FINAL REPORT

CURRENT KNOWLEDGE AND DEVELOPING TECHNOLOGY FOR CONTROLLING EVAPORATION FROM ON-FARM STORAGE

2002

Community Education and Extension Support Unit and Rural Water Use Efficiency Initiative

Department of Natural Resources and Mines, Queensland

NATIONAL PROGRAM FOR
Sustainable Irrigation

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FOREWORD

In late 2001, the National Program for Irrigation Research and Development (NPIRD) initiated a project to investigate the Practicality of and Potential for Controlling Evaporation Losses from On-Farm Storages. The project was one funded jointly by NPIRD and the Rural Water Use Efficiency Initiative (RWUEI), Queensland.

The aim of the project was to produce a framework that would ultimately be published as a final research report. To achieve this aim, the project identified numerous studies and trials into evaporation reduction and control and has reported recent work in Australia and some from overseas in Appendix A. The investigation was highlighted by a one-day workshop in April 2002 that included 35 participants representing several sectors of the water use industry. Appendix B is a report on the workshop proceedings.

While there is much theoretical knowledge about evaporation and its control, there has been little work done in Australia as far as applying this knowledge to large on-farm storages. There is also a deficiency in economic data pertinent to evaporation control studies and this has been recognised as central to future investigations.

This report outlines the concept of evaporation and various ways to measure its incidence in storages. It then goes on to explain the methods used to control evaporation, and practical limitations of implementing of the methods. Also, several options for integrating methods are offered, but because only small investigative studies have been carried out in this area, these options are presented as a guide and should not be relied upon for decision-making.

Developing evaporation control and management strategies has the potential to improve productivity and on-farm water efficiency considerably. On a broader scale, savings in water may also have benefits to catchments and communities because of reduced pressures on river systems. Nevertheless, the challenge remains to develop solutions that can pay for themselves in a reasonable period and be readily applied and maintained.

CONTENTS

EVAPORATION FROM ON-FARM STORAGES – HOW MUCH OF A PROBLEM?

The potential for evaporation from farm storages in Australia is enormous. It has been calculated, using Bureau of Meteorology (BOM) data, that annual evaporation from open water surfaces varies between 700mm in South West Tasmania to 3000mm in the Great Sandy Desert in Western Australia (Brown, 1988). Seventy per cent of the country experiences a mean evaporation for each month greater than its mean rainfall, and for nearly half of Australia mean annual evaporation is more than twice the mean annual rainfall (Fietz, 1970).

In cotton growing districts of northern NSW, pan evaporation (see below) is over 2000mm per year and estimated loss of water from off-stream storages in those areas is up to 50% of volume (Sainty, 1995). Similar evaporation losses have been reported from other cotton growing regions in southern Queensland. A recent study in Western Australia reports that annual losses from storages in the State's wheat belt can range from 1000mm in the south to over 2500mm in northern areas (Hipsey – University of WA).

It is probable that throughout Australia hundreds of thousands of megalitres of water evaporate each year from private water facilities. As a consequence, production opportunities worth tens of millions of dollars are lost. Dams and storages need to be designed and built to counter expected evaporation losses which will result in larger, and more expensive, embankments.

WHAT IS EVAPORATION?

Evaporation, also known as vaporisation, is the process by which a liquid changes state to become a vapour (gas). It occurs at the surface of a liquid. As liquid absorbs heat the molecules become more energetic and move around faster. Some molecules will move fast enough to escape the liquid and enter the atmosphere as vapour.

If we could observe a container of water at a molecular level (Figure 1), we would see water molecules moving into the atmosphere (vaporising) and others entering the water from the atmosphere (condensing). However, this is only part of the evaporation phenomenon.

As water molecules leave the liquid, the air near the surface gets wetter or more humid. The vapour pressure above the surface increases until the air becomes saturated (100% relative humidity). At this point, vaporisation and condensation of molecules reaches equilibrium and the nett loss by evaporation is nil. This can happen on a still day.

Where there is air movement (wind), the vapour will be moved away and the the vapour pressure in the atmosphere will be less than at the water surface. Under this condition vaporisation will exceed condensation and the water will eventually 'dry up', or more correctly, enter the atmosphere as vapour.

Several parameters affect the occurrence and rate of evaporation; these are described in the following section.

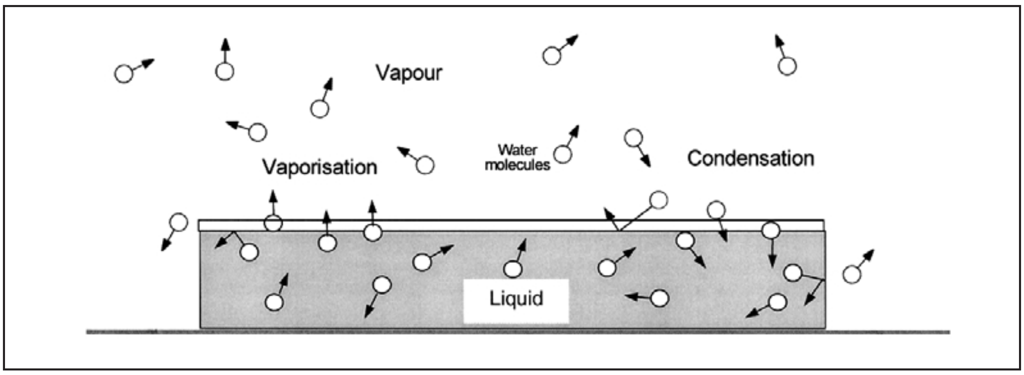


Figure 1.
Molecules of liquid vaporising and condensing. When conditions allow, e.g. when it is hot or windy or both, more molecules will vaporise than condense so the liquid will dry up. (Diagram courtesy Ian Burston, RMIT)

WHAT AFFECTS EVAPORATION RATE?

The rate of evaporation is the amount of water evaporated over a given period of time. On open bodies of water, the rate is affected by several ground and atmospheric factors of which the main ones are shown below:

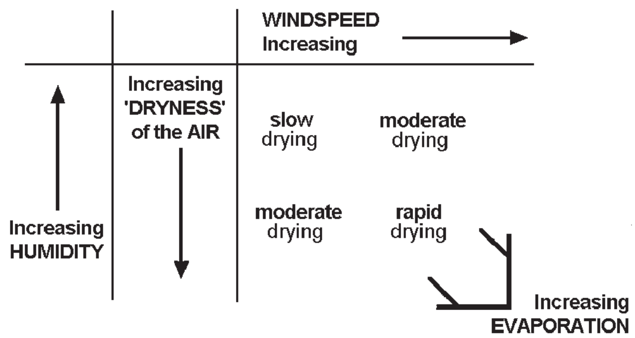
Solar radiation is essentially energy from the sun. How much energy is delivered by radiation varies in accordance with several conditions such as the sun's position throughout the day and seasons, the extent of cloud cover and the number and type of particles in the atmosphere. The impact of solar radiation is greatest during summer and on fine sunny days. Radiation also influences air and water temperatures.

Relative humidity is the percentage of moisture in the air compared to that of saturated air. Humidity influences vapour pressure which in turn affects evaporation rate. Evaporation increases as humidity falls.

Winds transport water vapour away from an evaporating surface. Generally, evaporation rate rises with increasing wind speed.

Figure 2 shows how changing windspeed and humidity influence the drying of clothes on a line. Drying is rapid on a windy day with low humidity and, if the sun is shining and air temperatures high, then the clothes will dry faster.

Figure 2.
As humidity decreases and windspeed increases, so the evaporation rate increases (courtesy Nigel Hancock, Uni of Southern Qld).



The **temperature of the air** around a water surface may also provide energy into the system. As air temperatures rise, so may the evaporation rate.

The **area of water surface** determines how much water is available for evaporation. Evaporation rate is proportional to surface area (i.e.under the same conditions, a dam covering two hectares will evaporate at twice the rate of a dam of one hectare).

The influence on evaporation rate of **land use surrounding a body of water** on evaporation rate is significant. A dam may be situated on bare open plains, as is the case after harvesting or during the early stages of crop growth. Hot air moving across the open plains will cool as it crosses the water in the dam. The cooling adds more energy into the water thus promoting evaporation.

This process is called advection, and can typically increase evaporation by a factor of two in hot, open-space conditions. However, the effect may be less where the surroundings are dominated by vegetation.

Evaporation rates are normally expressed as a depth loss in millimetres over a period of time (e.g. mm/day). Of course, it may be convenient to choose other units to demonstrate losses over other time periods, such as mm/hr or metres per year.

