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Water and energy usage for individual activities within Australian feedlots

Part A Report: Water usage at Australian feedlots

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Abstract

Whilst total annual water records by lot feeders are usually good, little data exists on actual usage levels in individual components viz drinking water, feed management, cattle washing, administration and sundry activities.

Eight feedlots were selected representing a cross-section of geographical, climatic and feeding regimes within the Australian feedlot industry.

At seven of these feedlots, water meters were installed to allow an examination of usage by individual activities. The major water (viz drinking water, feed management, cattle washing) usage activities were monitored and recorded.

This report provides factual information on the quantity of clean water used within individual activities of seven Australian feedlots for the period March 2007 to February 2008.

Executive Summary

The Australian red meat industry, as with most primary industries, is coming under increasing pressure from both the community and government to document and justify its impacts on the environment. Currently, a lack of credible supply chain data prevents the industry from being able to respond in a meaningful manner.

Meat and Livestock Australia (MLA) has undertaken a project (FLOT.328) to measure environmental costs associated with the production of one kilogram of meat from modern Australian feedlots. As part of this project, factual information data on water use was obtained via a detailed on-line survey of feedlot inputs and outputs including cattle numbers, intake and sale weights and dressing percentages. Annual water usage was estimated on the basis of one kilogram of dressed hot standard carcass weight gain while in the feedlot (kg HSCW gain). In this context, HSCW gain is the difference between total dressed carcass weights of cattle leaving the feedlot less the estimated total dressed carcass weight of cattle entering the feedlot.

Whilst total annual clean water records by lot feeders are usually good, little data exists on actual usage levels in individual components viz drinking water, feed processing, cattle washing. More information is required on the water usage of individual components before these figures can be reliably reported and before water use efficiency activities can be undertaken.

The purpose of this study is to quantify the clean water usage and indirect and direct energy usage from individual feedlot activities. Eight feedlots were selected representing a cross section of geographical, climatic and feeding regimes within the Australian feedlot industry. The sub-system boundary as defined here is the feedlot site itself plus the transport component of bringing cattle and feed into the feedlot and delivering cattle from the feedlot.

Water meters and/or power meters were installed at eight feedlots to allow an examination of usage by individual activities. The major clean water usage includes cattle drinking water, feed management, cattle washing, administration, repairs and maintenance and dilution of effluent. Similarly, activities that use a significant amount of energy include water supply, feed management, waste management, administration and repairs and maintenance.

The water and power meter data collected were supplemented with existing data collected on-site including fuel consumption (diesel, LPG) and cattle performance data. Performance data included market types, incoming and outgoing liveweights, dressing percentages, feed data and other parameters that allow HSCW gain to be estimated. Information was collected on a monthly basis.

At most feedlots, intensive assessments of minor water use operations were undertaken. Activities that were investigated this way included trough cleaning, hospital cleaning, induction yard cleaning and vehicle washing. These minor activities are too numerous to monitor economically using inline water meters.

The data was analysed to obtain water and energy use associated with a number of feedlot indices including a per-head basis, per tonne grain processed and per kilogram of hot standard carcase weight gain (kg HSCW gain). A breakdown of resource use within the major feedlot activities and associated operations is provided.

This report covers the issue of water usage by feedlots.

Total annual clean water use (without dilution of effluent) ranged from 30-104 L/kg HSCW gain over the period March 2007 to February 2008 for the seven feedlots in which water usage was measured. This is a similar range to that found in earlier work (34-90 kg/HSCW gain) by Davis & Watts (2006). Drinking water contributed about 90% of the total water usage in the months when no cattle were washed. This reduces to about 75% during months when cattle washing is undertaken. As expected drinking water consumption is driven by rainfall and heat load. During rainfall, drinking water consumption is suppressed and increases to maximum levels during periods of high heat load.

The average drinking water consumption across all feedlots for March 2007 to February 2008 ranged from 31 L/head/day to 47 L/head/day, with an average in the order of 40 L/head/day. Feedlot E, located in a subtropical environment, had the highest average drinking water consumption of 48 L/head/day, whilst Feedlot B which experiences cold winters, mild summers and high rainfall when compared with other feedlot locations, had the lowest drinking water consumption of 31 L/head/day.

These levels are less than the often quoted figure within the industry of an average of 65 L/head/day. It is believed that the 65 L/head/day figure is based on the maximum daily requirement of 5 L per 50 kg LWT, hence representing the water requirements of a 650 kg beast.

The maximum monthly drinking water consumption recorded at an individual feedlot was 70 L/head/day during January 2008 and the minimum of 4 L/head/day was recorded in June 2007.

The relationship between drinking water consumption, heat load index and rainfall is clearly evident on a daily basis. During periods of rainfall, drinking water consumption is suppressed, whilst during periods of high heat load, drinking water is at its highest.

Feed processing water usage is the second highest consumer of water in feedlots where no cattle washing is undertaken. Three different feed processing systems are represented within the seven feedlots and included tempering, reconstitution and steam flaking. Feed processing is about 4% of water usage and is dependent on the grain processing system employed at the feedlot. This figure can vary from month to month depending on the management of the various systems.

Feed processing water usage ranges from 90 to 390 L/t grain processed. Water added to the grain ranges from 45 to 90% of the total water used. For tempering only systems, the water added to the grain is similar to the total water used. Hence, it has a very low volume of unaccounted for water. The difference between measured water and water added to grain is defined as unaccounted for water. For reconstitution, an average of 40 L/t grain is unaccounted whilst water usage and unaccounted for water within steam flaked systems is variable with an average figure of 225 L/t grain unaccounted. Therefore, in steam flaking, if the tempering component water usage is reflected in additional water in the grain, the majority of unaccounted water can be attributed to the process of steam generation and delivery. A number of factors will influence feed processing water usage including the system employed, grain type, target moisture and management of the system.

Cattle washing is the second highest consumer of water in feedlots in months when it is undertaken. The total water usage in some feedlots comprises clean and recycled water. Cattle washing can contribute up to 25% as a function of HSCW gain of the total water usage.

Cattle washing water used from 800 L/head to 2600 L/head. However, a monthly water usage up to 3900 L/head was recorded at one feedlot. Recycled water can account for 50 to 75% of the total water usage. The water required for cattle washing is dependent on the dirtiness of the cattle and the cleaning requirements.

Administration water usage comprises that used in office and staff amenities and for watering of lawns and gardens. Average administration water usage ranged from 0.6 to 3.2 L/kg HSCW gain over the period March 2007 to February 2008. Administration represents a small proportion of the total usage, representing about 2% and is driven primarily by the volume of water irrigated onto lawns and gardens.

