50,000. For the discounted cumulative cost, the aforementioned NPV formula was used to apply a discount rate of 3.5% per year. As the results show, this makes future costs appear to have less impact and the cumulative discounted cost in this case is equal to £24,276 over 50 years.

Appendix 2

Typical Water Uses and Associated Volumes

Each person in the UK currently uses about 150 litres of water per day, with approximately one third (50 litres) of this being used to flush the W.C. The average UK per capita water demand is predicted to rise to 165 litres per person per day by early 2020.

In a typical home the W.C. is the appliance that uses the most water, with the bath and shower forming the next largest contributions respectively. Other common end-uses can include: washing machine, wash basin, drinking, food preparation, garden irrigation and car washing.

Harvested rainwater is not normally used for potable purposes. Even though it is technically possible to treat collected rainwater to any quality required, it is often not cost effective to do so. Harvested rainwater is usually reserved for non-potable uses, such as toilet/urinal flushing, garden irrigation, washing machines and vehicle washing. In well designed and maintained RWH systems that have adequate particle filtration, the quality of water should be good enough for these end-uses without requiring any further treatment, such as disinfection.

Tables A2.1 and A2.2 show a variety of water uses and a typical range of volumes associated with each (figures are for the UK).

Table A2.1 – Non-potable end uses

Application	Volume (litres)	Comments
W.C. flushing	4.3-14.5/flush (mean = 9)	Average daily domestic usage is 43 litres/person/day. Modern 'standard' WC's use 6 litres/flush
Urinal flushing	7-9/flush	2 flushes per hour is not uncommon
Garden irrigation	1000-1200/ irrigation session	Garden irrigation has been estimated to occur once every five days in the May to August period.
Garden sprinkler	10/min	Usage varies with season
Washing machine	40-50/load	Average per person per day usage is 13-30 litres
Vehicle washing	Up to 300/wash	Assumes a hose pipe is used.

W.C. = water closet (toilet)

Table A2.2 – Potable end uses

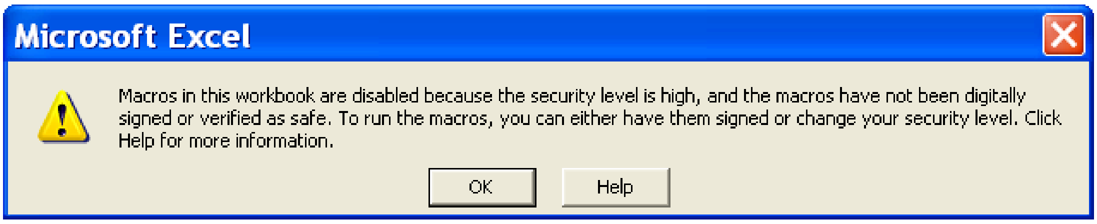
Application	Volume (litres)	Comments
Bath	Up to 80/bath	
Shower	Up to 35/shower	
Power shower	Up to 112/shower	Assumes showering lasts for 8 minutes
Wash basin	2-13/person/day	
Drinking/cooking	5-25/person/day	
Dishwasher	20-50/load	Average per person per day figure is 9-45 litres
Other uses	18-50/person/day	Non-specified uses

Both tables demonstrate that the 'average' water usage per person per day can vary significantly. However, this can be taken into account by using RainCycle's ability to model above average, average and below average daily water demand profiles.

Appendix 3

Trouble Shooting

1) None of RainCycle Standard's functions appear to be working and I get the error message shown below when I try to use the application.



In order for RainCycle Standard© to function correctly, you must have Macros enabled. This will allow Excel to run the computer code associated with the application (the code is contained within Excel's Visual Basic for Applications [VBA] module). The code only interacts with the RainCycle Standard application itself. It will not affect any other spreadsheets or other computer programs that may be running, nor will it affect the PC in any way. To enable Macros, go to: Tools > Macro > Security. Change the security setting to *low* or *medium* (medium is recommended) and click OK. You will have to close the application and then reopen it in order for the changes to take effect.

2) The individual worksheets do not fit onto one screen, or they do but the text and other features are unclear because they are too small.

