Economic Ready Reckoner for Evaporation Mitigation Systems

Reference Manual

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National Program for Sustainable Irrigation

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENT

The Queensland Department of Natural Resources and Mines (NR&M) is acknowledged for providing access to its SILO evaporation data base. This data is essential input to the Ready Reckoner and the generosity of the Department is appreciated.

READY RECKONER TECHNICAL COMMENTS

The Ready Reckoner was compiled using Microsoft Excel™ 2002. The 'Goal Seek' function is required for the Ready Reckoner to run. Hence the Ready Reckoner will run on versions of Excel™ where the 'Goal Seek' function is available.

The Ready Reckoner makes use of macros. These macros have been written in Visual Basic code. If nonsense values are input then the macros may not run successfully. If this occurs an error message may appear. In addition, nonsense input values may also deliver results such as '#DIV/0'. This is a standard Excel™ error message and indicates that data input is not complete or not appropriate. Users are advised to ensure that all input values are appropriate to avoid the above problems.

Glossary of Terms

Circular Ring Tank	Above-ground, circular storage. Also known as a 'turkey's nest'
Chemical Monolayer	A cetyl/steryl alcohol which forms a one molecule thick film (or monolayer) on the water surface to act as a barrier against evaporation
Evaporation Mitigation System	System used to reduce evaporation losses from water storages. Systems include impermeable and permeable covers, modular impermeable covers and changes to storage design
Gully Dam	A water storage built in a natural gully, where by a wall is built across the gully to impound water
Hydrological Analysis	A whole property analysis of irrigation water supply and demand to determine water availability and reliability
Impermeable Cover	A non-porous cover such as plastic or tarpaulin installed on a water storage to act as a barrier against evaporation
Modular Cover	Individual floating modules placed on the water surface that acts as a barrier to evaporation. Many different forms and sizes available. Can be installed to move freely or tethered together
Rectangular Ring Tank	Similar to a circular ring tank, however rectangular (or square) in shape. Also known as a 'turkey's nest'
Seepage	Water losses through the floor and walls of an earthen storage
Shadecloth	Similar to shadecloth covers installed over orchards, backyard patios, etc. Requires a structure to remain suspended over the water surface. Reduces solar radiation incidence and wind speed to reduce evaporative losses
Storage	Impoundment of water (for irrigation or stock and domestic uses)

Other terms used, but not explicitly addressed here, are included at appropriate sections in the report.

1 BACKGROUND TO THE PROJECT

Significant evaporation losses typically occur from on farm water storages. A national workshop in 2002 initiated by Queensland Department of Natural Resources and Mines (NR&M), a review paper commissioned by NRM (GHD, 2003) and scoping studies initiated by the National Program for Sustainable Irrigation (NPSI, 2002 and Watts, 2005) have all highlighted the importance of these losses. In response to these studies NRM through the Rural Water Use Efficiency Initiative (RWUEI) funded a project to assess methods to control evaporation loss from water storages. Craig *et al*, (2005) provided an assessment of:

- The effectiveness of different evaporation mitigating systems (EMS's) in reducing evaporation from commercial water storages across a range of climate regions
- Practical and technical limitations of different EMS's
- Economics of different EMS's on water storages used for irrigation.

This study provided a good understanding of the factors affecting evaporative loss from water storages, evaporation mitigation methodologies and factors affecting the economics of utilising an evaporation mitigation system.

Craig *et al*, (2005) and Watts (2005) identified a number of areas for further research and investment in this area of evaporation. One of these is the development of a computer model ('Ready Reckoner') which allows site specific assessment of evaporation mitigation systems. Evaporation mitigation systems (EMS's) include installing a cover over the water, applying a chemical monolayer or modifying the shape of the storage dam. For example, increasing the storage depth reduces the relative surface area of the volume of water stored, hence reducing evaporative losses.

The 'Ready Reckoner' is a model which performs a simple, site-specific economic assessment of the viability of evaporation mitigation systems. The user enters appropriate data to customise the 'Ready Reckoner' to their site. The 'Ready Reckoner' returns the volume of water saved (in ML) and the cost of the evaporation mitigation system used to save this water ($/ML/year).

The 'Ready Reckoner' was developed as a Microsoft Excel™ spreadsheet for ease of use and portability. This reference manual was developed to assist the user in the operation of the 'Ready Reckoner'.

2 OBJECTIVES

The objectives of the reference manual are to provide guidance on the use of the evaporation mitigation systems 'Ready Reckoner'.

The manual includes the following sections:

Ready Reckoner Setup and Operation
Provides instructions for setting up the spreadsheet on the user's computer ready for use.

Data Entry
This section provides a detailed listing and explanation of required input data.

Method of Calculation
This provides an overview of the calculation methodology employed in the Ready Reckoner. Appendix A provides a more detailed description of the formulae used.

Running the Ready Reckoner
This section details the procedure to run the Ready Reckoner.

Results
This section provides a description and explanation of the Ready Reckoner output.

Assumptions
This section provides a listing of the assumptions made to simplify model calculations.

Case Studies
Three Case Studies are included to guide and help the user understand the Ready Reckoner.

Hydrological Studies
Three hydrological studies are included to highlight the sensitivity of estimating amount of water stored and storage time.

Formulae Used by the Ready Reckoner
All formulae used by the Ready Reckoner are included as a reference.

3 'Ready Reckoner' Setup and Operation

To use the 'Ready Reckoner' model Microsoft Excel™ needs to be installed on the user's computer. Open the file explorer (i.e. 'My Computer') and locate the file Ready Reckoner.xlt. This is a template file and will open in Excel™ with a unique filename (i.e. Ready Reckoner1.xls, Ready Reckoner2.xls, etc). This ensures that the original file is not overwritten.

Note: When the file Ready Reckoner.xlt is opened from within Excel™ a new filename is not assigned to each new file. This allows the user to modify the template (.xlt) file. However this is not desirable as the original file should not be modified.

A message will appear that will inform the user that the 'Ready Reckoner' contains macros. A choice is given whether to disable or enable these macros. The macros must be enabled for the 'Ready Reckoner' to function. Once the 'Enable Macros' button is selected the 'Ready Reckoner' will open.

Separate model runs can be saved for later use. These can be saved under the filename given or a new filename can be assigned. To do this, click 'Save As…' on the main menu bar and enter a new filename for each model run.

4 Inputs

The 'Ready Reckoner' requires a number of inputs from the user to evaluate evaporation mitigation systems for their particular storage. These are input onto the 'User Inputs' worksheet. The inputs are grouped into six fields: Storage Type and Geometry, Evaporation, Average Amount of Water Stored per Month, Average Percentage of Years that the Storage Contains Water, Seepage Information and Evaporation Mitigation System Information.

Input fields are highlighted in light green. All input data for each field is entered into pale yellow coloured cells. All input data is entered on this worksheet. Do not enter input data on any other worksheet.

Before entering any data the button 'CLEAR ALL DATA FIELDS' (cell 'A4') button should be pressed. This clears all input data fields.

The data that is required for these sections are outlined below.

4.1 Storage Type and Geometry

Storage Type and Geometry data is required to determine the storage volume, the surface area of water and the water depth.

The Ready Reckoner will cater for three different configurations of water storage: Rectangular Ring Tanks, Circular Ring Tanks and Gully Dams. Clicking on the pale yellow input cell adjacent to 'Step 1 – Select Type of Storage' will display an arrow button (see

Figure 1). Clicking on this button displays a drop down list of storage types. To make a selection, click on the appropriate storage type in the drop down list.

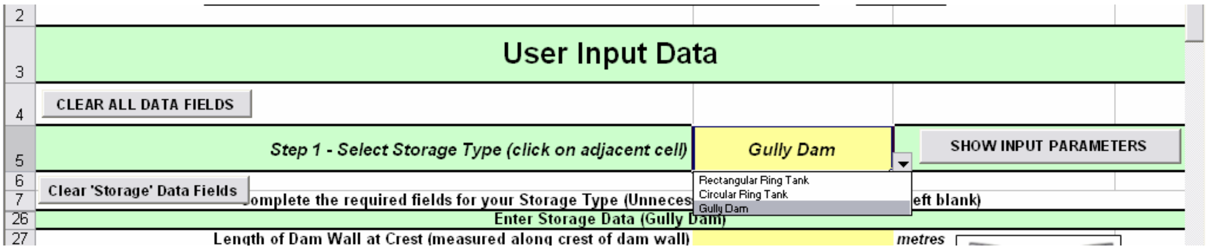

FIGURE 1 – SELECTING STORAGE TYPE

Once the storage type has been selected, click on the button 'SHOW INPUT PARAMETERS' (cell 'C5'). This will show the relevant storage geometry parameters that need to be input.

The data requirements for each storage type are detailed below. Data only needs to be entered for the storage type selected. To assist in the definitions of storage geometry parameters the 'Diagrams' worksheet provides schematic diagrams of the storage types.

The units for each input follow the description in square brackets, i.e. *[metres]*. Note that *[dim.]* means that the input is dimensionless (no units).

4.1.1 Rectangular Ring Tank

The user is required to enter the following inputs.

Length at Centreline
Length of the longer wall of the ring tank, measured along the centreline of the wall. *[metres]*

Width at Centreline
Length of the shorter wall of the ring tank, measured along the centreline of the wall. *[metres]*

Corner Radius at Centreline
Radius of each corner of the ring tank, measured along the centreline of the wall. *[metres]*

Storage Wall Crest Width
Width at the top of the storage wall. *[metres]*

Average Bank Height
Average height of the storage wall, measured from the original natural ground level to the crest, i.e. not from the base of a borrow pit or sump. *[metres]*

Batter Slope of the Storage Inside Wall
Inner slope of the storage wall input as a ratio, i.e. 3 in 1, 4 in 1, etc. *[dim.]*

Batter Slope of the Storage Outside Wall

Outer slope of the storage wall input as a ratio, i.e. 3 in 1, 4 in 1, etc. *[dim.]*

Full Supply Volume
Maximum storage volume when full, whilst maintaining the freeboard stated. *[ML]*

Freeboard
Vertical distance between the water surface level when full and the storage wall crest. *[metres]*

Figure 2 displays the data entry process for a rectangular ring tank.

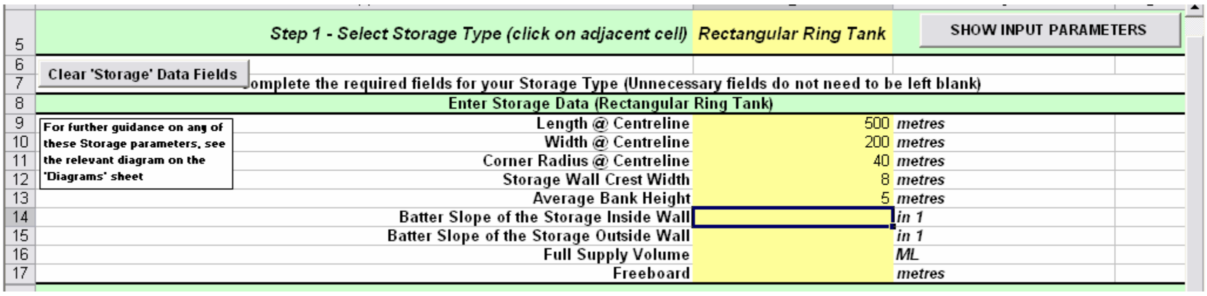

FIGURE 2 – RECTANGULAR RING TANK STORAGE GEOMETRY DATA INPUT

4.1.2 Circular Ring Tank

The user is required to enter the following inputs.

Radius at Centreline
Radius of the ring tank, measured from the centre of the ring tank to the centreline of the wall. *[metres]*

Storage Wall Crest Width
Width at the top of the storage wall. *[metres]*

Average Bank Height
Average height of the storage wall, measured from the original natural ground level to the crest, i.e. not from the base of a borrow pit or sump. *[metres]*

Batter Slope of the Storage Inside Wall
Inner slope of the storage wall input as a ratio, i.e. 3 in 1, 4 in 1, etc. *[dim.]*

Batter Slope of the Storage Outside Wall
Outer slope of the storage wall input as a ratio, i.e. 3 in 1, 4 in 1, etc. *[dim.]*

Full Supply Volume
Maximum storage volume when full, whilst maintaining the stated freeboard. *[ML]*

Freeboard
Vertical distance between the water surface level when full and the storage wall crest. *[metres]*

Figure 3 displays the data entry process for a circular ring tank.

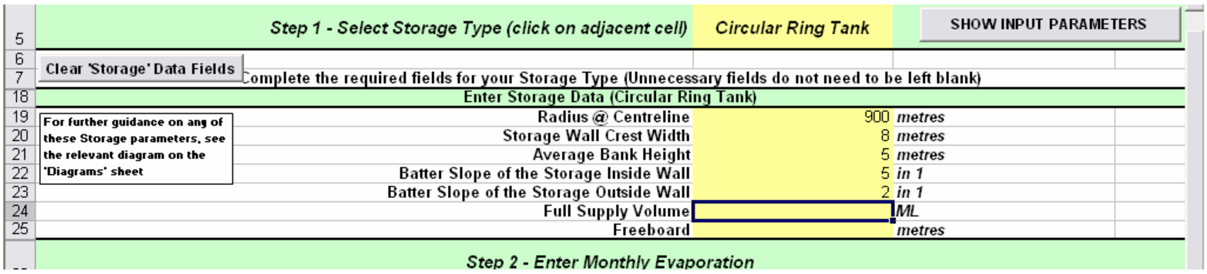

FIGURE 3 – CIRCULAR RING TANK STORAGE GEOMETRY DATA INPUT

4.1.3 Gully Dam

The user is required to enter the following inputs.

Length of Dam Wall (measured along crest of the dam wall)
Length measured along the top of the dam wall. *[metres]*

Length of Dam Wall at Base (measured along base of dam wall)
Length measured along the base of the dam wall. This distance can be equal to zero if the gully sides meet. *[metres]*

Maximum Bank Height
Maximum height of the dam wall, measured from the lowest point of the gully. *[metres]*

Gully Cross-Section Coefficient (at the Dam Wall, see diagram and note)
A coefficient describing the cross section that best approximates the gully shape where the dam wall is located, selected from the diagram provided in the spreadsheet. A guidance note is provided in the spreadsheet to assist the user. *[dim.]*

Maximum Width of Water Across the Dam Wall
Maximum width of water at the dam wall when the storage is full. *[metres]*

Maximum Depth of Water at the Dam Wall
Maximum depth of water at the dam wall when the storage is full. *[metres]*

Length of Longest Stretch of Water Surface (when full)
Longest length of water surface (when full) from the dam wall, measured perpendicular to the dam wall. *[metres]*

Gully Cross-Section Coefficient (where Water is Stored, see diagram and note)
A coefficient describing the cross section that best approximates the gully shape where water is actually stored, selected from the diagram provided in the spreadsheet. This may or may not be the same as the coefficient for the dam wall. A guidance note is provided in the spreadsheet to assist the user. *[dim.]*

Full Supply Volume

Maximum storage volume when full. *[ML]*

Figure 4 displays the data entry process for a gully dam.

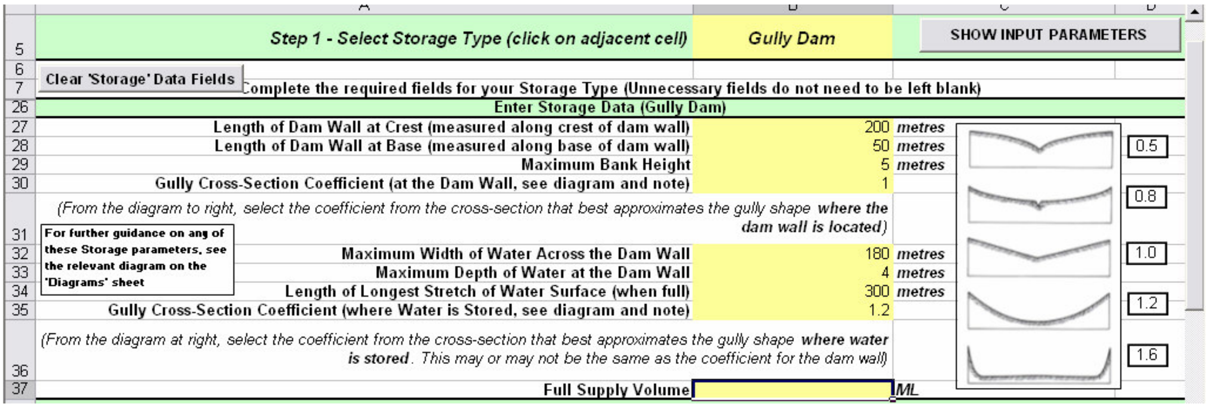

FIGURE 4 – GULLY DAM STORAGE GEOMETRY DATA INPUT

4.2 Monthly Evaporation

The evaporation rate, in millimetres per month, needs to be input to determine the potential evaporative loss from the storage for each month of the year.

The evaporation rate can be found by accessing http://www.npsi.gov.au/readyreckoner/index.html. This webpage was established to download this manual and the Ready Reckoner and to extract evaporation data. The evaporation for any site in Australia can be downloaded and saved to the user's computer. The only information required is the location (latitude and longitude) of the water storage in question (eg Toowoomba 27° South, 151° East, see Figure 5).

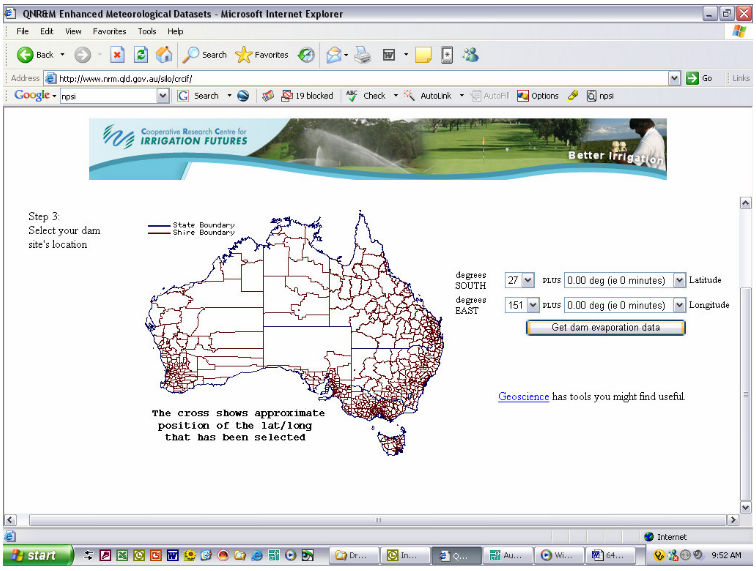

FIGURE 5 – ACCESSING EVAPORATION DATA FROM QNR & M WEBSITE

Evaporation data supplied from the SILO website represents point potential evaporation (http://www.npsi.gov.au/readyreckoner/index.html) and is recommended by the Bureau of Meteorology for estimating evaporation losses from storage dams. A map of annual evaporation rates, as shown in Figure 6 for Australia is given in the 'Ready Reckoner' on the 'Diagrams' worksheet for comparison purposes.

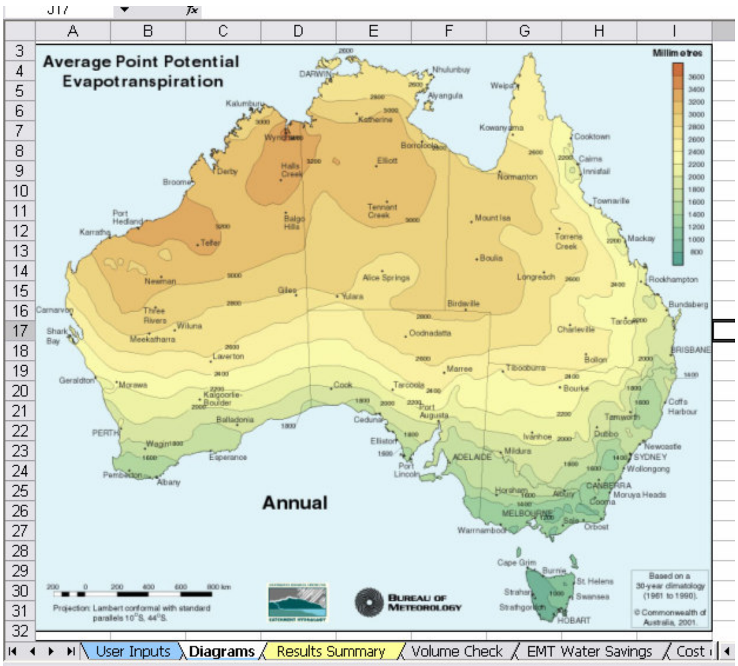

FIGURE 6 – MAP IN READY RECKONER TO CHECK ANNUAL EVAPORATION DATA

The data provided by the NR&M website is in the same format as required by the Ready Reckoner. A monthly evaporation input table is provided in the 'Ready Reckoner' (cell 'B40'). The user is required to transfer the evaporation loss data from NR&M website into the appropriate cell for each month.

The cell at the base of the monthly evaporation input table (cell 'B52') calculates the total annual evaporation. This cell does not require data entry from the user. This cell will highlight any errors in data entry to the user. Figure 7 displays the monthly evaporation input table.