The sundry water losses ranged from 0.03 L/head/day to 4.1 L/head/day. Evaporation from water storages, water trough cleaning and road watering are the three largest sundry water uses. Variation between feedlots may be explained by feedlot design (surface area open water storages, size of troughs), location (climate) and management operations including frequency of trough cleaning and road maintenance (dust control).

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1 Background

The Australian red meat industry, as with most primary industries, is coming under increasing pressure from both the community and government to document and justify its impacts on the environment. Currently, a lack of credible supply chain data prevents the industry from being able to respond in a meaningful manner.

Meat and Livestock Australia (MLA) is undertaking a project (COMP.094) to address these issues and provide credible data on the industry's environmental impacts and sustainability for use by industry, including its interactions with government, community groups and the media. This project will use the standardised tool, Life Cycle Assessment (LCA), to quantify natural resource consumption and environmental interventions to water, soil and air. The goal of the LCA is to identify key environmental impacts of products. Environmental impact categories considered in LCA include but are not limited to resource energy, climate change (global warming), eutrophication, acidification, human toxicity (pesticide use) and land use.

LCA is a form of cradle-to-grave systems analysis developed for use in manufacturing and processing industries to assess the environmental impacts of products, processes and activities by quantifying their environmental effects throughout the entire life cycle. LCA can be used to compare alternative products, processes or services; compare alternative life cycles for a product or service; and identify those parts of the life cycle where the greatest improvements can be made. An international standard has now been developed to specify the general framework, principles and requirements for conducting and reporting LCA studies (Standards Australia, 1998). LCA differs from other environmental tools (e.g. risk assessment, environmental performance evaluation, environmental auditing, and environmental impact assessment) in a number of significant ways. In LCA, the environmental impact of a product or the function a product is designed to perform is assessed, the data obtained are independent of any ideology and it is much more complex than other environmental tools. As a systems analysis, it surpasses the purely local effects of a decision and indicates the overall effects (Peters et al. 2005).

The functional unit for COMP.094 was the output of 1 kg of Hot Standard Carcass Weight (HSCW) meat at the abattoir gate. "Hot" indicates the meat in question has not entered any chilling operations. This output-related functional unit was chosen, rather than an input-related one, in order to describe the human utility of the processes under consideration – the provision of nutrition for people. Although the meat could be served in different ways, this functional unit makes the different processes under consideration "functionally equivalent" from a dietary perspective.

In LCA methodology, usually all inputs and outputs from the system are based on the 'cradle-to-grave' approach. This means that inputs into the system should be flows from the environment without any transformation from humans and outputs should be discarded to the environment without subsequent human transformation (Standards Australia, 1998). Each system considers upstream processes with regard to the extraction of raw materials and the manufacturing of products being used in the system and it considers downstream processes as well as all final emissions to the environment.

FIGURE 1 shows the generalised system boundary for the red-meat sector as defined for the COMP.094 project. Within this boundary, there is a sub-system for the feedlot sector. The boundary chosen here (shown in red on FIGURE 1) is the feedlot site itself plus the transport component of bringing cattle and feed into the feedlot and delivering cattle from the feedlot.

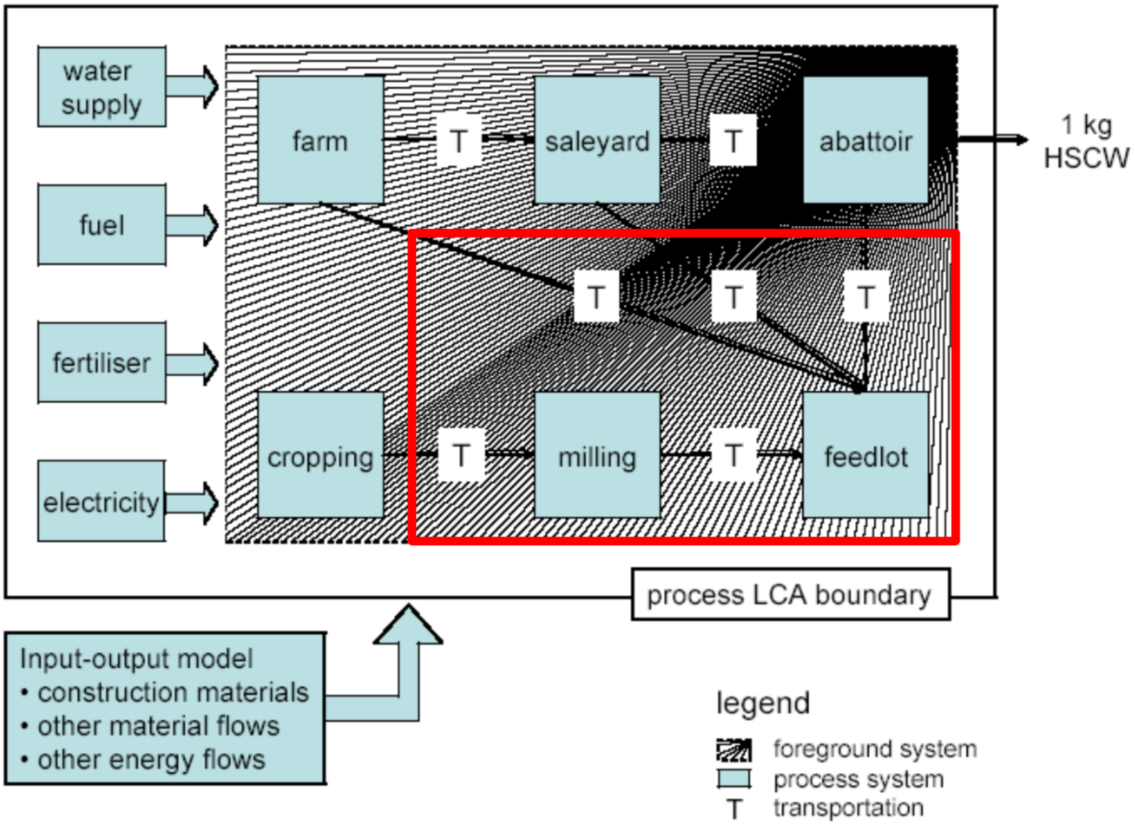


Figure 1 – Generalised system model for the red meat sector with feedlot sub-system

As part of the COMP.094 industry project, the beef cattle lot feeding sector has recently completed a related MLA project (FLOT.328) that will contribute to the whole-of-industry dataset, but more importantly addresses the public misconceptions concerning the environmental sustainability of the feedlot industry. The Terms of Reference for FLOT.328 required the researchers to address, in the context of a LCA, the feedlot-relevant natural resource management (NRM) issues water quality and water use efficiency, salinity, soil erosion, nutrient management and soil acidification, weeds, feral animals, biodiversity, vegetation management, energy efficiency and greenhouse gas emissions and solid waste. These issues were identified as issues of concern to the red meat industry.