The suggested screen resolution for running RainCycle Standard© is 1024x768 pixels. If the resolution is lower than this then the individual worksheets will not fit within the screen space available and it will be necessary to scroll the display in order to access all the features. If the resolution is higher, the individual worksheets will fit on the screen but the text and other features may be too small to be readable or usable. If this is the case you should change the resolution to the recommended 1024x768 pixels. To do this, place the mouse pointer on the desktop and click the right mouse button. A menu will appear. Select: Properties > Settings. In the dialog box that appears, there will be a section labelled 'Screen Resolution'. You can change the resolution to the recommended 1024x768 here, if you so wish.

Also check that Excel's Zoom function is set to the correct value for use with RainCycle. Go to: View > Zoom and make sure that the magnification is set to 100%.

3) Whenever I try to copy/paste data from RainCycle Standard© to another workbook it copies all the cell formatting and the formulas. All I want are the actual figures!

In order to copy only the figures, select the range you want and copy it into memory. Then, on the destination worksheet, right-click on the target cell and from the menu that appears select *Paste Special*. Another menu will appear. Select either *Values* (if you just want the actual values) or *Values and number formats* if you also want to retain cell formatting.

Frequently Asked Questions

Q) Can RainCycle Standard© be used to model greywater or combined rainwater/greywater systems?

A) The application can model the *hydraulics* and *whole life costs* of such systems by using the Additional Inputs module to take into account the inflow of greywater to the storage tank and the maintenance planner in the WLC module to take into account the maintenance requirements. However, it should be noted that there are additional water quality issues with greywater systems and that RainCycle Standard does not explicitly model these.

Q) I don't understand what the discount rate is all about. Help!

A) The discount rate is explained in appendix 1. However, the concept is not always easy to grasp and the term itself is not widely known outside of accounting circles. In order to use the program it is not strictly necessary to take the discount rate into account. It is likely to be most applicable to businesses or large organisations that need to undertake proper financial accounting of future cash flows. It may not be particularly useful to people simply wanting a small domestic system. If this is the case, the discount rate field can be set to zero, resulting in all future costs simply being reported back at their *equivalent current price*s i.e. what those items cost right now.

Q) Why doesn't the financial analysis take into account the mains supply standing charge?

A) Any standing charge costs are assumed to apply equally to both the RWH system (due to the presence of mains back-up) and an equivalent mains-only system. Because the standing charge applies equally to both systems (i.e. it costs the same) then it makes no overall difference to the comparative study and so was left out of the analysis.

Q) When simulating a system, is it necessary to utilise all of the features, as demonstrated in chapter 3 of the manual (the tutorial chapter)?

A) No. The chapter 3 tutorial demonstrates how to use all of RainCycle Standard's main features and highlights its powerful analytical functions. However, the level of detail that you go into when performing your own analysis is entirely up to you. For example, it is not strictly necessary to use the Optimise Tank Size and Optimise Savings modules. RWH system details can be input directly into the main hydraulic and analysis modules without the need to run the optimisation part of the analysis first, although this may ultimately lead to a less robust design.

Q) How reliable are the results?

A) As with any computer simulation, the accuracy of the results depends to a large extent on the accuracy of the information input by the user. As always, the acronym GIGO (garbage in, garbage out) applies. Therefore, the data input into the application should be as accurate and applicable to the catchment area/system under study as possible. Further, any computer simulation is only a representation of the real world. Simulations are useful tools but they will never be 100% accurate due to fundamental limits in human knowledge. They are unlikely to include any unusual site-specific criteria nor be able to model all the 'fine details'. However, this particular modelling tool includes all the major components that are applicable to rainwater harvesting systems and is based on current best practice methods and state-of-the-art research. Hence the results, although they should not be treated as definitive, will be accurate enough to give a good indication of likely system performance and whole life costs.

Q) Why didn't you include feature 'X' in RainCycle Standard?

A) We tried to include all the major components employed by the majority of rainwater harvesting systems, although it is acknowledged that some may have uncommon site specific requirements and so cannot be modelled explicitly with the application. However, even in these cases there should be enough flexibility in the software to be able to model *most* of the system components and for the results to still be useful in predicting the hydraulic performance and whole life costs. The full version of the RainCycle application contains additional analytical features and so this can be used if a more detailed analysis is required.