38	*Step 2 - Enter Monthly Evaporation*			
39	*The monthly evaporation rate for your location can be found at http://www.nrm.qld.gov.au/silo/crcif/. Follow the instructions given, download the data and enter the monthly values into the appropriate cells below. A map of annual evaporation is given to check the data downloaded (see sheet titled 'Diagrams')*			
40		*January*	251	*mm*
41	Clear 'Evaporation' Data Fields	*February*	243	*mm*
42		*March*	210	*mm*
43		*April*	183	*mm*
44		*May*	143	*mm*
45		*June*	96	*mm*
46		*July*	85	*mm*
47		*August*		*mm*
48		*September*		*mm*
49		*October*		*mm*
50		*November*		*mm*
51		*December*		*mm*
52		*Annual Total (Note: No data entry required in this cell)*	1211	*mm*

FIGURE 7 – ENTERING EVAPORATION DATA

4.3 Average Amount of Water Stored per Month

The amount of water stored per month, when water is in storage, expressed as a percentage of the total storage volume is required. This is necessary to determine the depth and corresponding surface area of water stored. The average amount of water stored per month needs to be carefully considered as a cover over an empty storage will not save water. For each particular month, the average amount of water (expressed as a percentage of total water storage volume) that would be expected to be in storage in any particular year (when water is stored) needs to be entered.

In its simplest form, this parameter is determined by the user through experience. For example, the user may know that for the months April through October, when water is stored, the storage is 100 % full. Hence 100 % would be entered for these months. Similarly it is known that during months January and February the storage is empty. Hence 0% is entered for these months. Values for the other months would be determined in a similar way. Figure 8 shows the data entry process.

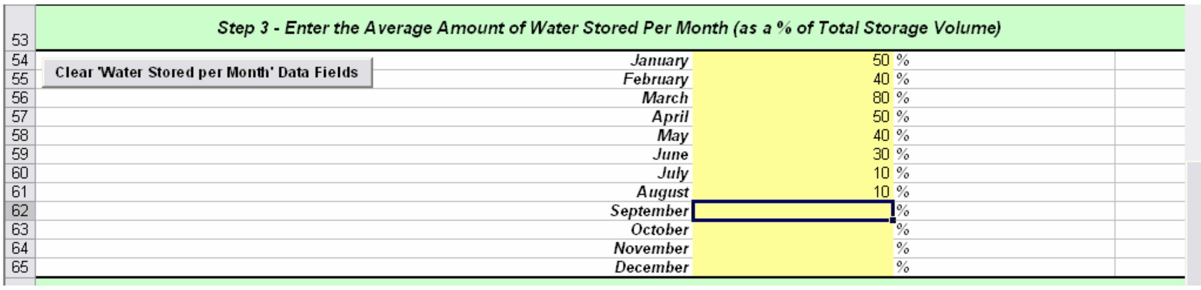

FIGURE 8 – ENTERING AVERAGE AMOUNT OF WATER STORED PER MONTH DATA

A hydrological analysis of the storage is a more accurate method of determining the average amount of water stored per month. Three example hydrological analyses are included in Appendix B.

4.4 Average Percentage of Years that the Storage Contains Water

This section allows the user to input the reliability of the water storage. The years that the storage contains water (expressed as a percentage) is required to determine the percentage of years the storage is likely to contain water for that particular month. For example, on average a storage may only ever contain water every second year in May (regardless of the amount of water stored). Hence 50 % would be entered for May. Similarly if a storage only contains water in September two out of every five years (on average) then 40 % would be entered for September. If the storage was very reliable in January, containing some water every year during this month, then 100 % would be entered for January.

This parameter can be confused with the average amount of water stored. However, it is possible that the storage can have an average amount of water stored of, say 100 % in April, in 50 % of years. This means that the storage, when water is available, is usually full in April, however this only occurs on average every second year. Figure 9 shows the data entry process.

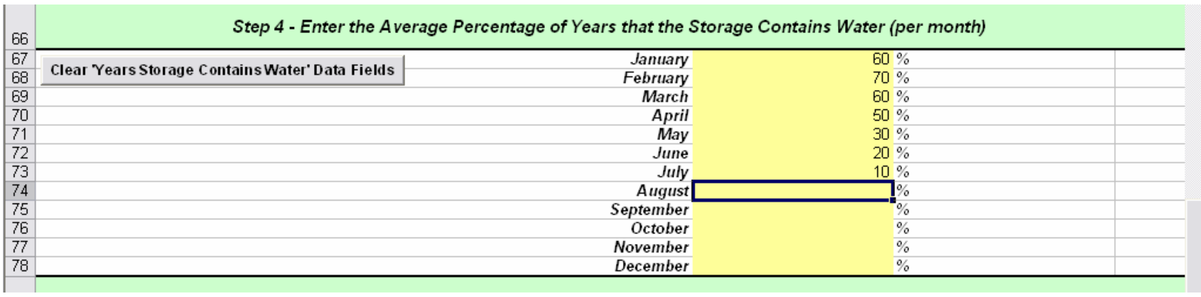

FIGURE 9 – ENTERING YEARS STORAGE CONTAINS WATER DATA

A hydrological analysis of the storage is a more accurate method of determining the years that a storage contains water for each month. Three example hydrological analyses are included in Appendix B.

The user is alerted to the fact that the Ready Reckoner is sensitive to this input and that the viability of any evaporation mitigation system will be significantly affected by the values entered.

4.5 Seepage

The user is required to input information on seepage from the storage. If the earthworks evaporation mitigation system is chosen an increase in seepage loss may occur. This will impact on the volume of water saved.

To select a seepage option click on the pale yellow cell adjacent to the 'Select your Most Applicable Seepage Option from the drop down list'. Clicking on this button displays a drop down list of seepage options. To make a selection, click on the appropriate seepage option in the drop down list (see Figure 10).

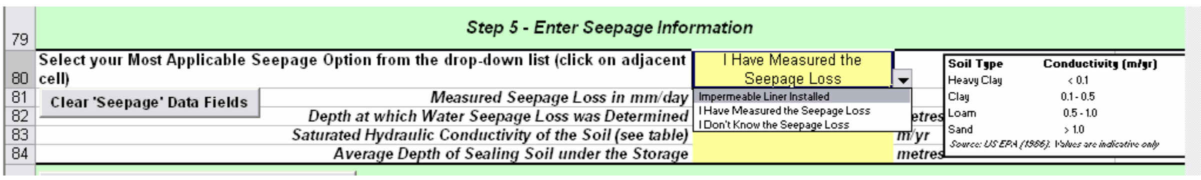

FIGURE 10 – SELECTING SEEPAGE OPTION

The three options are 'Impermeable Liner Installed', 'I Have Measured the Seepage Loss' and 'I Don't Know the Seepage Loss'. Upon selecting one of these options a list of data inputs will appear specific to that option.

4.5.1 Impermeable Liner Installed

If this option is selected zero seepage loss is assumed no further data entry is required. Figure 11 shows the display when this option is selected.

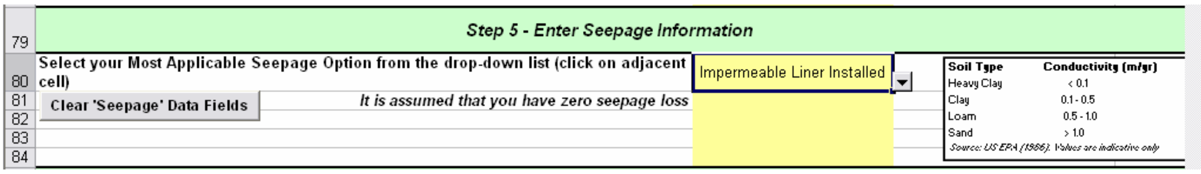

FIGURE 11 – SCREEN SHOWN WHEN 'IMPERMEABLE LINER INSTALLED' OPTION IS SELECTED

4.5.2 I Have Measured the Seepage Loss

If this option is chosen four data entry fields appear, as shown in Figure 12.

Measured Seepage loss in millimetres per day
The user should enter the measured value of seepage loss in mm/day for the storage.

Depth at which Water Seepage Loss was Determined
The user should enter the depth of water contained in the storage (in metres) at which the seepage loss measurement was made. This allows the seepage estimate model to be calibrated to the measured seepage loss.

Saturated Hydraulic Conductivity of the Soil (see table)
This is an estimate of the rate of flow of water through the soil at the base of the storage. The user should enter the saturated hydraulic conductivity of the soil in metres/year. A table of hydraulic conductivities for different soil types is given to assist the user.

Average Depth of Sealing Soil under the Storage
The user should enter the depth, in metres, of 'sealing' soil under the storage. This is the depth of soil, be it clay or otherwise, that acts to seal the storage from seepage.

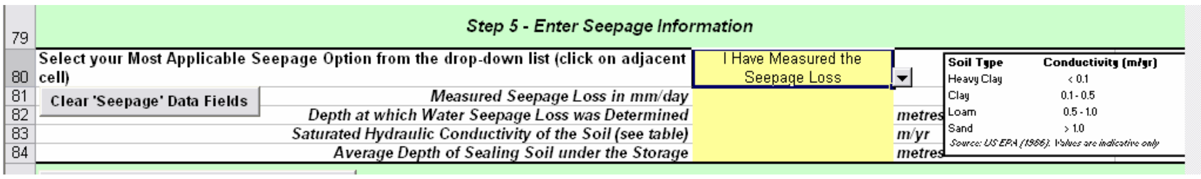

FIGURE 12 – SCREEN SHOWN WHEN 'I HAVE MEASURED THE SEEPAGE LOSS' OPTION IS SELECTED

4.5.3 I Don't know the Seepage Loss

If this option is chosen two data entry fields appear, as shown in Figure 13.

Saturated Hydraulic Conductivity of the Soil (see table)

This is an estimate of the rate of flow of water through the soil at the base of the storage. The user should enter the saturated hydraulic conductivity of the soil in metres/year. A table of hydraulic conductivities for different soil types is given to assist the user.

Average Depth of Sealing Soil under the Storage

The user should enter the depth, in metres, of 'sealing' soil under the storage. This is the depth of soil, be it clay or otherwise, that acts to seal the storage from seepage.

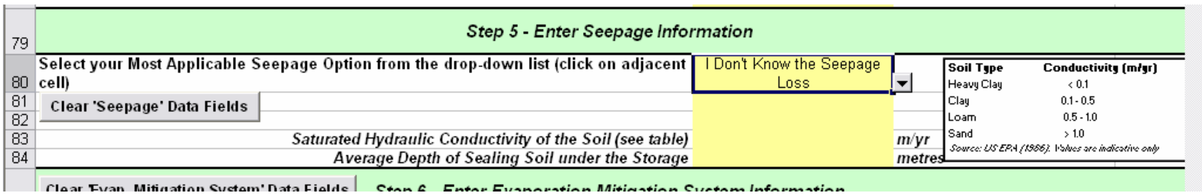

FIGURE 13 – SCREEN SHOWN WHEN 'I DON'T KNOW THE SEEPAGE LOSS' OPTION IS SELECTED

4.6 Evaporation Mitigation System

The user is required to input their proposed evaporation mitigation system. Five different evaporation mitigation system options are given: Impermeable Cover, Shadecloth, Chemical Monolayer, Modular Cover and Increase Wall Height.

Clicking on the cell adjacent to the 'Select an Evaporation Mitigation System' will display an arrow button and a drop down list provides these five options. To make a selection, click on the desired option from the drop down list, as shown in Figure 14.

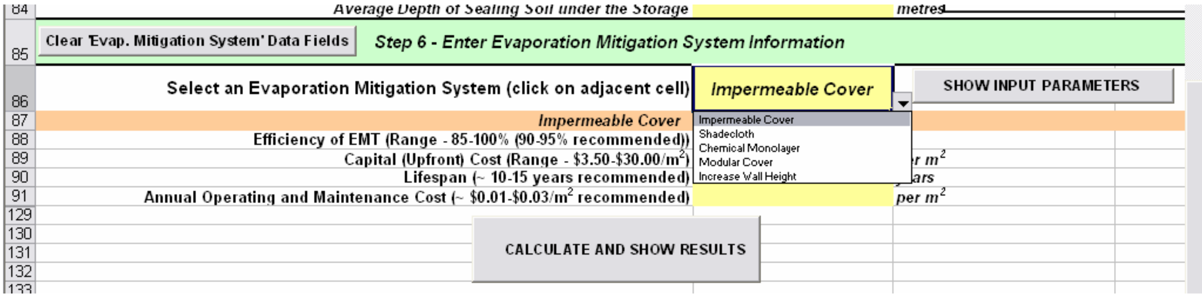

FIGURE 14 – SELECTING AN EVAPORATION MITIGATION SYSTEM OPTION

Once the storage type has been selected, click on the button 'SHOW INPUT PARAMETERS' (cell 'C86'). This will show the relevant storage geometry parameters that need to be input. Data only needs to be entered for the evaporation mitigation system selected.

Note that when a data input is to be expressed per square metre, this is in reference to the maximum water surface area of the storage at full supply level. (The calculator assumes full cover of the water body). For example, the 'Capital (Upfront) Cost of the Impermeable Cover' needs to be entered as dollars per square metre. This can be found by dividing the total cost at installation by the full supply level surface area (in square metres) of the storage.

Note that the actual area covered by the evaporation mitigation system may be greater than the full supply level surface area. This will occur if material extends beyond the edge of the full supply level.

The units for each data requirement follow the description in square brackets, i.e. *[metres]*. Note that *[dim.]* means that the data requirement is dimensionless (no units).

4.6.1 Impermeable Cover

An impermeable cover usually floats on the water surface or can be secured to the storage or both. Covers currently available allow rainfall to enter the storage whilst also significantly reducing evaporation. A photograph of an impermeable cover is shown in Figure 15.

FIGURE 15 – IMPERMEABLE COVER

The user is required to enter the following inputs.

Efficiency of EMS (Range - 85-100% (90-95% Recommended))
The efficiency of the impermeable cover in reducing evaporative losses, expressed as a percentage reduction of total evaporative losses. An expected range of values and recommended values are given in the model. These values are based on applied research into the evaporation mitigation system. *[%]*

Capital (Upfront) Cost
The capital cost of the entire EMS (cover and associated tethering structures) at installation, expressed as a cost per square metre. *[$/m^2]*

Lifespan
The expected, claimed or experienced lifespan of the impermeable cover. *[years]*

Annual Operating and Maintenance Cost
The expected, claimed or experienced costs of operation and maintenance of the impermeable cover, expressed as a cost per square metre. *[$/m^2]*

Figure 16 shows the data entry process.

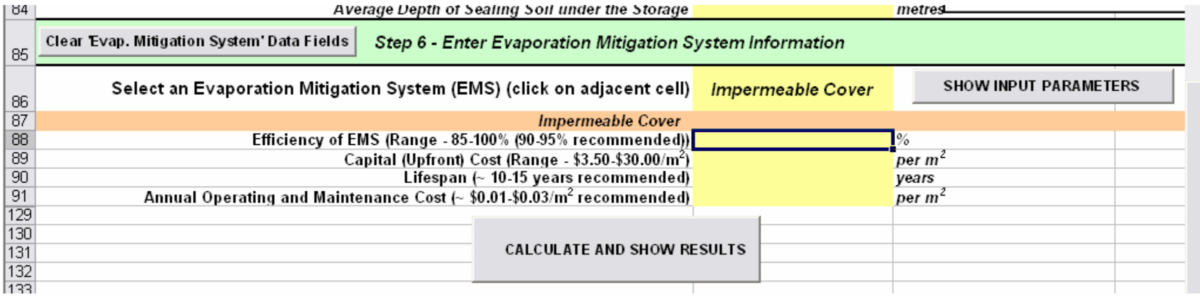

FIGURE 16 – ENTERING IMPERMEABLE COVER EMS DATA

4.6.2 Shadecloth

Shadecloth is usually suspended above the top water level surface of the storage with a permanent structure and cable stays. The permeability of shadecloth allows rainfall to enter the storage. A photograph of a shadecloth structure over a water storage is shown in Figure 17.

FIGURE 17 – SHADECLOTH

The user is required to enter the following inputs.

Efficiency of EMS (Range - 60-80% (70-75% Recommended))
The efficiency of the shadecloth in reducing evaporative losses, expressed as a percentage reduction of total evaporative losses. An expected range of values and recommended values are given. These values are based on applied research into the EMS. *[%]*

Capital (Upfront) Cost
The capital cost of the entire EMS (shadecloth and structure) at installation, expressed as a cost per square metre. *[$/m^2]*

Capital Cost (Shadecloth Only)
The capital cost of the shadecloth only. The shadecloth commonly deteriorates more quickly than the suspension structure. Expressed as a cost per square metre. *[$/m^2]*

Lifespan (Structure)
The expected, claimed or experienced lifespan of the structure that suspends the shadecloth. *[years]*

Lifespan (Shadecloth)
The expected, claimed or experienced lifespan of the shadecloth itself. *[years]*

Annual Operating and Maintenance Cost
The expected, claimed or experienced costs of operation and maintenance of the entire shadecloth EMS (both the structure and the shadecloth itself), expressed as a cost per square metre. *[$/m^2]*

Figure 18 shows the data entry process.

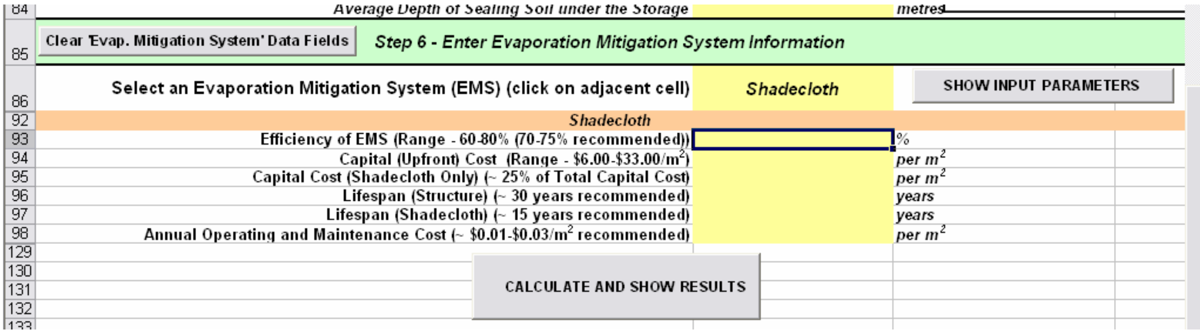

FIGURE 18 – ENTERING SHADECLOTH EMS DATA

4.6.3 Chemical Monolayer

Chemical monolayers are chemicals that can be applied to the water surface. Chemical monolayers act as a barrier to reduce the rate of evaporation. The application can be carried out manually but is usually applied through an automated system. A photograph of a chemical monolayer is shown in Figure 19.

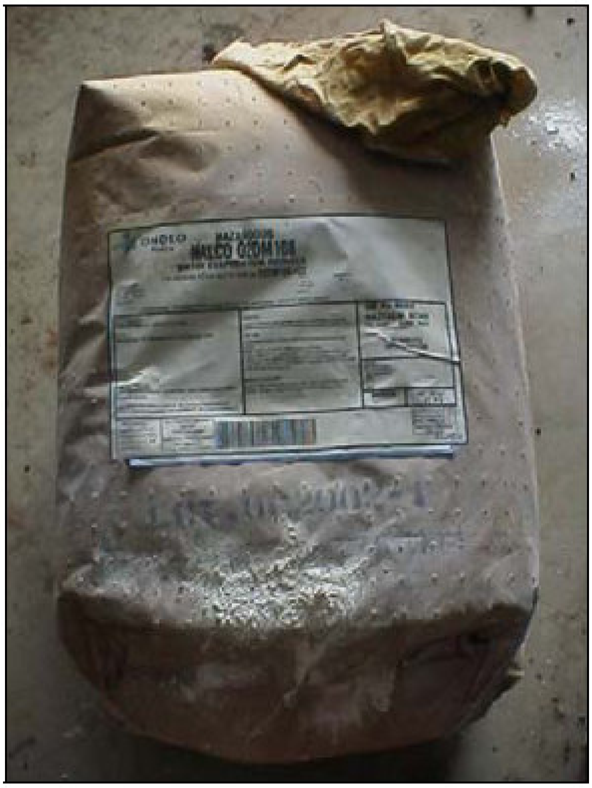

FIGURE 19 – CHEMICAL MONOLAYER

The user is required to enter the following inputs.

Efficiency of EMS (Range - 5-40% (Recommended 5-15%))
The efficiency of the chemical monolayer in reducing evaporative losses, expressed as a percentage reduction of total evaporative losses. An expected range of values and recommended values are given. These values are based on applied research into the EMS. *[%]*

Capital (Upfront) Cost
The capital cost of the entire EMS (including mixing, delivery and application equipment) at installation, expressed as a cost per square metre. *[$/m^2]*

Lifespan of Application Equipment
The expected, claimed or experienced lifespan of the mixing, delivery and application equipment. *[years]*

Annual Operating and Maintenance Cost (application equipment)
The expected, claimed or experienced costs of operation and maintenance of the mixing, delivery and application equipment and labour used in application, expressed as a cost per square metre. *[$/m^2]*

Cost of Chemical Monolayer
The cost of the chemical monolayer used. *[$/kg]*

Number of Days in Month that Monolayer is Applied
The number of days in any particular month (on average) that the monolayer is reapplied. For example, if the monolayer is reapplied every 3 days, then the monolayer would be applied 10 days each month. *[days]*

Application Rate
The application rate of the chemical monolayer to the water surface, expressed as kilograms of product applied per hectare. *[kg/hectare]*

Months that Monolayer is Applied (type Y or N)
Months of the year that the monolayer is applied. Enter a 'Y' if the monolayer is used in that month or an 'N' if it is not used for that month. Note that the data entry fields are not case-sensitive. In most instances it is most cost effective to only apply the monolayer in high evaporation months. In months where the storage is empty the calculations will automatically assume no monolayer is applied.