The outcomes of FLOT.328 identified and quantified, where possible, the environmental costs (water, energy, GHG, and nutrient cycling) associated with the production of one kilogram of grained beef. It provided factual information on the volume of clean water and energy used at Australian cattle feedlots under a range of climatic, size and management conditions.

This study found that, whilst total annual clean water records by lot feeders are usually good, little data exists on actual usage levels in individual activities, viz. drinking water, feed processing and cattle washing. In addition, little is known about the variation in water use throughout the year. Similarly, total annual energy consumption records were usually limited by the lot feeders inability to separate out the electricity consumption of individual activities. Hence, more information is required on the water usage and energy usage of individual components before these figures can be reliably reported. These data are essential for efficiency improvements at a feedyard level.

MLA's goal in commissioning this project is to address the lack of accurate data and quantify the contribution of individual feedlot activities on the total annual water usage and total indirect and direct energy usage.

1.1 B.FLT.0339 Project Description

The purpose of this study was to quantify the clean water usage and indirect and direct energy usage from individual feedlot activities. An MLA steering committee oversaw the selection of the feedlots such that the feedlots represented a cross section of geographical, climatic and feeding regimes within the Australian feedlot industry.

The sub-system boundary, as defined for the feedlot sector in FLOT.328, has been adopted for this project. The boundary (shown in red on FIGURE 1) is the feedlot site itself plus the transport component of bringing cattle and feed into the feedlot and delivering cattle from the feedlot.

Water meters and/or power meters were installed at eight feedlots to allow an examination of usage by individual activities. The major clean water-using activities include cattle drinking water, feed management, cattle washing, administration, repairs and maintenance and dilution of effluent. Similarly activities that use a significant amount of energy include water supply, feed management, waste management, administration and repairs and maintenance.

The water and power meter data collected was supplemented with existing data collected on-site including fuel consumption (diesel, LPG) and cattle performance data. Performance data included market types, incoming and outgoing liveweights, dressing percentages, feed data and other parameters that allow HSCW gain to be estimated. Information was collected on a monthly basis.

At most feedlots, a series of intensive assessments of minor water use operations were undertaken. Activities that were investigated this way included trough cleaning, hospital cleaning, induction yard cleaning and vehicle washing. These minor activities are too numerous to monitor economically using inline water meters.

The data was analysed to obtain water and energy usage associated with a number of feedlot indices including a per head basis, per tonne grain processed and per kilogram of hot standard carcase weight gain (kg HSCW gain). A breakdown of resource use within the major feedlot activities and associated operations was provided.

2 Project Objectives

The primary objectives of the project were as follows:

- To capture the clean water and energy usage from individual activities and performance data from eight feedlots representing a cross section of geographical, climatic and feeding regime diversity within the Australian feedlot industry, thus allowing the clean water and energy usage to be evaluated on the basis of one kilogram of dressed hot standard carcass weight gain (kg HSCW gain).
- To communicate the results of the study to MLA in a format suitable for dissemination to industry stakeholders.

The outcomes of this project will allow the feedlot industry to develop a better understanding of the total annual clean water and energy usage and the relativity and contributions that various feedlot sector activities have on annual clean water and energy usage. This will allow the industry to reliably report actual usage levels in individual components viz drinking water, feed management, cattle washing etc. Data will be used for individual feedlot planning, for industry wide planning (e.g. FLOT.132 – Vision 2020 project) and to propose water and energy use efficiency options for feedlots.

This report covers the issue of water usage by feedlots. Water usage includes consumption within the major feedlot activities of feed management, drinking water, cattle washing and other minor uses including administration and repairs and maintenance. Water losses due to evaporation in storages and water troughs are also included.

Water is both the most important feed component fed to cattle and the most valuable natural resource (after land) in Australia. Hence, it is of critical importance to lot feeders. There is a perception in the popular press that red meat production requires large quantities of fresh water. For example, it is often stated (with little presentation of reference material) that it takes 50,000 L of water to produce 1 kg of beef. However, in Australia, there are few facts to back up these claims.

For this report, the definition of water use is that used by Foran et al. (2005).

‘Managed water use denotes the consumption of self-extracted water (water from rivers, lakes and aquifers, mainly extracted by farmers for irrigation) as well as mains water, in units of litres (L). Collected rainfall, such as in livestock dams on grazing properties is not included in these figures’.

Water for feedlots can be obtained from a variety of sources including shallow and artesian bores, rivers, creeks, irrigation channels, water harvesting of overland flow into on-farm dams and reticulated pipelines. In this analysis, only water supplied from bores, rivers, creeks, irrigation channels, reticulated pipelines and on-farm storages is considered. Rainfall on the feedlot surface is not considered. This report includes a literature review of clean water usage at feedlots, data collection and results as well as an analysis and discussion of the data collected.

2.1 Project Reporting Structure

This project includes the collection and analysis of a large quantity of data from operational feedlots on the water and energy usage associated feedlot operation. All data will be standardised to a number of indices including a per head basis, per tonne grain processed and per kilogram of hot standard carcase weight gain (kg HSCW gain). To ensure all this data and information is presented in a suitable manner, two reports were compiled.

A. Water Usage at Australian Feedlots. This report presents a background literature review of water usage within individual activities of feedlots, data collection and results, as well as an analysis and discussion of the data collected. It includes consumption within the major activities of cattle drinking water, feed management and cattle washing and other minor uses such as administration and repairs and maintenance.

B. Energy Usage at Australian Feedlots. This report presents a review of total direct and indirect energy usage at feedlots, data collection and results, as well as an analysis and discussion of the data collected. It includes consumption within the major feedlot activities of feed management, water supply, waste management, cattle washing and other minor uses including administration and repairs and maintenance. In addition, indirect energy consumption within the areas of incoming and outgoing cattle and commodity delivery are included.

3 Literature Review

3.1 Water Supply

Water is both the most important feed component fed to cattle and the most valuable natural resource (after land) in Australia. Hence, it is of critical importance to lot feeders. Water is required or used at cattle feedlots for cattle drinking water, cleaning of water troughs, evaporation and other losses from water troughs and pipes, cattle washing, evaporation from holding storages, feed processing, dust control, staff amenities, dust control and dilution of effluent.