If you would like to see any specific feature in future versions, then drop us a line at support@sudsolutions.com and if the idea has merit then we will consider including it in future versions of the software.

Appendix 4

Validating the Hydraulic Model

In order to ensure that RainCycle's predictions of future RWH system performance are realistic, the hydraulic components were validated against an existing methodology.

Model validation was conducted by comparing the hydraulic outputs of RainCycle against a methodology described by Fewkes & Warm in their 2001 conference paper *A Method of Modelling the Performance of Rainwater Collection Systems in the UK*. (Fewkes and Warm, 2001). This method involved modelling the daily performance of rainwater harvesting systems at eleven locations in the UK using a computer based behavioural model in conjunction with site-specific rainfall data. Performance curves (tank size vs. percentage of demand met) for each site were determined, and from these a set of generic curves created which can be used to predict the performance of RWH systems anywhere within the UK. These performance prediction curves "…*provide a valuable design aid for the accurate and therefore economic sizing of rainwater collection systems*."

Site-specific performance curves were generated by a computer program utilising Fewke's approach. Five parameters were used to create the curves: average annual rainfall for the catchment under study (mm/yr), catchment surface area (m^2), average daily demand (litres/day), catchment surface runoff coefficient and rainwater filter coefficient.

Both the RainCycle and Fewke's methods were used to model the RWH systems from the tutorial chapter and the three case studies from appendix 4. Recorded rainfall statistics were used with RainCycle in order to ensure maximum realism. These were selected from data sets recorded at the Emily Moor weather station located in Huddersfield, West Yorkshire. A year with a total rainfall depth of 886mm/yr was used since this is close to the yearly average for the Yorkshire region (885mm/yr).

The results from these comparisons are the focus of this appendix.

Validation 1: Tutorial Case Study

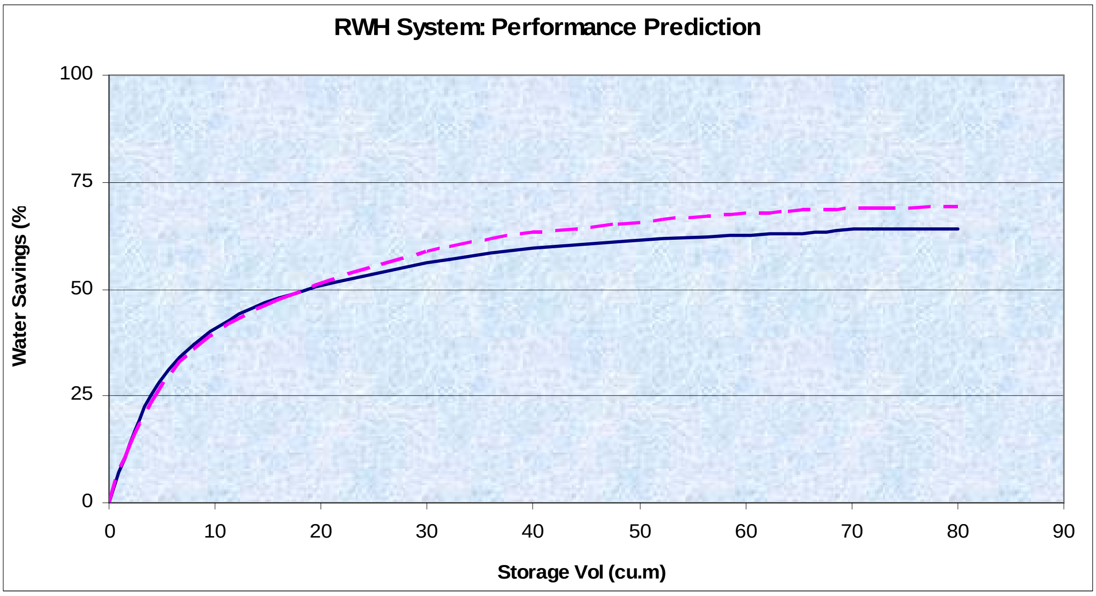
See chapter 3 for specific details about the tutorial RWH system. The parameter values used to generate the Fewkes performance curves for this case study are as follows:

Parameter	Value
Average annual rainfall (mm/yr)	886
Catchment surface area (m^2)	1,845m^2
Average daily water demand (litres/day)	4,236
Runoff coefficient	0.85
Filter coefficient	0.90

Comparison of Results

The following table and corresponding graph show the tank size vs. percentage of demand met predicted by both the Fewkes methodology and the RainCycle model.

