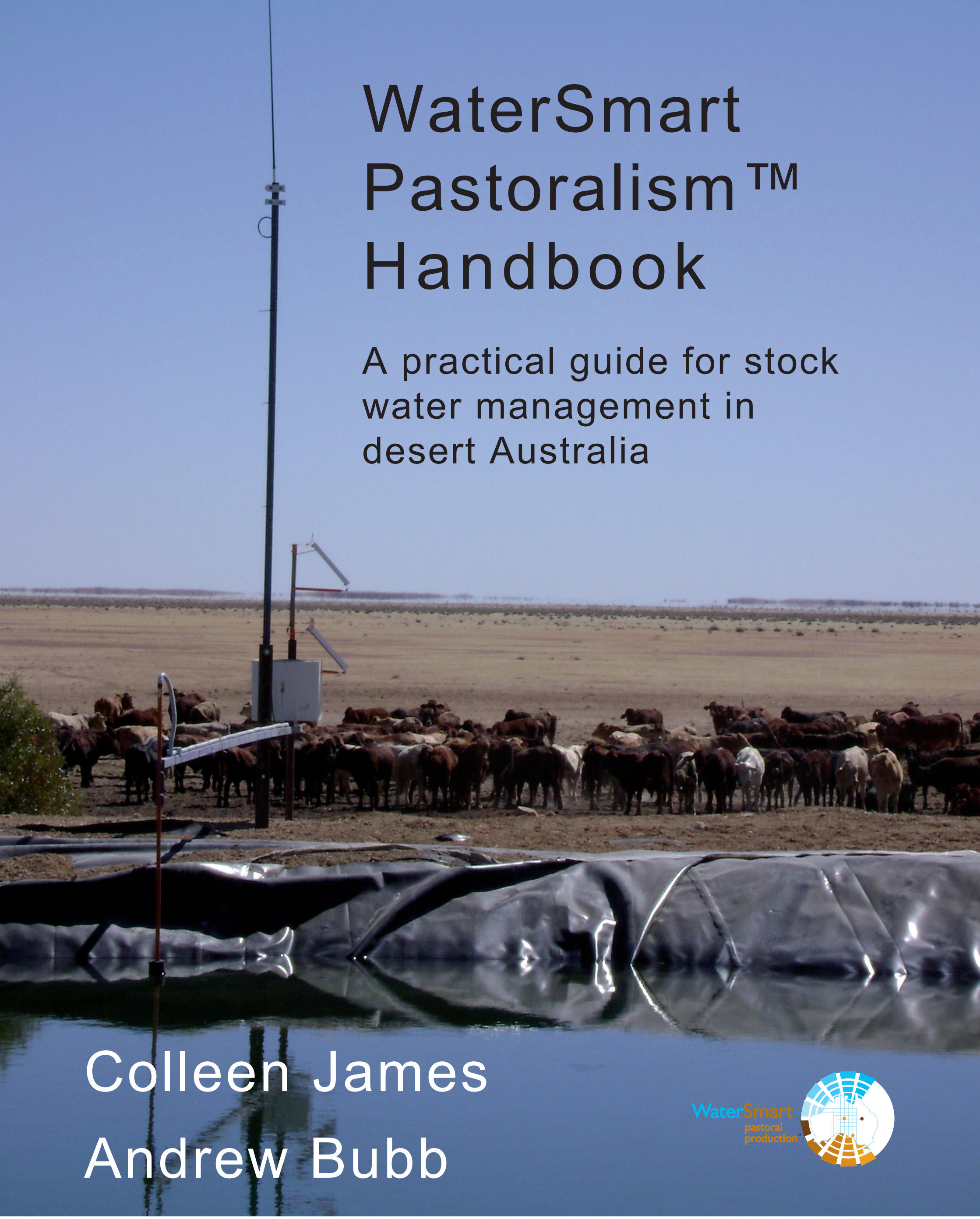

WaterSmart Pastoralism™ Handbook

A practical guide for stock water management in desert Australia

Colleen James

Andrew Bubb

WaterSmart pastoral production™

Australian Government
Department of Agriculture, Fisheries and Forestry

LANDCARE

CRC AUSTRALIA

DESERT KNOWLEDGE CRC

Contributing author information

Colleen James
Desert Channels Qld Inc
P O Box 601 Longreach Qld 4730
Ph: 07 4652 7826
mob: 0428 580 998
email: colleen.james@dcq.org.au

Andrew Bubb
Desert Knowledge CRC and Department of Primary Industry, Fisheries and Mines
P O Box 3971 Alice Springs, NT 0871
ph: 08 8951 8139
mob: 0438 848 023
email: andrew.bubb@nt.gov.au

Image contributors to this handbook can be contacted at these email addresses:
Adrian James: adrian.james@nt.gov.au
Deb Allen: allen.deborah2@saugov.sa.gov.au
Deb Desreaux: monkira@napco.com.au
Patrick Francis: francis@ozonline.com.au

The Desert Knowledge Cooperative Research Centre is an unincorporated joint venture with 28 partners whose mission is to develop and disseminate an understanding of sustainable living in remote desert environments, deliver enduring regional economies and livelihoods based on Desert Knowledge, and create the networks to market this knowledge in other desert lands.