Figure 20 shows the data entry process.

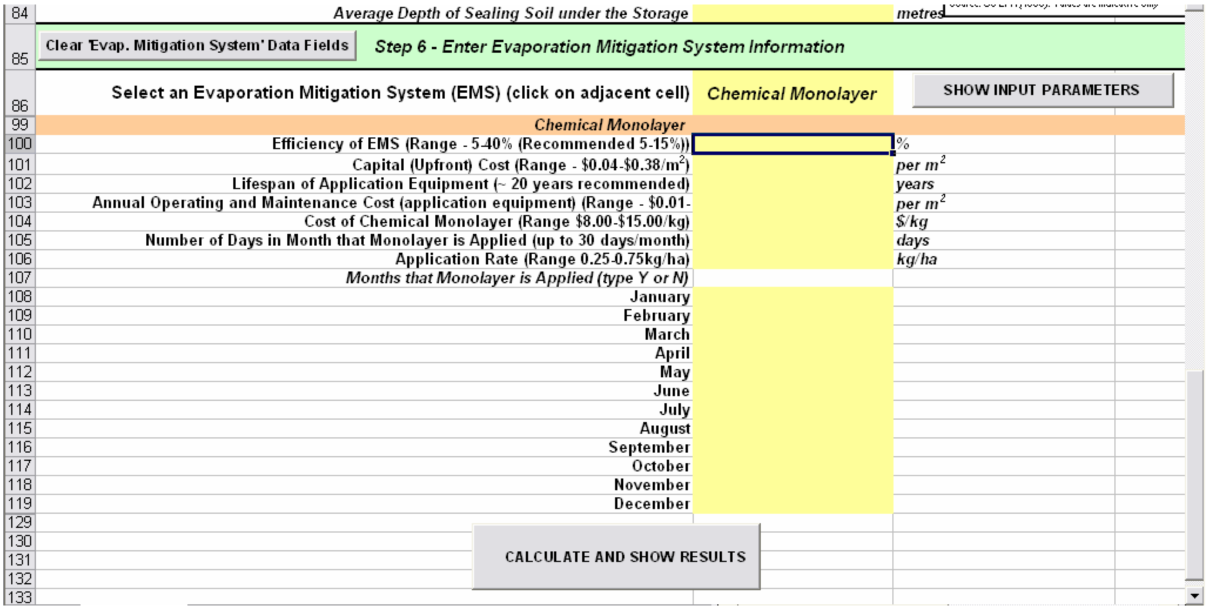

FIGURE 20 – ENTERING CHEMICAL MONOLAYER EMS DATA

4.6.4 Modular Cover

The user is required to enter the following inputs.

Modular covers have a broad range and there are a number of commercial systems available. Modular systems use individual (modular), usually floating, objects as barriers to reduce the surface area of water available for evaporation. They usually cannot achieve 100 % coverage of the water surface and as such they allow rainfall to enter the water storage. An example of a modular cover system is shown in Figure 21.

FIGURE 21 – MODULAR COVER

Surface Area Coverage
The surface area of water covered by the modules at any particular time, expressed as a percentage of the full supply level surface area. *[%]*

Capital (Upfront) Cost
The capital cost of the entire EMS, including modules and any tethering system, at installation, expressed as a cost per square metre. *[$/m^2]*

Lifespan
The expected, claimed or experienced lifespan of the modules and any tethering system used. *[years]*

Annual Operating and Maintenance Cost
The expected, claimed or experienced costs of operation and maintenance of the modular cover, expressed as a cost per square metre. *[$/m^2]*

Figure 22 shows the data entry process.

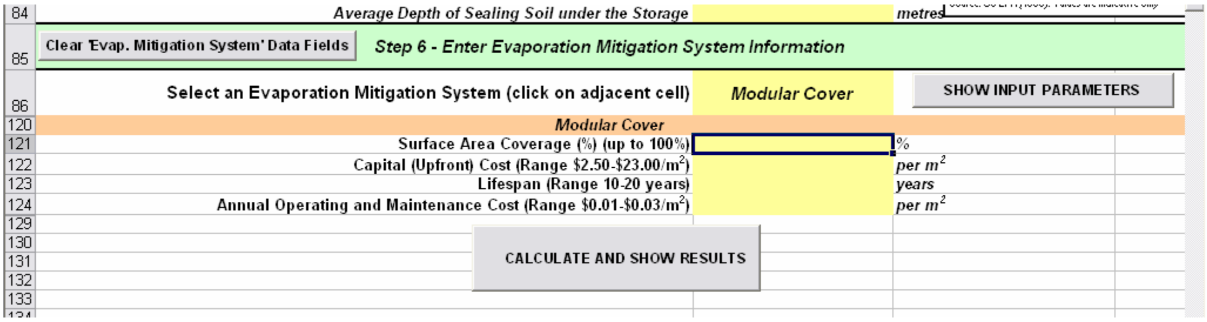

FIGURE 22 – ENTERING MODULAR COVER EMS DATA

4.6.5 Increase Wall Height

Increasing the wall height can effectively reduce the evaporative loss. This occurs by increasing the amount of water stored whilst effectively maintaining the same surface area, thus maintaining similar levels of evaporative loss.

The user is required to enter the following inputs.

Wall Height Increase
The increase in wall height of the storage. *[metres]*

Increase in Annual Operating and Maintenance Cost
The increase in operating and maintenance costs due to the extra height of the storage, over and above the existing operating and maintenance costs of the storage wall(s). *[$]*

Cost of Earthworks
The cost of earthworks expected for the user's location. *[$/m^3]*

Figure 23 shows the data entry process.

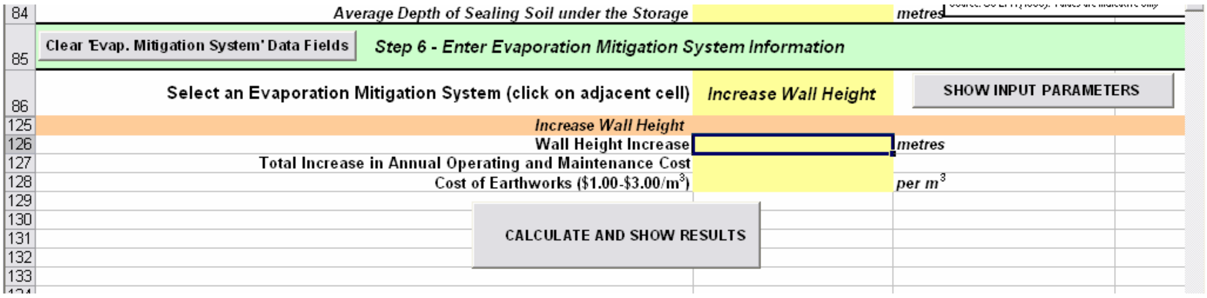

FIGURE 23 – ENTERING INCREASE WALL HEIGHT EMS DATA

4.7 Saving Input Data

After all data has been entered the file should be saved. If more than one evaporation mitigation system is to be evaluated each individual run of the model should be saved under a different filename for later reference. To do this, select 'Save As…' from the main menu bar. Use a filename that indicates the model run. For example, a run for Storage A with a Shadecloth evaporation mitigation system might be named Storage_A_Shade.xls.

4.8 Clearing Data Fields

A 'Clear Data Field' button has been included for each data entry section on the 'User Inputs' sheet, as shown in Figure 24. The user can clear all data fields for that section by clicking on the appropriate button, located at the upper left relative to that section. This is useful if another evaporation mitigation system is to be evaluated as it can be used to clear data only from the evaporation mitigation system section. Alternatively, at the top of the 'User Inputs' page a 'Clear All Data Fields' button is included. Clicking on this button will clear ALL data fields.

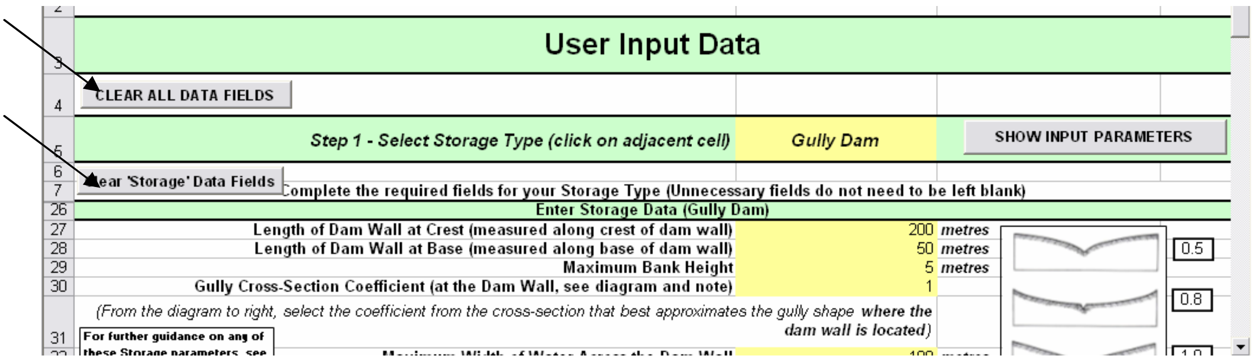

FIGURE 24 – CLEAR DATA FIELDS BUTTONS

The user is alerted to the fact that using the ‘Clear Data Fields’ button is not reversible using the ‘Undo’ function in Microsoft Excel™. Hence these buttons should be used with care otherwise data will need to be re-entered.

It is the responsibility of the user to ensure that all the relevant data fields have been entered (with sensible values) to avoid erroneous results being returned.

5 METHOD OF CALCULATION

The method of calculation is as follows:

- Calculations of storage geometry are carried out from user input data (to determine storage volume, surface area and depth)
- Calculations of potential evaporation loss are performed on a monthly basis
- Seepage losses are estimated on a monthly basis
- Water savings due to EMS are calculated on a yearly basis (after considering any possible increase in seepage losses)
- The cost of the evaporation mitigation system is calculated on a yearly basis
- Results calculated and delivered as cost ($) per ML water saved per year.

Results from the calculator rely heavily on the data entered by the user. The user is encouraged to vary input parameters (within expected ranges) to gain an understanding of the cost range of evaporation mitigation systems particular to their site.

A full description of all formulae used is included for reference in Appendix C.

6 ASSUMPTIONS

A number of assumptions were made when formulating the calculations to be performed in the model. These should be considered when evaluating the outputs. The assumptions relative to each storage type and evaporation mitigation system and general assumptions are outlined below.

6.1 Storage Type Assumptions

6.1.1 Rectangular Ring Tank

It is assumed that:

- Depth varies linearly with volume (volume of water stored in borrow pits inside the storage ignored)
- Surface area varies linearly with volume
- Seepage loss occurs only from the surface area of the base of the storage, regardless of the amount of water stored
- Increasing the wall height of the ring tank does not significantly change the surface area at top water level.

6.1.2 Circular Ring Tank

It is assumed that:

- Depth varies linearly with volume (volume of water stored in borrow pits inside the storage ignored)
- Surface area varies linearly with volume
- Seepage loss occurs only from the surface area of the base of the storage, regardless of the amount of water stored
- Increasing the wall height of the ring tank does not significantly change the surface area at top water level.

6.1.3 Gully Dam

It is assumed that:

- Water depth is not linear with volume (determined through calculation)
- Width and length of stored water level varies linearly with depth
- Surface area can be calculated using a triangular approximation (width x length / 2)
- Area available for seepage is equivalent to the area of the water surface.

6.2 Evaporation Mitigation System Assumptions

It is assumed that:

- For the modular cover EMS, the percentage coverage is taken as a proportion of the full supply level water surface area
- The modular cover has an efficiency of 100 % for the area covered
- Evaporation savings associated with increasing the storage wall height are calculated as unit volume saved per unit volume stored, and expressed in terms of the *original* stored volume

6.3 General Assumptions

It is assumed that:

- All rainfall that falls onto the surface of the storage is collected
- A discount rate of 5 % applies in calculating annuity cost.

7 MODEL EVALUATION

Once all appropriate input data fields have been entered, the user is required to click on the button titled 'CALCULATE AND SHOW RESULTS'. This button is located at the very bottom of the 'User Inputs' worksheet, as shown in Figure 25. The aim of this is to perform the economic analysis and deliver the user to the 'Results Summary' page.

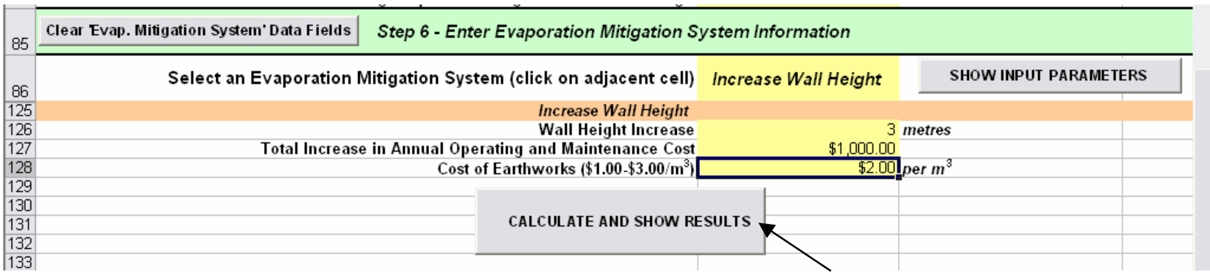

FIGURE 25 – CALCULATE AND SHOW RESULTS BUTTON

8 MODEL OUTPUTS

Once the computations are complete the ‘Results Summary’ worksheet is active. At the top of the ‘Results Summary’ page, a large cell indicates whether calculations have been carried out successfully (see Figure 26). If not, an error message will appear (as shown in Figure 27) indicating that an error has been made in the input data for the storage geometry. The Ready Reckoner calculates the storage volume and compares this to the entered storage volume. If the two vary by more than 20 %, the error message is displayed. The user is directed to check all storage geometry inputs before proceeding.

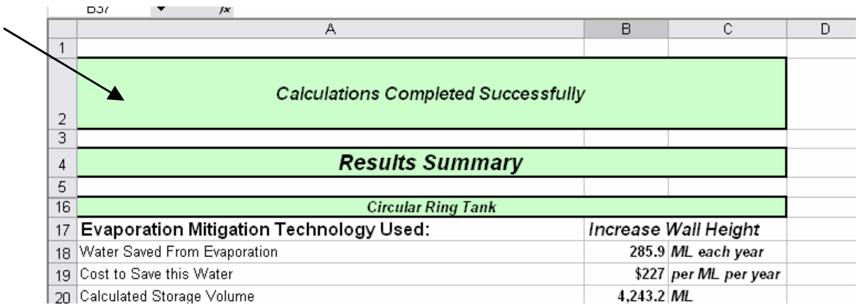

FIGURE 26 – CELL INDICATING SUCCESSFUL CALCULATION

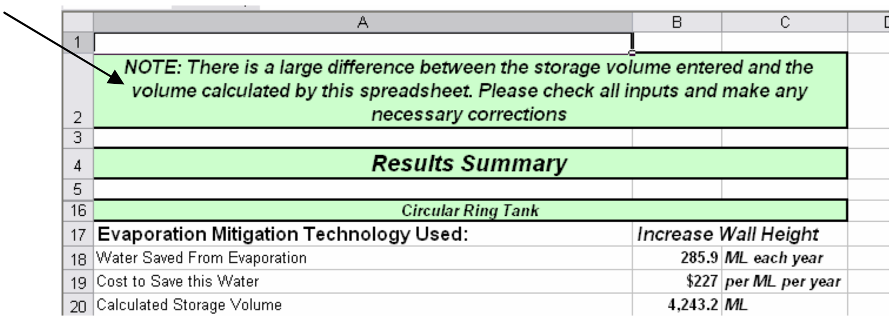

FIGURE 27 – CELL INDICATING ERROR IN CALCULATION PROCEDURE

The type of storage and evaporation mitigation system used is shown along with the following outputs in the ‘Results Summary’ worksheet.

Water Saved From Evaporation
The volume of water (ML) that the EMS saves each year by reducing evaporation losses.

Cost to Save this Water
The cost of saving each megalitre of water from evaporation (using the EMS) each year.

Calculated Storage Volume
The calculated storage volume (ML) at full supply level.

Surface Area at Full Supply Level
The surface area (ha) at full supply level of the storage, as calculated by the Ready Reckoner using the storage geometry data entered by the user.

Total Cost of EMS at Installation
The total installed cost of the EMS.

Annual Operating and Maintenance Cost
The total operating and maintenance cost of the EMS per year.

If the 'Increase Wall Height' EMS option is chosen, the following outputs are also delivered.

Total Extra Earthworks to Increase Wall Height
The total volume (in cubic metres) of earthworks required to increase the wall height.

Calculated Storage Volume at Full Supply Level after Increasing Wall Height
The calculated storage volume (ML) at full supply level after increasing the wall height.

The advantage of the Ready Reckoner is that the range of costs associated with evaporation mitigation systems can be identified given a range of input parameters. However the assumptions made when formulating this model must be noted.

The greatest value of the Ready Reckoner is to provide an estimate of the cost of evaporation mitigation systems and to show the relative importance of the numerous parameters that affect cost and water savings. Users are encouraged to vary input parameters to examine the sensitivity of these parameters on cost and water savings.

9 REFERENCES

Craig, I., Green, A., Scobie, M., and Schmidt, E. 2005. *Controlling Evaporation Loss from Water Storages.* National Centre for Engineering in Agriculture Publication 1000580/1. University of Southern Queensland, Toowoomba.

GHD 2003. *Methods for Reducing Evaporation from Storages used in Urban Water Supplies.* Final report. Queensland Department of Natural Resources and Mines. http://www.nrm.qld.gov.au/compliance/wic/pdf/reports/urban_wateruse/evapinstorages.pdf

NPSI 2002. Department of Natural Resources and Mines Queensland 2002. *Current Knowledge and Developing Technology for Controlling Evaporation from On-Farm Storages*. NPIRD Report QNR29.

Watts P.J 2005. Scoping Study - Reduction of Evaporation from Farm Dams. Final Report to National Program for Sustainable Irrigation. Feedlot Services Australia Pty Ltd. Toowoomba. http://www.lwa.gov.au/downloads/publications_pdf/ER050936.pdf

Appendix A. CASE STUDIES

Three case studies in different climatic areas have been prepared to demonstrate the Ready Reckoner.

Note that these Case Studies use *representative* data created purely for demonstration purposes. They do not depict existing on-ground storages.

A.1. Cotton Production – Emerald, Central Queensland

A.1.1. Introduction

Water for irrigated cotton production in Central Queensland is predominantly sourced from the Emerald Irrigation Scheme (using water from Fairbairn Dam) or overland flow / flood harvesting events. Water is not generally sourced from groundwater supplies for irrigated cotton production.

Water storages are generally quite large due to the high evaporation rates and, where appropriate, the infrequent nature of flooding events.

This Case Study models the scenario where a relatively large ring tank was used to store water captured from an overland flow or flood harvest event.

A.1.2. Step 1 – Storage Type and Geometry

The physical details of a typical rectangular ring tank storage in Emerald are detailed in Table 1 below.

TABLE 1 – TYPICAL STORAGE DETAILS – RECTANGULAR RING TANK (EMERALD, CENTRAL QUEENSLAND)

Parameter	Value	Units
Length at Centreline	1000	metres
Width at Centreline	700	metres
Corner Radius at Centreline	50	metres
Storage Wall Crest Width	8	metres
Average Bank Height	5	metres
Batter Slope of the Storage Inside Wall	5:1	
Batter Slope of the Storage Outside Wall	2:1	
Full Supply Volume	2550	ML
Freeboard	1.0	metres

A.1.3. Step 2 - Evaporation

The Queensland Department of Natural Resources website (http://www.npsi.gov.au/readyreckoner/index.html) was accessed to supply monthly evaporation data for Emerald, Central Queensland (23°30' South, 148°09' East). Values are shown in Table 2.

TABLE 2 – EVAPORATION DATA FOR EMERALD (23°30' S, 148°09' E)

Month	Evaporation (mm)
January	273
February	222
March	238
April	192
May	153
June	130
July	141
August	174
September	220
October	264
November	269
December	284
Annual Total	*2562*

A.1.4. Step 3 – Average Amount of Water Stored per Month

Rainfall in Central Queensland region is characterised by infrequent, intense events, predominantly during the summer months. As a result, overland flow and flood harvest opportunities are generally limited to these summer months.

