FEEDLOT DESIGN AND CONSTRUCTION

16. Shade

AUTHORS: Mairead Luttrell and Orla Keane

Shade structures – longitudinal rows

Introduction

Cattle have a remarkable ability to cope with environmental stress but a combination of high temperature and humidity, with high levels of solar radiation and minimal air movement, can exceed the animal's ability to dissipate body heat.

Excessive heat load (EHL) in feedlot cattle during summer months can result in significant production losses, animal welfare problems and under extreme conditions, the death of cattle. Shade structures are one strategy that has been used to reduce the impact of heat wave conditions on cattle.

Shade is a thermal radiation shield that reduces heat load on the animal. Shade does not readily affect air temperature but can reduce exposure to solar radiation and also enhance minimal air movement for cooling. Major design considerations for shade structures are orientation, space, height and shading material.

Shade structures – central square

Design objectives

The design objectives for a shade structure are to

- provide adequate shade for each animal in the pen (square metres per animal)
- provide a structurally sound and durable structure
- minimise obstructions when cleaning the pen
- maximise air flow under the shade
- maximise pen drying under the shade
- design a structure that suits the geographical location.

Mandatory requirements

The Australian Animal Welfare Standards and Guidelines for Cattle (DAFF, 2013) states

S10.4 A person in charge must do a risk assessment each year for the heat load risk at the feedlot and implement appropriate actions to manage ongoing heat load risk.

S10.5 A person in charge must have a documented Excessive Heat Load Action Plan and must implement appropriate actions in the event of a heat load emergency.

Shade structures – separate panels

Technical requirements

Any shade should be designed and constructed in accordance with the Australian Standards for Wind Loads – AS 1170.2.

Shade area per animal

Cattle will use shade when it is available. Lot feeders who have installed shade for cattle have provided between 1.6 m^2 and 6 m^2 of shade per head. Shade structures suitable for Australian conditions should ideally provide more than 2 m^2 of shaded pen floor space per animal, recognising that it is beneficial to spread cattle during excessive heat load events. Overcrowding cattle under shade during normal summer conditions will limit any potential production benefit.

Shade options

Each feedlot has its own distinctive location, topography, climatic conditions, cattle breeds, feeding categories, customers and capital capability. The choice of shade structure and materials for the feedlot will depend on a number of these factors.

Types of shade structure

Three types of shade structure can be used in feedlots

- longitudinal rows – long thin shade structures that stretch over many different pens
- centre squares – large tent-like structures in the centre of the pen
- separate panels – structures connected in a grid-like pattern and providing alternating shade spots through each pen.

Insufficient shade area can result in cattle bunching and over-heating

Spacing in shade structure

Both longitudinal row and centre squares shade structures may have spaces or gaps throughout the structure to encourage the pen floor to dry during the day and to increase air flow. Sunlight reaching different parts of the pen at different times of the day should prevent a buildup of wet manure.

With longitudinal rows, these spaces may run along or across the rows. Spaces within the structure encourage cattle to stand in groups and to move across the pen following the shade areas. This decreases site specific wet spots and also promotes airflow.

A disadvantage with centre square structures is that a portion of the pen will always be in the shade and hence will remain wet.

The area of shade provided by the shade structures and the frequency of the spacing in between is important as narrow strips of shade with a high frequency of spacing can result in the cattle bunching and over-heating.

Orientation of longitudinal row – shade area at midday (above) and during the afternoon (below)

Orientation

Orientation of the structure will determine the pattern of the shade underneath and also the amount of shade available to the cattle. The best orientation may depend on the overall design of the feedlot pens, the local climate and the prevailing winds that assist in ventilation and cooling.

The orientation of the longitudinal row shade structure should be north-south, especially if it has no strips to allow for drying, while the orientation of centre square and separate panel structures is unimportant.

Longitudinal row shade structures positioned in the north-south direction with the shade material orientated east-west can have the eastern side of the structure elevated to provide a 10-15° pitch. This encourages better pen floor drying in the morning hours, provides more shade area during the afternoon and increases air flow under the shade structure. A north-south orientation works well with a compacted clay or gravel floor because the sun strikes every part of the pen floor under and on either side of the shade at some time during the day.

Clear-span structures minimise columns within the pens. Columns are best positioned in the subdivision fence lines.