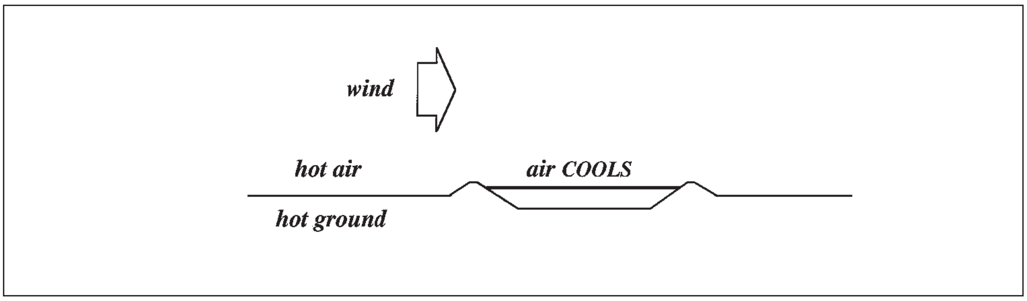


Figure 3.
Hot air moving across a space where the air is cooler, e.g. an open storage, will add energy into the system and increase the rate of evaporation. This process is called advection (courtesy Nigel Hancock, USQ).

Rates can be converted easily to show the loss as a volume. A loss of 1mm per day over $1m^2$ is $1m^2$ x 1mm/day (0.001m/day) or 1 litre per m^2 per day (1 L/m^2/day). Since one hectare is $10,000m^2$, a loss of 1mm/day over one hectare equals 10,000 L/ha/day.

HOW IS EVAPORATION MEASURED?

The most common ways of measuring evaporation are with the following instruments and method:

- pan evaporimeter
- weather station
- water balance method
- Bowen ratio installation.

Pan evaporimeters use a standard evaporation pan based on the US Class A pan, originally developed by the US Weather Bureau.

A US Class A pan is a circular tub of 1210mm internal diameter; 250mm deep and constructed of one millimetre thick galvanised sheet steel. On site, the pan is placed on a raised timber platform about 1220mm square and 150mm high. Pans are usually covered with open mesh wiring to stop animals from drinking or using the water. The whole assembly should be located as near as possible to the storage.

Evaporation is determined by measuring changes in water level in the pan. This can be done manually or automatically with electronic equipment. The Department of Natural Resources and Environment in Victoria has a fact sheet on the construction and operation of an evaporation pan. This can be found on their web site at *http://www.nre.vic.gov.au*.

Some regional newspapers publish recent weather observations including local evaporation pan figures, and these may be used to estimate losses from storages.

Class A pan evaporimeter with recording equipment on the shoreline (courtesy Sarah Hood, Department of Primary Industries).

LOCATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
GATTON	0.89	0.91	0.81	0.66	0.52	0.45	0.41	0.52	0.67	0.75	0.78	0.84
INGLEWOOD	0.92	0.96	1.01	0.76	0.58	0.47	0.38	0.59	0.85	0.89	1.01	0.91
THEODORE	0.80	0.87	0.75	0.65	0.56	0.48	0.45	0.55	0.65	0.72	0.75	0.83

Table 1.
Monthly pan factors for three localities in Queensland (Turner et al, 1993)

It is important to note that the effects of ground and atmospheric conditions on large water bodies can be different to the effects on an evaporation pan. For instance, the pan may absorb more energy through its sides and experience a higher evaporation rate than the storage due to the resulting elevated temperature.

To take account of the differences, pan evaporation measurements need to be equated to the nearby water body by applying a multiplying factor, commonly referred to as a pan factor. Monthly pan factors have been calculated for selected localities throughout the country and may be available from State Government departments that administer land and water resources or primary industries. Generally, the pan factor varies according to locality and season. Table 1 shows some examples from Queensland.

WEATHER STATIONS

Weather stations are instruments for measuring meteorological information at selected sites. The Australian Bureau of Meteorology coordinates and collects data from established weather stations at numerous centres across the country. Much of this data is collated into their web site at *www.bom.gov.au*.

Evaporation data can be accessed via the home page by clicking on:

1. Climate Averages
2. a State or Territory and
3. a weather station (near your property).

Some stations show mean daily evaporation for each month in their data tables. Where specific daily evaporation data for a particular station is required the Bureau can supply that information for a fee.

Also, several companies manufacture and retail compact and portable weather stations for the private user. Weather stations for the private market usually have the facility to record data automatically and calculate evaporation using an established formula. These stations also provide the means to download information onto a computer for further evaluation.

Weather stations are common in cotton growing areas where they are used to monitor evaporative losses from soil and crops. Where it is intended to use them to measure losses from a dam, the data from the station requires the application of a pan factor as discussed above.

The **water balance method** of determining evaporation requires the estimation of inflow and outflow from the storage and the measurement of change to the storage water level over a selected period.

You will need to estimate or measure:

- ☐ inflows of rainfall, runoff and waterharvesting
- ☐ outflows of water e.g. irrigation
- ☐ seepage through the base and banks
- ☐ storage water levels.

A common method of measuring water levels is by taking readings from a gauge board installed in the storage. Gauge board scales are usually in centimetre divisions and readings from the board will not be precise, especially when the surface is rippled. Therefore, it is best to record water level changes over long periods, such monthly or quarterly.

Estimates of rainfall, runoff, waterharvesting, irrigation and seepage need to be translated into units of depth (e.g. centimetres or metres). For events where bulk quantities of water enter or depart the storage, water level changes may be recorded directly from a gauge board. A rain gauge located at the storage will measure rainfall and this may be converted to the required units. It is necessary to have a rain gauge only where the storage has no other catchment (e.g. ring tanks) than the storage area itself.

Seepage is not easily measured but it can be estimated by using soil permeability values. Some State government departments may be able to help with permeability of soils for your local area. Otherwise, an approximation based on local knowledge is possible.

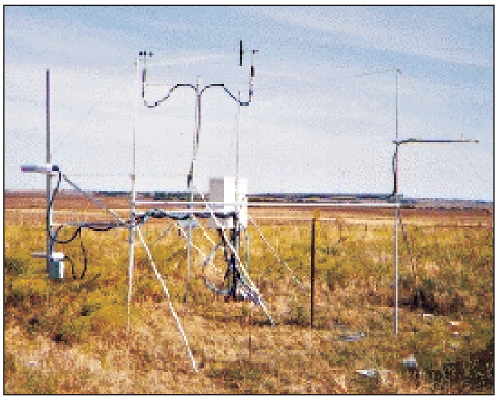
Once all the estimations are done, evaporation can be calculated using a simple equation.

Evaporation = Change in storage level + Inflows – Outflows – Seepage

Example:
Water level in a dam drops 1 metre over three months. The rainfall in that time is 50mm and an opportunity for water harvesting adds 48 cm. A crop has been watered and the water fell 95 cm. Seepage has been estimated at 50 mm per month.

Evaporation (mm) = 1000 (1 metre) + (50 + 480) – (950) – (3 x 50) = 430 mm
The water balance method will not give accurate evaporation data because of the uncertainties in measuring and estimation, but it will provide a reasonable indication of evaporation losses.

The Bowen ratio system uses an in-field installation of various sensors to estimate evaporation. Estimates are made using measurements of vertical flow of heat energy; vertical gradients of temperature and relative humidity; net solar radiation; windspeed and atmospheric pressure. Bowen ratio installations are very expensive and are usually set up for specialised scientific investigation.



An example of a Bowen ratio installation (www.arm.gov – Atmospheric Radiation Measuring, ARM program – US Dept. of Energy)

METHODS OF CONTROLLING EVAPORATION AND THEIR PRACTICAL LIMITATIONS

The general ways to limit evaporation are to:

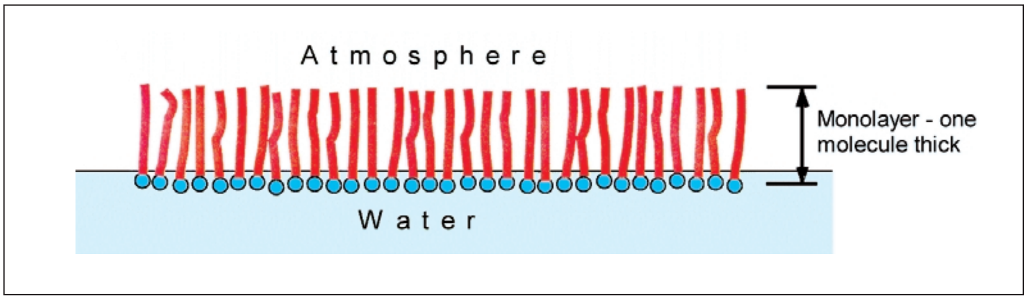
- provide a barrier at or over the surface (suspended or floating)
- build structures to reduce wind speed
- reduce the surface area.