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For additional information please contact
Desert Knowledge CRC
Publications Officer
PO Box 3971
Alice Springs NT 0871
Australia
Telephone +61 8 8959 6000 Fax +61 8 8959 6048
www.desertknowledgecrc.com.au

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WaterSmart Pastoralism™ project partners

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Partners are Desert Channels Queensland Inc., The South Australian Arid Lands Natural Resource Management Board, The Northern Territory Department of Primary Industry, Fisheries and Mines, and the Great Artesian Basin Coordinating Committee.

Industry partners are The North Australian Pastoral Company, Grundfos, Dinocrete Troughs, Observant, Aqua Pumping & Solar, Bushmans, Mono, E P Windmills & Pumps, Stockman Telemetry, Iplex Pipelines, Stokcrete Troughs, Blackmore's Power and Water, Agfloat, Darling Downs Tarpaulins and Harrington Electrics (uSee).

Further information on the project can be found at:
http://www.desertknowledgecrc.com.au/watersmart

Project products available

The following WaterSmart Pastoralism™ products are available through the DKCRC or on the WaterSmart Pastoralism™ Website at: www.desertknowledgecrc.com.au/watersmart

- WaterSmart Pastoralism™ Flyer
- Report providing an overview of WaterSmart Pastoralism™ Information days that illustrates what was achieved
- WaterSmart Pastoralism™ Case Study report: Mount Ive Station
- WaterSmart Pastoralism™ Case Study report: Monkira Station
- WaterSmart Pastoralism™ Case Study report: De Rose Hill Station
- WaterSmart Pastoralism™ Case Study report: Napperby Station
- WaterSmart Pastoralism™ Literature Review: Loss of storage water through evaporation (Craig 2008)
- WaterSmart Pastoralism™ Literature Review: Water reticulation equipment for rangeland pastoral application (Williams & Pezzaniti 2008)
- WaterSmart Pastoralism™ Literature Review: Groundwater salinity, desalination equipment and practices applicable to the rangelands pastoral industry (de Vries 2008a)
- WaterSmart Pastoralism™ Literature Review: Impact of artificial water points on rangeland biodiversity (Howes & McAlpine 2008)
- WaterSmart Pastoralism™ Literature Review: Telemetry systems for remote water monitoring control equipment (de Vries 2008b)

Intention of handbook

Water availability and management has always been a key issue for pastoralism in the arid and semi-arid regions. Recent drought conditions throughout Australia have highlighted the need to seek new and innovative ways to plan for future challenges in water supply management.

This handbook aims to be an initial source of information for pastoralists. It details important considerations for stock water delivery and outlines technologies which can reduce the cost of water delivery and storage. The handbook details siting a new bore, equipping a bore, grazing impacts of a bore, animal water requirements, water storage and water point monitoring.

1. Siting a new bore

1.1 How

How and where a bore is placed is influenced by many factors, including type of country, size of property, etc. Where a bore is located will influence the management options for the property, so important things to consider are:

- What information is already available on groundwater in the area?
- What type of pasture is present in terms of quality and quantity?
- What is the distance to existing water points?

1.2. Capacity of bore

The capacity of a bore (how much water it can produce) will determine if and how it can be used for stock watering purposes. The volume of water that can be produced is termed 'flow'.

The water demands for each watering point and for the system as a whole must be accurately estimated before determining the size of the pipe and head or pressure needed to deliver water. The system needs to be designed with the ability to meet the absolute maximum demand predicted with maximum stock numbers, hot summer conditions and dry feed.

Table 1: Stock water consumption

Stock type	Consumption per day (L)
Sheep	
Weaners	2 – 4
Adult dry sheep	2 – 6
Grassland	4 – 12
Saltbush	4 – 10
Lactating ewe	4 – 10
Cattle	
Grassland	40 – 100
Saltbush	70 – 140
Young stock	25 – 50
Dry stock	35 – 80
Horses	
Working	40 – 50

Source: Adapted from PIRSA 2008

1.3. Water quality

Water quality can have a big impact on the animals that drink it and can have major effects on overall station production. The factors to be considered when assessing water for stock use are:

- physical causes (materials that are physically suspended in the water, i.e. silts)
- biological (living organisms or their remains)
- bacteriological
- chemical (i.e. salts)

Some of the common problems that effect water quality are hardness, algae, acidity, iron, bacterial growth and salinity. Laboratory testing of water samples can determine its quality and subsequent suitability for stock use.

Water with high salt concentrations increases the amount individual animals drink and also reduces their food intake; this can have negative impacts on their production. Stock that graze on saltbush or salty feeds are less tolerant of saline water, whereas stock grazing on green feed can tolerate higher salt concentrations than the same stock on dry feed.

To keep water salinity levels as low as possible, clean tanks before summer, and scrub and flush troughs frequently. Also, check salinity levels over the summer months.

Table 2: Salinity tolerances of livestock

Salinity tolerances of livestock in milligrams per litre (mg/L) of total soluble salts			
Animal	Maximum concentration for healthy growth	Maximum concentration to maintain condition	Maximum concentration tolerated
Sheep	6000	13000	*
Beef cattle	4000	5000	10000
Dairy cattle	3000	4000	6000
Horses	4000	6000	7000

* Maximum level depends on type of feed available – for example saltbush vs greenfeed.

Source: PIRSA 2008

1.4. Water point location

In extensive pastoral systems, animals concentrate grazing around watering points. Sheep concentrate their grazing within 2.5 km of the watering point and cattle within 5 km. When animals are required to walk further than this, they often expend more energy than is gained from the forage consumed.