Too many support posts make pen cleaning more complicated; fewer structures would need to be strengthened. Encasing posts in concrete protects them from corrosion, damage during pen cleaning and reduces injury to cattle.

Shading material is often supported on cable suspended between columns, posts or supports. Infrastructure must be engineered for rain, hail and wind loadings.

Position in the pen

Shade structures are typically erected towards the centre of the pens so that cattle can follow the shaded area as it moves across the pen during the day.

Shade positioning should take advantage of the morning sun for drying while maximising the shaded area in the afternoon summer sun.

Shade should not be positioned over water troughs or near a fence line; water troughs and feed bunks should be kept outside the shaded area (particularly in the hottest time of the day). Ideally, strips of shade should be constructed parallel to the feed bunk but not close to it. Shade over the troughs or bunks encourages cattle to congregate around them, limiting access for extensive periods while increasing pen surface pitting in these already high traffic areas.

Support posts and cables

Obstructions in the pen should be minimised to allow easy cleaning and less risk of animal injury. Clear-span structures are preferred with few or no support posts in pens. Separate panel shade structures do not require any posts in the pen to hold them up as a cable network is constructed with posts on the fence line. However, fewer support structures means that they will need to be engineered to support the shading material and withstand the force of high winds, and hence are more costly. Support posts should preferably be in line with the perimeter fences. Centre square and longitudinal row shade structure often need support posts within the pen and this can create areas which are extremely difficult to clean.

Columns are commonly made from steel but the base should be encased in concrete to prevent corrosion, to provide better protection from equipment damage during pen cleaning operations and to reduce injury to cattle that bump into them.

Roofing material is often supported on cable strung between supports that are determined by calculated engineering load. Cables should be storm rated for the feedlot site but should be at least 11mm cable to ensure good tension and long life. The thread should be high density, low shrinkage, abrasion resistant and unaffected by cleaning agents, acid rain, mildew, chlorine, saltwater and industrial pollutants. End assembly strainers should be outside the pen.

Shade material

The most commonly used shading materials are shade cloth and galvanised iron sheet (Table 1).

Shade cloth is available in many densities and strengths. It is generally manufactured from lightweight knitted or woven polypropylene fabric that is resistant to rot and mildew, does not become brittle and is water permeable. It provides a good shade, reflects heat, diffuses light, has long life and is easily supported with adequate assemblies.

Knitted shade cloth is heavy duty with a longer life expectancy. Polypropylene woven shade cloth is slightly cheaper, has a considerably shorter life expectancy and has a tendency to unravel and fall apart if not taped. Woven synthetic shade materials are available in varying degrees of strength and texture. However,

Table 1. Advantages of shade cloth and iron sheeting for shade

	Shade materials and structures	
	Shade cloth	Iron sheeting
Suitability	May be retractable allowing pens to dry out in winter months.	Typically permanent fixed shade structures.
UV radiation protection (UPF)	UPF varies with colour, fabric density and degree of stretch (from <50% to >90% UPF). A shade rating of 90% will give a UPF of only 10.	Excellent protection with UPF 50+.
Light transmission	Lighter colours allow more light but reflect and scatter more UV radiation.	None.
Solar heat gain	Barrier to direct solar radiation while allowing ventilation. Darker colours are hotter and reflect less UV radiation.	Better thermal performance if painted white on topside.
Structural implications	Minimal down or uplift force as material is porous (if clean). Shade cloth can be damaged by wind unless sufficiently tensioned.	Requires well-engineered support structures fixed to manufacturer's specification and designed to wind codes and potential loads.
Permeability	Mainly permeable unless sealed with dust. Pen maintenance problems if the area beneath shade becomes permanently wet.	Not permeable, but can concentrate heavy runoff leading to pen maintenance issues.
Ease of replacement	Readily available. Re-fitting is generally easy and low cost.	Material readily available and easily fitted.
Maintenance requirements	Keep clear of tree debris. Dust can reduce porosity, increase tension and concentrate heavy rainfall on the down slope.	Requires minimal maintenance to the structure itself. Remove all metal shards after installation to prevent staining and corrosion under moisture.
	Needs to be at an appropriate height to allow machinery and vehicles access to the pen.	Water runoff on down slope side under heavy rainfall can create wet patches, increasing pen maintenance.
	Retractable shade cloth can allow pens to dry out in winter.	Wet shaded areas may cause dags on cattle, increasing maintenance requirements.
Life span	About five years depending on location, less in windy locations. Retractable shades generally last longer if stored appropriately.	Long life if well maintained. Fixings and flashing materials should have a lifetime similar to that of the roof covering material.

woven shade cloth can accumulate dust and so become impermeable to rain and hail while also harbouring birds and rodents.

