FEEDLOT DESIGN AND CONSTRUCTION

43. Automatic weather stations

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Well-sited 2 metre AWS with no nearby obstructions and a low security fence.

Tipping bucket rain gauge (pluviometer) with the cover removed – records rainfall total and intensity (mm/hr).

Introduction

Weather monitoring is an important aspect of feedlot management. Adverse weather conditions can affect cattle production and welfare, particularly during the hotter months. Feedlot operators should closely monitor local climatic conditions and review weather forecasts to monitor and manage the risk of heat stress in cattle. Weather monitoring may also be required to support feedlot environmental licences or development approval applications, particularly if there is the potential for odour or dust to affect neighbouring properties. Weather data can also be used for scheduling of crop planting (e.g. soil temperature) and/or effluent irrigation.

Design objectives

The design objectives for an automatic weather station (AWS) at a feedlot may include

- provision of climatic data to calculate Heat Load Index (HLI) and Accumulated Heat Load Units (AHLU)
- provision of climatic data to monitor or predict odour dispersion
- provision of climatic data for scheduling effluent irrigation
- provision of climatic data for scheduling manure and/or compost spreading
- storage of historical climate data
- compliance with environmental licences or development approvals
- siting to ensure representative data collection
- siting and installation to minimise potential damage and to facilitate maintenance.

Mandatory requirements

Feedlot environmental licences and development approvals may require the operator to collect meteorological measurements, with the parameters specified in the licence. This may be as simple as daily rainfall or as complex as wind stability on a 10 minute basis.

In NSW, the Environment Protection Authority guidelines for odour assessment require the collection of at least 12 months meteorological data for development approval applications where odour impact is expected. These data are used in odour dispersion modelling for the proposed site. A weather station may also have to be installed at the site to collect data for a minimum of two to three months so that the results can be correlated with a local Bureau of Meteorology (BOM) station if available.

In these cases, the design and siting of the weather station may have to comply with AS2922-1987 Ambient Air – Guide to the Siting of Sampling Units and AS2923-1987 Ambient Air – Guide for Measurement of Horizontal Wind for Air Quality for the data to be useable for legal and licensing situations.

NFAS standards require all feedlots to monitor HLI and AHLU of the cattle on feed. While an on-site weather station is not mandatory, it is strongly recommended because of the possible variation between the on-site micro climate and local weather forecasting.

Technical requirements

An AWS is a stand alone set of equipment constructed to measure and record specific attributes of the ambient environment. It relies on sensors to measure a physical property or condition over time.

A typical AWS setup with sensors for wind direction and speed, and black globe solar radiation mounted on the cross-arm. Logger is mounted inside blue box.

Climatic parameters

Typical standard climatic parameters measured by an on-site AWS include

- rainfall
- ambient temperature
- relative humidity
- wind speed
- wind direction
- global incoming solar radiation
- global radiation on exposed surface (black globe).

These parameters allow calculation of Heat Load Index, Accumulated Heat Load Units and evapotranspiration.

Additional parameters may include

- barometric pressure
- soil temperature.

If the weather station is to be used to collect data for odour dispersion modelling or dispersion prediction, the following additional parameters must be recorded

- wind speed at 10 m and 2 m
- wind direction at 10 m

AWS configuration

Automatic weather stations fall into two basic categories.

- Preconfigured – these stations feature a standard suite of pre-wired sensors, easy installation and simplified programming. Typically they are not expandable, with no provision for additional sensors to be added. The standard suite of sensors includes rainfall, wind speed, wind direction, air temperature and relative humidity.
- Custom – these stations offer a wider selection of sensors and data transfer peripherals providing greater flexibility and expansion capabilities, but are more expensive.

The black-globe sensor has a temperature probe inside to measure internal air temperature.

Siting

The main determinants of how and where to site an AWS are the intended application and the surrounding environment of the desired location. The quality of the weather data from an AWS is a function of the quality of the sensors used and the appropriateness of its siting.