Barriers. Barriers, which are applied to the water's surface, include covers and chemical monolayers.

What is a monolayer? A monolayer is formed on a water surface when long-chained alcohols such as cetyl alcohol (hexadecanol) are spread across the water. The chemical spreads spontaneously across the surface resulting in a layer only one molecule thick (about two millionths of a millimetre).

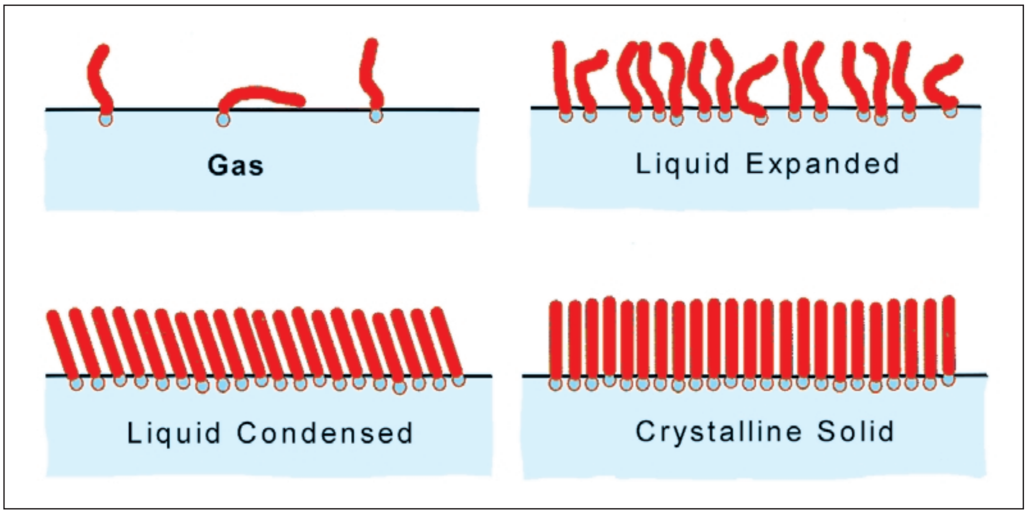
The molecules of the monolayer 'stand' on the surface because they are amphiphilic i.e. they have a soluble end and an opposing insoluble end (Figure 4).

Figure 4. Monolayer molecules 'standing' on the water surface (courtesy Geoff Barnes, University of Queensland).



It is when the molecules are 'standing' upright next to one another that the monolayer is most effective in controlling evaporation. This will happen when enough chemical is spread on the surface to compress the monolayer into a crystalline solid state (Figure 5). Monolayers can exist in other expanded states where not enough chemical is used for the required surface area. On the other hand, too much chemical will cause the monolayer to collapse.

Figure 5. Monolayers exist in various states depending on the amount of surface compression (courtesy Geoff Barnes, University of Queensland).



Only small amounts of chemical are needed. Just two kilograms of cetyl alcohol will cover about one square kilometre with a crystalline solid.

Monolayers can be introduced to water as a solution or as a solid in the form of crystals or flakes. When it is in solution form the chemical is combined with a solvent. As it spreads across the surface, the solvent evaporates leaving the monolayer on the water. The solid crystals or flakes will also spread spontaneously when they come into direct contact with the water.

As a layer of close-packed molecules on the surface, the monolayer inhibits the transfer of water vapour to the atmosphere. However, the transmission of other gasses such as oxygen and carbon dioxide are barely affected.

Numerous experiments and trials with monolayers have been conducted in laboratories and by field research in many countries (Fietz, 1970). Under ideal conditions, they have been shown to work well, reducing evaporation by up to 60% (Jones, 1992), but in field trials on large storages they have been much less effective, possibly up to 40% in winds less than 8 km/hr (Fitzgerald and Vines, 1963). Monolayers are greatly affected by wind and wave action and their effectiveness in strong winds is very low.

Although monolayers can spread again after being damaged, they will not recover if they have been deposited on the shore. Therefore, to maintain its effectiveness a monolayer needs to be reapplied frequently.

Covers

Covering the water will reduce the incidence of solar radiation and, depending on the type of cover, may also decrease the effects of wind. A cover can be suspended or floating.

Suspended covers may be practical on small storages where support distances are short. Even so, suspension systems need to have good tensile strength and be well anchored. Depending on the span and weight of the cover, the system may need the assistance of flotation or supports. Suspended covers will provide shade from the sun but may not give protection from the effects of wind. Effectiveness will depend on the percentage of coverage across the dam.

The photo below shows a 67 x 45m earth dam covered with a suspended shade cloth of 70% shade.

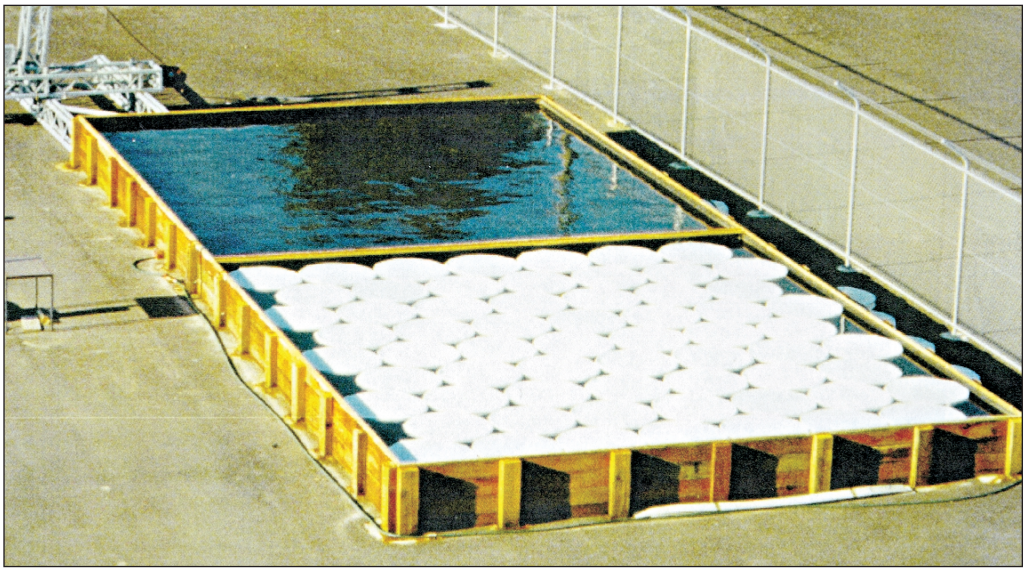
Salmon Gums School Dam – Western Australia (courtesy Salmon Gums Landcare Group).

Floating covers are effective in reducing evaporation. Just about anything that floats will provide a barrier. Experimental work in the past using small tanks has shown that evaporation can be reduced by up to 95% using a variety of materials and cover areas (Cooley, 1983). Protecting large areas of water with a cover is expensive and a number of practicalities should be considered. These are:

- effectiveness in controlling evaporation
- long-term durability
- installation issues such as anchoring and joining
- stability in windy conditions.

A cover should also allow rainfall into the storage and some exchange of gases between water and air. Increasing the reflectivity of the cover to reduce solar radiation and increase its durability may enhance its effectiveness. A cover over the entire storage area may also have an effect on water quality and this could impact on aquatic life in the storage.

Covers don't have to span the entire area. It may be economical to partially cover the storage with a number of floating units. Savings in evaporation would depend on the type of cover and the area of surface that is concealed. Individual units would need to be anchored to hold them steady against the effects of wind. Where enough units are placed on the water their arrangement could promote self-stability and some wave dampening effects.



Experimental work on evaporation control – Melbourne (courtesy Ian Burston, Royal Melbourne Institute of Technology).

Structures to reduce windspeed

Windbreaks are a common feature in many rural areas to reduce wind damage to cropping. They can also be used near dams to give a small measure of protection from evaporation.

Planting trees strategically around a storage or inside a storage on purpose-built banks can have a minor effect in reducing evaporation. Trees should not be planted directly on or adjacent to embankments because the roots may increase the risk of piping failure. Experimental work by CSIRO has shown that the value of trees in controlling evaporation depends on several factors:

- the ratio of distance from windbreak to height of windbreak
- windbreak density (tree spacing and foliage density)
- angle of orientation to wind direction.

At best, expected evaporation reduction would only be up to 20% (Condie and Webster, 1995) and this would not be consistent across the whole storage surface. A more likely average would possibly be less than 10% (Crow and Manges, 1967).