Hence the amount of water stored per month can vary widely between years. However, on average, it will be more common to find a greater amount of water stored during the summer months due to water harvesting. The lowest amount of water stored will occur towards the end of the winter months and during the spring season. It is remembered that this average represents the expected amount of water in storage in any particular year *when water is stored*. The 'Average Percentage of Years that the Storage Contains Water' parameter indicates whether water is stored or not.

Considering the above, the Average Amount of Water Stored per Month is set at the values listed in Table 3 for each month.

Note that these values are somewhat arbitrary and in most cases will be estimated through experience. The final results will be impacted significantly with variation to these values.

TABLE 3 – AVERAGE AMOUNT OF WATER STORED PER MONTH (EMERALD, CENTRAL QUEENSLAND)

Month	Average Amount of Water Stored
January	60%
February	70%
March	60%
April	40%
May	30%
June	20%
July	10%
August	10%
September	20%
October	40%
November	50%
December	60%

A.1.5. Step 4 – Average Percentage of Years that the Storage Contains Water

There are periods where a storage in Central Queensland does not contain water due to the infrequent nature of flooding events. Hence, the percentage of years that the storage contains water was commonly less than 100 %.

Considering the above, the Average Percentage of Years that the Storage Contains Water is set at the values listed in Table 4 for each month.

Note that these values are somewhat arbitrary and in most cases will be estimated through experience. The final results will be impacted significantly with variation to these values.

TABLE 4 – AVERAGE PERCENTAGE OF YEARS THAT THE STORAGE CONTAINS WATER (EMERALD, CENTRAL QUEENSLAND)

Month	Average Percentage of Years that the Storage Contains Water
January	70%
February	80%
March	70%
April	50%
May	20%
June	10%
July	5%
August	5%
September	10%
October	20%
November	40%
December	60%

A.1.6. Step 5 – Enter Seepage Information

The size of the storage has meant that any seepage mitigation works have been too costly to implement. The storage has been built on heavy clay soil commonly found in Central Queensland and was subject to seepage loss. The seepage loss has not been quantified.

The option 'I Don't Know the Seepage Loss' option was selected.

The saturated hydraulic conductivity of the soil was not accurately known. The table of values suggests that values less than 0.1 m/year are indicative for heavy clays. Hence 0.1 m/year was entered for the saturated hydraulic conductivity of the soil.

The depth of sealing soil under the storage was 5 metres.

A.1.7. Step 6 – Enter Evaporation Mitigation System Information

The Chemical Monolayer evaporation mitigation system was chosen for this Case Study.

Chemical monolayers have been shown to reduce evaporative losses. However their performance will vary depending on local conditions. It was assumed that the efficiency of the monolayer in this Case Study was 15 %.

The size of this storage ensured that application of the chemical monolayer was automated. The capital cost of the application equipment (the only upfront cost) was determined to be $50,000 or $0.075 per square metre.

The application equipment is well built and maintained. The lifespan of the application equipment was hence set at 20 years.

The maintenance of the application equipment was set at $2,500/year or $0.004 per square metre.

The chemical monolayer costs $13.00 / kg and was applied 15 days per month at 0.5 kg / ha.

The evaporation data in Table 2 shows that evaporation is highest in the months September through March. The greatest volume of water will be saved when the chemical monolayer is used for these months. Hence a 'y' for the months September - March was entered into the Ready Reckoner.

A.1.8. Results

The Ready Reckoner showed that the chemical monolayer evaporation mitigation system saved **86 ML** of water from evaporation each year from the 2,545 ML capacity, 66.8 ha surface area storage, at a cost of **$591 per ML**. The total capital cost of the system was **$50,121** with **$2,673** in total maintenance costs annually.

A copy of the 'User Inputs' and 'Results Summary' sheets from the Ready Reckoner are included for reference.

User Input Data

CLEAR ALL DATA FIELDS

Step 1 - Select Storage Type (click on adjacent cell) Rectangular Ring Tank | SHOW INPUT PARAMETERS

Clear 'Storage' Data Fields

Complete the required fields for your Storage Type (Unnecessary fields do not need to be left blank)

For further guidance on any of these Storage parameters, see the relevant diagram on the 'Diagrams' sheet

Enter Storage Data (Rectangular Ring Tank)		
Length @ Centreline	1000	metres
Width @ Centreline	700	metres
Corner Radius @ Centreline	50	metres
Storage Wall Crest Width	8	metres
Average Bank Height	5	metres
Batter Slope of the Storage Inside Wall	5	in 1
Batter Slope of the Storage Outside Wall	2	in 1
Full Supply Volume	2550	ML
Freeboard	1	metres

Step 2 - Enter Monthly Evaporation

The monthly evaporation rate for your location can be found at http://www.npsi.gov.au/readyreckoner/index.html. Follow the instructions given, download the data and enter the monthly values into the appropriate cells below. A map of annual evaporation is given to check the data downloaded (see sheet titled 'Diagrams')

Clear 'Evaporation' Data Fields

January	273	mm
February	222	mm
March	238	mm
April	192	mm
May	153	mm
June	130	mm
July	141	mm
August	174	mm
September	220	mm
October	264	mm
November	269	mm
December	284	mm
Annual Total (Note: No data entry required in this cell)	2562	mm

Step 3 - Enter the Average Amount of Water Stored Per Month (as a % of Total Storage Volume)

Clear 'Water Stored per Month' Data Fields

January	60	%
February	70	%
March	60	%
April	40	%
May	30	%
June	20	%
July	10	%
August	10	%
September	20	%
October	40	%
November	50	%
December	60	%

Step 4 - Enter the Average Percentage of Years that the Storage Contains Water (per month)

Clear 'Years Storage Contains Water' Data Fields

January	70	%
February	80	%
March	70	%
April	50	%
May	20	%
June	10	%
July	5	%
August	5	%
September	10	%
October	20	%
November	40	%
December	60	%

Step 5 - Enter Seepage Information

Select your Most Applicable Seepage Option from the drop-down list (click on adjacent cell) — I Don't Know the Seepage Loss

Clear 'Seepage' Data Fields

Saturated Hydraulic Conductivity of the Soil (see table)	0.1	*m/yr*
Average Depth of Sealing Soil under the Storage	5	*metres*

Soil Type	Conductivity (m/yr)
Heavy Clay	< 0.1
Clay	0.1 - 0.5
Loam	0.5 - 1.0
Sand	> 1.0

Source: US EPA (1986). Values are indicative only

Clear 'Evap. Mitigation System' Data Fields

Step 6 - Enter Evaporation Mitigation System Information

Select an Evaporation Mitigation System (EMS) (click on adjacent cell) — ***Chemical Monolayer***

SHOW INPUT PARAMETERS

Chemical Monolayer		
Efficiency of EMS (Range - 5-40% (Recommended 5-15%))	15	*%*
Capital (Upfront) Cost (Range - $0.04-$0.38/m^2)	$0.08	*per m^2*
Lifespan of Application Equipment (~ 20 years recommended)	20	*years*
Annual Operating and Maintenance Cost (application equipment) (Range - $0.01-$0.09/m^2)	$0.004	*per m^2*
Cost of Chemical Monolayer (Range $8.00-$15.00/kg)	$13.00	*$/kg*
Number of Days in Month that Monolayer is Applied (up to 30 days/month)	15	*days*
Application Rate (Range 0.25-0.75kg/ha)	0.5	*kg/ha*
Months that Monolayer is Applied (type Y or N)		
January	y	
February	y	
March	y	
April	n	
May	n	
June	n	
July	n	
August	n	
September	y	
October	y	
November	y	
December	y	

CALCULATE AND SHOW RESULTS

Calculations Completed Successfully

Results Summary

Rectangular Ring Tank

Evaporation Mitigation System Used:	***Chemical Monolayer***
Water Saved From Evaporation	**85.5** ***ML each year***
Cost to Save this Water	**$591** ***per ML per year***
Calculated Storage Volume at Full Supply Level	**2,545.3** ***ML***
Surface Area at Full Supply Level	**66.8** ***ha***
Total Cost of EMT at Installation	**$50,121**
Annual Operating and Maintenance Cost	**$2,673**

A.2. Horticulture – Lockyer Valley, South-East Queensland

A.2.1. Introduction

Horticulture in the Lockyer Valley is predominantly irrigated from groundwater bores. In some areas, the flow rate out of a bore is not sufficient to directly supply the needs of an irrigation system. Hence in these areas balancing storages are used to store enough water to supply a typical irrigation event. These balancing storages are generally small in size (< 20 ML). The bore supplies water to the storage continuously, with a higher capacity pump supplying the irrigation system with water from the storage when required.

This Case Study models the scenario where a small balancing storage is used.

A.2.2. Step 1 - Storage Type and Geometry

The physical details of a typical rectangular ring tank storage in the Lockyer Valley are detailed in Table 5 below.

TABLE 5 – TYPICAL STORAGE DETAILS – RECTANGULAR RING TANK (LOCKYER VALLEY, SOUTH-EAST QUEENSLAND)

Parameter	Value	Units
Length at Centreline	50	metres
Width at Centreline	50	metres
Corner Radius at Centreline	10	metres
Storage Wall Crest Width	2	metres
Average Bank Height	2	metres
Batter Slope of the Storage Inside Wall	3:1	
Batter Slope of the Storage Outside Wall	2:1	
Full Supply Volume	2.4	ML
Freeboard	0.5	metres

A.2.3. Step 2 - Evaporation

The Queensland Department of Natural Resources website (http://www.npsi.gov.au/readyreckoner/index.html) was accessed to supply monthly evaporation data for the Lockyer Valley. Coordinates for Gatton, the major township within the Lockyer Valley, were used (27°33’ South, 152°15’ East). Values are shown in Table 6.

TABLE 6 – EVAPORATION DATA FOR GATTON (27°33' S, 152°15' E)

Month	Evaporation (mm)
January	236
February	191
March	191
April	146
May	111
June	93
July	105
August	132
September	169
October	205
November	220
December	241
Annual Total	*2038*

A.2.4. Step 3 – Average Amount of Water Stored per Month

Typically, irrigated crops are grown all year round in the Lockyer Valley. Hence the storage contains some water for most of the year. As water is drawn from the storage for irrigation, there will be periods where the storage contains water at less than full supply level. This type of storage cycles between nearly empty and full throughout the year. Hence regardless of the time between full cycles the *average* amount of water stored per month is approximately 50 %.

Therefore the Average Amount of Water Stored per Month was set at 50 % for each month.

A.2.5. Step 4 – Average Percentage of Years that the Storage Contains Water

Groundwater was used to supply the storage. It was assumed that this water supply was reliable and was able to be accessed every year. Hence for each month of each year, the storage will contain water, even if it is not full.

Therefore the Average Percentage of Years that the Storage Contains Water was set at 100 % for each month.

A.2.6. Step 5 – Enter Seepage Information

This storage is relatively small. Hence in most cases dam lining is economically feasible. It is not uncommon to find that these types of storages are lined to prevent seepage losses. The option 'Impermeable Liner Installed' was selected and zero seepage loss is assumed.

A.2.7. Step 6 – Enter Evaporation Mitigation System Information

Two of the five evaporation mitigation system choices are analysed for this case study. They are Impermeable Cover and Shadecloth. They were chosen because the size of the storage makes their use practical.

All other parameters remain the same for both analyses.

Impermeable Cover – Evaporation Mitigation System Parameters
Impermeable covers are very good at reducing evaporative losses. It was assumed that the impermeable cover was maintained to a high standard. Hence the efficacy of the cover was set at 90 %.

Due to the proximity of the Lockyer Valley to Brisbane, the capital costs of the cover will be lower than average. This was a result of increased competition, availability, labour and reduced transport costs. The capital cost of the cover was set at $7.00 per square metre.

As the cover was assumed to be well maintained, the lifespan of the cover was set at 15 years.

The annual operating and maintenance costs of the cover were set very high to reflect the level of maintenance and small size of the storage, at $0.20 per square metre.

Shadecloth - Evaporation Mitigation System Parameters
Shadecloth is also very good at reducing evaporative losses. However it does not match an impermeable cover. It was also assumed that the shadecloth is maintained to a high standard. Hence the efficacy of the shadecloth was set at 75 %.

Again due to the proximity of the Lockyer Valley to Brisbane, the capital costs of the shadecloth were lower than average. This was a result of increased competition, availability, labour and reduced transport costs. The capital cost of the shadecloth was set at $8.00 per square metre. It was assumed that 25 % of the capital cost was the shadecloth itself. Hence the cost of the shadecloth only was set at $2.00 per square metre.

As the shadecloth was assumed to be well maintained, the lifespan of the shadecloth structure was set at 30 years. The lifespan of the shadecloth itself was set at 15 years.

The annual operating and maintenance costs of the cover were set very high to reflect the level of maintenance and small size of the storage, at $0.15 per square metre.

A.2.8. Results

Impermeable Cover
The Ready Reckoner showed that the evaporation mitigation system saved **3.0 ML** of water from evaporation each year from the 2.4 ML capacity, 0.2 ha surface area storage, at a cost of **$590 per ML**. The total capital cost of the system was **$13,837** with **$395** in total maintenance costs annually.

Shadecloth

The Ready Reckoner showed that the evaporation mitigation system saved **2.5 ML** of water from evaporation each year from the 2.4 ML capacity, 0.2 ha surface area storage, at a cost of **$598 per ML**. The total capital cost of the system was **$15,814** with **$297** in total maintenance costs annually.

A copy of the 'User Inputs' and 'Results Summary' sheets from the Ready Reckoner for both evaporation mitigation systems are included for reference.

User Input Data

CLEAR ALL DATA FIELDS

Step 1 - Select Storage Type (click on adjacent cell) Rectangular Ring Tank SHOW INPUT PARAMETERS

Clear 'Storage' Data Fields

Complete the required fields for your Storage Type (Unnecessary fields do not need to be left blank)

For further guidance on any of these Storage parameters, see the relevant diagram on the 'Diagrams' sheet

Enter Storage Data (Rectangular Ring Tank)		
Length @ Centreline	50	metres
Width @ Centreline	50	metres
Corner Radius @ Centreline	10	metres
Storage Wall Crest Width	2	metres
Average Bank Height	2	metres
Batter Slope of the Storage Inside Wall	3	in 1
Batter Slope of the Storage Outside Wall	2	in 1
Full Supply Volume	2.4	ML
Freeboard	0.5	metres

Step 2 - Enter Monthly Evaporation

The monthly evaporation rate for your location can be found at http://www.npsi.gov.au/readyreckoner/index.html. Follow the instructions given, download the data and enter the monthly values into the appropriate cells below. A map of annual evaporation is given to check the data downloaded (see sheet titled 'Diagrams')

Clear 'Evaporation' Data Fields

January	236	mm
February	191	mm
March	191	mm
April	146	mm
May	111	mm
June	93	mm
July	105	mm
August	132	mm
September	169	mm
October	205	mm
November	220	mm
December	241	mm
Annual Total (Note: No data entry required in this cell)	2038	mm

Step 3 - Enter the Average Amount of Water Stored Per Month (as a % of Total Storage Volume)

Clear 'Water Stored per Month' Data Fields

January	50	%
February	50	%
March	50	%
April	50	%
May	50	%
June	50	%
July	50	%
August	50	%
September	50	%
October	50	%
November	50	%
December	50	%

Step 4 - Enter the Average Percentage of Years that the Storage Contains Water (per month)

Clear 'Years Storage Contains Water' Data Fields

January	100	%
February	100	%
March	100	%
April	100	%
May	100	%
June	100	%
July	100	%
August	100	%
September	100	%
October	100	%
November	100	%
December	100	%

Step 5 - Enter Seepage Information

Select your Most Applicable Seepage Option from the drop-down list (click on adjacent cell) — Impermeable Liner Installed

Clear 'Seepage' Data Fields

It is assumed that you have zero seepage loss

Soil Type	Conductivity (m/yr)
Heavy Clay	< 0.1
Clay	0.1 - 0.5
Loam	0.5 - 1.0
Sand	> 1.0

Source: US EPA (1986). Values are indicative only

Clear 'Evap. Mitigation System' Data Fields

Step 6 - Enter Evaporation Mitigation System Information

Select an Evaporation Mitigation System (EMS) (click on adjacent cell) — *Impermeable Cover*

SHOW INPUT PARAMETERS

Impermeable Cover		
Efficiency of EMS (Range - 85-100% (90-95% recommended))	90	%
Capital (Upfront) Cost (Range - $3.50-$30.00/m^2)	$7.00	per m^2
Lifespan (~ 10-15 years recommended)	15	years
Annual Operating and Maintenance Cost (~ $0.01-$0.03/m^2 recommended)	$0.200	per m^2

CALCULATE AND SHOW RESULTS

Calculations Completed Successfully

Results Summary

Rectangular Ring Tank

Evaporation Mitigation System Used:	***Impermeable Cover***
Water Saved From Evaporation	**3.0** ***ML each year***
Cost to Save this Water	**$590** ***per ML per year***
Calculated Storage Volume at Full Supply Level	**2.4** ***ML***
Surface Area at Full Supply Level	**0.2** ***ha***
Total Cost of EMT at Installation	**$13,837**
Annual Operating and Maintenance Cost	**$395**

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User Input Data

CLEAR ALL DATA FIELDS

Step 1 - Select Storage Type (click on adjacent cell) *Rectangular Ring Tank*

SHOW INPUT PARAMETERS

Clear 'Storage' Data Fields

Complete the required fields for your Storage Type (Unnecessary fields do not need to be left blank)

For further guidance on any of these Storage parameters, see the relevant diagram on the 'Diagrams' sheet

Enter Storage Data (Rectangular Ring Tank)		
Length @ Centreline	50	*metres*
Width @ Centreline	50	*metres*
Corner Radius @ Centreline	10	*metres*
Storage Wall Crest Width	2	*metres*
Average Bank Height	2	*metres*
Batter Slope of the Storage Inside Wall	3	*in 1*
Batter Slope of the Storage Outside Wall	2	*in 1*
Full Supply Volume	2.4	*ML*
Freeboard	0.5	*metres*

Step 2 - Enter Monthly Evaporation

The monthly evaporation rate for your location can be found at http://www.npsi.gov.au/readyreckoner/index.html. Follow the instructions given, download the data and enter the monthly values into the appropriate cells below. A map of annual evaporation is given to check the data downloaded (see sheet titled 'Diagrams')

Clear 'Evaporation' Data Fields

January	236	*mm*
February	191	*mm*
March	191	*mm*
April	146	*mm*
May	111	*mm*
June	93	*mm*
July	105	*mm*
August	132	*mm*
September	169	*mm*
October	205	*mm*
November	220	*mm*
December	241	*mm*
Annual Total (Note: No data entry required in this cell)	2038	*mm*

Step 3 - Enter the Average Amount of Water Stored Per Month (as a % of Total Storage Volume)

Clear 'Water Stored per Month' Data Fields

January	50	%
February	50	%
March	50	%
April	50	%
May	50	%
June	50	%
July	50	%
August	50	%
September	50	%
October	50	%
November	50	%
December	50	%

Step 4 - Enter the Average Percentage of Years that the Storage Contains Water (per month)

Clear 'Years Storage Contains Water' Data Fields

January	100	%
February	100	%
March	100	%
April	100	%
May	100	%
June	100	%
July	100	%
August	100	%
September	100	%
October	100	%
November	100	%
December	100	%

Step 5 - Enter Seepage Information

Select your Most Applicable Seepage Option from the drop-down list (click on adjacent cell) — Impermeable Liner Installed

Clear 'Seepage' Data Fields

It is assumed that you have zero seepage loss

Soil Type	Conductivity (m/yr)
Heavy Clay	< 0.1
Clay	0.1 - 0.5
Loam	0.5 - 1.0
Sand	> 1.0

Source: US EPA (1986). Values are indicative only

Clear 'Evap. Mitigation System' Data Fields

Step 6 - Enter Evaporation Mitigation System Information

Select an Evaporation Mitigation System (EMS) (click on adjacent cell) — ***Shadecloth***

SHOW INPUT PARAMETERS

Shadecloth

Efficiency of EMS (Range - 60-80% (70-75% recommended))	75	%
Capital (Upfront) Cost (Range - \$6.00-\$33.00/m^2)	\$8.00	per m^2
Capital Cost (Shadecloth Only) (~ 25% of Total Capital Cost)	\$2.00	per m^2
Lifespan (Structure) (~ 30 years recommended)	30	years
Lifespan (Shadecloth) (~ 15 years recommended)	15	years
Annual Operating and Maintenance Cost (~ \$0.01-\$0.03/m^2 recommended)	\$0.150	per m^2

CALCULATE AND SHOW RESULTS

Calculations Completed Successfully

Results Summary

Rectangular Ring Tank

Evaporation Mitigation System Used:	***Shadecloth***
Water Saved From Evaporation	**2.5** ***ML each year***
Cost to Save this Water	**$598** ***per ML per year***
Calculated Storage Volume at Full Supply Level	**2.4** ***ML***
Surface Area at Full Supply Level	**0.2** ***ha***
Total Cost of EMT at Installation	**$15,814**
Annual Operating and Maintenance Cost	**$297**

A.3. Cotton Production – Bourke, North-Western New South Wales

A.3.1. Introduction

Irrigated cotton production at Bourke, North-Western New South Wales is sustained with water from the Darling River. The Darling River system near Bourke does not have a major impoundment supplying allocation water. Hence water can generally only be obtained through overland flow or flood harvesting opportunities. The infrequent nature of these flooding events combined with high evaporation rates requires that storages are quite large to store adequate water for irrigation purposes until the next overland flow or flood harvest event.