An AWS records the weather exactly at the point it is located. In a ‘microclimate’ application, readings may need to be inferred over a radius of 1–2 kilometres; in a ‘meso-scale’ application, readings may be intended to be inferred as valid for up to 25 kilometres. In terms of monitoring heat load events, the ‘microclimate’ or climatic conditions actually experienced by the cattle in the feedlot, including the effects of the immediate local terrain, are the most

AWS mast with wind speed, wind direction and solar radiation at 10 metres, and other sensors at 2 m.

Well sited 2 metre AWS located in the centre of a feedlot with no nearby obstructions and a security fence to keep out livestock.

A less well sited AWS on a mound and shaded by close vegetation. Records would be unrepresentative of ambient conditions.

relevant. The 'meso-scale' will be important when the intended application is to measure the potential impacts to the surrounding environment such as odours, dust or other airborne particles.

The AWS should be sited so the variables measured are representative of the area of interest, and so it is located as close as possible to this area. However, subtle variations in exposure may still mean that the data may not be representative. Wind, air temperature, and water vapour pressure measurements may be affected by the ground surface type and roughness, soil moisture, regional topography and obstructions. For example

- Rainfall collection efficiency varies with height due to wind turbulence effects. Rain measured at 1 m above ground level is only 97% of rain measured at 300 mm.
- Temperatures measured over or close to a bitumen surface are significantly different to those measured over a grass surface.
- Wind speed measured at 3 m is significantly less than wind speed measured at 10 m. The wind direction may also be different.

In addition to difficulties with the correct exposure of instruments, changes in the long term exposure of the site should be considered. New structures such as buildings, shade, silos or water tanks, or vegetative screenings such as trees planted close to the instrument enclosure, will result in the area of representativeness being reduced and may also affect remote communication systems.

The AWS should be inspected regularly and any changes in the siting properly documented.

To ensure consistency between sites, an Australian set of standards for the physical siting and exposure of the meteorological instruments has been developed by the Australian Government's Bureau of Meteorology (BOM) using the World Meteorological Organisation's (WMO) guidelines (Bureau of Meteorology 1997).

Australian Standards have also been developed for siting and measurement of ambient air quality (AS2922-1987 Ambient Air – Guide to the Siting of Sampling Units; AS2923-1987 Ambient Air – Guide for Measurement of Horizontal Wind for Air Quality).

Ideally, the AWS should be placed in the centre of an open space of at least 12 m by 12 m which is covered by short grass and fenced robustly so that sensors are not damaged by livestock. If the weather station has sensors that are housed together, the area of the enclosure can be reduced. However, the fence must NOT affect sensor readings by shading, influencing wind movement or producing a rainfall shadow.

The site should be on level ground and not shielded by trees or buildings. It should not be close to steeply sloping land or in a depression where temperatures are frequently higher during the day and cooler at night. Rock outcrops, stone or gravel surfaces near the AWS should be avoided. Suggested heights and exposure of AWS sensors are provided in Table 1 and Figure 1.

To achieve optimum results, the BOM and Australian Standards should be consulted.