Tank Size (m^3)	Fewkes: % Demand Met	RainCycle: % Demand Met	Difference (%)
0.000	0	0	0%
2.006	14	13	-5%
4.011	25	23	-7%
8.022	37	36	-3%
16.044	48	48	-1%
32.088	57	60	5%
48.132	61	65	6%
64.176	63	68	8%
72.198	64	69	7%
80.220	64	69	8%



Key: blue solid line = Fewkes methodology. Dashed purple line = RainCycle model

The results show that the predicted performance in terms of tank size vs. percentage of demand met is similar for both the Fewkes methodology and the corresponding RainCycle model. The RainCycle results are slightly more optimistic for larger tank sizes although all results are still within +/-8% of each other with an average difference of 2%.

Validation 2: Case Study 1 – Typical Domestic System

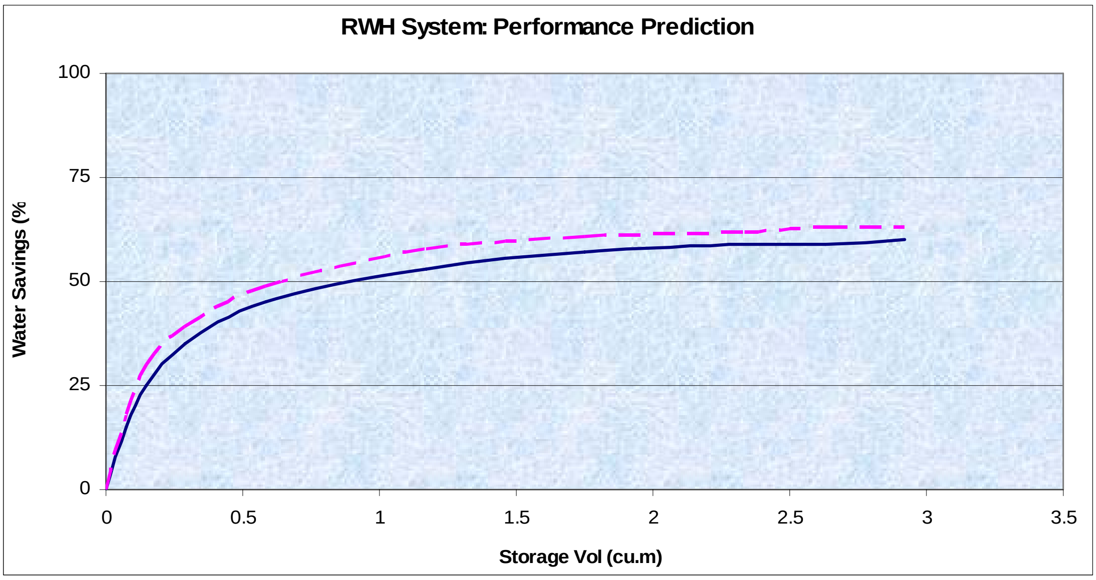
See appendix 4 for specific details about the case study 1 RWH system. The parameter values used to generate the Fewkes performance curves for this case study are as follows:

Parameter	Value
Average annual rainfall (mm/yr)	886
Catchment surface area (m^2)	50
Average daily water demand (litres/day)	146
Runoff coefficient	0.85
Filter coefficient	0.90

Comparison of Results

The following table and corresponding graph show the tank size vs. percentage of demand met predicted by both the Fewkes methodology and the RainCycle model.