This Case Study models the scenario where a relatively large ring tank is used to store water captured from an overland flow or flood harvest event.

A.3.2. Step 1 - Storage Type and Geometry

The physical details of a typical circular ring tank storage at Bourke are detailed in Table 1 below.

TABLE 7 – TYPICAL STORAGE DETAILS – CIRCULAR RING TANK (BOURKE, NORTH-WESTERN NEW SOUTH WALES)

Parameter	Value	Units
Radius at Centreline	600	metres
Storage Wall Crest Width	8	metres
Average Bank Height	5	metres
Batter Slope of the Storage Inside Wall	5:1	
Batter Slope of the Storage Outside Wall	2:1	
Full Supply Volume	4200	ML
Freeboard	1.0	metres

A.3.3. Step 2 - Evaporation

The Queensland Department of Natural Resources website (http://www.npsi.gov.au/readyreckoner/index.html) was accessed to supply monthly evaporation data for Bourke, North Western New South Wales (30°06' South, 145°54' East). Values are shown in Table 8.

TABLE 8 – EVAPORATION DATA FOR BOURKE (30°06' S, 145°54' E)

Month	Evaporation (mm)
January	333
February	274
March	258
April	174
May	112
June	81
July	89
August	128
September	178
October	239
November	278
December	333
Annual Total	*2477*

A.3.4. Step 3 – Average Amount of Water Stored per Month

Flooding and high flow events occurring in the Darling River at Bourke are considerably random due to the extent of the catchment upstream. The majority of the catchment is in a summer dominated rainfall area, meaning that flow events are more common at this time of year. However there have been times where high flows occur during the cooler months.

Hence the amount of water stored per month can vary widely between years. However, on average, it will be more common to find a greater amount of water stored during the summer months due to water harvesting. The lowest amount of water stored will occur towards the end of the winter months and during the spring season. It is remembered that this average represents the expected amount of water in storage in any particular year *when water is stored*. The 'Average Percentage of Years that the Storage Contains Water' parameter indicates whether water is stored or not.

Considering the above, the Average Amount of Water Stored per Month was set at the values listed in Table 9 for each month.

Note that these values are somewhat arbitrary and in most cases will be estimated through experience. The final results will be impacted significantly with variation to these values.

TABLE 9 – AVERAGE AMOUNT OF WATER STORED PER MONTH (BOURKE, NORTH WESTERN NEW SOUTH WALES)

Month	Average Amount of Water Stored
January	80%
February	70%
March	50%
April	20%
May	10%

June	10%
July	10%
August	20%
September	40%
October	50%
November	70%
December	70%

A.3.5. Step 4 – Average Percentage of Years that the Storage Contains Water

There will be extended periods where a storage at Bourke does not contain water due to the infrequent nature of high flow events. Hence, the percentage of years that the storage contains water is commonly less than 100 %.

However, in general it is slightly more likely that a storage at Bourke will contain *some* water during the summer months, and vice-versa for the winter months.

Considering the above, the Average Percentage of Years that the Storage Contains Water was set at the values listed in Table 10 for each month.

Note that these values are somewhat arbitrary and in most cases will be estimated through experience. The final results will be impacted significantly with variation to these values.

TABLE 10 – AVERAGE PERCENTAGE OF YEARS THAT THE STORAGE CONTAINS WATER (BOURKE, NORTH WESTERN NEW SOUTH WALES)

Month	Average Percentage of Years that the Storage Contains Water
January	60%
February	50%
March	30%
April	20%
May	5%
June	5%
July	5%
August	10%
September	10%
October	20%
November	40%
December	50%

A.3.6. Step 5 – Enter Seepage Information

The size of the storage has meant that any seepage mitigation works have been too costly to implement. The storage has been built on red clay soil commonly found near Bourke and was subject to seepage loss. The seepage loss was accurately quantified when the storage was full (i.e. 5 metres deep) at 1 mm/day.

The option 'I Have Measured the Seepage Loss' option was selected.

The saturated hydraulic conductivity of the soil is not accurately known. The table of values suggests that values between 0.1 and 0.5 m/year are indicative for clays. Hence 0.3 m/year was entered for the saturated hydraulic conductivity of the soil.

The depth of sealing soil under the storage was 3 metres.

A.3.7. Step 6 – Enter Evaporation Mitigation System Information

The Increase Wall Height evaporation mitigation system was chosen for this Case Study.

Increasing the wall height will not reduce the actual amount of water lost to evaporation. It will, however, allow more water to be stored whilst maintaining the same level of evaporation. Hence the ratio of water lost through evaporation to water stored will be increased, which results in a net saving of water.

The Wall Height Increase was set at 3 metres, to bring the total wall height to 8 metres.

The extra total cost in maintenance of this extra wall height was expected to be minimal. A value of $1,000 was entered for this parameter.

The cost of earthworks for the Bourke area was set at $2.00 per cubic metre.

A.3.8. Results

The Ready Reckoner showed that increasing the wall height from 5 to 8 metres increased the capacity of the storage from 4,243 ML to 7,240 ML. The full supply level surface area remained the same at 110 ha.

Increasing the wall height saved **282 ML** of water from evaporation each year from the storage, at a cost of **$231 per ML**. A total of **605,071** m^3 of earthworks was required to increase the wall height. The total capital cost of the system was **$1,210,141** with **$1,000** in total maintenance costs annually.

A copy of the 'User Inputs' and 'Results Summary' sheets from the Ready Reckoner are included for reference.

User Input Data

CLEAR ALL DATA FIELDS

Step 1 - Select Storage Type (click on adjacent cell) Circular Ring Tank | SHOW INPUT PARAMETERS

Clear 'Storage' Data Fields

Complete the required fields for your Storage Type (Unnecessary fields do not need to be left blank)

For further guidance on any of these Storage parameters, see the relevant diagram on the 'Diagrams' sheet

Enter Storage Data (Circular Ring Tank)		
Radius @ Centreline	600	metres
Storage Wall Crest Width	8	metres
Average Bank Height	5	metres
Batter Slope of the Storage Inside Wall	5	in 1
Batter Slope of the Storage Outside Wall	2	in 1
Full Supply Volume	4200	ML
Freeboard	1	metres

Step 2 - Enter Monthly Evaporation

The monthly evaporation rate for your location can be found at http://www.npsi.gov.au/readyreckoner/index.html. Follow the instructions given, download the data and enter the monthly values into the appropriate cells below. A map of annual evaporation is given to check the data downloaded (see sheet titled 'Diagrams')

Clear 'Evaporation' Data Fields

January	333	mm
February	274	mm
March	258	mm
April	174	mm
May	112	mm
June	81	mm
July	89	mm
August	128	mm
September	178	mm
October	239	mm
November	278	mm
December	333	mm
Annual Total (Note: No data entry required in this cell)	2477	mm

Step 3 - Enter the Average Amount of Water Stored Per Month (as a % of Total Storage Volume)

Clear 'Water Stored per Month' Data Fields

January	80	%
February	70	%
March	50	%
April	20	%
May	10	%
June	10	%
July	10	%
August	20	%
September	40	%
October	50	%
November	70	%
December	70	%

Step 4 - Enter the Average Percentage of Years that the Storage Contains Water (per month)

Clear 'Years Storage Contains Water' Data Fields

January	60	%
February	50	%
March	30	%
April	20	%
May	5	%
June	5	%
July	5	%
August	10	%
September	10	%
October	20	%
November	40	%
December	50	%

Step 5 - Enter Seepage Information

Select your Most Applicable Seepage Option from the drop-down list (click on adjacent cell) — I Have Measured the Seepage Loss

Clear 'Seepage' Data Fields

Measured Seepage Loss in mm/day	1	
Depth at which Water Seepage Loss was Determined	5	*metres*
Saturated Hydraulic Conductivity of the Soil (see table)	0.3	*m/yr*
Average Depth of Sealing Soil under the Storage	3	*metres*

Soil Type	Conductivity (m/yr)
Heavy Clay	< 0.1
Clay	0.1 - 0.5
Loam	0.5 - 1.0
Sand	> 1.0

Source: US EPA (1986). Values are indicative only

Clear 'Evap. Mitigation System' Data Fields

Step 6 - Enter Evaporation Mitigation System Information

Select an Evaporation Mitigation System (EMS) (click on adjacent cell) — ***Increase Wall Height***

SHOW INPUT PARAMETERS

Increase Wall Height

Wall Height Increase	3	*metres*
Total Increase in Annual Operating and Maintenance Cost	$1,000.00	
Cost of Earthworks ($1.00-$3.00/m^3)	$2.00	*per m^3*

CALCULATE AND SHOW RESULTS

Calculations Completed Successfully

Results Summary

Circular Ring Tank

Evaporation Mitigation System Used:	***Increase Wall Height***
Water Saved From Evaporation	**281.5** ***ML each year***
Cost to Save this Water	**$231** ***per ML per year***
Calculated Storage Volume	**4,243.2** ***ML***
Surface Area at Full Supply Level	**109.7** ***ha***
Total Cost of EMT at Installation	**$1,210,141**
Annual Operating and Maintenance Cost	**$1,000**
Total Extra Earthworks to Increase Wall Height	**605,071** ***m3***
Calculated Storage Volume at Full Supply Level after Increasing Wall Height	**7,240** ***ML***

Appendix B. HYDROLOGICAL STUDIES

Three hydrological studies were prepared to demonstrate the Ready Reckoner and the importance of an accurate hydrological assessment of the amount and timing of water stored in the dam.

A professional hydrological study would be required if the user is not able to estimate the 'Average Amount of Water Stored per Month' and 'Average Percentage of Years that the Storage Contains Water' parameters accurately.

However, the user can gain an understanding of the cost range of various EMSs for their site by varying these parameters within expected ranges.

B.1. Cotton Production – Darling Downs (Dalby), Southern Queensland

B.1.1. Introduction

Irrigated cotton production on the Darling Downs is sustained with water from numerous sources. In addition to overland flow, the Condamine River supplies regulated allocation water and flood harvest water. The Darling Downs is also situated above an irrigable aquifer with many growers holding groundwater allocations.

This Hydrological Study models an actual 550 ha cotton irrigation property where three ring tanks are used to store water captured from overland flow, flood harvesting and a bore allocation.

Table 11 details the parameters used to run the hydrological model. The model was run using 24 years of historical evaporation, rainfall and river flow data. The hydrological model accurately determines the 'Average Amount of Water Stored per Month' and 'Average Percentage of Years that the Storage Contains Water' input parameters for the model.

The Ready Reckoner was then used to carry out an economic assessment of an evaporation mitigation system installed on the 1500 ML storage.

TABLE 11 – PROPERTY SPECIFIC PARAMETERS ENTERED INTO HYDROLOGICAL MODEL

Description	Value
Property Size (Irrigable Area)	550 ha
Storage 1 Capacity	1500 ML
Storage 1 Depth	5.5 m
Storage 1 Surface Area	28.5 ha
Storage 2 Capacity	400 ML
Storage 2 Depth	2.0 m
Storage 2 Surface Area	16.4 ha
River Storage Capacity	500 ML
River Storage Depth	6.0 m
River Storage Surface Area	11.1 ha
Total Storage Sump Capacity	60 ML
Sump Depth	2 m
Maximum Take (Flood Harvest) from Condamine River (minimum river flow = 10 m^3/s)	86.4 ML/day
Maximum Take (Flood Harvest) from Condamine River (minimum river flow = 7.5 m^3/s)	25.0 ML/day
Overland Flow Catchment (26" + 20" pumps)	900 ha
Bore Allocation (maximum 200 % carryover)	410 ML/year
Combined Maximum Bore Flow Rate	150 L/s
Transfer Rate between River Storage to Storages 1 and 2	100 ML/day

B.1.2. Step 1 - Storage Type and Geometry

The physical details of the 1500 ML ring tank are detailed in Table 12.

TABLE 12 – TYPICAL STORAGE DETAILS – RECTANGULAR RING TANK (DALBY, DARLING DOWNS, SOUTHERN QUEENSLAND)

Parameter	Value	Units
Length at Centreline	600	metres
Width at Centreline	500	metres
Corner Radius at Centreline	50	metres
Storage Wall Crest Width	8	metres
Average Bank Height	6	metres
Batter Slope of the Storage Inside Wall	4:1	
Batter Slope of the Storage Outside Wall	2:1	
Full Supply Volume	1500	ML
Freeboard	0.5	metres

B.1.3. Step 2 - Evaporation

The Queensland Department of Natural Resources website (http://www.npsi.gov.au/readyreckoner/index.html) was accessed to supply monthly evaporation data for Dalby, Darling Downs, Southern Queensland (27°09' South, 151°15' East). Values are shown in Table 13.

TABLE 13 – EVAPORATION DATA FOR DALBY (27°09' S, 151°15' E)

Month	Evaporation (mm)
January	245
February	200
March	204
April	153
May	111
June	88
July	99
August	127
September	168
October	212
November	230
December	252
Annual Total	*2087*

B.1.4. Step 3 – Average Amount of Water Stored per Month

The hydrological study determined the average amount of water stored per month in the 1500 ML storage. The values returned by the model are shown in Table 14.

TABLE 14 – AVERAGE AMOUNT OF WATER STORED PER MONTH (DALBY, DARLING DOWNS, SOUTHERN QUEENSLAND)

Month	Average Amount of Water Stored
January	42%
February	47%
March	49%
April	55%
May	57%
June	59%
July	58%
August	57%
September	58%
October	47%
November	43%
December	39%

B.1.5. Step 4 – Average Percentage of Years that the Storage Contains Water

The hydrological study determined the average percentage of years that the 1500 ML storage contained water. The values returned by the model are shown in Table 14.

TABLE 15 – AVERAGE PERCENTAGE OF YEARS THAT THE STORAGE CONTAINS WATER (DALBY, DARLING DOWNS, SOUTHERN QUEENSLAND)

Month	Average Percentage of Years that the Storage Contains Water
January	85%
February	83%
March	82%
April	78%
May	78%
June	78%
July	80%
August	82%
September	82%
October	82%
November	75%
December	87%

B.1.6. Step 5 – Enter Seepage Information

The size of the storage has meant that any seepage mitigation works have been too costly to implement. The storage has been built on the heavy black soils characteristic of the Darling Downs and was subject to seepage loss.

The option 'I Don't know the Seepage Loss' option was selected.

The saturated hydraulic conductivity of the soil is not accurately known. The table of values suggests that values less than 0.1 m/year are indicative for heavy clays. Hence 0.1 m/year was entered for the saturated hydraulic conductivity of the soil.

The depth of sealing soil under the storage was not known accurately. A depth of 10 metres was assumed.

B.1.7. Step 6 – Enter Evaporation Mitigation System Information

The Shadecloth evaporation mitigation system was chosen for this Hydrological Study.

Shadecloth is quite good at reducing evaporative losses. Hence the efficiency of the shadecloth was set at 70 %.

Due to the proximity of the Darling Downs to major population centres, the capital costs of the shadecloth were lower than average. This was a result of increased competition, availability, labour and reduced transport costs. The capital cost of the shadecloth was set at $8.00 per square metre. It was assumed that 25 % of this capital cost was the shadecloth itself. Hence the cost of the shadecloth only was set at $2.00 per square metre.

As the shadecloth was assumed to be well maintained, the lifespan of the shadecloth structure was set at 30 years. The lifespan of the shadecloth itself was set at 15 years.

The annual operating and maintenance costs of the cover were set to reflect the level of maintenance and size of the storage, at $0.02 per square metre.

B.1.8. Results

The Ready Reckoner showed that the shadecloth evaporation mitigation system saved **313 ML** of water from evaporation each year from the 1,500 ML capacity, 28.5 ha surface area storage, at a cost of **$571 per ML**. The total capital cost of the system was **$2,282,257** with **$5,706** in total maintenance costs annually.

A copy of the 'User Inputs' and 'Results Summary' sheets from the Ready Reckoner are included for reference.

B.1.9. Results using Property Owner's Estimates of Hydrological Parameters

The property owner had kept some records of the amount of water stored in the dam over the past three years. This information was used to make a comparison between the hydrological model and his experience.

The hydrological parameters were similar, which indicated that the hydrological model had simulated the property well.

The Ready Reckoner showed that, using the property owners records, the shadecloth evaporation mitigation system saved **346 ML** of water from evaporation each year from the 1,500 ML capacity, 28.5 ha surface area storage, at a cost of **$515 per ML**. The total capital cost of the system was the same at **$2,282,257** with **$5,706** in total maintenance costs annually.

The difference between the hydrological model estimate and the property owner's experience was that the model underestimated the percentage of years the storage contained water. This resulted in the differences in water saved and cost shown above.

User Input Data

CLEAR ALL DATA FIELDS

Step 1 - Select Storage Type (click on adjacent cell) Rectangular Ring Tank

SHOW INPUT PARAMETERS

Clear 'Storage' Data Fields

Complete the required fields for your Storage Type (Unnecessary fields do not need to be left blank)

For further guidance on any of these Storage parameters, see the relevant diagram on the 'Diagrams' sheet

Enter Storage Data (Rectangular Ring Tank)		
Length @ Centreline	600	metres
Width @ Centreline	500	metres
Corner Radius @ Centreline	50	metres
Storage Wall Crest Width	8	metres
Average Bank Height	6	metres
Batter Slope of the Storage Inside Wall	4	in 1
Batter Slope of the Storage Outside Wall	2	in 1
Full Supply Volume	1500	ML
Freeboard	0.5	metres

Step 2 - Enter Monthly Evaporation

The monthly evaporation rate for your location can be found at http://www.npsi.gov.au/readyreckoner/index.html. Follow the instructions given, download the data and enter the monthly values into the appropriate cells below. A map of annual evaporation is given to check the data downloaded (see sheet titled 'Diagrams')

Clear 'Evaporation' Data Fields

January	245	mm
February	200	mm
March	204	mm
April	153	mm
May	111	mm
June	88	mm
July	99	mm
August	127	mm
September	168	mm
October	212	mm
November	230	mm
December	252	mm
Annual Total (Note: No data entry required in this cell)	2087	mm

Step 3 - Enter the Average Amount of Water Stored Per Month (as a % of Total Storage Volume)

Clear 'Water Stored per Month' Data Fields

January	42	%
February	47	%
March	49	%
April	55	%
May	57	%
June	59	%
July	58	%
August	57	%
September	58	%
October	47	%
November	43	%
December	39	%

Step 4 - Enter the Average Percentage of Years that the Storage Contains Water (per month)

Clear 'Years Storage Contains Water' Data Fields

January	85	%
February	83	%
March	82	%
April	78	%
May	78	%
June	78	%
July	80	%
August	82	%
September	82	%
October	82	%
November	75	%
December	87	%

Step 5 - Enter Seepage Information

Select your Most Applicable Seepage Option from the drop-down list (click on adjacent cell) — I Don't Know the Seepage Loss

Clear 'Seepage' Data Fields

Saturated Hydraulic Conductivity of the Soil (see table)	0.1	*m/yr*
Average Depth of Sealing Soil under the Storage	10	*metres*

Soil Type	Conductivity (m/yr)
Heavy Clay	< 0.1
Clay	0.1 - 0.5
Loam	0.5 - 1.0
Sand	> 1.0

Source: US EPA (1986). Values are indicative only

Clear 'Evap. Mitigation System' Data Fields

Step 6 - Enter Evaporation Mitigation System Information

Select an Evaporation Mitigation System (EMS) (click on adjacent cell) — ***Shadecloth***

SHOW INPUT PARAMETERS

Shadecloth		
Efficiency of EMS (Range - 60-80% (70-75% recommended))	70	*%*
Capital (Upfront) Cost (Range - \$6.00-\$33.00/m^2)	\$8.00	*per m^2*
Capital Cost (Shadecloth Only) (~ 25% of Total Capital Cost)	\$2.00	*per m^2*
Lifespan (Structure) (~ 30 years recommended)	30	*years*
Lifespan (Shadecloth) (~ 15 years recommended)	15	*years*
Annual Operating and Maintenance Cost (~ \$0.01-\$0.03/m^2 recommended)	\$0.020	*per m^2*

CALCULATE AND SHOW RESULTS

Calculations Completed Successfully

Results Summary

Rectangular Ring Tank

Evaporation Mitigation System Used:	***Shadecloth***	
Water Saved From Evaporation	**312.8**	***ML each year***
Cost to Save this Water	**$571**	***per ML per year***
Calculated Storage Volume at Full Supply Level	**1,447.6**	***ML***
Surface Area at Full Supply Level	**28.5**	***ha***
Total Cost of EMT at Installation	**$2,282,257**	
Annual Operating and Maintenance Cost	**$5,706**	

B.1.10. Sensitivity Analysis

The hydrological model accurately determines the 'Average Amount of Water Stored per Month' and 'Average Percentage of Years that the Storage Contains Water' parameters. To demonstrate the sensitivity of these parameters additional economic analyses were performed.

Sensitivity Analysis 1
The 'Average Amount of Water Stored per Month' and 'Average Percentage of Years that the Storage Contains Water' parameters were increased by 10 %. All other parameters remained the same.