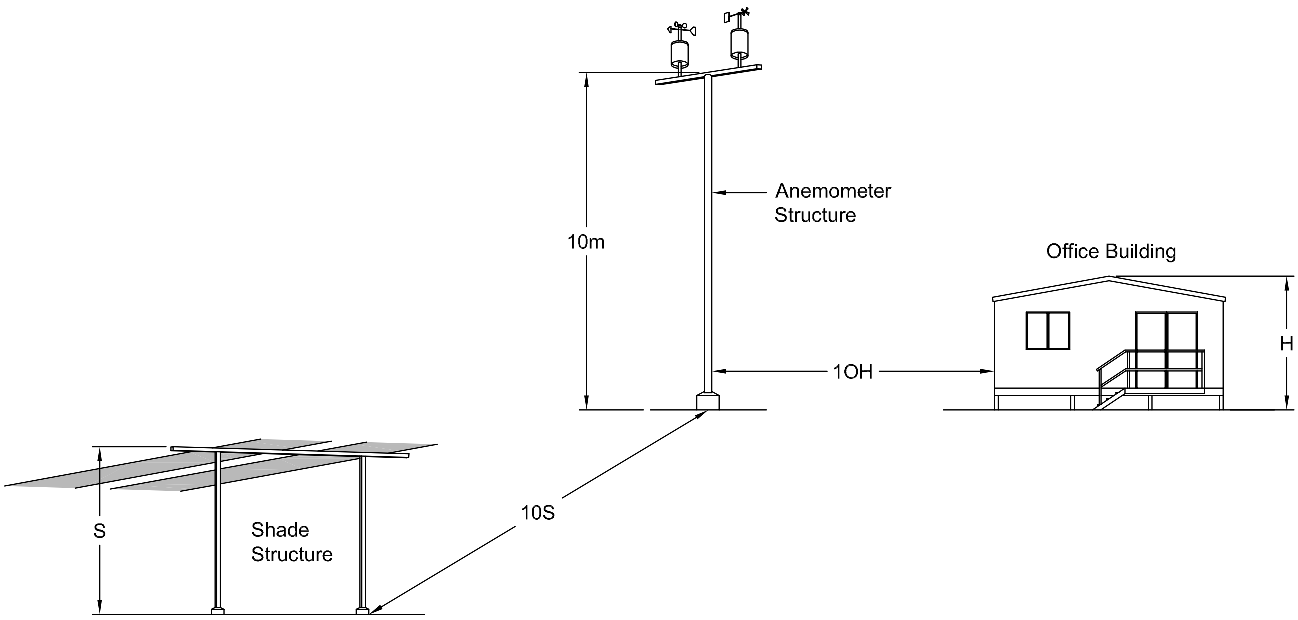
In an attempt to measure the actual conditions experienced by cattle, some feedlot managers have placed weather stations inside a pen or cattle alley. However, pen conditions can be extremely aggressive and can result in

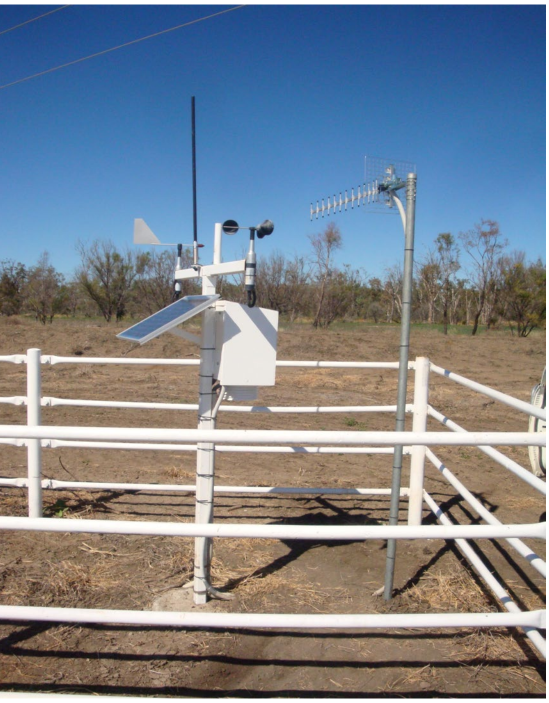
- dust accumulating on and in sensors
- corrosive attack by organic matter
- sensor damage by cattle
- wiring damage by rodents
- sensors and wiring damage by birds
- sensors and circuitry damaged by electromagnetic fields from welding during pen repairs
- equipment damage by cleaning machinery and routine feedlot maintenance.

Table 1. Suggested heights and exposure of AWS sensors (Standards Australia (1987b)

Sensor type	Measurement height above ground level	Exposure considerations
Wind	2 m / 10 m	No closer than 10 times the obstruction's height – See Figure 1.
Air temperature and relative humidity	1.25–2 m	The sensors must be housed in a ventilated radiation shield to protect the sensor from thermal radiation. No closer than four times the obstruction's height and at least 30 m from large paved areas.
Solar radiation	To facilitate levelling/ cleaning install at a height of 3 m or less	The sky should not be blocked by any surrounding object. Objects less than 100 above the horizontal plane of the sensor are allowed.
Rain	300 mm (at greater height wind affects the accuracy of measurement)	The sensor no closer than four times the obstruction's height. The orifice of the gauge must be in a horizontal plane, open to the sky, above the level of in-splashing.

Figure 1. Schematic siting requirements for an AWS





Typical 2 m solar-powered AWS with remote access.