Tank Size (m^3)	Fewkes: % Demand Met	RainCycle: % Demand Met	Difference (%)
0.000	0	0	0%
0.073	15	18	17%
0.146	25	30	17%
0.292	35	39	10%
0.584	45	49	8%
1.168	53	58	9%
1.752	57	61	7%
2.336	59	62	5%
2.628	59	63	6%
2.920	60	63	5%



Key: blue solid line = Fewkes methodology. Dashed purple line = RainCycle model

The RainCycle model predicted slightly more optimistic results than Fewkes. Predicted system performance is within +/-17% if all results are taken into account. Ignoring the outliers means that 8 out of 10 results are within +/-10%. The average difference is 8% (including the outliers).

Validation 3: Case Study 2 – Another Typical Domestic System

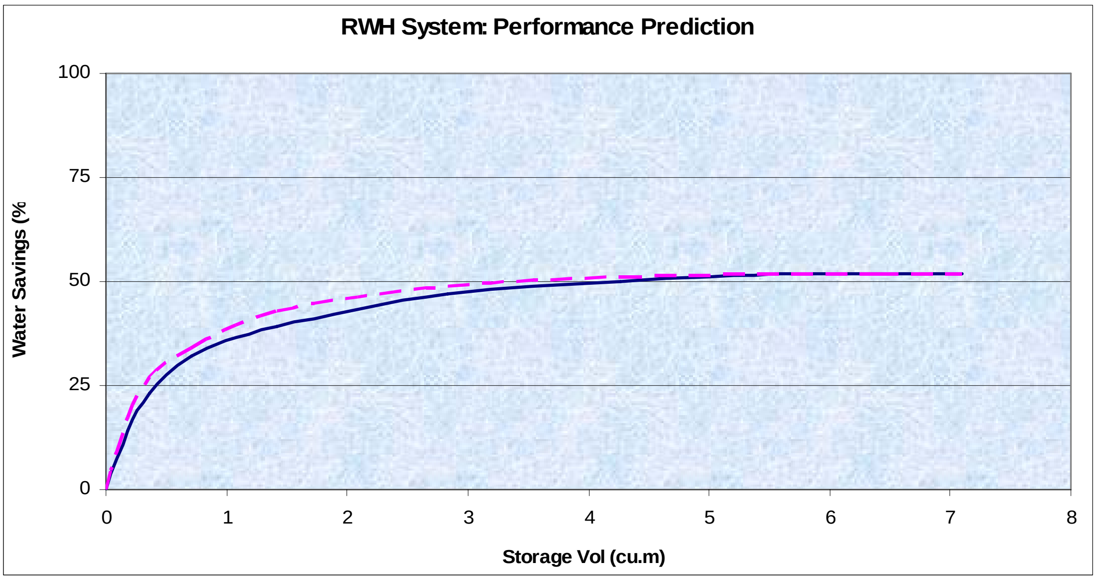
See appendix 4 for specific details about the case study 2 RWH system. The parameter values used to generate the Fewkes performance curves for this case study are as follows:

Parameter	Value
Average annual rainfall (mm/yr)	886
Catchment surface area (m^2)	100
Average daily water demand (litres/day)	355
Runoff coefficient	0.85
Filter coefficient	0.90

Comparison of Results

The following table and corresponding graph show the tank size vs. percentage of demand met predicted by both the Fewkes methodology and the RainCycle model.

Tank Size (m^3)	Fewkes: % Demand Met	RainCycle: % Demand Met	Difference (%)
0.000	0	0	0%
0.178	14	17	18%
0.355	23	27	15%
0.710	32	34	6%
1.420	39	43	9%
2.840	47	49	4%
4.260	50	51	2%
5.680	52	52	0%
6.390	52	52	0%
7.100	52	52	0%



Key: blue solid line = Fewkes methodology. Dashed purple line = RainCycle model

In this instance RainCycle gave slightly more optimistic results for the smaller tank sizes. For the larger tank sizes (700 litres and greater) the results are closely matched. All results are within +/-18%. Ignoring the outliers means that 8 out of 10 results are within +/-9%. The average difference is 5% (including the outliers).