In large paddocks the distance of pasture from water can limit carrying capacity. Strategic location of water points will use available feed while reducing concentrated grazing pressure. If stock require more water due to lactation, salinity or dry feed, they may need to drink more than once a day. This will also reduce their forage radius.

Optimal distance between water points is 5–8 km for sheep, and up to 10 km for cattle. The expense of water development in poorly watered areas could be justified by improved animal performance and increased carrying capacity.

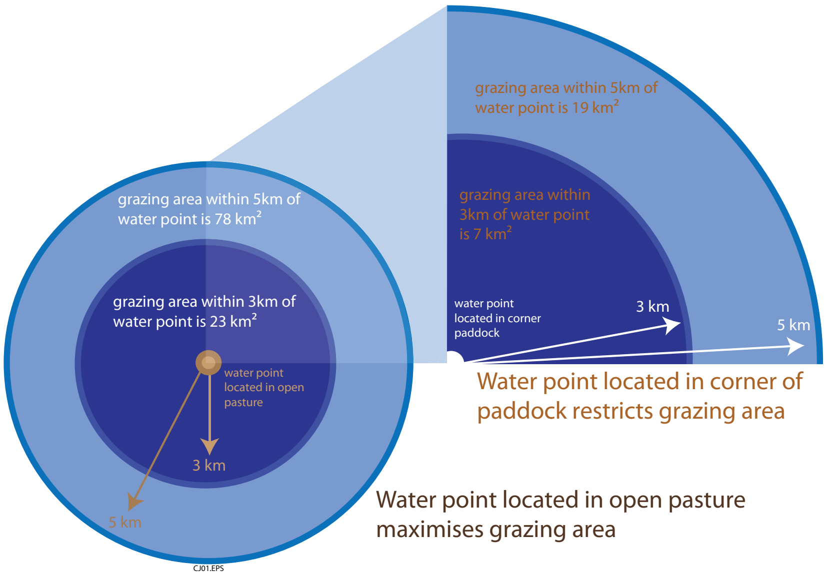

Figure 1: Benefits of strategic water point location

Source: Colleen James

2. Equipping a bore

The primary source of water for rangeland reticulation of water is from groundwater bores. Depending on the location of the bore, either subartesian or artesian bores may be developed. Artesian bores may experience high water temperature and high water pressure, and require special infrastructure. Two components where problems may occur are:

- casing
- well head.

Casing is required to prevent bore collapse and to act as a safe housing for any pump installed in the bore. Casing materials include:

- steel
- PVC
- thermoplastic (ABS)
- fibreglass reinforced plastic (FRP)

Choice of material will depend on strength requirements, corrosion resistance, ease of handling, cost considerations, type of formation, method of drilling, bore design, construction techniques, and license or permit requirements.

Table 3: Bore casing material properties

Material	Specific gravity	Tensile strength (MPa)	Tensile modulus (105 kPa)	Impact strength (relative to PVC)	Upper temp. limits (°C)
Steel	7.85	350	2068	v.high	800–1000
Stainless Steel	8.00	517	2000	v.high	800–1000
PVC	1.40	55	28	x1	40
ABS	1.04	31	20	x6	50
FRP	1.89	115	158	x20	80

Source: Williams 2008

A **well head** is used on subartesian wells to protect the underlying aquifer from contamination by surface water and allows flow to be controlled from artesian wells. Artesian wells need to be made strong enough to handle the pressure and flow, without interfering with the pump or reticulation system.

Artesian bore water can be corrosive and requires the use of quality well head and valves that are rated to handle the high temperature and pressure. Typically, stainless steel is used, although advances in epoxy coatings and electroplating have allowed materials such as cast iron and bronze to be considered. For temperatures exceeding 50^{o}C or flow exceeding 15 litres per second, a main isolating valve of equivalent diameter to the inner casing should be incorporated in the headworks between the bore casing and the distribution outlets (Williams 2008).

2.1 Pumps

Pumps may be required to draw water from the ground or deliver water to holding storages and drinking troughs. In areas where artesian pressure is sufficient, pumps may not be required. The most common pumps available that will have application for pastoral use include:

- centrifugal: moves water by using a motor to rotate a propeller, which creates a vacuum allowing atmospheric pressure to push the water
- jet: generally surface mounted centrifugal pumps, fitted with either deep well or shallow well injector kits to enhance suction lift
- submersible borehole pumps: usually electrically driven, they consist of submersible multi-stage centrifugal or mixed flow units, with the motor located directly under the pump
- helical rotor pumps: a positive displacement type pump, where the water is moved up the rotor by being confined between the rotor and stator (the part of the fan’s motor that is stationary).
- piston pumps: work by drawing water into a cylinder on the upstroke and expelling it on return (a windmill is a common application).

The distance and height water can be pumped is determined by the ‘Total Dynamic Head’ (TDH). Total Head is the height water needs to be pumped to, measured from the water level at the source to the highest delivery point. TDH takes into account the friction loss created by the movement of water through the delivery pipeline.

TDH = Static lift + Static height + Friction loss

Static lift: the height in metres from the low water level to the ground level where the pump's power source will be mounted.

Static height: the height in metres from where the power source will be mounted to the highest point along the delivery pipeline.

Friction loss: the amount of pressure required to 'force' liquid through pipe and fittings.