A reinforcing tape border around the shade panels prevents the cloth from unravelling, and must be used when grommets are inserted to allow cables to be used to secure the shade cloth to the support posts. For shade cloth without grommets, shade clips can be used to attach the shade cloth to structures or wire supports. No tools are required and the clips simply snap into place.

Corrugated roofing iron requires more support through the structure but has the advantage of being self-cleaning in rain, sheds heavy rain and hail, provides increased rigidity in high winds, is resistant to birds and rodents and has a longer life span than shade cloth.

Iron sheeting can also reflect solar radiation; a silver or white coating on the surface can significantly reduce radiant heat.

Height of shade structure

Higher structures will allow better ventilation but result in increased wind loads and costs. As low shade cloth structures may discourage cattle from entering an area the minimum height is 4 m, but 5 m will reduce the risk of pen cleaning machinery tearing cloth with an extended loader bucket or tipping tray, or burning holes in it with an exhaust pipe.

Shade height also determines the area of shade cast at different times of the day.

Shade structures should be high enough for machinery. Higher shade structures offer better ventilation but limit the area of shaded footprint and have higher wind loading.

With galvanised iron sheets in hotter climates a pitch of 1:3 increases air movement and shade coverage in the afternoon.

Retractable shade improves drying of pen surface during winter months in high rainfall areas.

This shade can be retracted using a pulley system connected to the PTO shaft of a tractor.

Inclination of shade structure

Inclined shade structures may increase the sunlit area in the morning and extend shade coverage in the afternoon sun, thereby increasing the shadow area accessible by cattle. Sloping fabric will shed more rain water.

Shapes that have little curvature and tension will deform under load and become unstable and move about. Outside the agricultural industry, the best shade designs from a structural stability perspective are thought to be shade sails that have a significant difference in height of posts, where one corner is much higher than the other. The shade sail is essentially pulled taut and twisted so one axis is convex and the other axis concave.

With suspended iron sheeting, a lower pitched roof (1:4 pitch or less) can result in lower air movement whereas a steeper roof pitch results in greater air movement (e.g. 1:3 pitch is suggested for a hotter climate).

Retractable shade structures

Shade can be retractable so that it can be removed during the winter when not required, especially in winter rainfall regions. Retracted shades help to keep the pen surface dry when evapo-transpiration is low. Retracting shade cloth helps prolong its life. Other shade cloth structures can be removed for winter periods but need to be stored correctly to maintain life expectancy.

Rainfall zone

Rainfall zone can influence the type of shade to be used. Feedlots located in winter-dominant rainfall areas would favour north-south orientation with retractable shade cloth, as this would allow for optimum pen drying.

In high rainfall areas, solid shade covering can concentrate runoff resulting in ponding on the pen surface. The pen floor beneath the shade must be given the opportunity to dry when the sun is shining.

Structural design

Shade cloth needs to be structurally sound in order to withstand wind loads. The impact of excessive wind load at the feedlot site should be considered in the design of an appropriate shade structure and accompanying strengthening assemblies.

The movement of wind against a solid structure results in directional loads on the structure. Wind moving against a wall causes a static side load. As wind moves up and over an inclined surface roof structure, it causes a download on the front face of the roof and an upload on the leeward face as a result of an induced area of low pressure. These forces must be taken into account when designing a shade structure, especially if the shade itself is sloped to obtain advantages in shading and ventilation. A sloping shade structure will act either as a wing or as an aerofoil depending upon the direction of the wind.

Structural design should be undertaken by a suitability qualified, licensed and experienced structural engineer.

Preparing a shadow diagram

A shadow diagram should be prepared to ascertain how a shade structure is likely to affect the shadows cast.

The following figures are provided to illustrate the preparation of a shadow diagram for a feedlot site.