Water for feedlots can be obtained from a variety of sources including shallow and artesian bores, rivers, creeks, irrigation channels, water harvesting of overland flow into on-farm dams and reticulated pipelines. When choosing between possible sources, reliability of supply, costs and water quality are important determining factors (Watts et al. 1994).

Shallow bores are generally the preferred source because they are more reliable than most surface sources and supply water at ambient temperatures. However, water quality should be checked to ensure that the supply is not too salty. Pumping costs vary depending on the actual depth of the water.

Artesian bores are expensive to install but may have no pumping costs if water flows to the surface. Water quality may again be an issue and should be tested. High water temperatures can be a dilemma and water may need to be stored for a time in cooling dams. Algal growth in temporary cooling storages can be a difficulty.

The reliability of water supply from rivers and creeks depends on whether the feedlot owns a water allocation and the reliability of that allocation. Supplies of water from rivers without allocations are very unreliable during drought times. Turbidity and excessive algal growth can be problems with river supplies. Salinity is not usually a problem.

Water harvesting of overland flow and stored in on-farm dams tend to be the least reliable water source. Water quality issues are similar to those for rivers and creeks (Watts et al. 1994).

As a rule of thumb, the maximum daily requirement for stock watering is 5 litres per 50 kg liveweight. The total average annual water requirement for feedlots in Queensland, as required for licensing, is approximately 24 ML/1000 head. However, whilst this figure makes a small allowance for other uses other than cattle drinking requirements, such as trough cleaning, minor leakages and veterinary purposes, it does not allow for significant usage for the purposes of feed processing, dust control, dilution of effluent (Skerman 2000).

All feedlots should have a temporary water supply close to the feedlot that acts as a buffer storage. This storage is usually sufficient to supply water under summer conditions to the cattle for a few days until pump or main pipeline breakdowns from the water source to the buffer storage can be repaired. The number of days of storage required depends on the anticipated time needed to repair the system. Typically, one to six days of buffer storage is provided. Most temporary storages are either above-ground concrete tanks or earthen turkey's nest dams. Typically, they are located such that they can gravity-feed water to the feedlot pens. However, this is not always the case. Growth of algae and aquatic weeds in temporary storages can be a problem, particularly in summer (Watts et al. 1994).

The water supply must be of suitable quality for stock use as poor quality water can reduce water intake (and subsequently feed intake) and could result in sickness and death (Watts et al. 1994). The Australian Water Quality Guidelines (ANZECC 1992) suggest that the desirable maximum total dissolved solids (TDS) concentration for healthy growth of beef cattle is 4000 mg/L (6.25 dS/m). However, beef cattle are reasonably tolerant of water TDS up to 10000 mg/L (15.2 dS/m) for short periods.

3.2 Drinking Water

Water is the most vital single requirement of livestock as they are dependent on it for survival. Water is an extremely important nutrient since it makes up about two thirds of the fat free animal's body. Water is essential for electrolyte metabolism and function (Church 1979).

Water is required by feedlot cattle for regulation of body temperature, growth, digestion, metabolism, excretion, hydrolysis of proteins, fat and carbohydrates, regulation of mineral homeostasis, joint lubrication, nervous system cushioning, sound transmission and sight. Restriction of water intake immediately reduces feed intake and cattle performance (Utley, Bradley & Boling 1970).

The water requirements of livestock are met by three different sources:
- Water consumed voluntarily (i.e. water that is drunk).
- Water consumed in feed.
- Water obtained within the body due to oxidation reactions involved in metabolism formed within the body as a result of oxidation in the tissues.

Water intake is the sum of water consumed voluntarily and water consumed as part of feed. It is regulated by the hypothalamus. If the temperature-regulating centre in the anterior hypothalamus is warmed (e.g. in a hot environment), the animal will consume more water than usual (McDowell 1972 cited in Lyndon 1994).

The minimal water requirement of feedlot cattle is equal to the sum of the minimum losses in faeces and urine, evaporative and respiration losses and water used in weight gain. The actual intake of water consistently exceeds the calculated minimum requirement. Water is the only nutrient for which the requirement is based on voluntary intake (Standing Committee on Agriculture, 1992).

Water is constantly being expelled from the animal's body through secretory products, wastes, exhalation and sweat. A minimal water loss of 2-5% of the total body water is vital to the animal as it ensures the continuation of the respiratory process and the excretion of metabolic products through urine and faeces. FIGURE 2 is a conceptual illustration of the water balance of a 450 kg feedlot steer from Davis and Watts (2006). Water is taken into the animal mainly as drinking water but a little is contributed by the feed. Water leaves the animal in manure (faeces and urine), sweat and respired air.

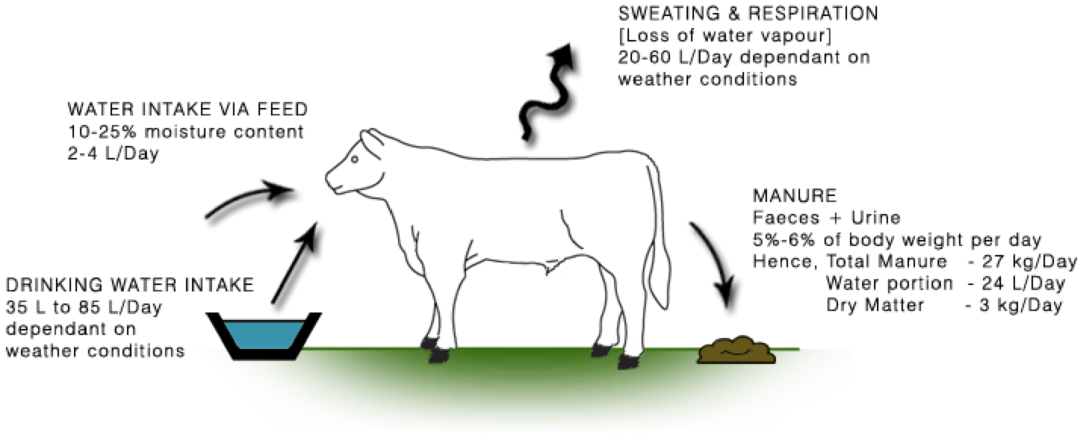


Figure 2 – Conceptual water balance of a 450kg steer (Davis & Watts 2006)

By way of definition, water consumption is 'free water' drunk by cattle while water intake includes both water drunk and water contained in feed. Cattle drinking at water troughs are shown in PHOTOGRAPH 1.