Source: WD Moore 2008

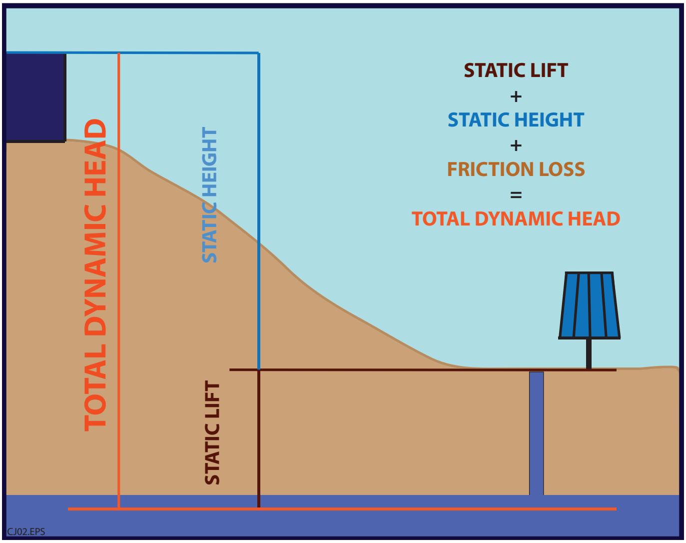

Figure 2: Total dynamic head

Source: adapted from WD Moore 2008

Pressure: the comprehensive stress within water, defined by units of kilo pascals (kPa).

Pressure (kPa) = Height (m) x Gravity (m/s²)

Specific gravity: is the weight of a liquid at approximately 20°C in comparison to water (SG=1)

Flow rate: the volume of water passing a given point in a given time. Cubic metres per second (m³/s) is the basic unit for measuring flow rate.

Links to friction loss and pressure calculators are available on the WaterSmart Pastoralism™ website: www.desertknowledgecrc.com.au/watersmart

Pumps can be selected based on the pressure and volume of water required. These operating conditions will also dictate the power required to drive the pump. The main forms of pump power available include:

- electric
- solar
- wind
- diesel/petrol

2.2. Electric

Electric power from the national electricity grid is an ideal power source for running pumps and is usually the cheapest. Pumps can be easily set to start automatically in many different conditions. Where troughs are fed via gravity from holding tanks, tanks can be filled in off-peak times, reducing pumping costs. Where possible, it is usually cheaper to locate pumps near existing power sources rather than running power to a new pump location. However, where distances are large other power sources may be more appropriate. Pumps that run on electric power may be subject to power failures. Electric motor speeds are fixed, which will influence the method of connecting the pump to the motor.

2.3. Solar

Solar powered pump systems may be more expensive to install, but are generally reliable and require little maintenance. They perform best in summer and are well suited to remote site pumping. Solar powered submersible pumps are becoming more popular and can replace less reliable windmills at stock drinking points for only a small increase in cost (typical systems, including solar panels, are in the order of $10 000). Backup supply, such as a diesel generator, may be also be required.

Figure 3: Solar pump used to push water up a hill

Source: Image courtesy of Adrian James

2.4 Windmills

Installing wind powered pumps can be expensive and they may require regular maintenance. There may also be periods of low wind during particular times of the year. Backup power supplies may be required. The power that can be derived from traditional windmill pumps is determined by the fan diameter. Typically, windmills need to be placed in areas where turbulence is minimal, and they usually need to be located away from trees and up on high towers, which may be a potential work hazard during maintenance. Traditional windmill-driven pumps are increasingly being replaced with solar powered submersible pumps

2.5. Diesel/Petrol

Petrol engine–driven pumps are mostly applicable for low use or mobile pumping units. Diesel engines are more appropriate for permanent and frequent use installations. Costs, including fuel, maintenance and ease of automation, need to be considered when choosing between a renewable energy power supply and petrol/diesel engines. A diesel or petrol engine may be appropriate as a backup supply.

3. Water delivery

Due to improvements in plastic pipe technologies and in methods of dealing with high temperature and high pressure water, pastoralists now have more reticulation options available to them than only using open channel delivery of water. By piping water, evaporation and seepage losses are eliminated, and unnecessary wastage of water through free flowing bores is also prevented. This results in:

- higher quality water for stock
- reduction in land degradation and erosion from water flowing through open channels
- a more flexible and reliable supply of water to stock
- reduced numbers of pests and vermin that are attracted to water in open channels.

3.1 Pipes

The introduction of poly pipe has transformed the way landholders manage their country. Early systems used class 'B' agricultural pipe, which provided a cheaper alternative to class 'A' but will not withstand the pressure required to move water long distances. New poly pipe provides a much wider range of standards, diameters, and properties to meet particular needs, but the improvements are also reflected in the price. Making the right choices about costs and benefits is difficult, but it can be made easier by having a clear understanding of the relationship between pressure, friction and elevation.

Some general notes to consider:

- Friction loss is the resistance to water flow and is expressed as height in metres per kilometre of pipe.
- For a given flow rate, a LARGER diameter pipe will have a lower velocity and pipe friction loss.
- For a given flow rate, a SMALLER diameter pipe will have a higher velocity and higher pipe friction loss.
- Higher velocity in a larger diameter pipe produces less pipe friction loss when compared with the same velocity in a smaller pipe.
- Higher pipe friction losses require larger pumps or can reduce the flows at outlets. They can also result in higher power costs to run pumps.

4. Water storage

The type of water storage used on a station is determined by how much water needs to be stored at a location and if the area is suitable for building a dam. Rates of evaporation and seepage for an area can also influence whether a dam will be a suitable option.