1. Place the north point on the plan.
2. Determine the angle (azimuth) of the sun (Figure 1) at the feedlot site for three or more times during the day e.g. 9 am, 12 noon and 3 pm (Figure 2). Solar azimuth and elevation calculations can be obtained from the internet.
3. Determine the shadow cast by a structure of unit height at each time of day. The shadow length is calculated by multiplying the height of the structure by the shadow cast length (Figure 3).
4. Project the shadow cast onto the site layout. The effect of width and height of shade structure on the amount of shade cast can be analysed by varying the parameters of the shade structure. Figure 4 steps lot feeders through the process of preparing a shadow diagram.

Corrugated iron sheets can concentrate rainfall runoff to localised areas; ponding will damage the pen surface.

Altitude and Azimuth of the sun in mid-summer – 21st December	
Latitude	27°23
Longitude	151°32
Sunrise	4.58 am
Sunset	6.48 pm

The sun is shown in the noon position

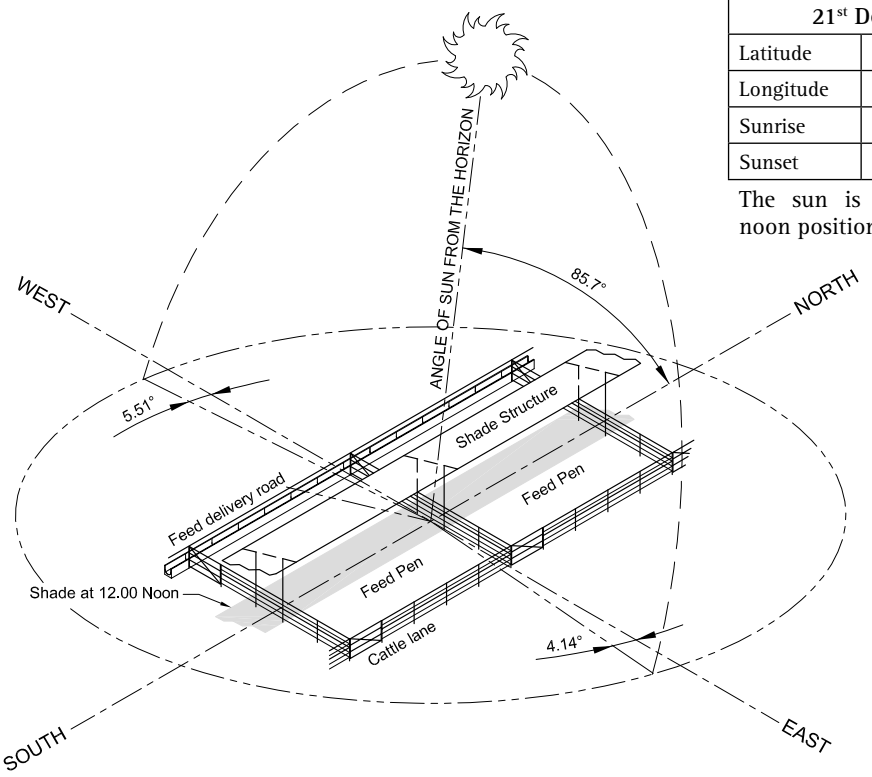
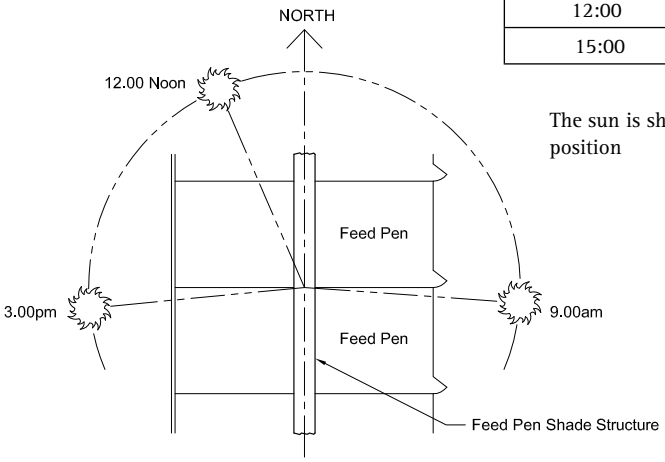


Figure 1. Altitude and azimuth of sun in mid-summer

Shade sails should be pulled taut and twisted so one axis is convex and the other axis concave. Shapes with little curvature and tension will deform under load and become unstable. Sloping fabric will ensure good shedding of water and hail.