Increasing these parameters increased the amount of water saved to **346.9 ML** (11 % increase) at a cost of **$514 per ML** (11 % decrease). The capital cost and total annual maintenance costs remained the same.

Sensitivity Analysis 2
The 'Average Amount of Water Stored per Month' parameter was increased by 20 %. The 'Average Percentage of Years that the Storage Contains Water' parameter was decreased by 20 %. All other parameters remained the same.

Increasing these parameters decreased the amount of water saved to **254.4 ML** (19 % decrease) at a cost of **$702 per ML** (23 % increase). The capital cost and total annual maintenance costs remained the same.

Sensitivity Analysis 3
The 'Average Amount of Water Stored per Month' parameter was decreased by 20 %. The 'Average Percentage of Years that the Storage Contains Water' parameter was increased by 20 % (to a maximum of 100 %). All other parameters remained the same.

Increasing these parameters increased the amount of water saved to **366.4 ML** (17 % increase) at a cost of **$487 per ML** (15 % decrease). The capital cost and total annual maintenance costs remained the same.

Sensitivity Analysis 4
The 'Average Amount of Water Stored per Month' parameter was decreased by 10 %. The 'Average Percentage of Years that the Storage Contains Water' parameter was maintained at the original values. All other parameters remained the same.

Decreasing the 'Average Amount of Water Stored per Month' parameter by 10 % decreased the amount of water saved to **310.3 ML** (1 % decrease) at a cost of **$575 per ML** (1 % increase). The capital cost and total annual maintenance costs remained the same.

Sensitivity Analysis 5
The 'Average Amount of Water Stored per Month' parameter was maintained at the original values. The 'Average Percentage of Years that the Storage Contains Water' parameter was decreased by 10 %. All other parameters remained the same.

Decreasing the 'Average Percentage of Years that the Storage Contains Water' parameter by 10 % decreased the amount of water saved to **281.5 ML** (10 % decrease) at a cost of

$634 per ML (11 % increase). The capital cost and total annual maintenance costs remained the same.

All results from the Sensitivity Analyses are summarised in Table 16.

TABLE 16 – SENSITIVITY ANALYSES RESULTS SUMMARY

Sensitivity Analysis	Change to 'Average Amount of Water Stored per Month' parameter	Change to 'Average Percentage of Years that the Storage Contains Water' parameter	Change in Water Saving	Change in Cost of Water Saved
1	+10 %	+10 %	+11 %	-11 %
2	+20 %	-20 %	-19 %	+23 %
3	-20 %	+20 %	+17 %	-15 %
4	-10 %	*no change*	-1 %	+1 %
5	*no change*	-10 %	-10 %	+11 %

B.1.11. Sensitivity Analysis Conclusions

The most important conclusion from the Sensitivity Analysis is that the 'Average Percentage of Years that the Storage Contains Water' parameter is the most sensitive. The sensitivity analysis showed that an error in estimating this parameter results in a similar error in the results.

The sensitivity analysis also showed that the 'Average Amount of Water Stored per Month' parameter is less sensitive than the 'Average Percentage of Years that the Storage Contains Water' parameter. A large error in the 'Average Amount of Water Stored per Month' parameter does not impact the results significantly (as shown in Sensitivity Analysis 4).

Hence the user is alerted to this fact and care should be taken when considering results from the Ready Reckoner. This is especially important when 'guesstimates' are made of the 'Average Percentage of Years that the Storage Contains Water' parameter. Users are again encouraged to vary *all* input parameters to examine the sensitivity of the parameters on cost and water savings.

B.2. Dairy Production – Shepparton, Northern Victoria

B.2.1. Introduction

Irrigated dairy production in Northern Victoria is sustained with regulated allocation water from the major rivers, namely the Goulburn-Murray River system.

This Hydrological Study models a 60 ha dairy operation sourcing irrigation water from the Goulburn River system. Tailwater from bay-irrigated pastures is captured in a small (4.7 ML) below-ground rectangular storage. The Ready Reckoner was not specifically written to accommodate this type of storage. However it was still able to generate meaningful results.

All information was supplied by a representative of the dairy industry in Northern Victoria.

The Ready Reckoner was used to carry out an economic assessment of an evaporation mitigation system installed on the 4.4 ML tailwater capture storage.

B.2.2. Step 1 - Storage Type and Geometry

The physical details of the 4.4 ML rectangular excavated tank are detailed in Table 17.

TABLE 17 – TYPICAL STORAGE DETAILS – RECTANGULAR EXCAVATED TANK (SHEPPARTON, NORTHERN VICTORIA)

Parameter	Value	Units
Length at Centreline	300	metres
Width at Centreline	15	metres
Corner Radius at Centreline	1	metres
Storage Wall Crest Width	0	metres
Average Bank Height	2.0 *	metres
Batter Slope of the Storage Inside Wall	2:1	
Batter Slope of the Storage Outside Wall	- #	
Full Supply Volume	5	ML
Freeboard	0.5	metres

** In this case this represents the depth of the storage*
 # The storage is below-ground; hence there is no outside batter

B.2.3. Step 2 - Evaporation

The Queensland Department of Natural Resources website (http://www.npsi.gov.au/readyreckoner/index.html) was accessed to supply monthly evaporation data for Shepparton, Northern Victoria (36°27' South, 145°15' East). Values are shown in Table 18.

TABLE 18 – EVAPORATION DATA FOR SHEPPARTON, NORTHERN VICTORIA (36°27' S, 145°15' E)

Month	Evaporation (mm)
January	260
February	224
March	186
April	110
May	59
June	35
July	40
August	65
September	97
October	149
November	197
December	245
Annual Total	*1667*

B.2.4. Step 3 – Average Amount of Water Stored per Month

The number of irrigations per month for the property is shown in Table 19. Best management practices would involve having the storage empty prior to irrigation. The storage would fill during irrigation, and be pumped dry two days after irrigation. Hence assuming irrigation takes around one day, for each irrigation event the storage contains water for about three days.

TABLE 19 – IRRIGATION PRACTICES ON THE PROPERTY

Month	No. of Irrigations
January	4
February	4
March	3
April	2
May	1
June	0
July	0
August	0
September	1
October	1
November	2
December	3

Hence after each irrigation event the storage is 100 % full for three days. For all other days the storage is empty.

The storage is 50 % full over the winter period, containing any remaining irrigation water runoff and rainfall runoff.

The above analysis of the irrigation practices determined the average amount of water stored per month in the 4.4 ML storage. These values are shown in Table 20.

TABLE 20 – AVERAGE AMOUNT OF WATER STORED PER MONTH (SHEPPARTON, NORTHERN VICTORIA)

Month	Average Amount of Water Stored
January	40%
February	40%
March	30%
April	20%
May	10%
June	50%
July	50%
August	50%
September	10%
October	10%
November	20%
December	30%

B.2.5. Step 4 – Average Percentage of Years that the Storage Contains Water

An analysis of the water authority allocation history for the property and the security of supply to the area have shown that irrigation water allocations are quite secure. In 97 years out of 100, 100 % of irrigation allocation is supplied to users (Goulburn-Murray Water, http://www.g-mwater.com.au/browse.asp?ContainerID=security_of_supply, viewed 20 March 2006). In dry years when full irrigation allocation is not available most dairy farms in the area will buy additional water in order to maintain production. Hence for the property it is assumed that full allocation is always available.

As a result, the storage will capture irrigation runoff in 100 % of years. The storage contains water in every month, either from irrigation or rainfall runoff. Hence 100 % is set for the 'Average Percentage of Years that the Storage Contains Water' parameter for each month.

B.2.6. Step 5 – Enter Seepage Information

No seepage mitigation works have been implemented on the storage. The storage has been built on the clay loam soils characteristic of the area and was subject to seepage loss.

The option 'I Don't Know the Seepage Loss' option was selected.

The saturated hydraulic conductivity of the soil is not accurately known. The table of values suggests that 0.5 m/year are indicative for clay loams. Hence 0.5 m/year was entered for the saturated hydraulic conductivity of the soil.

The depth of sealing soil under the storage was not known accurately. A depth of 10 metres was assumed.

B.2.7. Step 6 – Enter Evaporation Mitigation System Information

The Shadecloth evaporation mitigation system was chosen for this Hydrological Study.

Shadecloth is quite good at reducing evaporative losses. Hence the efficiency of the shadecloth was set at 70 %.

The capital cost of the shadecloth was set at $8.00 per square metre. It was assumed that 25 % of this capital cost was the shadecloth itself. Hence the cost of the shadecloth only was set at $2.00 per square metre.

As the shadecloth was assumed to be well maintained, the lifespan of the shadecloth structure was set at 30 years. The lifespan of the shadecloth itself was set at 15 years.

The annual operating and maintenance costs of the cover were set to reflect the level of maintenance and size of the storage, at $0.08 per square metre.

B.2.8. Results

The Ready Reckoner showed that the shadecloth evaporation mitigation system saved **3.0 ML** of water from evaporation each year from the 4.4 ML capacity, 0.39 ha surface area storage, at a cost of **$884 per ML**. The total capital cost of the system was **$30,992** with **$310** in total maintenance costs annually.

A copy of the 'User Inputs' and 'Results Summary' sheets from the Ready Reckoner are included for reference.

User Input Data

CLEAR ALL DATA FIELDS

Step 1 - Select Storage Type (click on adjacent cell) Rectangular Ring Tank

SHOW INPUT PARAMETERS

Clear 'Storage' Data Fields

Complete the required fields for your Storage Type (Unnecessary fields do not need to be left blank)

For further guidance on any of these Storage parameters, see the relevant diagram on the 'Diagrams' sheet

Enter Storage Data (Rectangular Ring Tank)		
Length @ Centreline of Crest	300	metres
Width @ Centreline of Crest	15	metres
Corner Radius @ Centreline of Crest	1	metres
Storage Wall Crest Width	0	metres
Average Bank Height	2	metres
Batter Slope of the Storage Inside Wall	2	in 1
Batter Slope of the Storage Outside Wall	0	in 1
Full Supply Volume	4.4	ML
Freeboard	0.5	metres

Step 2 - Enter Monthly Evaporation

The monthly evaporation rate for your location can be found at http://www.npsi.gov.au/readyreckoner/index.html. Follow the instructions given, download the data and enter the monthly values into the appropriate cells below. A map of annual evaporation is given to check the data downloaded (see sheet titled 'Diagrams')

Clear 'Evaporation' Data Fields

January	260	mm
February	224	mm
March	186	mm
April	110	mm
May	59	mm
June	35	mm
July	40	mm
August	65	mm
September	97	mm
October	149	mm
November	197	mm
December	245	mm
Annual Total (Note: No data entry required in this cell)	1667	mm

Step 3 - Enter the Average Amount of Water Stored Per Month (as a % of Total Storage Volume)

Clear 'Water Stored per Month' Data Fields

January	40	%
February	40	%
March	30	%
April	20	%
May	10	%
June	50	%
July	50	%
August	50	%
September	10	%
October	10	%
November	20	%
December	30	%

Step 4 - Enter the Average Percentage of Years that the Storage Contains Water (per month)

Clear 'Years Storage Contains Water' Data Fields

January	100	%
February	100	%
March	100	%
April	100	%
May	100	%
June	100	%
July	100	%
August	100	%
September	100	%
October	100	%
November	100	%
December	100	%

Step 5 - Enter Seepage Information

Select your Most Applicable Seepage Option from the drop-down list (click on adjacent cell) — I Don't Know the Seepage Loss

Clear 'Seepage' Data Fields

Saturated Hydraulic Conductivity of the Soil (see table)	0.5	*m/yr*
Average Depth of Sealing Soil under the Storage	10	*metres*

Soil Type	Conductivity (m/yr)
Heavy Clay	< 0.1
Clay	0.1 - 0.5
Loam	0.5 - 1.0
Sand	> 1.0

Source: US EPA (1986). Values are indicative only

Clear 'Evap. Mitigation System' Data Fields

Step 6 - Enter Evaporation Mitigation System Information

Select an Evaporation Mitigation System (EMS) (click on adjacent cell) — ***Shadecloth***

SHOW INPUT PARAMETERS

Shadecloth		
Efficiency of EMS (Range - 60-80% (70-75% recommended))	70	*%*
Capital (Upfront) Cost (Range - $6.00-$33.00/m^2)	$8.00	*per m^2*
Capital Cost (Shadecloth Only) (~ 25% of Total Capital Cost)	$2.00	*per m^2*
Lifespan (Structure) (~ 30 years recommended)	30	*years*
Lifespan (Shadecloth) (~ 15 years recommended)	15	*years*
Annual Operating and Maintenance Cost (~ $0.01-$0.03/m^2 recommended)	$0.080	*per m^2*

CALCULATE AND SHOW RESULTS

Calculations Completed Successfully

Results Summary

Rectangular Ring Tank

Evaporation Mitigation System Used:	***Shadecloth***
Water Saved From Evaporation	**3.0** ***ML each year***
Cost to Save this Water	**$884** ***per ML per year***
Calculated Storage Volume at Full Supply Level	**4.4** ***ML***
Surface Area at Full Supply Level	**0.39** ***ha***
Total Cost of Evaporation Mitigation System at Installation	**$30,992**
Annual Operating and Maintenance Cost	**$310**

B.3. Viticulture – Birdwood, Adelaide Hills, South Australia

B.3.1. Introduction

Viticulture in the Adelaide Hills is sustained with irrigation in addition to rainfall. Irrigation is also used to limit the damaging effects of frost on the vines. Water is supplied from rainfall runoff (overland flow) and groundwater.

This Hydrological Study models a small (9 ML) gully dam storage used to store overland flow water for irrigation in a vineyard. The storage also acts as a balancing storage for extracted groundwater used for irrigation and frost mitigation purposes

All information was supplied from the property owner and a Departmental representative who has worked closely with the property owner.

The Ready Reckoner was used to carry out an economic assessment of an evaporation mitigation system installed on the 9 ML storage.

B.3.2. Step 1 - Storage Type and Geometry

The physical details of the 9 ML gully dam are detailed in Table 21.

TABLE 21 – TYPICAL STORAGE DETAILS – GULLY DAM (BIRDWOOD, ADELAIDE HILLS, SOUTH AUSTRALIA)

Parameter	Value	Units
Length of Dam Wall at Crest	150	metres
Length of Dam Wall at Base	120	metres
Maximum Bank Height	4.8	metres
Dam Cross-Section Coefficient	1	dim.
Maximum Width of Water Across the Dam Wall	140	metres
Maximum Depth of Water at the Dam Wall	4.3	metres
Length of Longest Stretch of Water Surface (when full)	75	metres
Gully Cross-Section Coefficient	0.5	dim.
Full Supply Volume	9	ML

B.3.3. Step 2 - Evaporation

The Queensland Department of Natural Resources website (http://www.npsi.gov.au/readyreckoner/index.html) was accessed to supply monthly evaporation data for Birdwood, Adelaide Hills, South Australia (34°51' South, 138°57' East). Values are shown in Table 22.

TABLE 22 – EVAPORATION DATA FOR BIRDWOOD, ADELAIDE HILLS, SOUTH AUSTRALIA (34°51' S, 138°57' E)

Month	Evaporation (mm)
January	242
February	215
March	175
April	108
May	61
June	37
July	44
August	68
September	100
October	146
November	186
December	225
Annual Total	*1607*

B.3.4. Step 3 – Average Amount of Water Stored per Month

The storage is used to capture overland flow and as a balancing storage for extracted groundwater. Due to the demands of irrigation in the warmer months, and frost mitigation in the cooler months, the storage is required to be full at all times to ensure an adequate supply of water is on hand when required. When overland flow is minimal or non-existent in the summer months, groundwater is used to top up the storage.

As the storage is managed in this way, the average amount of water stored per month has been set at 80 % for each month. This accounts for usage and any lag effect in refilling the storage after use for irrigation or frost mitigation.

TABLE 23 – AVERAGE AMOUNT OF WATER STORED PER MONTH (BIRDWOOD, ADELAIDE HILLS, SOUTH AUSTRALIA)

Month	Average Amount of Water Stored
January	80%
February	80%
March	80%
April	80%
May	80%
June	80%
July	80%
August	80%
September	80%
October	80%
November	80%
December	80%

B.3.5. Step 4 – Average Percentage of Years that the Storage Contains Water

The storage is managed in such a way that there is always some water present at all times. The storage contains water in every month of every year, either from rainfall runoff or supplemented from groundwater.

Hence 100 % is set for the 'Average Percentage of Years that the Storage Contains Water' parameter for each month.

B.3.6. Step 5 – Enter Seepage Information

The storage has been built on the heavy clay soils characteristic of the area and was subject to seepage loss. The storage has been clay lined (300 mm thick) to reduce seepage losses.

The option 'I Don't Know the Seepage Loss' option was selected.

The saturated hydraulic conductivity of the soil is not accurately known. The table of values suggests that 0.1 m/year or less is indicative for clay loams. Hence 0.1 m/year was entered for the saturated hydraulic conductivity of the soil.

The depth of sealing soil under the storage is 1.5 metres, which includes the clay liner.

B.3.7. Step 6 – Enter Evaporation Mitigation System Information

The Impermeable Cover evaporation mitigation system was chosen for this Hydrological Study.

Impermeable covers are very good at reducing evaporative losses. Hence the efficiency of the impermeable cover was set at 90 %.

The capital cost of the impermeable cover was set at $7.00 per square metre.

As the impermeable cover was assumed to be well maintained, the lifespan of the impermeable cover was set at 15 years.

The annual operating and maintenance costs of the cover were set to reflect the level of maintenance and size of the storage, at $0.06 per square metre.

B.3.8. Results

The Ready Reckoner showed that the impermeable cover evaporation mitigation system saved **6.1 ML** of water from evaporation each year from the 9.4 ML capacity, 0.53 ha surface area storage, at a cost of **$652 per ML**. The total capital cost of the system was **$36,750** with **$315** in total maintenance costs annually.

A copy of the ‘User Inputs’ and ‘Results Summary’ sheets from the Ready Reckoner are included for reference.

User Input Data

CLEAR ALL DATA FIELDS

Step 1 - Select Storage Type (click on adjacent cell) — *Gully Dam*

SHOW INPUT PARAMETERS

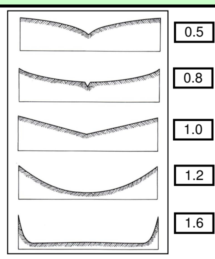
Clear 'Storage' Data Fields

Complete the required fields for your Storage Type (Unnecessary fields do not need to be left blank)

Enter Storage Data (Gully Dam)

Length of Dam Wall at Crest (measured along crest of dam wall)	150	metres
Length of Dam Wall at Base (measured along base of dam wall)	120	metres
Maximum Bank Height	4.8	metres
Gully Cross-Section Coefficient (at the Dam Wall, see diagram and note)	1	
Maximum Width of Water Across the Dam Wall	140	metres
Maximum Depth of Water at the Dam Wall (cannot be zero)	4.3	metres
Length of Longest Stretch of Water Surface (when full)	75	metres
Gully Cross-Section Coefficient (where Water is Stored, see diagram and note)	0.5	

For further guidance on any of these Storage parameters, see the relevant diagram on the 'Diagrams' sheet



(From the diagram at right, select the coefficient from the cross-section that best approximates the gully shape ***where water is stored****. This may or may not be the same as the coefficient for the dam wall)*

Full Supply Volume 9.1 *ML*

Step 2 - Enter Monthly Evaporation

The monthly evaporation rate for your location can be found at http://www.npsi.gov.au/readyreckoner/index.html. Follow the instructions given, download the data and enter the monthly values into the appropriate cells below. A map of annual evaporation is given to check the data downloaded (see sheet titled 'Diagrams')

Clear 'Evaporation' Data Fields

Month	Evaporation	
January	242	mm
February	215	mm
March	175	mm
April	108	mm
May	61	mm
June	37	mm
July	44	mm
August	68	mm
September	100	mm
October	146	mm
November	186	mm
December	225	mm
Annual Total (Note: No data entry required in this cell)	**1607**	mm

Step 3 - Enter the Average Amount of Water Stored Per Month (as a % of Total Storage Volume)

Clear 'Water Stored per Month' Data Fields

Month	Water Stored	
January	80	%
February	80	%
March	80	%
April	80	%
May	80	%
June	80	%
July	80	%
August	80	%
September	80	%
October	80	%
November	80	%
December	80	%

Step 4 - Enter the Average Percentage of Years that the Storage Contains Water (per month)

Clear 'Years Storage Contains Water' Data Fields

Month	Years	
January	100	%
February	100	%
March	100	%
April	100	%
May	100	%
June	100	%
July	100	%
August	100	%
September	100	%
October	100	%
November	100	%
December	100	%

Step 5 - Enter Seepage Information

Select your Most Applicable Seepage Option from the drop-down list (click on adjacent cell) — I Don't Know the Seepage Loss

Clear 'Seepage' Data Fields

Saturated Hydraulic Conductivity of the Soil (see table)	0.1	*m/yr*
Average Depth of Sealing Soil under the Storage	1.5	*metres*

Soil Type	Conductivity (m/yr)
Heavy Clay	< 0.1
Clay	0.1 - 0.5
Loam	0.5 - 1.0
Sand	> 1.0

Source: US EPA (1986). Values are indicative only

Clear 'Evap. Mitigation System' Data Fields

Step 6 - Enter Evaporation Mitigation System Information

Select an Evaporation Mitigation System (EMS) (click on adjacent cell) — *Impermeable Cover*

SHOW INPUT PARAMETERS

Impermeable Cover

Efficiency of EMS (Range - 85-100% (90-95% recommended))	90	%
Capital (Upfront) Cost (Range - \$3.50-\$30.00/m^2)	\$7.00	*per m^2*
Lifespan (~ 10-15 years recommended)	15	*years*
Annual Operating and Maintenance Cost (~ \$0.01-\$0.03/m^2 recommended)	\$0.060	*per m^2*

CALCULATE AND SHOW RESULTS

Calculations Completed Successfully

Results Summary

Gully Dam

Evaporation Mitigation System Used:	***Impermeable Cover***	
Water Saved From Evaporation	**6.1**	***ML each year***
Cost to Save this Water	**$652**	***per ML per year***
Calculated Storage Volume	**9.4**	***ML***
Surface Area at Full Supply Level	**0.53**	***ha***
Total Cost of Evaporation Mitigation System at Installation	**$36,750**	
Annual Operating and Maintenance Cost	**$315**	

Appendix C. FORMULAE USED IN READY RECKONER

The description of the formulae used in calculations has been broken into sections for clarity and ease of understanding. These sections are:

- Storage Geometry
- Evaporation Loss Estimation
- Water Savings
- Seepage Loss Estimation
- Evaporation Mitigation System Costings
- Results Formulation.