Note omni-directional antenna fixed to AWS mast and separate uni-directional high gain antenna on stand alone post. Data can be downloaded and all sensors checked by remotely dialling into the AWS.

Sensor configuration

Sensors should be selected to be appropriate to the user's requirements. The quality of the final data recorded can only be as good as the quality of the sensors used, and no subsequent analysis of the data can improve its accuracy or reliability.

The integral component of the sensor is a 'transducer' which detects one form of energy and converts it to another. For example, a temperature sensor detects temperature of a probe and converts it into an electrical signal. Electronic circuitry in the sensor itself or in a centralised processor gathers these signals. As the mechanical and/or electrical components of sensors degrade over time, the characteristics of the transducer and signal may alter over time; hence, the need for high quality sensors and regular sensor calibration for accurate measurement over time.

Fundamental characteristics which make up the accuracy and precision of a sensor are

- *Resolution* – the smallest change the device can detect. Note that this is not the same as the accuracy of the device.
- *Repeatability* – the ability of the sensor to measure a parameter more than once and produce the same result in identical circumstances.
- *Response time* – normally defined as the time the sensor takes to measure 63% of the change.
- *Drift* – the stability of the sensor's calibration with time.
- *Hysteresis* – the ability of the sensor to produce the same measurement whether the parameter being measured is increasing or decreasing.
- *Linearity* – the deviation of the sensor from ideal straight line behaviour.

All of these factors go into defining the accuracy and precision of a sensor but some are more important in particular situations than others. For example, for monitoring climatic temperature changes, a significant amount of data is collected over a long period so the sensor should have very little drift. To measure short term wind gusts, the repeatability of the device and the response time become more important.

For a feedlot application, the most important factor is the robustness of the sensors. In general, feedlots are harsh environments so the sensors need to be well designed and constructed, have strong waterproof housings for the electronics and be able the withstand extremes of climate variability.

Sampling period and recording frequency

Digital recording should provide for a sampling of sensor readings at intervals of no longer than 60 seconds.

The period over which a parameter is averaged depends upon the application. Wind speed and wind direction are averaged over a 10 minute or 15 minute period. One hour averages are used for most other parameters.

Most parameters measured are averaged with a simple arithmetic method. However, wind direction must be computed with a method that accounts for the angular nature of the values.

In those feedlots that are required to record climatic parameters as part of licence conditions, the recording frequency will be stated in those conditions.

Algorithms

Using information from the sensors it is possible to calculate a host of important variables for feedlots, including heat load on cattle and potential evaporation. For example, irrigation requirements can be determined using potential evapotranspiration readings to determine the rate of water loss from irrigation areas receiving effluent water.

The algorithms used to derive meteorological variables should be meaningful, documented and comparable between different weather stations.

For example, the maximum temperature derived from 1 second readings can be quite different to a maximum temperature derived from hourly readings, wind gusts based on 1 second readings will be significantly greater than gusts based on 3 second readings, and scalar averaging of wind direction generally produces meaningless results.

Lot feeders or their consultant should confirm with the manufacturer the algorithms used and the meaning of the meteorological variables derived. The algorithms used and all changes to those algorithms should be documented.

Heat Load Index (HLI)

Heat Load Index (HLI) has been developed as an indicator of the environmental heat load placed on cattle. The HLI has been tested and proves to be a good indicator of physiological stress.

Refer to the Katestone Environmental website for the current method of calculating HLI. (*www.katestoneenvironmental.com.au*)

Accumulative Heat Load Units (AHLU)

The accumulative time of exposure to thermal load is crucial to determining the thermal status and wellbeing of feedlot cattle. AHLU has been developed to give some indication of the amount of heat that is accumulated by an animal when it is exposed to environmental conditions that are above its ability to maintain thermoneutral conditions (threshold value). The threshold value is selected on the basis of the animals' suspected vulnerability to high heat load. Every hour that an animal is above its threshold HLI value, it will gain heat. This additional heat load accumulates over time and is reflected as an increase in body temperature.