Photograph 1 – Cattle drinking at water troughs

Lyndon (1994) undertook a comprehensive review of literature available at the time on the factors influencing water consumption. These included environmental factors such as temperature and humidity, drinking water temperature and salt content, ration composition (nature of food and dry matter content), feed intake, size of the animal, breed, rate and composition of gain, frequency of watering and individual variation between animals. A detailed review of the above factors can be found in Lyndon (1994) and Davis et al. (2006).

Environmental Factors

The animal's environment directly influences its drinking pattern, performance and even survival. The water consumption of feedlot cattle increases dramatically during hot periods. Water helps to offset the negative effects of metabolic heat during periods of hot weather. It is required to prevent dehydration, but many animals will drink and use extra water just to cool the body by placing the tongue and nose in the water to dissipate body heat (Sparke et al. 2001).

Each of these factors influences the animal's final physiological state, thus determining the volume of water consumed by the animal. It is important to consider each of these factors individually.

Exposure of cattle to thermal stress leads to a number of physiological responses, such as: increased sweating rate, elevated rectal temperature, increased respiration rate and/or increased pulse rate. Associated with these are declines in feed intake and dry matter intake (DMI) (a direct attempt to reduce heat production), growth, health and well being (McDowell 1972; Kabunga 1992; Hahn & Nienaber 1993; Gaughan et al. 2002). McDowell (1972) compiled the following factors for an animal, which is compensating following exposure to increasing ambient temperature:

- Change in vascular blood flow
- Increased sweating rate
- Increased respiration rate
- Changes in hormone secretion or endocrine activity
- Changes in behavioural patterns
- Increased water intake
- Increased body temperature
- Changes in the uses of body water
- Change in the state of hydration

The order in which these functions take place has not been reliably determined. It has been argued that behavioural changes take place before there is any physiological response. Robertshaw (1985) stated that the first response to increasing thermal load is behavioural. Animals firstly change posture, seek shade, wallow, and/or decrease DMI. If these are not options, then the animal will use physiological functions (e.g. blood flow, sweating, panting) to alter body temperature. Young and Hall (1993) listed behaviours which could identify cattle experiencing excessive heat load, with the onset of open-mouthed panting, laboured panting and excessive salivation/drooling suggested as indicators of an animal failing to cope and needing immediate attention to avoid collapse and possible death.

There has been a lot of research conducted with regard to environmental factors effect on heat stress in cattle (Flamenbaum et al. 1986, Hicks et al. 1988, Sparke, et al. 2001, EA Systems Pty Ltd 2002, Gaughan et al. 2002, EA Systems Pty Ltd 2003). With the exception of Hicks et al. (1988), the majority of this research has concentrated on the effects of shade, diet modification, microclimate, cooling water and the development of an index for heat stress. The effect of environmental factors on subsequent water intake has received little focus (Davis & Watts 2006).

Environmental factors such as ambient temperature, relative humidity, wind speed, solar radiation and rain influences the animal's final physiological state, thus determining the volume of water consumed by the beast. It is important to consider each of these factors individually. Conditions of high humidity, wind and rainfall all tend to decrease the voluntary intake of water (ARC 1980).

Cattle exposed to high ambient temperatures will inevitably become hot and need to cool themselves. Increasing water intake is an important method of reducing body temperature due to its involvement in the evaporative cooling process. High ambient temperatures tend to increase the consumption of water (ARC 1980).

In temperate climates, water is required mainly to met physiological needs. Species vary in their ability to tolerate dehydration and in their ability to use water to maintain a state of homeothermy (ARC 1980).

The potential for evaporative heat loss is influenced by the difference between the water vapour pressure at the skin surface temperature and the actual vapour pressure of the ambient air. As the humidity of the air increases, the ability to lose heat by evaporation is reduced, becoming zero at a relative humidity of 100%. Increasing humidity associated with high temperatures reduces total water intake but cattle drink more frequently. This may be partly due to the lower feed intake and the reduced vaporisation of water (ARC 1980).

Radiation from the sun, sky and surroundings contribute to the animal’s heat load (EA Systems Pty Ltd 2003). The amount of heat an animal absorbs from solar radiation is influenced by the intensity of the radiation, the animal’s orientation to the sun and the absorptive reflective capacity of the animal’s coat. McArthur (1987) found that radiation is directly responsible for increased skin temperature which stimulates the secretion from the sweat glands. There are particular situations where wind can influence the heat transfer between an animal and its environment.

Rain reduces water intake due to the associated heat loss through evaporation. Rain falls onto the animal’s coat and evaporates, reducing thermal stress. The cooling effect is directly related to the depth of water penetration into the coat (Davis & Watts 2006).

Winchester and Morris (1956) related water intake per day to ambient temperature, dry matter intake and breed. They found that water intake increased with increased ambient temperature. There are very few references available in North America or Australia that allow reliable predictions of water consumption for feedlot cattle to be made.

Breed

Winchester and Morris (1956) indicate a definite breed difference in water consumption patterns. They provide data relating water intake per day to ambient temperature, dry matter intake and breed. Their studies indicate that *Bos indicus* cattle drink significantly less than the *Bos taurus* breeds.

These breed differences in water intake are not fully understood. However, *Bos indicus* cattle have an adaptive advantage in hot environments compared to the European and British breeds. They are better able to maintain body temperature in hot conditions. *Bos indicus* cattle have a greater surface area to weight ratio than the *Bos taurus* breeds (Blackshaw & Blackshaw 1991). From these results, it would be reasonable to assume that a greater surface area would provide a greater area from which heat may be dissipated. Worstell & Brody (1953) and Bianca (1963) cited in Lyndon (1994), attributed the low heat tolerance of *Bos taurus* breeds to their inefficient cooling mechanisms, poor sweating rate and their thick coat which hamper the evaporation of sweat. This may explain the significant water intake differences.

Diet Composition, Feed Intake and Body Size

The ingestion of feed leads to an increase in heat production (i.e. heat increment). The calorigenic effect of feed ranges between 35% and 70% of ME, depending on the class of nutrients consumed. Fat has the lowest heat increment, followed by carbohydrates while proteins have the highest calorigenic value (Blackshaw & Blackshaw 1991). The dry matter content and the nature of feed both influence water consumption requirements (ARC 1980). Generally, increased levels of feed intake are associated with increased voluntary consumption of water. When feeds with high moisture content are offered, less water needs to be supplied as drinking water (Luke 1987).