Each is detailed below. Note that the calculated parameter is followed in brackets by its term and units, i.e. (L_TWL, m)

C.1. Storage Type and Geometry

C.1.1. Rectangular Ring Tank

TABLE 24 – RECTANGULAR RING TANK GEOMETRIC INPUT PARAMETERS

Term	Input Parameter	Units
L_RRT	Length at Centreline	metres
W_RRT	Width at Centreline	metres
CR_RRT	Corner Radius at Centreline	metres
CW_RRT	Storage Wall Crest Width	metres
H_RRT	Average Bank Height	metres
IBS_RRT	Batter Slope of the Storage Inside Wall	dim.
OBS_RRT	Batter Slope of the Storage Outside Wall	dim.
FSV_RRT	Full Supply Volume	ML
FB_RRT	Freeboard	metres

Length at Top Water Level (L_TWL_RRT, m)

= L_RRT – CW_RRT - (FB_RRT * IBS_RRT * 2)

Width at Top Water Level (W_TWL_RRT, m)

= W_RRT – CW_RRT - (FB_RRT * IBS_RRT * 2)

Surface Area at Top Water Level (SA_TWL_RRT, ha)

= ((W_TWL_RRT * L_TWL_RRT) - (CR_RRT – CW_RRT / 2 - (FB_RRT * IBS_RRT))^2 * (4 - pi)) / 10,000

Length at Inside Toe (L_IT_RRT, m)

= L_RRT – CW_RRT – (2 * H_RRT * IBS_RRT)

Width at Inside Toe (W_IT_RRT, m)

= W_RRT – CW_RRT – (2 * H_RRT * IBS_RRT)

Radius at Inside Toe (R_IT_RRT, m)

= CR_RRT – (CW_RRT / 2) – (H_RRT * IBS_RRT)

Surface Area at Inside Toe (SA_IT_RRT, ha)

= (W_IT_RRT * L_IT_RRT) – ($R\_IT\_RRT^2$ * (4 – pi)) / 10,000

Approximate Capacity (CAP_RRT, ML)

= (SA_TWL_RRT + SA_IT_RRT) * 10,000 * (H – FB) / 2,000

C.1.2. Rectangular Ring Tank (Increase Wall Height)

The following calculations are applied only when the evaporation mitigation option 'Increase Wall Height' is chosen.

TABLE 25 – RECTANGULAR RING TANK (INCREASE WALL HEIGHT) GEOMETRIC INPUT PARAMETERS

Term	Input Parameter	Units
L_RRT	Length at Centreline	metres
W_RRT	Width at Centreline	metres
CR_RRT	Corner Radius at Centreline	metres
CW_RRT	Storage Wall Crest Width	metres
H_RRT	Average Bank Height	metres
WH_INC_RRT	Wall Height Increase	metres
IBS_RRT	Batter Slope of the Storage Inside Wall	dim.
OBS_RRT	Batter Slope of the Storage Outside Wall	dim.
FSV_RRT	Full Supply Volume	ML
FB_RRT	Freeboard	metres

Length at Top Water Level (L_TWL_RRT, m)

= L_RRT – CW_RRT - (FB_RRT * IBS_RRT * 2)

Width at Top Water Level (W_TWL_RRT, m)

= W_RRT – CW_RRT - (FB_RRT * IBS_RRT * 2)

Surface Area at Top Water Level (SA_TWL_RRT, ha)

= ((W_TWL_RRT * L_TWL_RRT) - (CR_RRT – CW_RRT / 2 - (FB_RRT * IBS_RRT))^2 * (4 - pi)) / 10,000

Length at Inside Toe (L_IT_NEW_RRT, m)

= L_RRT – CW_RRT – (2 * (H_RRT + WH_INC_RRT) * IBS_RRT)

Width at Inside Toe (W_IT_NEW_RRT, m)

= W_RRT – CW_RRT – (2 * (H_RRT + WH_INC_RRT) * IBS_RRT)

Radius at Inside Toe (R_IT_NEW_RRT, m)

= CR_RRT – (CW_RRT / 2) – ((H_RRT + WH_INC_RRT)* IBS_RRT)

Surface Area at Inside Toe (SA_IT_NEW_RRT, ha)

= (W_IT_NEW_RRT * L_IT_NEW_RRT) – (R_IT_NEW_RRT^2 * (4 – pi)) / 10,000

Approximate Capacity (CAP_NEW_RRT, ML)

= (SA_TWL_NEW_RRT + SA_IT_NEW_RRT) * 10,000 * ((H_RRT + WH_INC_RRT) – FB) / 2,000

C.1.3. Circular Ring Tank

TABLE 26 – CIRCULAR RING TANK GEOMETRIC INPUT PARAMETERS

Term	Input Parameter	Units
R_CRT	Radius at Centreline	metres
CW_CRT	Storage Wall Crest Width	metres
H_CRT	Average Bank Height	metres
IBS_CRT	Batter Slope of the Storage Inside Wall	dim.
OBS_CRT	Batter Slope of the Storage Outside Wall	dim.
FSV_CRT	Full Supply Volume	ML
FB_CRT	Freeboard	metres

Radius at Top Water Level (R_TWL_CRT, m)

= R_CRT – (CW_CRT / 2) – (IBS_CRT * FB_CRT)

Surface Area at Top Water Level (SA_TWL_CRT, ha)

= pi * (R_TWL_CRT)^2 / 10,000

Radius at Inside Toe (R_IT_CRT, m)

= R_CRT – (CW_CRT / 2) – (H_CRT * IBS_CRT)

Surface Area at Inside Toe (SA_IT_CRT, ha)

$= pi * (R\_IT\_CRT)^2 / 10{,}000$

Approximate Capacity (CAP_CRT, ML)

= (SA_TWL_CRT + SA_IT_CRT) * 10,000 * (H_CRT – FB_CRT) / 2,000

C.1.4. Circular Ring Tank (Increase Wall Height)

The following calculations are applied only when the evaporation mitigation option 'Increase Wall Height' is chosen.

TABLE 27 – CIRCULAR RING TANK (INCREASE WALL HEIGHT) GEOMETRIC INPUT PARAMETERS

Term	Input Parameter	Units
R_CRT	Radius at Centreline	metres
CW_CRT	Storage Wall Crest Width	metres
H_CRT	Average Bank Height	metres
WH_INC_CRT	Wall Height Increase	metres
IBS_CRT	Batter Slope of the Storage Inside Wall	dim.
OBS_CRT	Batter Slope of the Storage Outside Wall	dim.
FSV_CRT	Full Supply Volume	ML
FB_CRT	Freeboard	metres

Radius at Top Water Level (R_TWL_CRT, m)

= R_CRT – (CW_CRT / 2) – (IBS_CRT * FB_CRT)

Surface Area at Top Water Level (SA_TWL_CRT, ha)

$= pi * (R\_TWL\_CRT)^2 / 10{,}000$

Radius at Inside Toe (R_IT_NEW_CRT, m)

= R_CRT – (CW_CRT / 2) – ((H_CRT + WH_INC_CRT)* IBS_CRT)

Surface Area at Inside Toe (SA_IT_NEW_CRT, ha)

$= pi * (R\_IT\_NEW\_CRT)^2 / 10{,}000$

Approximate Capacity (CAP_NEW_CRT, ML)

= (SA_TWL_CRT + SA_IT_NEW_CRT) * 10,000 * ((H_CRT + WH_INC_CRT) – FB_CRT) / 2,000

C.1.5. Gully Dam

TABLE 28 – GULLY DAM GEOMETRIC INPUT PARAMETERS

Term	Input Parameter	Units
LC_GD	Length of Dam Wall at Crest	metres
LB_GD	Length of Dam Wall at Base	metres
H_GD	Maximum Bank Height	metres
DC_GD	Dam Cross-Section Coefficient	dim.
WW_GD	Maximum Width of Water Across the Dam Wall	metres
DW_GD	Maximum Depth of Water at the Dam Wall	metres
LW_GD	Length of Longest Stretch of Water Surface (when full)	metres
GC_GD	Gully Cross-Section Coefficient	dim.
FSV_GD	Full Supply Volume	ML

Volume of Embankment Earthworks (V_E_GD, m^3)

= 1.05 * DC_GD * LC_GD * H_GD * (H_GD + 1)

Volume of Storage (V_S_GD, ML)

= (V_E_GD + (0.22 * WW_GD * DW_GD * LW_GD * GC_GD)) / 1,000

Surface Area at Top Water Level (SA_TWL_GD, ha)

= (WW_GD * LW_GD) / 20,000

Surface Area at Base (SA_B_GD, ha)

= 0 (set constant)

C.1.6. Gully Dam (Increase Wall Height)

The following calculations are applied only when the evaporation mitigation option 'Increase Wall Height' is chosen.

TABLE 29 – GULLY DAM (INCREASE WALL HEIGHT) GEOMETRIC INPUT PARAMETERS

Term	Input Parameter	Units
LC_GD	Length of Dam Wall at Crest	metres
LB_GD	Length of Dam Wall at Base	metres
H_GD	Maximum Bank Height	metres
WH_INC_GD	Wall Height Increase	metres
DC_GD	Dam Cross-Section Coefficient	dim.
WW_GD	Maximum Width of Water Across the Dam Wall	metres
DW_GD	Maximum Depth of Water at the Dam Wall	metres
LW_GD	Length of Longest Stretch of Water Surface (when full)	metres
GC_GD	Gully Cross-Section Coefficient	dim.
FSV_GD	Full Supply Volume	ML

Maximum Depth (after Wall Height Increase) (DW_NEW_GD, m)

= DW_GD + WH_INC_GD

Maximum Width (after Wall Height Increase) (WW_NEW_GD, m)

= (WW_GD / DW_GD) * DW_NEW_GD

Maximum Length (after Wall Height Increase) (LW_NEW_GD, m)

= (LW_GD / DW_GD) * DW_NEW_GD

Volume of Embankment Earthworks (V_E_NEW_GD, m^3)

= 1.05 * DC_GD * LC_GD * (H_GD + WH_INC_GD)* (H_GD + WH_INC_GD + 1)

Volume of Storage (V_S_NEW_GD, ML)

= (V_E_NEW_GD + (0.22 * WW_NEW_GD * DW_NEW_GD * LW_NEW_GD * GC_GD)) / 1,000

Surface Area at Top Water Level (SA_TWL_NEW_GD, ha)

= (WW_NEW_GD * LW_NEW_GD) / 20,000

Surface Area at Base (SA_B_GD, ha)

= 0

C.2. Evaporation Loss Estimation

All of the following estimates of evaporative loss are calculated on a monthly basis. Total evaporative loss is calculated through summation of the monthly values.

C.2.2. Rectangular Ring Tank

TABLE 30 – RECTANGULAR RING TANK EVAPORATION LOSS INPUT PARAMETERS

Term	Input Parameter	Units
WS	Water in Storage	%
H_RRT	Average Bank Height	metres
FB_RRT	Freeboard	metres
SA_TWL_RRT	Surface Area at Top Water Level	ha
SA_IT_RRT	Surface Area at Base	ha
E	Evaporation	mm
YW	Years Storage Contains Water	%

Current Depth (CD_RRT, m)

= (WS / 100) * (H_RRT - FB_RRT)

Current Surface Area (CSA_RRT, ha)

= (((SA_TWL_RRT - SA_IT_RRT) / (H_RRT - FB_RRT)) * CD_RRT) + SA_IT_RRT

Evaporative Loss (EL_RRT, ML)

= CSA_RRT * (E / 100) * (YW / 100)

C.2.3. Circular Ring Tank

TABLE 31 – CIRCULAR RING TANK EVAPORATION LOSS INPUT PARAMETERS

Term	Input Parameter	Units
WS	Water in Storage	%
H_CRT	Average Bank Height	metres
FB_CRT	Freeboard	metres
SA_TWL_CRT	Surface Area at Top Water Level	ha
SA_IT_CRT	Surface Area at Base	ha
E	Evaporation	mm
YW	Years Storage Contains Water	%

Current Depth (CD_CRT, m)

= (WS / 100) * (H_CRT - FB_CRT)

Current Surface Area (CSA_CRT, ha)

= (((SA_TWL_CRT - SA_IT_CRT) / (H_CRT - FB_CRT)) * CD_CRT) + SA_IT_CRT

Evaporative Loss (EL_CRT, ML)

= CSA_CRT * (E / 100) * (YW / 100)

C.2.4. Gully Dam

TABLE 32 – GULLY DAM EVAPORATION LOSS INPUT PARAMETERS

Term	Input Parameter	Units
WW_GD	Maximum Width of Water Across the Dam Wall	metres
DW_GD	Maximum Depth of Water at the Dam Wall	metres
LW_GD	Length of Longest Stretch of Water Surface (when full)	metres
GC_GD	Gully Cross-Section Coefficient	dim.
V_E_GD	Volume of Embankment Earthworks	m^3
V_S_GD	Volume of Storage	ML
WS	Water in Storage	%
SA_TWL_GD	Surface Area at Top Water Level	ha
SA_B_GD	Surface Area at Base	ha
E	Evaporation	mm
YW	Years Storage Contains Water	%

Current Depth (CD_GD, m), (calculations carried out through iteration)

WS * V_S_GD = (0.22 * GC_GD * CW_GD * CL_GD * CD_GD) + ((V_E_GD / DW_GD) * CD_GD) / 1000

where

Current Width (CW_GD, m)

= (WW_GD / DW_GD) * CD_GD

and

Current Length (CL_GD, m)

= (LW_GD / DW_GD) * CD_GD

Current Surface Area (CSA_GD, ha)

= (CW_GD * CL_GD) / 20,000

Evaporative Loss (EL_GD, ML)

= CSA_GD * (E / 100) * (YW / 100)

C.2.5. Gully Dam (Increase Wall Height)

The following calculations only apply when the evaporation mitigation option 'Increase Wall Height' is chosen.

TABLE 33 – GULLY DAM (INCREASE WALL HEIGHT) EVAPORATION LOSS INPUT PARAMETERS

Term	Input Parameter	Units
WW_GD	Maximum Width of Water Across the Dam Wall	metres
DW_GD	Maximum Depth of Water at the Dam Wall	metres
LW_GD	Length of Longest Stretch of Water Surface (when full)	metres
WH_INC_GD	Wall Height Increase	metres
GC_GD	Gully Cross-Section Coefficient	dim.
V_E_NEW_GD	Volume of Embankment Earthworks	m^3
V_S_NEW_GD	Volume of Storage	ML
WS	Water in Storage	%
SA_TWL_NEW_GD	Surface Area at Top Water Level	ha
SA_IT_GD	Surface Area at Base	ha
E	Evaporation	mm
YW	Years Storage Contains Water	%

Maximum Depth (after Wall Height Increase) (DW_NEW_GD, m)

= DW_GD + WH_INC_GD

Maximum Width (after Wall Height Increase) (WW_NEW_GD, m)

= (WW_GD / DW_GD) * DW_NEW_GD

Maximum Length (after Wall Height Increase) (LW_NEW_GD, m)

= (LW_GD / DW_GD) * DW_NEW_GD

Current Depth (CD_NEW_GD, m), (calculations carried out through iteration)

WS * V_S_GD = (0.22 * GC_GD * CW_NEW_GD * CL_NEW_GD * CD_NEW_GD) + ((V_E_GD / DW_NEW_GD) * CD_NEW_GD) / 1000

where

Current Width (CW_NEW_GD, m)

= (WW_NEW_GD / DW_NEW_GD) * CD_NEW_GD

and

Current Length (CL_NEW_GD, m)

= (LW_NEW_GD / DW_NEW_GD) * CD_NEW_GD

Current Surface Area (CSA_NEW_GD, ha)

= (CW_NEW_GD * CL_NEW_GD) / 20,000

Evaporative Loss (EL_GD, ML)

= CSA_NEW_GD * (E / 100) * (YW / 100)

C.3. Water Savings

Water savings are calculated on a monthly basis. Yearly water savings are a summation of the monthly values.

C.3.2. Rectangular Ring Tank

TABLE 34 – RECTANGULAR RING TANK WATER SAVINGS INPUT PARAMETERS

Term	Input Parameter	Units
EL_RRT	Evaporative Loss	ML
IMP_EFF	Evaporation Mitigation Efficiency – Impermeable Cover	%
SH_EFF	Evaporation Mitigation Efficiency – Shadecloth	%
MONO_EFF	Evaporation Mitigation Efficiency – Chemical Monolayer	%
MOD_EFF	Evaporation Mitigation Efficiency – Modular Cover	%
CAP_RRT	Approximate Maximum Capacity of Storage	ML
CAP_NEW_RRT	Approximate Maximum Capacity of Storage (After Wall Height Increase)	ML
SEEP_INC_RRT	Increase in Seepage Loss	ML

Impermeable Cover
Water Saved (WATER_SAVED_IMP_RRT, ML)

= EL_RRT * IMP_EFF / 100

Shadecloth
Water Saved (WATER_SAVED_SH_RRT, ML)

= EL_RRT * SH_EFF / 100

Chemical Monolayer
Water Saved (WATER_SAVED_MONO_RRT, ML)

If Monolayer in Use, = EL_RRT * MONO_EFF / 100
If Monolayer Not in Use = EL_RRT

Modular
Water Saved (WATER_SAVED_MOD_RRT, ML)

= EL_RRT * MOD_EFF / 100

Earthworks

Prior to Wall Height Increase
ML of Evaporation per ML of Water in Storage (RATIO_PRIOR_RRT, dim.)

= EL_RRT / CAP_RRT

After Wall Height Increase
ML of Evaporation per ML of Water in Storage (RATIO_AFTER_RRT, dim.)

= EL_RRT / CAP_NEW_RRT

Water Saved (WATER_SAVED_EARTH_RRT, ML)

= ((RATIO_PRIOR_RRT – RATIO_AFTER_RRT) * CAP_RRT) – SEEP_INC_RRT

C.3.3. Circular Ring Tank

TABLE 35 – CIRCULAR RING TANK WATER SAVINGS INPUT PARAMETERS

Term	Input Parameter	Units
EL_CRT	Evaporation Loss	ML
IMP_EFF	Evaporation Mitigation Efficiency – Impermeable Cover	%
SH_EFF	Evaporation Mitigation Efficiency – Shadecloth	%
MONO_EFF	Evaporation Mitigation Efficiency – Chemical Monolayer	%
MOD_EFF	Evaporation Mitigation Efficiency – Modular Cover	%
CAP_CRT	Approximate Maximum Capacity of Storage	ML
CAP_NEW_CRT	Approximate Maximum Capacity of Storage (After Wall Height Increase)	ML
SEEP_INC_CRT	Increase in Seepage Loss	ML

Impermeable Cover
Water Saved (WATER_SAVED_IMP_CRT, ML)

= EL_CRT * IMP_EFF / 100

Shadecloth
Water Saved (WATER_SAVED_SH_CRT, ML)

= EL_CRT * SH_EFF / 100

Chemical Monolayer
Water Saved (WATER_SAVED_MONO_CRT, ML)

If Monolayer in Use, = EL_CRT * MONO_EFF / 100
If Monolayer Not in Use = EL_CRT

Modular
Water Saved (WATER_SAVED_MOD_CRT, ML)

= EL_CRT * MOD_EFF / 100

Earthworks

Prior to Wall Height Increase
ML of Evaporation per ML of Water in Storage (RATIO_PRIOR_CRT, dim.)

= EL_CRT / CAP_CRT

After Wall Height Increase
ML of Evaporation per ML of Water in Storage (RATIO_AFTER_CRT, dim.)