4.1. Dams

Dams have long been used for water storage across pastoral stations and in the past have been the only practical option for storing large volumes of water. The amount of water that is collected in a dam will depend on the amount of runoff generated by the catchment and how efficiently this is channelled into the dam.

When creating a dam there are some points to consider:

- General topography
- Prevailing winds
- Existing water points
- Catchment
- Soil
- Design shape
- Seepage
- Stock consumption
- Evaporation

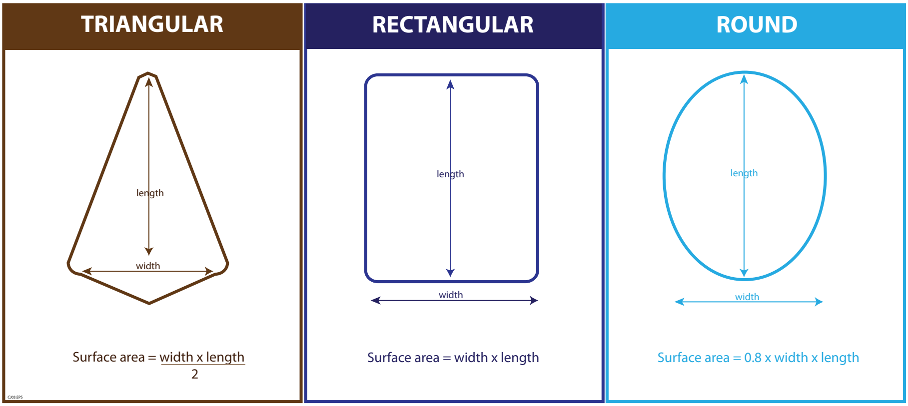

Figure 4: Surface area measurements

Source: Adapted from NSW Natural Resources 2008

The volume of a dam in cubic metres can be calculated using the following formula:

Volume (m³) = 0.4 x Surface area x depth

1 Megalitre (ML) = 1000 cubic metres (m³)

0.4 is a conversion factor that takes into account the slope of the sides of a dam.

Rectangular or square dams: **Surface area = length x width**

Triangular dams: **Surface area = width x length / 2**

Circular dams: **Surface area = 0.8 x width x length**

Depth: measure depth of water to the top of sediment in the bottom of dam.

Unlike a covered water storage unit, dams can attract feral animals and weed infestations.

4.2. Tanks

The use of tanks in the pastoral industry has been relatively low in the past due to the cost and size limits. New developments have reduced the cost and increased the size of available tanks; benefits of tanks include no seepage and no evaporation (when a cover is installed).

TANK VOLUME (litres) =
(3.14 x RADIUS x RADIUS (m) x WATER DEPTH (m))
x 1000

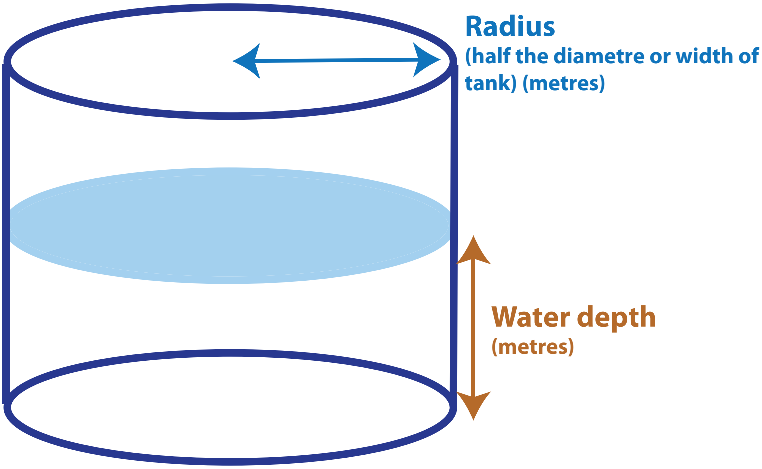

Figure 5: Calculating tank volume

Source: Adapted from NTG 2008

Example (from NSW Natural Resources 2008)

Tank radius = 2 metres

Tank depth = 3 metres

Tank volume = (3.14 x 2 m x 2 m x 3 m) x 1000

= (3.14 x 4 m^2 x 3 m) x 1000

= (3.14 x 12 m^2) x 1000

= 37.68 m^3 x 1000

= 37,680 litres

Steel tanks can be purchased in kit form allowing for easy transport to the location of construction. In the past, steel tanks have been subject to rust, although widespread use of plastic liners has negated this risk. Steel tanks can hold large volumes and can be quite economical.

Concrete tanks have a longer life expectancy against corrosion and damage than steel and plastic tanks. Concrete tanks can be difficult to construct in rural areas where delivery of materials and long construction times can make them uneconomical to some pastoral operations.

Polyethylene tanks have become increasingly popular due to lower cost and corrosion resistance. They are generally light and can be easily relocated. Sizes range from 26 000 to 47 000 litres. They must be installed correctly to prevent splitting or blowing away in the event of a broken pipe.

Fibreglass tanks resist corrosion and are generally not affected by chemicals. Fibreglass tanks are usually more expensive than polyethylene tanks, and as they are brittle they can crack or leak.

4.3. Evaporation

The rate of evaporation over most of Australia's land mass is in excess of 2 m per year, while the mean rainfall is less than 500 mm per year. It has been estimated that up to 95% of the rain which falls in Australia is re-evaporated and does not contribute to runoff (Craig 2008).