Some issues that have been raised about using trees as windbreaks are:

- they take a long time to reach an effective size
- they present a potential obstacle to aerial crop-dusting operations
- they pose a hazard to dam integrity if planted too close to the embankment.

However, trees grown as windbreaks could be incorporated into a strategy of building on-farm buffer zones or wildlife corridors.

Minimising surface area

Decreasing the surface area of a dam reduces the availability of water to evaporate and cuts evaporation proportionally.

The implication for a farm dam is to minimise the surface area by building the dam as deep as is practical for a set volume of water. It is probably the most immediate option for a storage designer, and many owners of large farm storages have already adopted this strategy.

Another strategy is to construct the dam into cells so the water can be managed to minimise surface area. A simple example is a dam divided into two equal size cells. When it is needed, water is drawn from one cell and, when possible, the balance of that cell is transferred to the other cell, thus reducing the surface area of the remaining volume (Figure 6).

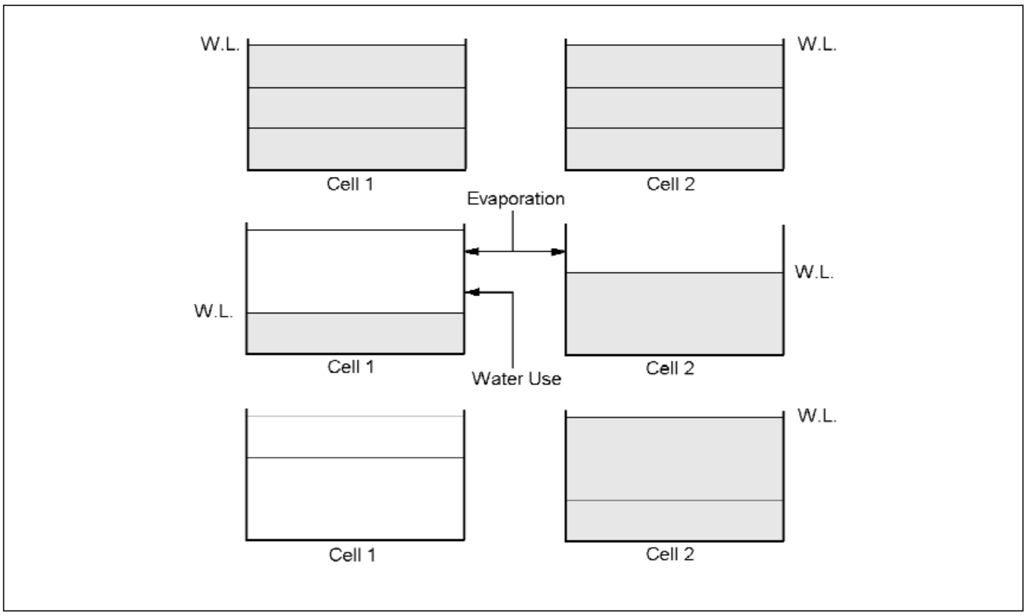


Figure 6.
A simplified diagram of water management with cells

Note: WL = water level

The number of cells will be determined by cost and the planned regime of water management.

Methods at a glance

Method of control	Effectiveness	Considerations
Covers	High	Cost, durability, installation, wind resistance
Monolayers	Low to moderate	Wind and wave action easily damage monolayer, need to be reapplied often (probably on a daily basis), cost of chemical
Windbreaks	Low	Long-term establishment, trees cannot be planted close to embankments
Minimising surface area	Low to moderate (depends on how much the surface area has been reduced)	Cost of construction per cubic metre increases with embankment height. Cells require extra earthworks and water transport infrastructure such as pipes and pumps.

Economics of methods

An important question about any method is, 'How much does it cost?' To determine an overall cost a number of factors need to be considered:

- ☐ What is the expected quantity of water saved?
- ☐ What is the cost of the materials used to save the water (construction costs, covers)?
- ☐ The life expectancy of materials used.
- ☐ Is there the opportunity to expand existing cropping using the saved water?
- ☐ What returns will be gained from the use of the extra water?
- ☐ What additional financial constraints will be imposed (e.g. interest on borrowings)?
- ☐ Will additional tax concessions be possible?

The following exercises present two scenarios using different evaporation control methods. In the first exercise a cover is applied to one hectare of surface area on a storage in the St George district of Queensland. Exercise 2 raises an existing ring tank from 5 metres to 8 metres high to reduce the surface area available to evaporation while maintaining the original storage volume. Results are summarised below.

Exercise 1. Covering a dam with a floating cover

POTENTIAL SAVINGS IN EVAPORATION	16 ML/HA		
COST TO PREVENT EVAPORATION (ASSUME COST OF COVER AS $3.5/M2)	$35,000 PER HA		
BENEFITS FROM THE POTENTIAL SAVINGS			
EXTRA INCOME			
EXTRA AREA OF COTTON (SEE NOTE 1)	8 ML/HA	2 HA	
EXTRA BALES OF COTTON	8 BALES/HA	16 BALES	
PRICE/BALE OF COTTON $/BALE	440	$7,040	
EXTRA PRODUCTION COSTS ($/HA) (SEE NOTE 2)	1,700	$3,400	
EXTRA GROSS MARGIN		$3,640	
OTHER SAVINGS			
ENERGY SAVINGS FROM NOT HAVING TO PUMP ADDITIONAL WATER	16 ML	$8 PER ML	$128
TAXATION ADVANTAGES FROM DEPRECIATION AND INTEREST ON INVESTMENT	34 %7000 ($35,000 OVER 5 YRS)		$2,380
	34 % 2,800 (8% OF $35,000)		$950
TOTAL SAVINGS			$7,098
TOTAL COSTS (SEE NOTE 3)			$35,000

COVER IS PAID OFF IN ABOUT 5 YEARS ASSUMING THE AREA IS AVAILABLE FOR ADDITIONAL PLANTING OF COTTON.

Notes:

1. It is assumed it takes 8 ML to grow one hectare of cotton in the St George region
2. This does not include the costs to establish a new area of cotton crop.
3. Does not account for the interest on a loan for the capital.
4. This does not compare dryland to irrigated cropping, as dryland is not economical in the St George area. For other regions it may be necessary to make this comparison.

Table 2. Economic validation of using plastic covers to minimise evaporation losses in the St George area and use of saved water to irrigate cotton.

Exercise 2 - Raising the height of a ring tank

This exercise examines the costs of raising the height of a ring tank from 5 to 8 m for a range of six capacities and three regular shapes, circle, square and rectangle. The calculated costs are shown in Table 3 below.

Figure 7 compares the cost per ML saved for each shape of ring tank using the earthworks construction price of $\$1.40/m^3$. The rectangular shape is shown to be the least expensive shape to construct.

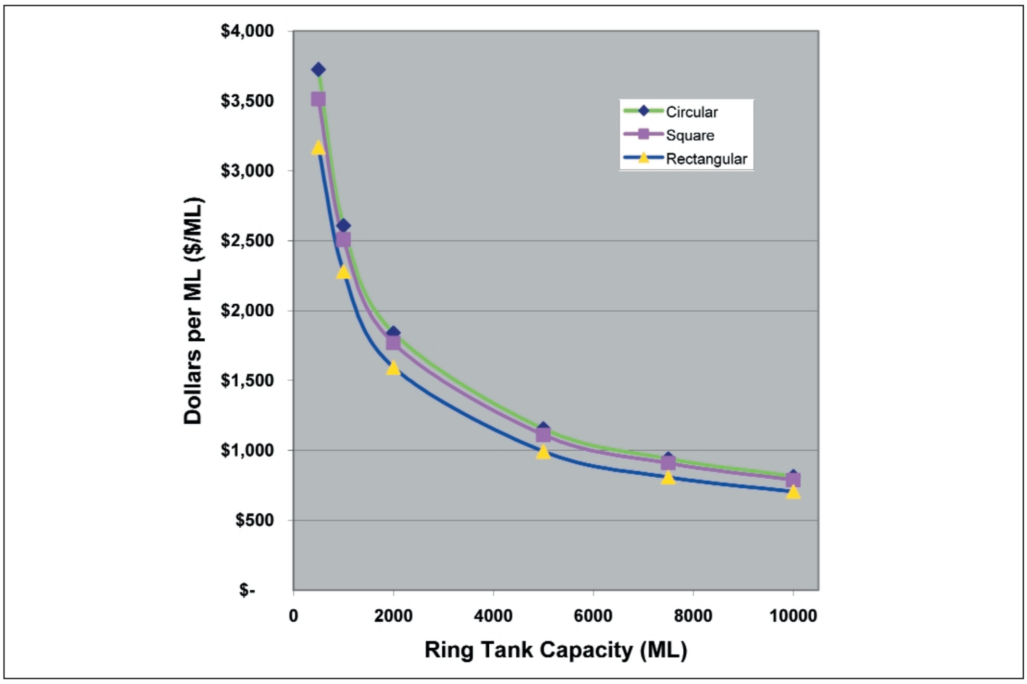


Figure 7. Comparison of cost for three shapes of ring tanks raised from 5 to 8 metres high at $1.40/m3 for earthworks