= EL_CRT / CAP_NEW_CRT

Water Saved (WATER_SAVED_EARTH_CRT, ML)

= ((RATIO_PRIOR_CRT – RATIO_AFTER_CRT) * CAP_CRT) – SEEP_INC_CRT

C.3.4. Gully Dam

TABLE 36 – GULLY DAM WATER SAVINGS INPUT PARAMETERS

Term	Input Parameter	Units
EL_GD	Evaporation Loss	ML
IMP_EFF	Evaporation Mitigation Efficiency – Impermeable Cover	%
SH_EFF	Evaporation Mitigation Efficiency – Shadecloth	%
MONO_EFF	Evaporation Mitigation Efficiency – Chemical Monolayer	%
MOD_EFF	Evaporation Mitigation Efficiency – Modular Cover	%
V_S_GD	Approximate Maximum Capacity of Storage	ML
V_S_NEW_GD	Approximate Maximum Capacity of Storage (After Wall Height Increase)	ML
SEEP_INC_GD	Increase in Seepage Loss	ML

Impermeable Cover
Water Saved (WATER_SAVED_IMP_GD, ML)

= EL_GD * IMP_EFF / 100

Shadecloth
Water Saved (WATER_SAVED_SH_GD, ML)

= EL_GD * SH_EFF / 100

Chemical Monolayer
Water Saved (WATER_SAVED_MONO_GD, ML)

If Monolayer in Use, = EL_GD * MONO_EFF / 100
If Monolayer Not in Use = EL_GD

Modular

Water Saved (WATER_SAVED_MOD_GD, ML)

= EL_GD * MOD_EFF / 100

Earthworks

Prior to Wall Height Increase

ML of Evaporation per ML of Water in Storage (RATIO_PRIOR_GD, dim.)

= EL_GD / V_S_GD

After Wall Height Increase

ML of Evaporation per ML of Water in Storage (RATIO_AFTER_GD, dim.)

= EL_GD / V_S_NEW_GD

Water Saved (WATER_SAVED_EARTH_GD, ML)

= ((RATIO_PRIOR_GD – RATIO_AFTER_GD) * V_S_NEW_GD) – SEEP_INC_GD

C.4. Seepage Loss Estimation

All of the following estimates of seepage loss are calculated on a monthly basis. Total seepage loss is calculated through summation of the monthly values.

C.4.2. Rectangular Ring Tank

TABLE 37 – RECTANGULAR RING TANK SEEPAGE LOSS INPUT PARAMETERS

Term	Input Parameter	Units
SOIL_DEPTH	Depth of Sealing Soil Under Storage	metres
CD_RRT	Current Depth of Water	metres
SA_IT_RRT	Surface Area at Base of Storage	ha
K_SAT	Saturated Hydraulic Conductivity	metres/year
YW	Years Storage Contains Water	%

Hydraulic Gradient (HYD_GRAD_RRT, dim.)

= (SOIL_DEPTH + CD_RRT) / SOIL_DEPTH

Seepage (SEEP_RRT, ML)

= SA_IT_RRT * 10 * (HYD_GRAD_RRT * K_SAT) * (YW / 100) / 12

C.4.3. Rectangular Ring Tank (Increase Wall Height)

TABLE 38 – RECTANGULAR RING TANK (INCREASE WALL HEIGHT) SEEPAGE LOSS INPUT PARAMETERS

Term	Input Parameter	Units
SOIL_DEPTH	Depth of Sealing Soil Under Storage	metres
CD_RRT	Current Depth of Water	metres
H_RRT	Average Bank Height	metres
WH_INC_RRT	Wall Height Increase	metres
FB_RRT	Freeboard	metres
SA_IT_RRT	Surface Area at Base of Storage	ha
K_SAT	Saturated Hydraulic Conductivity	metres/year
WS	Water in Storage	%
YW	Years Storage Contains Water	%

Current Depth of Water (with Wall Height Increase) (CD_NEW_RRT, m)

= (WS / 100) * (H_RRT + WH_INC_RRT- FB_RRT)

Hydraulic Gradient (HYD_GRAD_NEW_RRT, dim.)

= (SOIL_DEPTH + CD_NEW_RRT) / SOIL_DEPTH

Seepage (SEEP_NEW_RRT, ML)

= SA_IT_RRT * 10 * (HYD_GRAD_NEW_RRT * K_SAT) * (YW / 100) / 12

Increase in Seepage (SEEP_INC_RRT, ML)

= SEEP_NEW_RRT – SEEP_RRT

C.4.4. Circular Ring Tank

TABLE 39 – CIRCULAR RING TANK SEEPAGE LOSS INPUT PARAMETERS

Term	Input Parameter	Units
SOIL_DEPTH	Depth of Sealing Soil Under Storage	metres
CD_CRT	Current Depth of Water	metres
SA_IT_CRT	Surface Area at Base of Storage	ha
K_SAT	Saturated Hydraulic Conductivity	metres/year
YW	Years Storage Contains Water	%

Hydraulic Gradient (HYD_GRAD_CRT, dim.)

= (SOIL_DEPTH + CD_CRT) / SOIL_DEPTH

Seepage (SEEP_CRT, ML)

= SA_IT_CRT * 10 * (HYD_GRAD_CRT * K_SAT) * (YW / 100) / 12

C.4.5. Circular Ring Tank (Increase Wall Height)

TABLE 40 – CIRCULAR RING TANK (INCREASE WALL HEIGHT) SEEPAGE LOSS INPUT PARAMETERS

Term	Input Parameter	Units
SOIL_DEPTH	Depth of Sealing Soil Under Storage	metres
CD_CRT	Current Depth of Water	metres
H_CRT	Average Bank Height	metres
WH_INC_CRT	Wall Height Increase	metres
FB_CRT	Freeboard	metres
SA_IT_CRT	Surface Area at Base of Storage	ha
K_SAT	Saturated Hydraulic Conductivity	metres/year
WS	Water in Storage	%
YW	Years Storage Contains Water	%

Current Depth of Water (with Wall Height Increase) (CD_NEW_CRT, m)

= (WS / 100) * (H_CRT + WH_INC_CRT- FB_CRT)

Hydraulic Gradient (HYD_GRAD_NEW_CRT, dim.)

= (SOIL_DEPTH + CD_NEW_CRT) / SOIL_DEPTH

Seepage (SEEP_NEW_CRT, ML)

= SA_IT_CRT * 10 * (HYD_GRAD_NEW_CRT * K_SAT) * (YW / 100) / 12

Increase in Seepage (SEEP_INC_CRT, ML)

= SEEP_NEW_CRT – SEEP_CRT

C.4.6. Gully Dam

TABLE 41 – GULLY DAM SEEPAGE LOSS INPUT PARAMETERS

Term	Input Parameter	Units
SOIL_DEPTH	Depth of Sealing Soil Under Storage	metres
CD_GD	Current Depth of Water	metres
CSA_GD	Current Surface Area	ha
SA_B_GD	Surface Area at Base of Storage	ha
K_SAT	Saturated Hydraulic Conductivity	metres/year
YW	Years Storage Contains Water	%

Hydraulic Gradient (HYD_GRAD_GD, dim.)

= (SOIL_DEPTH + CD_GD) / SOIL_DEPTH

Seepage (SEEP_GD, ML)

= CSA_GD * 10 * (HYD_GRAD_GD * K_SAT) * (YW / 100) / 12

C.4.7. Gully Dam (Increase Wall Height)

TABLE 42 – GULLY DAM (INCREASE WALL HEIGHT) SEEPAGE LOSS INPUT PARAMETERS

Term	Input Parameter	Units
SOIL_DEPTH	Depth of Sealing Soil Under Storage	metres
CD_NEW_GD	Current Depth of Water	metres
CSA_NEW_GD	Current Surface Area	ha
SA_B_GD	Surface Area at Base of Storage	ha
K_SAT	Saturated Hydraulic Conductivity	metres/year
YW	Years Storage Contains Water	%

Hydraulic Gradient (HYD_GRAD_NEW_GD, dim.)

= (SOIL_DEPTH + CD_NEW_GD) / SOIL_DEPTH

Seepage (SEEP_NEW_GD, ML)

= SA_B_CRT * 10 * (HYD_GRAD_NEW_GD * K_SAT) * (YW / 100) / 12

Increase in Seepage (SEEP_INC_GD, ML)

= SEEP_NEW_GD – SEEP_GD

C.5. Evaporation Mitigation System Costings

The cost of all evaporation mitigation systems is determined over a 60-year period. A discount rate of 5 % is assumed.

C.5.2. Impermeable Cover

TABLE 43 – COST OF IMPERMEABLE COVER INPUT PARAMETERS

Term	Input Parameter	Units
YEAR_NUM	Year Number (1 to 60)	dim.
LIFE_IMP	Impermeable Cover Lifespan	years
COST_IMP	Impermeable Cover Cost	$\$/m^2$
OP_COST_IMP	Impermeable Cover Operating and Maintenance Cost	$\$/m^2$/year

The following calculations are carried out on a yearly basis.

Capital Cost (CAP_COST_IMP, $\$/m^2$)

IF MOD (YEAR_NUM, LIFE_IMP) = 0
THEN = COST_IMP
ELSE = 0

Total Yearly Cost (YEARLY_COST_IMP, $)

= CAP_COST_IMP + OP_COST_IMP

The following calculations are carried out over the entire 60-year period.

Net Present Value (NPV_IMP, $)

= NPV (5%, SUM (YEARLY_COST_IMP)) + CAP_COST_IMP

Annuity (ANN_IMP, $)

= PAYMENT (5%, 60 yrs, NPV_IMP)

C.5.3. Shadecloth

TABLE 44 – COST OF SHADECLOTH INPUT PARAMETERS

Term	Input Parameter	Units
YEAR_NUM	Year Number (1 to 60)	dim.
LIFE_SH_STR	Shadecloth Structure Lifespan	years
LIFE_SH	Shadecloth Lifespan	years
COST_ALL_SH	Shadecloth Cost (Entire System)	$\$/m^2$
COST_SH	Shadecloth Cost (Shadecloth Only)	$\$/m^2$
OP_COST_SH	Shadecloth Operating and Maintenance Cost	$\$/m^2$/year

The following calculations are carried out on a yearly basis.

Capital Cost (CAP_COST_SH, $\$/m^2$)

IF MOD (YEAR_NUM, LIFE_SH_STR)	= 0
THEN	= COST_ALL_SH
IF MOD (YEAR_NUM, LIFE_SH)	= 0
THEN	= COST_SH
ELSE	= 0

Total Yearly Cost (YEARLY_COST_SH, $)

= CAP_COST_SH + OP_COST_SH

The following calculations are carried out over the entire 60-year period.

Net Present Value (NPV_SH, $)

= NPV (5%, SUM (YEARLY_COST_SH)) + CAP_COST_SH

Annuity (ANN_SH, $)

= PAYMENT (5%, 60 yrs, NPV_SH)

C.5.4. Chemical Monolayer

TABLE 45 – COST OF SHADECLOTH INPUT PARAMETERS

Term	Input Parameter	Units
YEAR_NUM	Year Number (1 to 60)	dim.
LIFE_MONO_EQUIP	Application Equipment Lifespan	years
COST_ALL_MONO	Application Equipment Cost	$/m^2
OP_COST_MONO	Application Equipment Operating and Maintenance Cost	$/m^2/year
COST_CHEM_MONO	Chemical Monolayer Cost	$/kg
APPLN_RATE	Chemical Monolayer Application Rate	kg/ha
DAYS_APPLIED	Days in Month Chemical Monolayer Applied	days
MONTH_APPLIED	Months of Year Chemical Monolayer Applied	Y or N

Cost of Application (APPLN_COST, $/m^2)

IF MONTH_APPLIED = Y
THEN = DAYS_APPLIED * APPLN_RATE * COST_CHEM_MONO / 10,000
ELSE = 0

The following calculations are carried out on a yearly basis.

Capital Cost (CAP_COST_MONO, $/m^2)

IF MOD (YEAR_NUM, LIFE_MONO_EQUIP) = 0
THEN = COST_ALL_MONO
ELSE = 0

Total Yearly Cost (YEARLY_COST_MONO, $)

= CAP_COST_MONO + SUM (APPLN_COST)*(COUNTIF(MONTH_APPLIED))/12)

The following calculations are carried out over the entire 60-year period.

Net Present Value (NPV_MONO, $)

= NPV (5%, SUM (YEARLY_COST_MONO)) + CAP_COST_MONO

Annuity (ANN_MONO, $)

= PAYMENT (5%, 60 yrs, NPV_MONO)

C.5.5. Modular Cover

TABLE 46 – COST OF MODULAR COVER INPUT PARAMETERS

Term	Input Parameter	Units
YEAR_NUM	Year Number (1 to 60)	dim.
LIFE_MOD	Modular Cover Lifespan	years
COST_MOD	Modular Cover Cost	$\$/m^2$
OP_COST_MOD	Modular Cover Operating and Maintenance Cost	$\$/m^2/year$

The following calculations are carried out on a yearly basis.

Capital Cost (CAP_COST_MOD, $\$/m^2$)

IF MOD (YEAR_NUM, LIFE_MOD) = 0
THEN = COST_MOD
ELSE = 0

Total Yearly Cost (YEARLY_COST_MOD, $)

= CAP_COST_MOD + OP_COST_MOD

The following calculations are carried out over the entire 60-year period.

Net Present Value (NPV_MOD, $)

= NPV (5%, SUM (YEARLY_COST_MOD)) + CAP_COST_MOD

Annuity (ANN_MOD, $)

= PAYMENT (5%, 60 yrs, NPV_MOD)

C.5.6. Increase Wall Height

TABLE 47 – COST OF INCREASE WALL HEIGHT INPUT PARAMETERS

Term	Input Parameter	Units
YEAR_NUM	Year Number (1 to 60)	dim.
EARTHWORKS	Embankment Earthworks Before Wall Height Increase	m^3
EARTHWORKS_NEW	Embankment Earthworks After Wall Height Increase	m^3
COST_EARTHWORKS	Earthworks Cost	$\$/m^3$
OP_COST_INC_EARTH	Increase in Annual Operating and Maintenance Cost	$

Cost of Increased Earthworks (INC_EARTHWORKS_COST, $)

= (EARTHWORKS_NEW – EARTHWORKS) * COST_EARTHWORKS

Capital Cost (CAP_COST_EARTH, $/m²)

= INC_EARTHWORKS_COST

The following calculation is carried out on a yearly basis.

Total Yearly Cost (YEARLY_COST_EARTH, $)

= OP_COST_EARTH

The following calculation is carried out over the entire 60-year period.

Net Present Value (NPV_EARTH, $)

= NPV (5%, SUM (YEARLY_COST_EARTH)) + CAP_COST_EARTH

Annuity (ANN_EARTH, $)

= PAYMENT (5%, 60 yrs, NPV_EARTH)

C.6. Results Formulation

The total water saved from evaporation and cost of the saved water are delivered on a yearly basis.

C.6.2. Rectangular Ring Tank

TABLE 48 – RECTANGULAR RING TANK RESULTS DELIVERY INPUT PARAMETERS

Term	Input Parameter	Units
WATER_SAVED_IMP_RRT	Water Saved from Evaporation – Impermeable Cover	ML
WATER_SAVED_SH_RRT	Water Saved from Evaporation – Shadecloth	ML
WATER_SAVED_MONO_RRT	Water Saved from Evaporation – Chemical Monolayer	ML
WATER_SAVED_MOD_RRT	Water Saved from Evaporation – Modular Cover	ML
WATER_SAVED_EARTH_RRT	Water Saved from Evaporation – Increase Wall Height	ML
ANN_IMP	Annuity Cost – Impermeable Cover	$
ANN_SH	Annuity Cost – Shadecloth	$
ANN_MONO	Annuity Cost – Chemical Monolayer	$
ANN_MOD	Annuity Cost – Modular Cover	$
ANN_EARTH	Annuity Cost – Increase Wall Height	$
SA_TWL_RRT	Surface Area at Top Water Level	ha

Water Saved from Evaporation (TOTAL_WATER_SAVED_RRT)

Impermeable Cover

= SUM (WATER_SAVED_IMP_RRT)

Shadecloth

= SUM (WATER_SAVED_SH_RRT)

Chemical Monolayer

= SUM (WATER_SAVED_MONO_RRT)

Modular Cover

= SUM (WATER_SAVED_MOD_RRT)

Increase Wall Height

= SUM (WATER_SAVED_EARTH_RRT)

Cost to Save Water (COST_SAVED_WATER_RRT)

Impermeable Cover

= ANN_IMP / TOTAL_WATER_SAVED_RRT * 10,000 * SA_TWL_RRT

Shadecloth

= ANN_SH / TOTAL_WATER_SAVED_RRT * 10,000 * SA_TWL_RRT

Chemical Monolayer

= ANN_SH / TOTAL_WATER_SAVED_RRT * 10,000 * SA_TWL_RRT

Modular Cover

= ANN_SH / TOTAL_WATER_SAVED_RRT * 10,000 * SA_TWL_RRT

Increase Wall Height

= ANN_SH / TOTAL_WATER_SAVED_RRT

C.6.3. Circular Ring Tank

TABLE 49 – CIRCULAR RING TANK RESULTS DELIVERY INPUT PARAMETERS

Term	Input Parameter	Units
WATER_SAVED_IMP_CRT	Water Saved from Evaporation – Impermeable Cover	ML
WATER_SAVED_SH_CRT	Water Saved from Evaporation – Shadecloth	ML
WATER_SAVED_MONO_CRT	Water Saved from Evaporation – Chemical Monolayer	ML
WATER_SAVED_MOD_CRT	Water Saved from Evaporation – Modular Cover	ML
WATER_SAVED_EARTH_CRT	Water Saved from Evaporation – Increase Wall Height	ML
ANN_IMP	Annuity Cost – Impermeable Cover	$
ANN_SH	Annuity Cost – Shadecloth	$
ANN_MONO	Annuity Cost – Chemical Monolayer	$
ANN_MOD	Annuity Cost – Modular Cover	$
ANN_EARTH	Annuity Cost – Increase Wall Height	$
SA_TWL_CRT	Surface Area at Top Water Level	ha

Water Saved from Evaporation (TOTAL_WATER_SAVED_CRT)

Impermeable Cover

= SUM (WATER_SAVED_IMP_CRT)

Shadecloth

= SUM (WATER_SAVED_SH_CRT)

Chemical Monolayer

= SUM (WATER_SAVED_MONO_CRT)

Modular Cover

= SUM (WATER_SAVED_MOD_CRT)

Increase Wall Height

= SUM (WATER_SAVED_EARTH_CRT)

Cost to Save Water (COST_SAVED_WATER_CRT)

Impermeable Cover

= ANN_IMP / TOTAL_WATER_SAVED_CRT * 10,000 * SA_TWL_CRT

Shadecloth

= ANN_SH / TOTAL_WATER_SAVED_CRT * 10,000 * SA_TWL_CRT

Chemical Monolayer

= ANN_SH / TOTAL_WATER_SAVED_CRT * 10,000 * SA_TWL_CRT

Modular Cover

= ANN_SH / TOTAL_WATER_SAVED_CRT * 10,000 * SA_TWL_CRT

Increase Wall Height

= ANN_SH / TOTAL_WATER_SAVED_CRT

C.6.4. Gully Dam

TABLE 50 – GULLY DAM RESULTS DELIVERY INPUT PARAMETERS

Term	Input Parameter	Units
WATER_SAVED_IMP_GD	Water Saved from Evaporation – Impermeable Cover	ML
WATER_SAVED_SH_GD	Water Saved from Evaporation – Shadecloth	ML
WATER_SAVED_MONO_GD	Water Saved from Evaporation – Chemical Monolayer	ML
WATER_SAVED_MOD_GD	Water Saved from Evaporation – Modular Cover	ML
WATER_SAVED_EARTH_GD	Water Saved from Evaporation – Increase Wall Height	ML
ANN_IMP	Annuity Cost – Impermeable Cover	$
ANN_SH	Annuity Cost – Shadecloth	$
ANN_MONO	Annuity Cost – Chemical Monolayer	$
ANN_MOD	Annuity Cost – Modular Cover	$
ANN_EARTH	Annuity Cost – Increase Wall Height	$
SA_TWL_GD	Surface Area at Top Water Level	ha

Water Saved from Evaporation (TOTAL_WATER_SAVED_GD)

Impermeable Cover

= SUM (WATER_SAVED_IMP_GD)

Shadecloth

= SUM (WATER_SAVED_SH_GD)

Chemical Monolayer

= SUM (WATER_SAVED_MONO_GD)

Modular Cover

= SUM (WATER_SAVED_MOD_GD)

Increase Wall Height

= SUM (WATER_SAVED_EARTH_GD)

Cost to Save Water (COST_SAVED_WATER_GD)

Impermeable Cover

= ANN_IMP / TOTAL_WATER_SAVED_GD * 10,000 * SA_TWL_GD

Shadecloth

= ANN_SH / TOTAL_WATER_SAVED_CRT * 10,000 * SA_TWL_GD

Chemical Monolayer

= ANN_SH / TOTAL_WATER_SAVED_CRT * 10,000 * SA_TWL_GD

Modular Cover

= ANN_SH / TOTAL_WATER_SAVED_CRT * 10,000 * SA_TWL_GD

Increase Wall Height

= ANN_SH / TOTAL_WATER_SAVED_GD