Water intake is usually expressed as litres per day or as litres/body weight/day (Luke 1987). Growing animals require a greater intake and a better quality of water than animals that have finished growing and are being fattened (Gill 1984). Heavily finished cattle require additional water relative to leaner beasts. This is because they have a thicker subcutaneous fat layer that acts as an insulating sheet, trapping heat inside the animal (McDowell 1972). Fatter or larger sized animals will also have a reduced surface area to weight ratio (i.e. less surface area from which to dissipate heat), therefore having a greater water requirement than leaner or smaller cattle (McDowell 1972).

Frequency of Watering and Water Consumption

Housed cattle and those receiving supplementary feeding tend to drink more frequently than grazing animals (unsupplemented) (Tucker 1991). Cattle maintained under similar environmental conditions and receiving similar diets vary considerably in the amount of water they consume (ARC 1980). Winchester and Morris (1956) also found that there is also a high degree of variability within individual animals when comparing intake between days during which apparently identical conditions prevail.

It is desirable to provide ample water for cattle to access throughout all times of the day. To achieve this, it is not sufficient to consider the total annual drinking water requirement alone, or even the daily requirement as diurnal variations exist in cattle drinking patterns.

Limited studies on the diurnal variation of water consumption by lot fed cattle have been undertaken. Johnson et al. (1963) considered the diurnal trends in both water consumption and frequency of drinking with respect to temperature fluctuations. The results indicated that more water was consumed during the day and at more frequent intervals than at night, irrespective of rearing conditions and temperature. They also found that as temperature rose from 0° to 40°C, water consumption for all breeds increased by only two to three times during the day, whereas night consumption rose six to seven fold.

Water Intake Models

Winchester and Morris (1956), Hicks et al. (1988), Sanders et al. (1994), Parker et al. (2000), Doreau et al. (2004) and Arias and Mader (2008) have developed separate models to calculate daily water intake for cattle and each generate different daily requirements.

Winchester and Morris (1956) provide predictions of daily water intake for both *Bos taurus* and *Bos indicus* cattle. They relate water intake per day to ambient temperature, dry matter intake (DMI) and breed. Their trials were conducted in a constant temperature chamber.

Results showed that up to an ambient temperature of 30°C, the rate of water consumption per unit dry matter intake remained fairly constant. As the temperature exceeded this level, consumption rose dramatically due to increased evaporative (cooling) demand. Winchester and Morris (1956) measured actual water intakes of 16 L/kg DMI per day by *Bos taurus* breeds, and about 10 L/kg DMI per day for *Bos indicus* breeds.

Watts et al. (1994) developed the following relationships from the collated data of Winchester and Morris:

Bos taurus $\quad WI = DMI \times (3.413 + 0.01592\, e^{0.17596T})$ *Eqn 1*

Bos indicus $\quad WI = DMI \times (3.076 + 0.008461\, e^{0.17596T})$ *Eqn 2*

Where:

WI = water intake (litres/head/day)
DMI = dry matter intake (kg DM/head/day)
T = ambient temperature (degrees Celsius)

Hicks et al. (1988) estimated the litres of water required for per animal per day based on maximum daily temperature in degree Celsius, kilograms of DMI per head per day, average daily precipitation and the percentage of salt added to the diet.

The resulting formula (converted to metric units) is:

$$WI = -6.1 + 0.708 \times T + 2.44 \times DMI - 0.387 \times P - 4.44 \times S \qquad \textit{Eqn 3}$$

Where:

WI = water intake (L/head/day)
DMI = dry matter intake (kg DM/head/day)
T = daily maximum temperature (°C)
P = precipitation (mm/day)
S = dietary Salt (%)

Hicks et al. (1988) prediction of water intake needs to be treated with caution for salt inclusions in the diet of greater that 0.5 per cent. This is due to the equation predicting a decreasing water intake with increasing salt content in the diet. This relationship is contrary to findings by Murphy et al. (1983) for dairy cows where increasing salt content in the diet resulted in increased water consumption. Moreover, the sodium content of drinking water can significantly reduce liveweight gains in feedlot cattle (Saul & Flinn 1985).

Parker et al. (2000) measured water usage at a 50,000-head beef cattle feedlot in the Texas High Plains. Cattle types, mean liveweights and dry matter intakes were not reported. For a three-day period representing summer conditions, an average of 43.9 L/head/day was used. The drinking water component of this was measured to be 39.0 L/head/day or 88.9% of the total water usage. In winter, over a three-day period, an average total water usage of 51.8 L/head/day was measured, with drinking water comprising 65.6% or 34.1 L/head/day.

Parker et al. (2000) collated daily water usage data to derive the following relationship:

$$DWU = 10.8 + [-1.52 \sin \{(2\pi/365)(D+69.5)\}] \qquad \textit{Eqn 4}$$

Where:

DWU = daily water usage (gallons/head/day)

D = Julian day.

Mader and Davis (2004) studied a number of management factors aimed at reducing heat stress in feedlot cattle. They found that water intake for control cattle ranged from 0.96 to 1.33 L/kg of DMI.

Arias and Mader (2008) studied the daily water intake in lot fed cattle in Nebraska during the winter of 2000 and 2001 summer season. Their study utilised Angus or Angus crossbreds cattle fed for 105 days, with an average dry matter intake of 10.45 kg/day (23 lb/day). Climatic variables were compiled using a weather station located at the feedlot. Simple regression and multiple regression analyses were conducted to estimate factors affecting daily water intake. They found that simple regression best modelled their data.

Arias and Mader (2008) found that cattle finished during the summer consumed 8.6 gal/hd/day (32.5 L/head/day) and 4.6 gal/head/day (17.3 L/head/day) in winter. Therefore, cattle finished in summer consumed 86% more water than those finished during the winter.