In order to calculate the AHLU, several parameters are required

- Heat Load Index (HLI)
- Upper limit of the Thermoneutral Zone (UL)
- Lower limit of the Thermoneutral Zone (LL) (Fixed at 77)
- Interval (in hours) between successive HLI estimates (T)

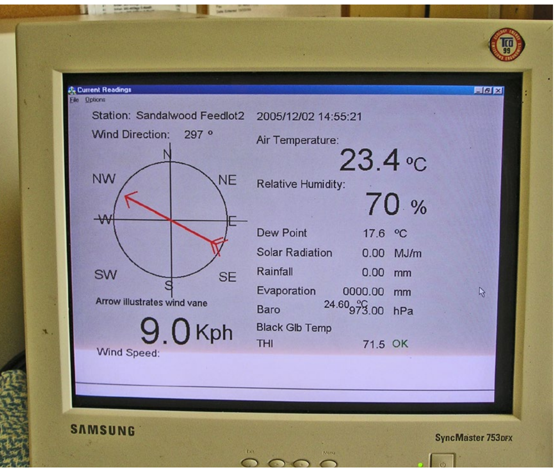
The Upper Limit is variable and depends on factors such as

- cattle characteristics
- pen management practices
- mitigation measures.

Refer to the Katestone Environmental website for the current method of calculating AHLU. *(www.katestoneenvironmental.com.au)*

Further information on estimation and forecasting of HLI and AHLU can be found at Katestone Environmental (*www.katestone.com.au*). The meteorological parameters that influence the HLI and the AHLU forecasts can vary significantly over relatively short distances and therefore an on-site AWS, sited reasonably close to the feedlot pens, will provide the best results.

Most AWS marketed for feedlots incorporate standard algorithms for the calculation of HLI and AHLU.



A direct link from the AWS to the feedlot office allows real time display of climatic conditions. This is particularly important during periods of high heat load.

Communication

AWS can be configured for direct download via a continuous communications link or remotely. The communications system used must be reliable, inexpensive and follow standard protocols for data transfer from the AWS to the user.

To select the best communication option, the following points should be considered

- how often you need to download your weather data
- power availability at the site
- capital expenditure versus running costs

A summary of each available communication option follows

- **Direct cable connection**
  This is a low-cost solution suitable for distances up to 100 metres, but it does need lightning protection. Normally, the cable connects to the serial port of a computer but it can be connected to your local area network (LAN) via a Serial to Ethernet converter if available. This type of connection is ideally suited as a continuous access between the office PC and AWS, providing 'live' weather monitoring.
- **Telephone landline**
  A standard telephone line can be used via either a mains powered or solar powered modem. Any PC connected to the Internet is able to contact the weather station using this connection, allowing access to the AWS from almost any PC in the world. This method is normally cost effective only if an existing phone line is available at the AWS site. Line rental and call costs have to be considered; this method is not suitable as a continuous link due to continuous time-of-use and associated call costs.
- **Mobile data connection**
  This style of connection allows a wireless link to the AWS from any PC connected to the Internet. It is simple to set up and will provide data from equipment sited in remote areas.

AWS with radio link to office.

Coverage must be available at the AWS site for the network and provider you choose. Both GSM (2G) and 3G networks can be used. The Australian 3G network has a wider regional coverage area.

- **Radio links**
  Radio links can be used where telephone services are not available, and for distances up to 10–20 kilometres. Line of sight is required but these systems can include repeaters to solve line of sight problems. Generally, radio links have higher capital costs, but no usage costs means that the overall cost is less for long term installations.
  The choice of system is dependent on the distances required and the availability of power on site or costs of solar power. This type of connection is ideally suited as a continuous access between the PC and AWS, thus providing 'live' weather monitoring.
- **Satellite connection**
  For completely remote access, a satellite phone can be fitted to the AWS.

Most feedlots use UHF, mobile or direct communication systems because they offer continuous or remote access at large distances from the office and they are similar to other telemetry used in agriculture, such as pump control systems or mobile phone links. AWS can be configured to issue warning messages of impending heat load events to the mobile phones of nominated people such as employees, vets and nutritionists.

A rain gauge installed on a 600mm post to prevent flooding.