Validation 4: Case Study 3 – Hotel System

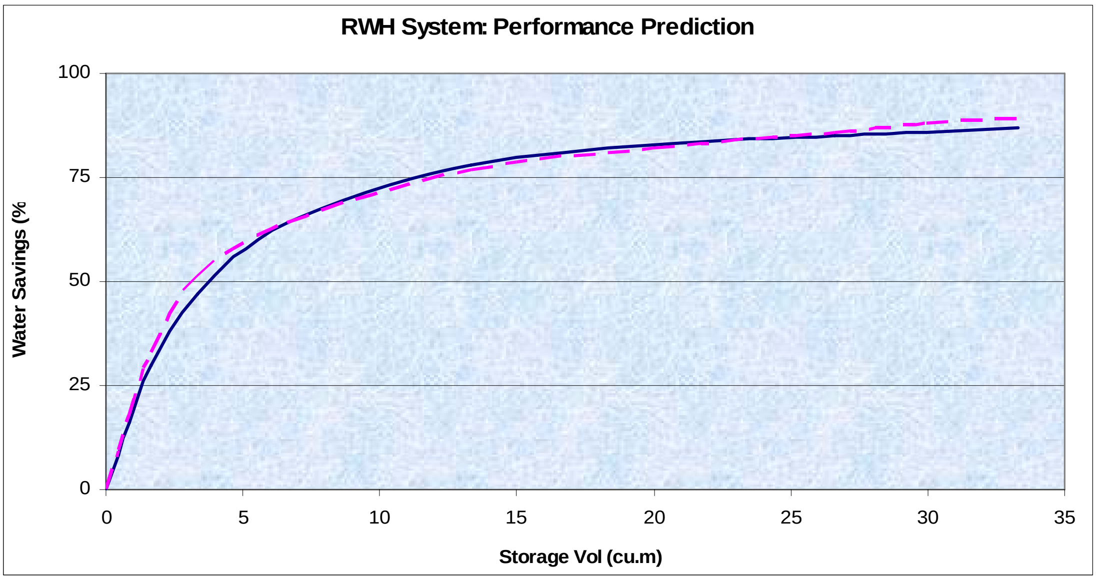
See appendix 4 for specific details about the case study 3 RWH system. The parameter values used to generate the Fewkes performance curves for this case study are as follows:

Parameter	Value
Average annual rainfall (mm/yr)	886
Catchment surface area (m^2)	2000
Average daily water demand (litres/day)	1664
Runoff coefficient	0.55
Filter coefficient	0.90

Comparison of Results

The following table and corresponding graph show the tank size vs. percentage of demand met predicted by both the Fewkes methodology and the RainCycle model.

Tank Size (m^3)	Fewkes: % Demand Met	RainCycle: % Demand Met	Difference (%)
0.000	0	0	0%
0.832	16	18	11%
1.664	30	33	9%
3.328	47	51	8%
6.656	64	64	0%
13.312	78	77	-1%
19.968	83	82	-1%
26.624	85	86	1%
29.952	86	88	2%
33.280	87	89	2%



Key: blue solid line = Fewkes methodology. Dashed purple line = RainCycle model

Again RainCycle gave slightly more optimistic results for the smaller tank sizes. For the larger tank sizes (660 litres and greater) the results are closely matched. All results are within +/-11%. Ignoring the outliers means that 7 out of 10 results are within +/-2%. The average difference is 3% (including the outliers).

Summary and Conclusions

The ability of RainCycle to accurately predict future RWH system performance was tested against an existing methodology (Fewkes & Warm, 2001). Both methods were used to test the performance of a number of RWH systems: 1 actual system and 3 theoretical (though realistic) systems.

The investigation showed that, for each system investigated, both methods gave similar results when predicting the percentage of demand met for a range of tank sizes. Ignoring the effects of any outliers, all results were within agreement by +/-10%, with an overall average difference of 5.5% (including any outliers).

In conclusion, the RainCycle method for predicting RWH system performance is in close agreement with the Fewkes methodology. Assuming that Fewkes gives accurate results then it can be stated with confidence that RainCycle also gives accurate results.

References

Fewkes & Warm (2001). *A Method of Modelling the Performance of Rainwater Collection Systems in the UK*. Proceedings from the First National Conference on Sustainable Drainage. 18th-19th June 2001. Coventry University.