Water is commonly harvested as run-off and stored in small storages and dams, but it is estimated that up to half of this may be lost due to evaporation.

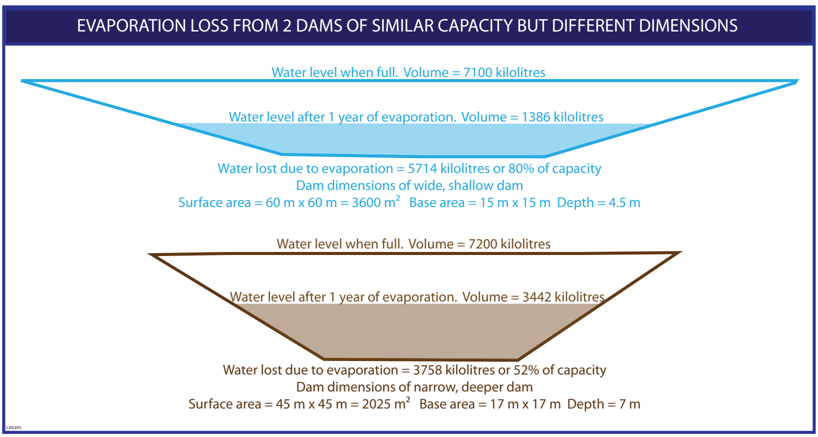

Figure 6: Evaporation from dams

Source: Adapted from image by Deb Allen of Rural Solutions, SA

Water losses from dams can be managed by increasing their depth. Windbreaks can also be used in certain circumstances, but their overall effect in reducing evaporation is likely to be small, as solar radiation rather than wind is the key driver in evaporation.

Installing an evaporation control device can save up to 90% of evaporation losses on farm dams.

Evaporation control devices available for the pastoral industry:

- continuous plastic sheets: floating covers act as an impermeable barrier that floats on the water surface to reduce evaporation.
- suspended covers: shade structures are suspended above the surface of the water to reduce solar radiation, wind speed and trap humid air.
- modular covers: comprise multiple individual units that float on the surface of the water. Performance will depend on how tightly the modules are packed together.
- chemical covers: form a thin oily layer on water surface.

Figure 7: Example of continuous plastic sheet evaporation control device

Source: Image courtesy of Deb Desreaux

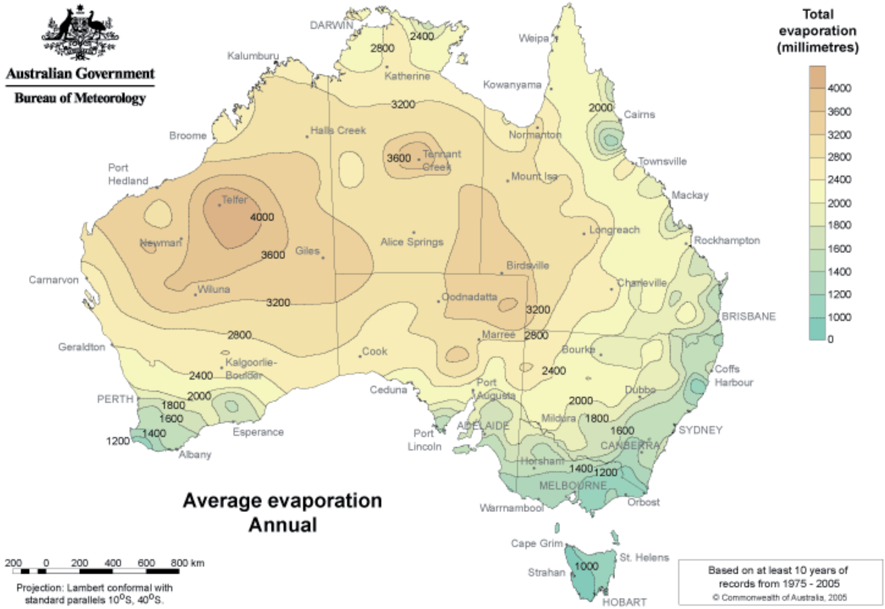

Figure 8: Annual average evaporation rates

Source: http://www.bom.gov.au/cgi-bin/climate/cgi_bin_scripts/evaporation.cgi

4.4 Seepage

The loss of water through the bed and sides of a dam is seepage. In some situations seepage losses can be as high as those from evaporation.

Water losses from dams can be managed by installing a good quality liner to prevent seepage. Installing a seepage control liner can reduce seepage by 100%.

There are many types and thicknesses of liners available for the pastoral industry. Most are UV stabilised and come with guarantees of 5–20 years.

It is recommended that any lined dams be fenced off from stock, wildlife and feral animals.

Figure 9: Example of dam liner used to control seepage losses
Source: Image courtesy of Colleen James

5. Costs of providing water

The cost of providing water to stock represents a high percentage of production costs. This can be broken down into three components:

- Installation
- Operating
- Monitoring

Decisions around what and where a watering point is installed can have large impacts on the ongoing operating and monitoring costs. The operating costs of equipment will be largely determined by what is initially installed. Ongoing monitoring costs will be determined by how the watering point is used and what level of monitoring the manager requires. The two basic options for monitoring watering points are physical inspections or remote monitoring.