Installation

Australian Standard AS2923-1997 provides instructions for siting, setup and commissioning of sensors for measurement of ambient air quality. Typically, manufacturers provide practical information on the setup and installation of their AWS and these should be consulted together with AS2923. The key issues to consider when setting up the AWS after the site has been selected are

Support posts – before concreting, ensure that support posts are

- orientated so that sensors or auxiliary equipment are aligned correctly (e.g. solar panels)
- set to the correct height
- vertically aligned.

Protection of cables – all exposed cabling needs to be protected from physical damage. Damage from maintenance activities such as whippersnippers and from bird chew are common.

Protection of the AWS – to prevent physical damage to the system, some form of fencing will need to be provided. The nature of the risk (e.g. livestock, machinery, people) will determine the type and size of the fencing. The effect of the fencing on measurement (e.g. sensor shading) needs to be considered.

A rain gauge installed in a site subject to stormwater flows. The gauge was inundated and all components had to be replaced.

Maintenance

Regular and proper maintenance of the AWS is essential for continuing accurate data. Integral to the sensor and its calibration is sensor maintenance. All sensors need to be cleaned and checked periodically to verify their calibration. A maintenance program should reassess the calibration of all sensors. The weather station should be easy to maintain, and maintenance should be possible without affecting the climate record and recording frequency. For example, sensors should be able to be unplugged whilst they are being serviced without affecting the recording of other variables.

Spider webs and dust may affect the ventilation of humidity and temperature sensors within the screen.

Dust – rain gauges need to be frequently inspected for dust accumulating in the bowl and cementing after heavy dew. Do not site AWS close to gravel roads.

Maintenance of site – grass and weed seeds blocking the funnel of the rain gauge will affect data quality.

AWS should be chosen for their ease of maintenance.

Many of the cheaper AWS lack robustness and require more frequent maintenance to replace electronics and/or sensors; they often cannot be serviced in the field and need to be returned to the manufacturer for periodic calibration or replacement. However, even the highest quality AWS do degrade over time and still need to be serviced and maintained regularly. In time, even the highest quality sensors will need to be recalibrated and/or replaced. Most good quality sensors simply need to be recalibrated rather than be replaced.

It is important to consider the lifetime costs of an AWS rather than just its initial purchase cost. Lifetime costs will include initial purchase (hardware and software), installation, annual maintenance, sensor replacement frequency and sensor, software update and data loss costs. Generally, the lower the initial cost, the higher the ongoing costs and the number of periods when little or no useful data is recorded.

More maintenance will be required if the weather station is in an aggressive environment (e.g. dusty or moist), and this will dictate the maintenance frequency. For example, AWS located in the feedlot will require more frequent maintenance due to higher dust loads than an AWS sited outside the feed pen area.

Maintenance should also be timed to ensure that the AWS is at its peak operating performance at critical times throughout the year such as prior to summer heat loads. If the weather station is located close to dust-generating areas, the primary maintenance problem will be dust accumulation on and in sensors. Poor maintenance can translate into poor management decisions affecting cattle production and welfare, data loss and increased repair costs with time.

As a guide, an AWS should be checked and serviced at a maximum of 12 months, with 3 to 6 months recommended in aggressive environments. For high quality data, sensor calibration should be checked every two years.

Basic routine and simple maintenance that can be carried out on an AWS by feedlot employees includes

- Regular checking and clearing the rain gauge collector of dust and debris. Bird droppings and accumulated dust during dry periods and with no flushing are a particular problem.
- Check the bearing in the wind speed anemometer sensor housing by listening for any noises as the cups rotate. The cup rotation can also be halted by hand to check for any friction evident at low wind speed. The only way to check the calibration in the field is with a newly calibrated anemometer.
- Check the bearing in the wind direction sensor housing by listening for any noises as the vane rotates.
- Remove any cobwebs from the wind speed anemometer cups and wind direction vanes.
- Check the solar radiation sensor for dust and debris and wipe clean the top of the sensor as required.
- Wipe off excess dust from the relative humidity and air temperature radiation housing.

- Keep grass short around the rain gauge to ensure that grass seeds or vegetative material do not block the gauge.
- Check for loose nuts, bolts, studs or cable connections and tighten or repair as required.
- Protect the sensor cables with flexible conduit to provide protection from damage. Typical issues include bird or animals such as foxes, mice and cattle that chew or inadvertently cause physical damage.