Time	Angle (°) (azimuth)
09:00	94
12:00	337
15:00	264

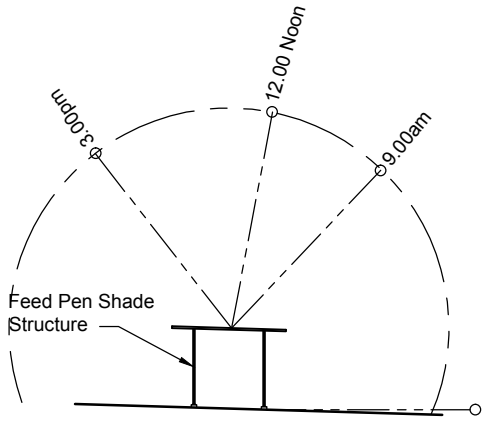
The sun is shown in the noon position



ANGLE OF SUN FROM TRUE NORTH ON 21st DECEMBER (AZIMUTH)

Figure 2. Azimuth of sun in mid-summer at three times during day

A taut peaked shade cloth structure. Sloping fabric will ensure good shedding of water and hail.



ANGLE OF SUN FROM THE HORIZON ON 21st DECEMBER (ALTITUDE)

Time	Angle (altitude)	Length of shadow cast by a 1m pole on flat land (m) (shadow length – Multiplier)
09:00	51	0.81
12:00	86	0.08
15:00	48	0.91

Figure 3. Length of shadow cast

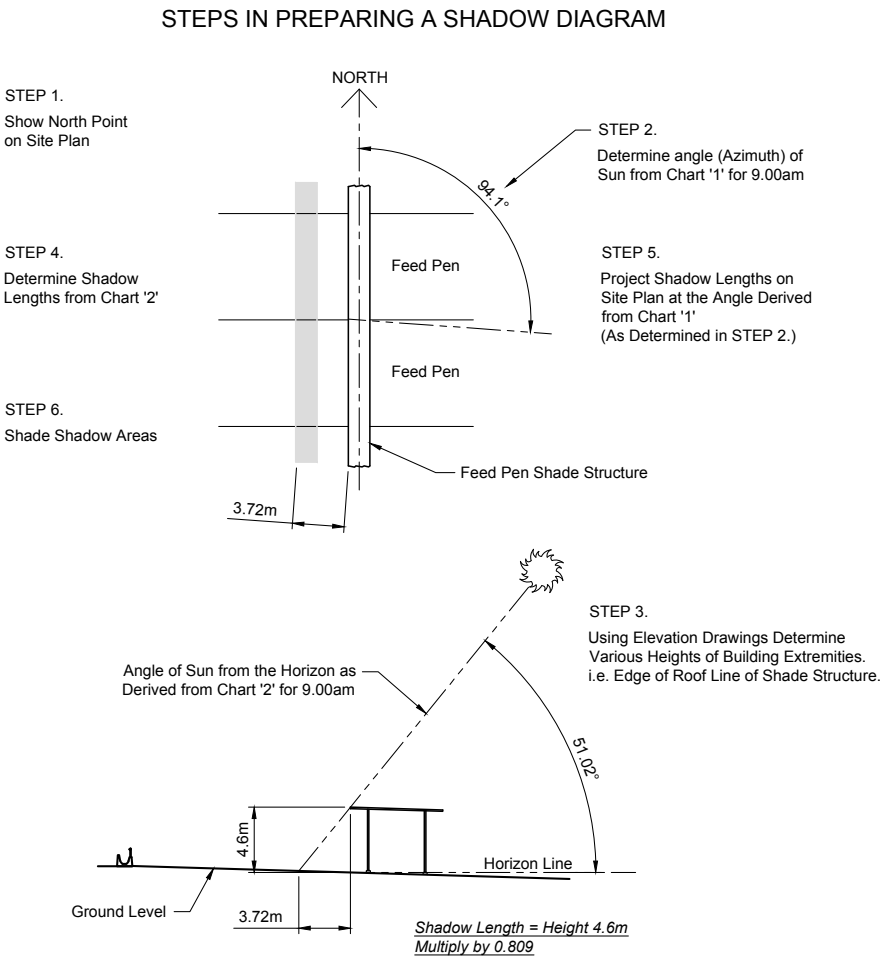
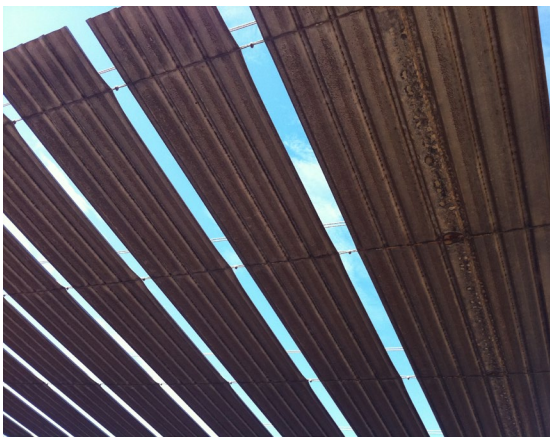