SHAPE OF EXISTING RING TANK	CAPACITY ML	COST PER ML SAVED FOR EACH EARTHWORKS RATE ($/M3)						
		$ 1.40	$ 1.50	$ 1.60	$ 1.70	$ 1.80	$ 1.90	$ 2.00
Circular	500	$ 3,725	$ 3,991	$ 4,257	$ 4,523	$ 4,790	$ 5,056	$ 5,322
	1000	$ 2,608	$ 2,794	$ 2,981	$ 3,167	$ 3,353	$ 3,539	$ 3,726
	2000	$ 1,841	$ 1,973	$ 2,105	$ 2,236	$ 2,368	$ 2,499	$ 2,631
	5000	$ 1,154	$ 1,237	$ 1,319	$ 1,402	$ 1,484	$ 1,567	$ 1,649
	7500	$ 940	$ 1,008	$ 1,075	$ 1,142	$ 1,209	$ 1,276	$ 1,344
	10000	$ 813	$ 872	$ 930	$ 988	$ 1,046	$ 1,104	$ 1,162
Square	500	$ 3,513	$ 3,764	$ 4,015	$ 4,266	$ 4,516	$ 4,767	$ 5,018
	1000	$ 2,509	$ 2,688	$ 2,867	$ 3,046	$ 3,225	$ 3,405	$ 3,584
	2000	$ 1,767	$ 1,893	$ 2,020	$ 2,146	$ 2,272	$ 2,398	$ 2,525
	5000	$ 1,111	$ 1,190	$ 1,269	$ 1,349	$ 1,428	$ 1,507	$ 1,587
	7500	$ 908	$ 973	$ 1,038	$ 1,103	$ 1,168	$ 1,233	$ 1,298
	10000	$ 787	$ 844	$ 900	$ 956	$ 1,012	$ 1,069	$ 1,125
Rectangular	500	$ 3,169	$ 3,395	$ 3,622	$ 3,848	$ 4,075	$ 4,301	$ 4,527
	1000	$ 2,281	$ 2,444	$ 2,607	$ 2,770	$ 2,933	$ 3,096	$ 3,259
	2000	$ 1,594	$ 1,708	$ 1,822	$ 1,935	$ 2,049	$ 2,163	$ 2,277
	5000	$ 993	$ 1,064	$ 1,135	$ 1,206	$ 1,277	$ 1,348	$ 1,418
	7500	$ 808	$ 865	$ 923	$ 981	$ 1,039	$ 1,096	$ 1,154
	10000	$ 705	$ 756	$ 806	$ 857	$ 907	$ 957	$ 1,008

Note: The following design parameters and assumptions were applied in the calculation of the costs in Table 3:

a. The capacity of the raised ring tank remains the same as the original storage.
b. Bank batters are 1:4 upstream and 1:3 downstream.
c. Crest widths are 4m and 4.6m respectively for the original and raised banks.
d. Freeboard to be 1 metre for ring tanks up to 2000ML and increasing to 1.1m, 1.2m and 1.3m respectively for the larger ones.
e. Soils used are inorganic clays of high plasticity and inorganic silts.
f. Embankments are constructed in 150mm lifts and compacted with Sheep Foot Rollers at Optimum Moisture Content achieving at least 95% Proctor Standard Density.
g. The raised embankment does not change conditions for licensing or hazard rating.
h. Seepage control measures such as filters and toe drains are not considered.
i. The existing pumping arrangement is sufficient for the raised dam.
j. Water stacking in other dams or cells is not used.
k. The Annual Net Evaporation Loss to be 1.5m for both the 5 and 8 metre storages.

Table 3.
Cost for each megalitre (ML) saved by raising the embankment

Conclusions from exercises 1 and 2

To cover a dam with a specialised plastic cover may require the investment of $35,000/ha ($3.50/m^2). This is a profitable exercise if additional profit levels are at $400/ML but **not** $200/ML. If the cover could be bought and installed for $25,000/ha and evaporation savings were 18 ML/ha, the exercise is profitable at $200/ML additional profit.

A square or rectangular shaped dam raised to 8 metres required smaller break-even storage capacities when additional profits were less than or equal to $200/ML. Investment in raising all three shapes was profitable at additional profitability levels greater than $500/ML and construction costs less than or equal to $2/m^3.

Further research is needed to assess the combined economic impact of new storage capacities and dam covers, but a preliminary analysis was encouraging.

The following assumptions have been made during the analysis of each exercise.

- ☐ The storage is full at the start of the analysis.
- ☐ A Discounted Cash Flow Analysis – New Investment is used to assess additional benefits and costs.
- ☐ The discount rate is 6%.
- ☐ Dam covers have a 10-year life.
- ☐ The new 8 m storages have a 50-year life.
- ☐ Repairs and maintenance of the new storage structure will not increase.
- ☐ A positive Net Present Value means a profitable investment.
- ☐ The analysis used a range of costs and prices.
- ☐ There were economies of scale in the new storage construction costs.

Table 4.
A sample of various crops and their irrigated profits for the Darling Downs and Goondiwindi districts of Qld

IRRIGATED CROP PROFITS IN $ PER ML - 2001 (SOURCE: DR. PETER WYLIE)

	DARLING DOWNS	GOONDIWINDI
PEANUTS	573	452
LUCERNE	282	158
PUMPKINS	271	271
ADZUKI BEANS	308	308
CORN	204	84
SOYBEANS	223	101
SORGHUM	172	79
COTTON	77	86
SOFT WHEAT	197	185

Note
a. Cotton profits can be as high as $400/ML at price levels of $500/bale.
b. At a yield of 8 bales per hectare and $400/bale, cotton profit is usually around $200/ML.

OPTIONS FOR INTEGRATING METHODS

There are a number of potential options for integrating methods to optimise evaporation control from large storages. They are 'potential' options because there has been little investigative or experimental work done with combined methods and the work that has been referenced does not have economic analyses attached. Therefore they cannot be fully substantiated as viable options for large farm storages, but do indicate the variety of possibilities.

In 1967, F.R. Crow and H.L. Manges experimented with monolayers in combination with artificial barriers (windbreaks) or shaded cover. Their results showed improvements in evaporation reduction when methods were combined. The best results from their work showed a 46% reduction in evaporation with the shaded cover and monolayers together. A reduction of 35% was recorded for shaded cover without monolayers. The experiments were performed on small purpose-built ponds and do not indicate the practical difficulties of applying the techniques to larger storages.

S.A. Condie and I.T. Webster in their report from 1995 suggested the potential for combining windbreaks using water-tolerant trees growing on the internal banks of a multi-celled storage. Possible reductions in evaporation were not quantified.

K. Daigo and V. Phaovattana conducted in-field and computer-aided trials in Thailand. Their report in 1999 showed improvements in evaporation control by combining the methods of covering, pond shape and use of multi-cells. The trials focussed on small farm ponds typical of many farms in Thailand and the results would be difficult to translate to large farm storages in Australia.

Perhaps the most readily applicable option is the integration of a deep storage with a multi-celled layout. The Condie and Webster report and other publications indicate that this option is already in extensive use in some cotton growing areas and the report offers encouragement for greater implementation of this approach.

SUMMARY

This framework has discussed evaporation and various methods of evaporation control. Of these methods, minimising surface areas, storage covers and to some degree monolayers offer reasonable improvements in water storage efficiency.

Depending on their type and extent, covers have been shown to save up to 95% of evaporation losses. In practice monolayers can save up to 40% as long as the effects of wind damage can be solved or managed. Minimising surface areas by raising embankments or constructing storages in cells is readily applied and is a well-accepted strategy in cotton growing areas.

Combining methods could give greater reductions in evaporation losses, but it is probable that implementation costs would escalate and the cost effectiveness would need to be investigated.

Windbreaks near storages can have a small effect on evaporation, with perhaps around 10% reduction. If it is possible to plant trees as a farm runoff or spray buffer zone near to the water, then they may serve as a cost-effective windbreak. This may be possible for smaller storages and some gully dams.