Arias and Mader (2008) developed three predictive daily water consumption relationships based on dry matter intake, solar radiation, daily minimum temperature, relative humidity and ambient temperature. Their relationships are:

$$DWI = -0.52677 + 0.1229 * DMI + 0.01137 * SR + 0.06529 * Tmin \qquad \textit{Eqn 5}$$

Where:

DWI = daily water intake (gallons/head/day)

DMI = dry matter intake (lb/day)

SR = solar radiation (kcal/day)
T = minimum daily temperature (°F)

$$DWI = 4.4433 - 0.0019 * Tmin - 1.1544 * e^{-3} * Tmin^{2} + 8.7853 * e^{-5} * Tmin^{3} - 8.0418 * e^{-7} * Tmin^{4} \qquad \textit{Eqn 6}$$

Where:

DWI = daily water intake (gallons/head/day)

Tmin = minimum daily temperature (^oF)

e = exponential (2.7183)

$$DWI = 1.6973 + 0.3861 * THI - 0.0187 * THI^2 + 3.568 * e^{-4} * THI^3 - 2.1034 * e^{-6} * THI^4 \quad \textit{Eqn 7}$$

Where:

DWI = daily water intake (gallons/head/day)

THI = temperature-humidity index = Ta – (0.55 – (0.55 * RH/100)) * (Ta - 58)

Ta = ambient temperature (^oF)

RH = relative humidity (%)

e = exponential (2.7183)

Diurnal water consumption patterns found by Sanders et al. (1994) in their study are shown in Figure 5 for an unshaded pen. The data has been normalised to a Standard Cattle Unit (SCU). Heat load index as developed by Gaughan (2004) and ambient temperature are also presented along with feeding times. The typical daily variation is characterised by very low consumption in the period 3 am – 5 am, followed by greatest water consumption within the period 6 am – 6 to 8 pm, low water consumption from 8 pm – 9 pm for 1-2 hours then increased water consumption from 9 pm for 2-3 hours, then a gradual in water consumption to minimal levels by 3 am (Watts & Davis 2006).

Watts et al. (1994) have also studied diurnal water consumption patterns, but not during heat wave conditions. Their findings were supportive of Johnson's work, stressing that cattle consume most of their water during the day. They recognised a definite water consumption trend over a 24-hour period, noting that water consumption is suppressed to insignificant levels between 11 pm and sunrise. The period where water deprivation is most likely to occur is from around 9 am to 8 pm, where water consumption requirements peak. They also found water consumption fell for about half an hour after feed delivery. Since water consumption peaks somewhere between 9am and 8pm, it is necessary to design water systems to match peak consumption demands at these times.

Sanders et al. (1994) found that solar radiation, relative humidity, average daily temperature, rainfall, and dry matter intake were the factors that had the most significant effect on daily water consumption.

They developed a predictive daily water consumption model based on rainfall, dry matter intake, shading and a weather factor that is a function of average daily temperature, solar radiation and relative humidity. Their model is:

$$WC = 1.337 - 0.037 \times P + 0.687 \times DMI + (1.592 - 0.199 \times shading) \times (weather)^{0.5}$$

Where:

WC = water consumption (litres per day per 100 kg LWT)
DMI = dry matter intake (kg DM per day per 100 kg LWT)
P = Rainfall (mm)
Weather = average daily temperature (°C) x solar radiation (MJ/m^2)/relative humidity (%)
Shading = 0 for unshaded pens, 1 for shaded pens.

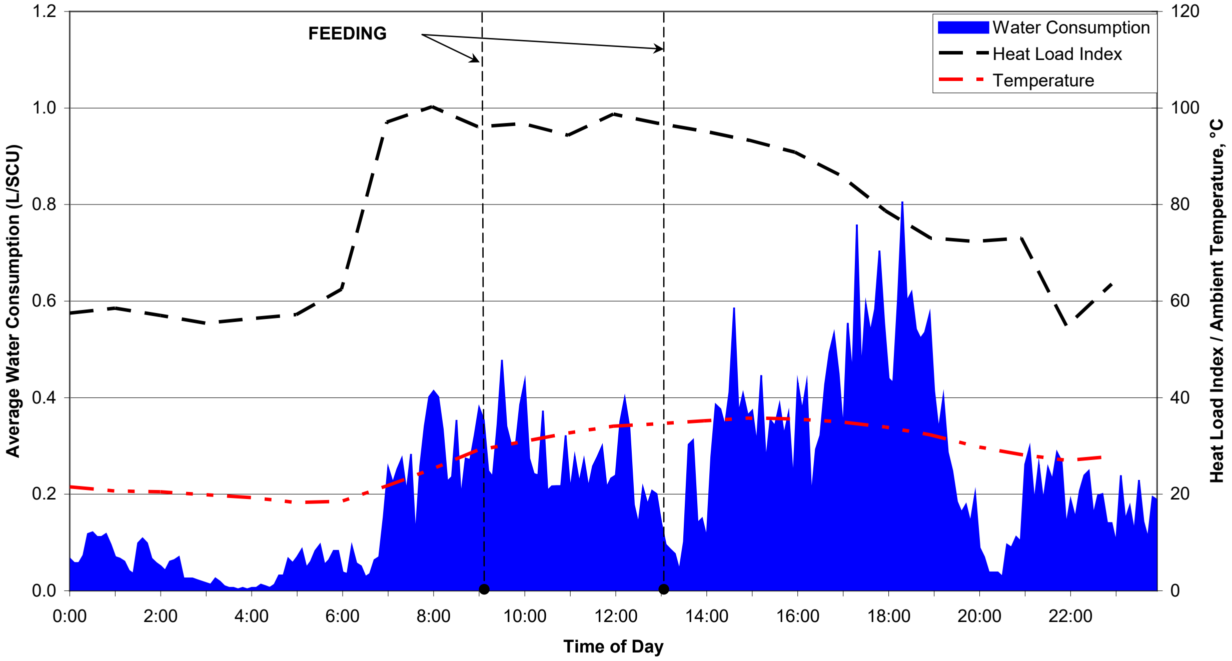


Figure 3 – Daily variation in feedlot water consumption – Unshaded Pen (07/01/1994)

Carter (2008) investigated lot-fed cattle water consumption and annual consumption patterns at a Darling Downs feedlot over the 2007/2008 summer period. Drinking water consumption for the feedlot was measured and logged at 3 min intervals. Climatic data was sourced from an on-site automatic weather station and herd data was collected. Carter (2008) fitted the Winchester and Morris (1956), Parker et al. (2000) and Sanders et al. (1994) predictive water consumption models to the data. Carter (2008) found that daily water consumption patterns throughout the year varied for each season. Summer and winter had two different diurnal patterns whilst autumn and spring have similar daily patterns.

Carter (2008) found that ambient temperature, black globe temperature, humidity, rainfall and dry matter intake all influence drinking water consumption. The results showed that parameters are inter-related, with climate (temperature and rainfall) influencing feed intake as well as water consumption. Ambient, blackglobe temperature and solar radiation were the most influential meteorological parameters on the daily drinking water consumption of lot-fed cattle. Both had high correlation with the water consumption patterns.