Sensors should be checked, serviced and calibrated on a regular basis — most likely by the manufacturer or experienced consultant. Simple calibration checks can be made using thermometers (ambient air temperature), sling psychrometers (relative humidity), hand held anemometers (wind speed), a sight compass (wind direction) and other calibrated sensors to benchmark readings. Pocket weather devices or weather meters are relatively inexpensive and are ideal for in-situ checking of AWS sensors by employees. For example, the Kestrel-type devices can measure and record wind speed, temperature, RH and barometric pressure.

Sensors should only be returned to the manufacturer when the deviation from the calibration reading is unacceptable.

The AWS manufacturer can provide advice regarding the inspection and maintenance of their units.

All cables to and from the AWS need to be protected from damage by machinery and animals. Cockatoos and rodents chewing on exposed cables lead to loss of data and expensive repairs.

Data management

The capture, storage, back-up and output of recorded data should be considered when selecting an AWS. The data management system used should be

- practical – the system should be flexible enough to allow additional sensors to be added without having to re-process the AWS records into a new format.
- user friendly – the system should be simple and the user should be able to directly read the output from the sensors and recorded data without proprietary or specialist programs to decode or manipulate the data.
- flexible – the data should be easily transferred between software applications e.g. from an ASCII text file straight into a Microsoft Excel spreadsheet. This also allows easy exchange of data between regulatory agencies, consultants and other users for review and processing with minimum reformatting.
- independent of the manufacturer – the data management should not be dependent upon a manufacturer's proprietary software. Proprietary software may reduce the ability to exchange data and the flexibility to manipulate data if required. This also impedes competition between manufacturers.

Well protected cabling on an AWS.

The use of standard software and standard formatting allows easy management of data and increases useability and functionality. The BOM has standard data formats and the data collected by the AWS should be configured to comply with one of these formats. The standard outputs include *one second format* (for maintenance and real time read-outs), *one minute format* (data logging, display), *ten or fifteen minute format* (data logging), *hourly format* (data logging) and daily maximum and minimum or totals format.

Archiving and retrieval

AWSs generate large volumes of data. The archival and retrieval of AWS data must be considered.

Development conditions may require data to be kept for a defined period but it is best to ensure that all AWS data be kept permanently.

This will require balancing the need to store high temporal resolution data against the large volumes generated.

When deciding on a data storage system, consideration should be given to the ease of quality control and retrieval of the data. This applies as equally to data stored on hard copy as to data held in electronic form.

The Bureau of Meteorology's National Climate Centre maintains the Bureau's data archives and, under certain conditions, stores data from other agencies. Before any data can be accepted into the Bureau's climatological database, the foregoing issues must be addressed.

The Bureau's Data Management Section (and the Climate and Consultancy Services Sections in each state) can provide advice regarding the requirements for data to be archived in the Bureau's climatological database. Generally, the AWS installation and operation should follow the procedures outlined in this document.

Quick tips

- Feedlots should install a AWS to at least monitor HLI and AHLU because there can be considerable variation between the on-site micro climate and local weather forecasts. A preconfigured AWS offers a standard suite of pre-wired sensors but no additional sensors can be added later.
- A custom AWS offers a wider selection of sensors and data transfer peripherals providing greater flexibility but at a higher cost.
- The AWS should be sited so the variables measured are representative of the area of interest and located as close as possible to the area of interest.
- Carefully consider the proposed site for an AWS and potential changes in the long term exposure of the site. New structures, such as buildings, shade, silos or water tanks or planting trees or shrubs near an AWS may affect the representativeness of the data recorded and/or the remote communication system.
- Refer to the Katestone Environmental website for the current method of calculating HLI and AHLU.
- Radio communication links between the AWS and the feedlot office have higher capital costs but small usage costs.
- Regular and proper maintenance of the AWS is essential to obtain accurate data.
- Basic routine and simple maintenance such as cleaning rain gauges, cobwebs and dust from solar panels on an AWS can be carried out by feedlot staff.

Further reading

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