The costs of implementing an evaporation control method on storages can be expensive, particularly with covers, and there are practical and financial risks. Only after a proper economic analysis has been conducted at the planning stage can the risks be assessed and so provide a basis for further development decisions.

THE FUTURE FOR EVAPORATION CONTROL

At the workshop on evaporation control (see Appendix B) in April 2002, it was recognised that more research into evaporation control was required and that such research programs need to:

- focus on larger storages
- produce case studies of operating storages
- provide cost-benefit assessments for each study
- conduct investigations in a reasonable spread across Australia.

New research efforts need to embrace several control methods, and the workshop recommended close attention to ways of minimising surface areas and to developing design and management options for those ways. In parallel with further research, other investigations were suggested in the following areas:

- controlling seepage from storages
- finding ways to value water more effectively
- developing wind-resistant chemical films to enhance monolayer efficiency
- developing simple tools for measuring evaporation.

Viable evaporation controls can significantly increase on-farm water use efficiency and, where possible, should be integrated into efficiency strategies for farm water distribution. It was seen as important, therefore, that governments and industry promote evaporation control with incentive schemes aligned with potential savings in water.

ACKNOWLEDGMENTS

The project team gratefully acknowledges the input from all participants in the reference group and the workshop. Thanks are owed specifically to those who made presentations, to Gordon Brown for his facilitation of the workshop, and to Bryan Mulligan and Marnie Stitz for organising media attention to the project and the workshop. Thanks also to the members of the project team for their friendship and advice.

APPENDIX 1.

REVIEW OF SOME RECENT STUDIES AND TRIALS IN AUSTRALIA

Reducing Loss from Evaporation – A report to the Cotton Research and Development Corporation (CRDC) by Sainty and Associates – July 1995

This report gathered information from the University of Western Sydney, RMIT, CSIRO Centre for Environmental Mechanics and from visits to six cotton farms in NSW and Queensland. The results of this report are briefly outlined below.

Chemical films (or Monolayers)

Condie and Webster, CSIRO, (1995) outlined the work on monolayers by Jones (1992).

Laboratory studies showed reductions in evaporation between 20% and 60% under controlled conditions. However, there are severe limitations to their use in the field on large storages where wind and wave action can easily destroy the film. Consequently, no practical applications were found and any future use would rely on reducing wind effects simultaneously.

Windbreaks

Condie and Webster reported on the work of Crow and Manges (1967), who discussed the effects of a windbreak in terms of the ratio of windbreak distance to windbreak height. There was minimal effect on evaporation reduction with a ratio of 50 while a ratio of 16 showed only a 9% reduction. Condie and Webster showed in their computer modelling a reduction of 20% is achieved with a wind speed of 11km/hr at the distance/height ratio of 10 with plants orientated at 90 degrees to prevailing winds or planted in north/south rows to maximise the shade in summer.

The roots of trees planted as windbreaks along embankments pose a problem to the banks themselves. However, water-tolerant trees such as Melaleuca could grow on purpose-built banks within the storage. Rows of trees at strategic spacings would not only act as windbreaks but provide shade and dampen wave action. A diagram showing the possible integration of windbreak and cell construction was included.

Storage design

Condie and Webster conducted computer modelling on storage design, and included economic analyses on reducing storage surface areas by deepening dams and building them in cells.

There has been some adoption of deeper storages by farmers, but many others perceive the extra costs of excavation and the increased risk of bank failure as a barrier to implementation. However, calculations show that the costs of increasing a 500 ML storage from three to six metres deep can be paid back in 3 to 4 years.

Using a system of multiple storages was discussed. An extra storage can be built beside an existing storage or the original storage can be divided into cells. In both cases, water is transferred from one cell to the other when water level is drawn down in both units. This strategy minimises water surface area. The cost of dividing a 500 ML storage into two cells was also calculated to be paid back in 3 to 4 years.

Floating materials

1. Microcosm Experiments conducted at the University of Sydney by Peter Adcock

This is a study of the effects on evaporation of floating aquatic plants. Tests were done in small tubs with various areas of plant coverage (0%; 25%; 50%; 75%; and 100%). Results showed insignificant reduction in evaporation and even suggested that the plants increased loss of water during days of low pan evaporation.

2. Fresh Water Storage – Evaporation Research conducted at RMIT by Ian Burston (1995)

The study has used 'backyard' swimming pool sized ponds to conduct four parallel experiments using floating plastic rings as a base.

A. a plastic ring by itself
B. a plastic ring containing floating water fern (Azolla)
C. a plastic ring supporting a plastic cover painted white ('Aquacap')
D. a pond of fresh water without a device was used as a control (for comparison).

A. The plastic ring (developed by A. Akbarzedah) by itself had little effect on evaporation losses but did reduce wave action.

B. Floating aquatic plants did little in the way of reducing evaporation with trials demonstrating about 5% reduction.

C. The plastic ring with the 'Aquacap' demonstrated about 65% evaporation reduction with less than 80% of the surface covered.

The report recommended further investigations should be conducted on a larger scale using 'Aquacaps' as the floating barrier.

3. Condie and Webster tabulated data from several sources showing evaporation reduction using various floating materials (plastic sheeting, rubber, polystyrene, wax blocks). All showed high reduction rates (from 40% up to 95%) depending on the type and extent of the cover. All the materials were studied in small storages.

Polystyrene rafts demonstrated the best reduction potential but it was pointed out that the polystyrene could not be expected to last more than 10 years.

Lightweight concrete was suggested as a more resilient material and calculations indicated that it could be 20% cheaper than polystyrene per unit of water saved.

Research, Development and Extension in Irrigation and Water Use Efficiency: A review for the Rural Water Use Efficiency Initiative edited by Steven Raine, Toowoomba, NCEA, pp.13-21 – (1999)

This review reports on the performance of on-farm water storages and distribution systems where evaporation and seepage losses are a major contributor to water use inefficiency. This is particularly so for the cotton industry, which relies on the use of large ring tanks to store harvested flows to supplement water supplies.

Only issues related to evaporation losses are discussed in this publication.

How much evaporation there is from a storage requires a knowledge of evaporation rate. The traditional approach to measuring evaporation is to use a monitoring pan (or evaporimeter).

Three approaches to evaporation monitoring are described in the report. These are:

- the US Class A pan
- the Australian sunken tank (similar to the US Class A pan only its water surface is at ground level)
- an energy-balance model with the assistance of formulae that use radiation and aerodynamic data derived from weather stations and other sensing tools.

A figure with two maps of Queensland shows average annual pan evaporation depths and lake evaporation estimates respectively.

The work of Sainty is reported with respect to evaporation losses and the methods that can be used to mitigate evaporation. Previous investigations into windbreaks, storage design and floating materials are outlined.

In regard to storage design, the work of Condie and Webster on cost recovery was discussed further. The cost-recovery period depends on the value of lost water (i.e. lost production opportunity). For a farm with limited land area, a cost-recovery equation could also include the potential for increasing production area.

Also, the calculations of Condie and Webster showed cost recovery of 3 to 4 years for constructing multiple cells within a storage. In a personal communication, Donnett (DNR) indicated that an internal divide within a storage used for cotton production in southern Queensland is not likely to be viable where that storage is less than 5,000 ML.

(A)"Are there methods to reduce evaporation in ring tanks?" and (B) "Selecting the optimum ring tank height for your farm" by M. Wheeler and S. Goudie – DPI Toowoomba – 1995

Both articles are fact sheets resulting from modelling of ring tank design and planning options for the Darling Downs region.

discusses various methods of evaporation control:

- planting trees (windbreaks)
- chemical surfactants (monolayers)
- covers (poly. beads and shade cloth)
- increasing depth of storage.

Comments on the methods were similar to those in other studies and the fact sheet concluded that increasing dam depth was the most economical method. It was recommended that to raise an existing embankment the storage should be empty and completely dry.

Storing water in the soil profile was put forward as a possible area for future study. Risks associated with this method are that losses to subsoil/watertable are probable and evaporation losses would still occur via the ground surface, although theory suggests the evaporation rate would be less than from an open water surface. Also, fallow management practices would need to be modified to contend with a constant wet profile compared to a dry profile where the soil is topped up just prior to planting. No trials of this method were identified.

discusses evaporation from ring tanks on the Darling Downs and compares costs of increasing storage depth and constructing multiple-cells. As an example a table shows the surface areas of a 1000 ML storage for various depths.

Results suggest that multi-celled storages are not as economical as single celled tanks. However, the best ring tank option would depend on several parameters:

- area of land available
- value of submerged land
- length of time water is stored
- value of water that the storage may potentially lose (evaporation and/or seepage)
- cost of pumping
- storage volume required
- location of the storage on the property.