5.1. Physical inspections

Physical inspections can be conducted by vehicle or aircraft and give the opportunity to see if water is present, if there is anything wrong at the watering point, and also to conduct basic maintenance of the equipment. How often this occurs will be influenced by a number of factors which will determine the overall cost.

The cost of physical inspections of water points can be calculated by collecting the following data:

- Kilometres travelled
- Vehicle costs
- Labour costs
- Fuel costs

These costs can be recorded using water run log books, and then the data can be transferred to a spreadsheet to calculate actual water management costs.

To estimate water management costs, water run log books (see Figure 10) can be kept in station vehicles and completed every time a water run is carried out.

To calculate labour costs, determine a standard figure for the enterprise based on a standard wage level.

To calculate vehicle costs, determine a kilometre rate for vehicles including fuel costs, wear and tear, etc.

To calculate fuel costs (for non-renewable energy generators) estimate an average cost per litre.

▼ This section is completed for each water run

NAME			◀ Put your name here
DATE			◀ Today's date
TIME START			◀ Time water run commenced
Water point name*	×		◀ mark if water point visited
Water point name*	15		◀ Number denotes 15 litres of fuel added when water point visited
Water point name*			◀ Leave blank if water point not visited
Water point name*			
Water point name*			
Water point name*			
Water point name*			
Water point name*			
Water point name*			
Water point name*			
Water point name*			* put individual water point name
KM TRAVELLED			◀ Total kilometres travelled
TIME FINISH			◀ Time when water run completed
WEATHER	SUNNY	CLOUDY	◀ Mark applicable weather
	HOT	COLD	
	RAIN	MILD	
TEMPERATURE	ºC		◀ Temperature in degrees Celsius
REPAIRS/ MAINTENANCE OF EQUIPMENT i.e. service motor, clean solar panel, change belt on motor, clean trough, etc.			◀ Write in any maintenance or repairs to equipment when visiting water points

Figure 10: Water run log sheet

Source: Colleen James

5.2. Remote monitoring

Remotely monitoring watering points using telemetry systems can allow for increased management of watering points while saving money. Telemetry is a technology that allows data to be gathered and recorded without having to be at the location. Information is instead transmitted from measuring devices (such as flow meters) using radio or cellular phone technology.

Figure 11: UHF unit in vehicle is used to remotely check water levels in tanks

Source: Image courtesy of Patrick Francis

Telemetry systems are currently capable of:

- Switching pumps or irrigation systems on and off
- Starting generators and monitoring pressure, temperature, voltage, etc.
- Monitoring dam or tank levels
- Recording rainfall
- Real time monitoring of security devices with an instant alarm if break-in occurs
- Monitoring and controlling operation of electric fences
- Remote reading of instruments such as weather and water flow gauges
- Monitoring the status of gates at remote locations
- Medicating water
- GPS vehicle tracking
- Remotely accessing digital cameras or a closed circuit television camera

Telemetry can be used:

- To reduce travel costs
- To save time and labour
- To reduce wear and tear on vehicles
- To manage infrastructure that is hard to get to (due to, for example, wet season inaccessibility)
- To create more security for remote infrastructure

The process of enquiring about a telemetry system involves:

- Deciding which water points are to be monitored (either now or in the future)
- Collecting GPS coordinates for each water point (taking information from maps or Google is not suitable)
- Prioritising the order of installation
- Contacting telemetry provider with this information

Example of costs and benefits of a telemetry system

Station Z has 15 water points.

Distance driven each bore run: 480 km
Average bore runs per year: 130 (average 2.5 per week)

Average bore run time: 8 hours

Vehicle running costs: $2.50/km (fuel, tyres, maintenance, depreciation, etc.)

Annual cost of bore runs is:
(Bore run distance) x (No. bore runs) x (Cost per km)

480 x 130 x 2.5 = $156 000

Station Z manager wants to invest in telemetry to reduce costs.

1 x Base station and software	$ 1 500
15 x Telemetry units with water level sensors	$30 000
3 x Remote start/stop units for diesel pumps	$ 3 500
1 x Repeater unit to get signal over hills	$ 2 000
Total cost	**$37 000**

Manager thinks this will result in 1 less bore run each week.
52 less runs each year will save:

480 x 52 x 2.5 = $62 400 each year.

The investment will pay for itself after (37 000/62 400 = 0.59) 0.59 years, or 7 months.

It will also save 8 hours of labour each week, totalling (8 x 52 = 416) 416 hours of labour each year.

The manager thinks the telemetry investment will last at least 10 years, so the investment should save Station Z at least (10 x 62 400 – 37 000) $587 000.

Bore run vehicle produces 330 grams of CO_2 per kilometre. Saving (52 x 480 = 24 960) 24 960 km each year will save (24 960 X 0.33 = 8236) 8236 kg carbon dioxide emissions each year.

A telemetry cost recovery calculator (James 2007) can be used to work out the rough costs and savings of installing a telemetry network on your property.

The calculator is available on the WaterSmart Pastoralism™ project website at http://www.desertknowledgecrc.com.au/research/downloads/Telemetry-Cost-Recovery-Calculator.xls.