Appendix 5

Bill of Quantities for a Typical RWH Storage Tank

The following information was obtained from a UK RWH system supplier (name withheld for reasons of confidentiality). The BoQ contains quantities but not costs since these are subject to change and are often site-specific. It is recommended that up-to-date and site-specific costs are calculated on a case-by-case basis e.g. by using the SPONS Civil Engineering and Highway Works Price Book or similar.

Standard Depth: 500mm to invert of storage tank

	Storage tank size (m^3)								
Item	**3.0**	**6.0**	**12.0**	**18.0**	**22.5**	**27.5**	**36.0**	**45.0**	**54.0**
Excavate not exceeding 4.5m deep and cart away from site	$11m^3$	$20m^3$	$36m^3$	$50m^3$	$59m^3$	$70m^3$	$86m^3$	$104m^3$	$122m^3$
Planking and strutting to sides of excavation n.e. 4.5m deep	$22m^2$	$31m^2$	$45m^2$	$52m^2$	$57m^2$	$64m^2$	$74m^2$	$85m^2$	$96m^2$
Level and ram bottom of excavation to receive concrete	$5m^2$	$8m^2$	$15m^2$	$16m^2$	$18m^2$	$22m^2$	$27m^2$	$32m^2$	$38m^2$
Concrete C30 in 150mm thick base	$5m^2$	$8m^2$							
Concrete C30 in 225mm thick base			$15m^2$	$16m^2$	$18m^2$	$22m^2$	$27m^2$	$32m^2$	$38m^2$
Fabric reinforcement (reference A142)			$15m^2$	$16m^2$	$18m^2$	$22m^2$	$27m^2$	$32m^2$	$38m^2$
Concrete C30 in 150mm thick surround hand compacted in 150mm layers	$4m^3$	$7m^3$							
Concrete C30 in 225mm thick surround hand compacted in 150mm layers			$17m^3$	$29m^3$	$32m^3$	$38m^3$	$45m^3$	$52m^3$	$60m^3$
Concrete C30 in 150mm thick surround to access shaft	$0.2m^3$	$0.2m^3$	$0.2m^3$	$0.2m^3$	$0.2m^3$	$0.2m^3$	$0.2m^3$	$0.2m^3$	$0.2m^3$
Formwork circular on plan to a radius of 450mm	$1.4m^2$	$1.4m^2$	$1.4m^2$	$1.4m^2$	$1.4m^2$	$1.4m^2$	$1.4m^2$	$1.4m^2$	$1.4m^2$

Quantities per additional 250mm depth to invert of storage tank

	Storage tank size (m^3)								
Item	**3.0**	**6.0**	**12.0**	**18.0**	**22.5**	**27.5**	**36.0**	**45.0**	**54.0**
Excavate not exceeding 4.5m deep and cart away from site	$1.3m^3$	$2.1m^3$	$3.2m^3$	$3.9m^3$	$4.5m^3$	$5.4m^3$	$6.7m^3$	$8.0m^3$	$9.5m^3$
Planking and strutting to sides of excavation n.e. 4.5m deep	$2.4m^2$	$3.3m^2$	$3.8m^2$	$4.0m^2$	$4.4m^2$	$5.0m^2$	$5.7m^2$	$6.6m^2$	$7.4m^2$
Concrete C30 in 150mm thick surround to access shaft	$0.2m^3$	$0.2m^3$	$0.2m^3$	$0.2m^3$	$0.2m^3$	$0.2m^3$	$0.2m^3$	$0.2m^3$	$0.2m^3$
Formwork circular on plan to a radius of 450mm	$1.4m^2$	$1.4m^2$	$1.4m^2$	$1.4m^2$	$1.4m^2$	$1.4m^2$	$1.4m^2$	$1.4m^2$	$1.4m^2$
Selected backfill material	$1.3m^3$	$2.1m^3$	$3.2m^3$	$3.9m^3$	$4.5m^3$	$5.4m^3$	$6.7m^3$	$8.1m^3$	$9.5m^3$