The efficiency of on-farm storages by Paul Dalton, Australian Cotton Grower, July – Aug 2001, pp. 48-51

The article was adapted from a study of water storage efficiencies on four storages in the McIntyre Valley between 1998 and 2000 by the National Centre for Engineering in Agriculture on behalf of the Cotton Research and Development Corporation.

The factors influencing storage efficiency were outlined, and evaporation was identified as a major contributor (up to 40%) to water losses. Minimising the surface area represented an effective strategy for evaporation reduction either by building deeper storages or covering the water surface or both.

A cost-benefit analysis was tabulated using a 3,500 ML storage at Goondiwindi as an example. The extra cost of doubling the depth of the storage was shown to be paid back in 1.6 years for a round-shaped storage and 2 years for a square shape.

The article concludes with a discussion on storage efficiency solutions (i.e. deeper storages; multiple cells; tree shelter belts and surface coverings) and suggested that mitigating evaporation should be by means of a systems approach. This would consider all parameters including whole-farm management, water resource management, and the cost of the evaporation control technique.

INTERNATIONAL

Report on the operation to reduce evaporation from the reservoirs in Ouagadougou – Capital city of Burkina Faso – West Africa, 1998 by Claudius Witting of GTZ (Technical Cooperation Project).

The report from Burkina Faso was obtained from Dr Rainer Knickmeyer, SASOL Germany GmbH, Manager Market Development, Fatty Alcohols & Derivatives, Überseering 40, 22297, Hamburg. (Rainer.Knickmeyer@de.Sasol.com)
The document is one report of three on the operation. The other two reports are available through the National Office of Water and Sanitation (ONEA) in Burkina Faso.

The operation used an evaporation retardant (monolayer) called HYDROTECTÔ in an attempt to prolong the supply of remaining water in two of the city's water supply barrages. The operation was conducted from February to June 1998.

HYDROTECT is an emulsion of 60% water with the other 40% made up of two aliphatic alcohols. These alcohols are used in most cosmetic products and are practically insoluble in water. Tests from different laboratories showed HYDROTECT posed no risk to health and that it broke down easily within 28 days.

Information on HYDROTECT is available at
http://www.condea.de/products/fattyalcohols/hydrotec.asp

The efficiency of the product during the operation depended on two main factors:
- absence of strong winds
- regular and even application.

Before starting the operation, a series of test were conducted to verify the effectiveness of HYDROTECT. These tests were conducted using several small storages at the city's water treatment facility.

The tests set out to verify:

- dispersing characteristics
- retarding effect on evaporation
- effects on water aeration
- if the product accumulates in water
- the effects on water treatment and aquatic life.

The test on the retarding effect took place over 12 days in November and December 1997. A small, 20m^2 basin was used and its results were compared with another basin that was not treated with HYDROTECT.

Two reported statements on evaporation measurement and its precision were not clear. The first, on test measurement, stated that 'It was found that 40 mm of water had evaporated from the treated basin as opposed to 100 mm, the usual level of evaporation (6mm per day).'

The second statement refers to measuring water levels in the barrages.

The average precision in measuring the water level was of the order of one centimetre. This gives a relative error over a 10-day period, equivalent to 70 mm drop in water level, of less than 2/70, or around 3%. This is a very satisfactory degree of precision, and at least as good as that obtained when measuring evaporation from tanks.

During testing, the temperature of both basins was recorded and the treated basin was 1 to 1.5°C warmer, indicating more energy had been stored in this basin because evaporation had been reduced.

All other tests were reported as successful with no detrimental effects observed and effectiveness confirmed.

Before the operation, it was decided to dilute the alcohol concentration of the product to about 5 to 8% in an effort to increase its spreadability.

The results of the operation are tabulated below:

	OUAGA III BARRAGE 20 FEB TO 10 MAY 1998	LOUMBILA BARRAGE 9 APRIL TO 4 JUN 1998
WATER LEVEL AT START	1.50 M	2.40 M
WATER LEVEL AT END	-0.15 M	1.68 M
NORMAL LEVEL OF EVAPORATION	106 CM	57 CM
ACTUAL EVAPORATION	72 CM	39 CM
VOLUME OF WATER DRAWN	773 873 M^3	1 027 396 M^3
VOLUME OF WATER RECOVERED	245 000 M^3	379 000 M^3
TOTAL SAVED VOLUME = 624 000 M^3 OR 624 ML		

The expense of the operation included costs for the product, equipment, fuel and labour. The total cost was given as 64 602 000 CFA francs (equivalent to A$178 000 using present day exchange rates). Given the saving of 624 ML, the cost can be translated to about A$0.29 per cubic metre saved.

Some of the main points of the report's summary are:

- The product HYDROTECT can reduce evaporation by up to 50% when used on a small basin (100 x 50 m) but a reduction of 25 to 35% can be obtained on a stretch of water with a surface area of 50 to 100 ha.
- Continuous application of the product is imperative. Interruptions would greatly reduce effectiveness.
- A number of technical difficulties are encountered on windy days i.e. distribution and distribution points must be adjusted according to wind direction as stability of the product is at risk on windy days.
- Treating the water surface caused the water temperature to rise by around 3 to 4°C and led to a slight increase in bacterial activity. This did not appear to have a negative effect on health.
- Cost of the operation should be evaluated for individual cases, taking account of climatic conditions, the surface area and shape of storage, cost to distribute the product, and the volume of product.

Recommendations for use of HYDROTECT:

- Apply the product twice a day, in the morning and late afternoon. It was noticed that a large proportion of film disappeared in the late afternoon, which meant there was still a lot of evaporation overnight.
- Ensure the product is applied as quickly as possible so that it is distributed under the same conditions, particularly with respect to wind direction.
- To reduce the undesirable effects of wind and to maintain an unbroken film over long distances, it was suggested that wooden or plastic floating grids be put on the surface. Grid size recommended was about 100 to 200 m squares. These would help with breaks in film over long distances and could mean the use of less product.
- It is essential that no boating or fishing be allowed during treatment as this will disturb the film.

Comment on the report

The report contains little in the way of hard data, particularly with measurement of evaporation and storage parameters. This may be included in other reports, which have not been sighted.

Evaporation and Percolation Control in Small Farm Ponds by Kosho Daigo & Virote Phaovattana, 1999, Japan Agricultural Research Quarterly, 33 (1). Also available at: http://ss.jircas.affrc.go.jp/engpage/jarq/33-1/daigo/daigo.html

This project was formulated on behalf of the Department of Land Development, Ministry of Agriculture and Cooperatives, Thailand.

The project looked at four methods for the study of evaporation and percolation control with particular emphasis on low cost and sustainability with the view that farmers could easily apply a method themselves. The methods were as follows:

1. Floating cover method
2. Compartment method (multi-storage study)
3. Pond shape method
4. Crushing and compaction (for percolation control study).

A typical small farm pond storage is 34 x 20 x 3.5 m deep with 1:2.0 internal batter slope (1.4 ML volume).

Floating cover method. Two experiments were conducted during 1995 and 1996. The 1995 experiment investigated four types of cover: polystyrene foam, bamboo, drinking water bottles, and duckweed. Each cover was measured against a control pond.
The results showed that the polystyrene foam was the most effective, with an evaporation reduction of 38%. However, the authors chose duckweed (9%) as the most suitable and sustainable material in view of its cost and lack of impact on the environment. The 1996 experiment used only duckweed to confirm its effectiveness.

Compartment method. The compartment method was assessed by computer calculations. The calculations considered two approaches: to divide a typical pond into compartments (cells) and to use several small ponds.

Assumptions for the calculations were as follows:

- ☐ evaporation was 5.0 mm/day
- ☐ percolation was 5.0 mm/day
- ☐ there was no rain
- ☐ daily water consumption per standard pond was 5.0 m^3/day.

The results showed that operating the multiple pond system was effective, four ponds being the best. With a four-pond regime a 13% saving in water loss could be expected and another 16 days of water supply secured.

Pond shape method. Computer calculation also determined the results of the pond shape method, and the same assumptions on water use and loss were applied. Sixteen cases were examined, eight rectangular ponds and eight rounded. Four slopes were trialled with each shape. They were; 1:2.0, 1:1.5, 1:1.2, and 1: 1.0.

The best results came from the round ponds with the steepest slope, with a saving of 23% in losses, securing 28 more days of water.

Crushing and compaction. This was a study of seepage only and is not reported here.

Integration of methods

The authors also conducted computer calculations on integrating the four methods. Several tables of all the cases examined outline their effectiveness. The best result was shown to be combining all four methods to reduce losses by 31% and to secure irrigation water for another 38 days.