Figure 12: Examples of telemetry systems used to remotely monitor water points

Sources: Adrian James and Patrick Francis

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Table 3: Useful conversions and measurements

Symbol	When you know	Multiply by	To find	Symbol
LENGTH				
in	inches	25.4	millimetres	mm
mm	millimetres	0.03937	inches	in
ft	feet	0.3048	metres	m
m	metres	3.281	feet	ft
mi	miles	1.609	kilometres	km
km	kilometres	0.6214	miles	mi
AREA				
in^2	Square inches	645.2	Square millimetres	mm^2
mm^2	Square millimetres	0.00155	Square inches	in^2
ft^2	Square feet	0.0929	Square metres	m^2
m^2	Square metres	10.764	Square feet	ft^2
yd^2	Square yard	0.8631	Square metres	m^2
m^2	Square metres	1.196	Square yard	yd^2
ac	acres	0.4047	hectares	ha
ha	hectares	2.471	acres	ac
mi^2	Square miles	2.59	Square kilometres	km^2
km^2	Square kilometres	0.3861	Square miles	mi^2
VOLUME				
fl oz	Fluid ounces	29.57	millilitres	mL
mL	millilitres	0.0338	Fluid ounces	fl oz
Gal (imp)	Imperial gallons	4.542	litres	L
l	litres	0.22	Imperial gallons	gal (imp)
gal (imp)	Imperial gallons	1.2	US gallons	gal (US)
gal (US)	US gallons	0.833	Imperial gallons	gal (imp)
ft^3	Cubic feet	0.02832	Cubic metres	m^3
m^3	Cubic metres	35.314	Cubic feet	ft^3
yd^3	Cubic yards	0.7646	Cubic metres	m^3
m^3	Cubic metres	1.3079	Cubic yards	yd^3
MASS				
oz	ounces	28.35	grams	gm
gm	grams	0.03527	ounces	oz
lb	pounds	0.4536	kilograms	kg
kg	kilograms	2.204	pounds	lb
kg	kilograms	0.001	tonnes	tonnes
tonnes	tonnes	1000	kilograms	kg
PRESSURE				
psi	Pound per square inch	6.895	kilopascals	kPa
kPa	kilopascals	0.145	Pounds per square inch	psi
psi	Pounds per square inch	0.704	Metres of water	m
m	Metres of water	1.42	Pounds per square inch	psi
kPa	kilopascals	0.102	Metres of water	m
m	Metres of water	9.797	kilopascals	kPa
FLOW				

Symbol	When you know	Multiply by	To find	Symbol
gal/(imp)/ min	Imperial gallons per minute	0.076	Litres per second	L/s
L/s	Litres per second	13.2	Imperial gallons per minute	gal/(imp)/min
gal/hr	Gallons per hour	0.00126	Litres per second	L/s
L/s	Litres per second	792	Gallons per hour	gal/hr
Gal/day	Gallons per day	0.0000526	Litres per secondLitres per second	L/s
L/s	Litres per second	19008.4	Gallons per hour	gal/day
L/s	Litres per second	0.001	Cubic metres per second	M³/s
M³/s	Cubic metres per second	1000	Litres per second	L/s
L/s	Litres per second	0.0864	Mega litres per day	ML/day
SALINITY				
EC	Electrical conductivity	0.64	Milligrams per litre (parts per million)	mg/l (ppm)
mg/l (ppm)	Milligrams per litre (parts per million)	1.67	Electrical conductivity	EC
grain/gal	Grains per gallon	14.25	Milligrams per litre (parts per million)	mg/l (ppm)
mg/l (ppm)	Milligrams per litre (parts per million)	0.07016	Grains per gallon	grain/gal
TEMPERATURE				
ºF	Fahrenheit	(F-32)/1.8	Celsius	ºC
ºC	Celsius	1.8xC+32	Fahrenheit	ºF
POWER				
HP	horsepower	745.7	watts	W
W	watts	0.00134	horsepower	HP
HEAT & ENERGY				
kW/hour	Kilowatt hour	3.6	mega joule	MJ
MJ	mega joule	0.2777	Kilowatt hour	kW/hour
kW/hour	Kilowatt hour	3412	British thermal unit per hour	BTU/hour
BTU/hour	British thermal unit per hour	0.000293	Kilowatt hour	kW/hour

Source: Williams 2007

WaterSmart Pastoral Production™ participants

- Government of South Australia – South Australian Arid Lands Natural Resources Management Board
- dinocrete pty ltd – hughenden 07 4741 5007
- desert channels Queensland
- NAP
- aqua pumping & solar – quality water products
- blackmore's power and water
- uSee
- E P Windmills & Pumps – Servicing the Gawler Ranges
- DDT Liners – An associate company of Darling Downs Tarpaulins
- Observant
- AgFloat
- Mono – National Oilwell Varco
- Stokcrete
- Bushmans
- Stockman Telemetry Systems
- Great Artesian Basin Coordinating Committee
- Northern Territory Government – Department of Primary Industry, Fisheries and Mines
- Grundfos

DKCRC Partners

- AIATSIS
- Australian Government Department of Families, Community Services and Indigenous Affairs
- ANU – The Australian National University
- Centre for Remote Health
- Charles Darwin University
- CSIRO
- Curtin University of Technology
- desert peoples centre
- Government of South Australia – Department of Water, Land and Biodiversity Conservation
- Government of Western Australia
- Griffith University
- JCU – James Cook University
- Murdoch University
- Northern Territory Government
- Newmont – The Gold Company
- NSW Department of Primary Industries
- Southern Cross University
- Tangentyere Council
- The University of Adelaide
- University of South Australia
- The University of Queensland
- The University of Western Australia
- University of Wollongong
- Waltja Tjutangku Palyapayi