Figure 4. Determining shadow length

Cattle bunching under limited afternoon shade.

The advantages of using either shade cloth or corrugated iron sheeting are listed in Table 1.



Quick tips

- Seek professional advice from a structural engineer when designing shade structures.
- Use shade cloth with a minimum solar rating of 80%, minimum 300 GSM (gram per square metre) and at least a 10-year warranty against UV degradation. Green or black material is recommended.
- Apply sufficient tension to shade cloth to prevent damage during windy conditions. Monitor tension regularly, especially after strong winds.
- A greater pitch is better than a low pitch structure as it enhances convective air movement, encourages dust/rainfall run-off and enhances drying during sunlight periods.
- Support posts used should be graded structural steel with the base encased in concrete to prevent corrosion and damage by pen cleaning machinery. Minimise the number of posts located in the pens.
- Galvanised iron sheets reflect more solar radiation.
- A minimum height of 5.0 m at the lower side of the shade should promote airflow and provide adequate clearance for pen cleaning machinery.

Further reading

DAFF, 2013, Australian Animal Standards and Guidelines for Cattle, Department of Agriculture, Forestry and Fisheries, Australian Government, Canberra, ACT

MLA 2001, Recommendations for reducing the impact of elements of the physical environment on heat load in feedlot cattle, FLOT.307. Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2001, Measuring microclimate variations in two Australian feedlots. Final Report FLOT.310. Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2002, Heat stress software development. FLOT.312. Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2002, Forecasting feedlot thermal comfort. FLOT.313. Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2003, Applied scientific evaluation of feedlot shade design. FLOT.315. Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2003, Development of an excessive heat load index for use in the Australian feedlot industry. FLOT.316. Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2003, Measuring the microclimate of eastern Australian feedlots. FLOT.317 Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2003, Refinement of the Heat Load Index Based on Animal Factors. FLOT.319 Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2003, Operation of a Weather Forecasting Service for Several Locations for Excessive Heat Load Events Over Summer 2002/2003 For The Australian Feedlot Industry FLOT.320 Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2004, Refined website based weather forecast service for the Australian feedlot industry, FLOT.324 Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2004, Cattle heat load forecasting service for 2004/2005 summer, FLOT.324 Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2005, Reducing the Risk of Heat Load for the Australian Feedlot Industry. FLOT.327. Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2005, Validation of the Heat Load Index for use in the feedlot industry, FLOT.330 Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2006, Tips and Tools Feedlots. Heat Load in Feedlot Cattle. Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2006, Cattle Heat Load Forecast Service for 2005/2006 Summer , FLOT.334 Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2006, Improved measurement of heat load in the feedlot industry, FLOT.335 Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2006, Revision of the Risk Analysis Program, FLOT.336 Meat & Livestock Australia Ltd. North Sydney, NSW

MLA 2007, NSW Cattle heat load forecasting summer 2006-2007, FLOT.340 Meat & Livestock Australia Ltd. North Sydney, NSW

EA Systems Pty Ltd, 2003, Applied scientific evaluation of feedlot shade design. Commercial-in-confidence, Final Report FLOT.315. Meat & Livestock Australia Ltd, North Sydney, NSW