Conclusions

- Continue experimentation with floating covers and compaction method.
- Excavate new ponds to a circular shape and keep internal slopes as steep as possible i.e. greater than 1:2.0.
- Recommend to farmers the cheap and easy option of a duckweed floating cover and compaction of the bed.
- If it were possible it was recommended that a compartmentalised (multi-pond) system be used where the water was pumped from one compartment to another thus decreasing the total water surface exposed to evaporation. This may be possible only where farmers can form a cooperative to use several ponds.

Comments on report

Building ponds with steep slopes may reduce the stability of the pond
Other studies show floating weeds (Azolla) to be relatively ineffective.

Trials in progress (no reports are available yet)

Earth ring tank of about 4 ha water surface area at the property of the Moon family, St George, Queensland

This project is trialling the E-VapCapÔ cover on a large surface area. The project is a cooperative effort between the developers of E-VapCap, the Moon family and the Rural Water Use Efficiency Initiative (RWUEI) in Queensland. RWUEI officer, Sarah Hood, is monitoring progress and data from the trial.

The cover was initially applied in October 2001. Unfortunately, strong winds during the covering phase tore the strips along the rivetted joins and the first trial was postponed. The storage was successfully covered in July 2002 using welded joins for each cover strip.

Placing of cover in progress, July 2002 (courtesy of Evaporation Control Services web site at http://www.evaporationcontrol.com.au/)

Trials on seven small earth ponds at the property of Parker Joint Venture, Emerald, Queensland

John Okello, RWUEI, is monitoring these trials. The project was initiated to investigate seepage problems at the 220 ML storage on the property. Seven comparative storages of 70,000 L each are trialling the following treatments.

1. Deep narrow storage
2. Shallow wide storage
3. Liner and cover
4. Liner with no cover
5. Cover with no liner
6. Compacted base
7. Bentonite seal.

A smaller, uncovered and unlined, storage (4 x 4 x 2 m deep) is used as a control. The storages are monitored once a week.

Project results are not yet available.

Salmon Gums School Dam Evaporation Project, developed by Salmon Gums Landcare Group at Salmon Gums via Esperance, WA, 1998

This project is located at Salmon Gums, about 100 km north of Esperance in Western Australia.

A shade cloth cover has been installed over an earth dam (67 x 45m) on the grounds of the Salmon Gums School.

The shade cloth cover and suspension system were built in 1998 – 99 at a cost of about $20,000. The shade cloth provides 70% shade over the whole dam.

At present the cover is in place. Unfortunately, since it was installed, the region has had above-average rainfalls and the dam storage level is lying above the expected level. Much of the cover is under water as a consequence. No monitoring has yet been possible.

Improving Rural Dam Efficiency in Semi-Arid Western Australia by Matthew Hipsey, Research Associate, University of Western Australia

The major focus of the project is to investigate evaporation reduction from wind-sheltered water bodies. The project has also included the production of a fact sheet entitled ‘Using windbreaks to reduce evaporation from farm dams’ in collaboration with Agriculture WA.

Matthew is also preparing two journal papers for submission. They are:

- **A numerical and field investigation into surface heat fluxes from small wind-sheltered waterbodies in semi-arid Western Australia,** Hipsey, M. and Sivapalan, M. *(To be submitted to Agricultural and Forest Meteorology.)*
- **An evaporation model for small waterbodies downwind of a windbreak or shelterbelt,** Hipsey, M. and Sivapalan, M. **(***To be submitted to Water Resources Research.)*

The fact sheet, in draft mode at present, provides information and guidance to small storage owners for enhancing water efficiency in their dams.

APPENDIX 2.

REPORT FROM THE PROJECT WORKSHOP

[I'd list the various participants and their positions, and include the summary. There is so much repetition in Appendix A, I can't see that we need still more in B.]

Workshop Summary

The program for the day consisted of about 70% presentation and 30% workshop session and managed to cover a lot of information and discussion on most aspects of evaporation control.

Workshop sessions discussed numerous issues, both general and specific, but the major concerns were the practicalities and the cost-benefit measures of control methods.

The overall view from participants was that research into evaporation methods and strategies should continue, with particular emphasis on economic assessment at farm and regional levels.

Specific recommendations included:

- Incorporating evaporation control strategies into a systems-based approach to efficiency
- developing simple tools for measuring evaporation
- aligning incentives (industry, government) with water savings from control methods
- using a geographic spread of trials for a variety of covers
- carrying out further research on raising dams and cell construction to develop design and management options
- employing a 'case study' style of research for trials
- focussing on seepage control and prevention
- continuing research into chemical methods, with an emphasis on incorporating polymers into the monolayer.

REFERENCES

Adcock, P. (n.d.), Microcosm Experiments. In *Reducing Loss from Evaporation: Report to the Cotton Research and Development Corporation*, Sainty & Associates 1995, NSW.

Are there methods to reduce evaporation in ring tanks? (Factsheet). 1995, DPI, Toowoomba, Qld.

Burston, I. A. & Akbarzadeh, A. 1995, *Fresh water storage – evaporation research.* RMIT, Melbourne.

Condie, S. A. & Webster, I. T. 1995, *Evaporation mitigation from on-farm water storages.* CSIRO, Canberra.

Crow, F. R. & Manges, H. L. 1967, Comparison of chemical and non-chemical techniques for suppressing evaporation from small reservoirs. *Transactions of the ASAE*, **10**, pp. 172-174.

Daigo, K. & Phaovattana, V. 1999, Evaporation and percolation control in small farm ponds. *Japan Agricultural Research Quarterly*, **33** (1). (online). http://ss.jircas.affrc.go.jp/engpage/jarq/33-1/daigo/daigo.html
[Accessed 10 April 2002].

Dalton, P. 2001, The efficiency of on-farm storages. *Australian Cottongrower*, **22**(4), pp. 49-51.

Dalton, P., Raine, S. & Foley, J. 1999, Performance of on-farm water storage and distribution systems. In *Research, development and extension in irrigation and water use efficiency: A review for the Rural Water Use Efficiency Initiative,* ed. S.R. Raine. NCEA, Toowoomba, Qld.

Donnett, R. (pers comm). 1999, quoted in *Research, development and extension in irrigation and water use efficiency: A review for the Rural Water Use Efficiency Initiative,* ed. S.R. Raine. NCEA, Toowoomba, Qld, p. 17.

Fietz, T. R. 1970, Engineering aspects of evaporation reduction for small surface water storages. Report No. 33, Water Research Foundation of Australia Limited. NSW?

Jones, F. E. 1992, *Evaporation of water – with emphasis on applications and measurements.* Lewis, Chelsea, Michigan.

Moore, B. 1999, *Salmon Gums community commitment to water supplies.* Dept of Conservation & Land Management, Perth, WA.

Sainty & Associates 1995, *Reducing Loss from Evaporation: Report to the Cotton Research and Development Corporation*, NSW.

Selecting the optimum ring tank height for your farm (Factsheet). 1995, DPI, Toowoomba, Qld.

Turner, A. J. et al 1993, *RUSTIC – A Runoff Storage and Irrigation Model*, Department of Natural Resources and Mines, Qld.

Witting, C. 1998, *Report on the operation to reduce evaporation from the reservoirs of Ouagadougou* (Technical Cooperation Project). GTZ, Ouagadougou, Burkina Faso.

FURTHER READING

Barnes, G. T. 1993, Optimum conditions for evaporation control by monolayers. *Journal of Hydrology,* 145, pp. 165-173.

Brown, J. A. H. 1988, The potential for reducing open water evaporation losses: a review. Snowy Mountains Engineering Corporation, Cooma, NSW.

Cooley, K. R. 1983, Evaporation reduction: Summary of long-term tank studies. *Journal of Irrigation & Drainage,* **109**, pp. 89-98.

Fitzgerald, L. & Vines, R. 1963, Retardation of evaporation by monolayers: Practical aspects of the treatment of large storages. *Australian Journal of Applied Science*, **14**, pp. 340-346.

Karpiscak, M. M., Foster K.E., Rawles L. E. 1984, Water harvesting and evaporation suppression. *Arid Land Newsletter*, **21**, pp.10-17.

Sanderson, J. 1999, Students put evaporation in the spotlight. *Australian Cottongrower*, **20**(6), p. 63.

Smith, A. 1995, *Reduction of evaporation in open water storages.* University of Qld, Gatton.

Vines, R. 1959, Reducing evaporation with cetyl alcohol films: A new method of treating large water storages. CSIRO, Melbourne.