Carter (2008) showed that the Sanders et al. (1994) and Hicks et al. (2000) models underestimated water consumption compared to the measured data. The Winchester and Morris model (using the *Bos indicus* data) underestimated water consumption for ambient temperatures <35°C and over-predict water consumption at higher temperatures. The Parker et al. (2000) model had the highest correlation with the measured data and therefore proved to be the most effective predictive model.

3.3 Water Usage in Feed Preparation

Feed preparation usually involves altering the physical (and sometimes chemical) nature of feed to optimise utilisation by animals and to enhance mixing and stability of the diet. The major components of the diet, roughage and grain are the feeds most likely to be processed (Forster 2007).

Livestock producers have long been aware of the fact that the amount of nutrient extractable from a given type of grain can be enhanced by processing of some type. In many cases, this is simply a matter of cracking or opening the seed coat that tends to be poorly penetrable by digestive juices and rumen or digestive tract microbial populations. In other cases, it is an overall disruption of the grain kernel itself to expose the matrix within and increase overall surface area. In yet other cases, the first two steps above are accomplished with an additional "change" in the molecular structure of the starch molecules within to increase digestibility (Blezinger 2005).

Processing grain significantly improves its digestibility for beef cattle. Processing of grain improves digestibility by 8% to 15%. The ability of rumen microbes to digest grain is primarily dependent on particle size and the integrity of the outer protein matrix that surrounds starch granules in the endosperm.

The common grains fed in Australian feedlots are barley and sorghum, although maize, wheat and triticale are fed when prices are competitive. The order of declining response of different grains to the extent of processing is sorghum > corn > barley > triticale > wheat. Therefore, more aggressive processing technologies (requiring greater capital and operational input associated with steam flaking or extended fermentation) are required to effectively process sorghum and corn, compared to wheat, triticale and barley (which are better suited to rolling with or without tempering), if the greatest possible metabolisable energy is to be utilised by the feedlot animal (Davis & Watts 2006).

Methods are usually categorised as either ‘dry’ or ‘wet’. The determining factor is whether water is added. The most common dry processing method is roller milling. Wet processing methods include tempering, steam flaking and reconstitution. With wet processing methods, grain is then further processed by rolling or less frequently, hammer milling to reduce the particle size of the grain kernel.

The amount of water used in feed preparation depends upon the feed preparation process used. Water is often added as a tempering agent before or during the processing by direct liquid application and/or as steam.

3.3.1 Grain Preparation Processes

3.3.1.1 Tempering

Grain tempering is the addition of water in order to strengthen the bran and soften the endosperm prior to milling. Typically, the water is added in a 'tempering bin'. This system incorporates an open spiral mixing auger which conveys and mixes the grain from the in-loading storage silo's, past a grain wetting station, to the tempering silos. At the grain wetting station (PHOTOGRAPH 2), the precise amount of moisturising medium is added. This can be water alone or water mixed with other suitable ingredients such as surfactants. This ensures that the water is added evenly to the grain. After water has been added, the grain must have time to equilibrate, i.e. the moisture has to penetrate through the entire kernel. The grain is transferred to a tempering silo where it is allowed to steep for several hours before rolling. This process toughens the bran coat and causes it to separate more completely from the endosperm during the rolling process. Rolling the grain involves passing the tempered grain between two rotating corrugated rollers that crack or crush the kernels (PHOTOGRAPH 3).

Photograph 2 – Wetting auger

Feed efficiency improvements of between 5-10% are gained when the grains are processed using tempering over feeding the whole kernel. Tempering the grain prior to rolling also increases roll energy efficiency and decreases dustiness.

Photograph 3 – Roller mill

Tempering usually results in grain with a moisture content between 18% and 22% compared to stored grain, which has a moisture content of about 12%. The final moisture content of grain after tempering is dependent on whether the grain is subject to further processing. The moisture content of tempered only grain is around 22% final moisture, whilst the moisture content of grain subject to further processing is about 18%. Increasing the moisture content of grain to between 18-22 % during the tempering process requires water. Each tonne of grain might have an initial moisture content of 12%, meaning that it comprises 120 kg of water and 880 kg of dry matter. Raising the moisture content of this tonne from 12 % to 18 - 22 % requires the addition of some 73-128 L of water. This equates to 0.073-0.128 kg (L) water per kilogram of feed (Watts & Davis 2006).

Factual data on the volume of water required for tempering is difficult to obtain. However it is estimated that the water used in tempering is similar to the amount of water added to the grain (John Doyle pers. comm.).

3.3.1.2 Steam Flaking

The energetic improvements of processing grain by steam flaking are well known (Owens et al. 1997; Zinn et al. 2002). Steam flaking subjects the grain to steam under atmospheric conditions for usually 15 to 30 minutes at 95 to 110°C, before rolling. Zinn (1990) suggests that 30 minutes of steam is sufficient to achieve efficient starch use.

Moisture, heat and pressure are essential components of the steam flaking process (Osman et al.1970). The flaking process causes gelatinisation of the starch granules (hydration or rupturing of the starch molecule) rendering them more digestible. The degree of flaking and level of gelatinisation appear to be influenced by such factors as steaming time, temperature, grain moisture, roller size and tolerance, processing rate, and type and variety of grain.

The steam flaking process has a number of steps. Firstly, the grain is tempered. This helps to maintain the integrity of the grain prior to flaking, and ultimately adds shelf life to the feed. The tempering process is identical to that described in Section 3.3.1.1.

Secondly, the grain passes through a steam chest at a predetermined temperature and pressure for a predetermined time. Finally, the grain is flaked between two rotating corrugated rollers. Large, heavy roller mills make the grain completely flat and rupture the cells improving digestibility. Typically, the flakes are sampled as the flakes come out from between the rollers, weighed to determine the density of the sampled flakes, and then the temperature, the pressure, the retention time, and the size of the gap between the rollers are adjusted (J McGrath pers. comms.). This quality control is undertaken so that the resulting flakes have a predetermined density and a predetermined amount of gelatinisation and so that the variability in the amount of gelatinisation is minimised.

Steam flaking usually results in grain with a moisture content similar to that of tempered only grain, i.e. around 22 %. The tempering process before flaking typically adds up to 6 percentage units of moisture to whole grain (Zinn 1990). The remaining moisture is added during the steam flaking process. A typical steam flaker is shown in PHOTOGRAPH 4.

During the flaking process, large quantities of water can be lost as escaping steam. Data on water use for this process is difficult to obtain but it is estimated that the water requirement is some 2-3 times the amount of water added to the grain (Powell 1994).

Raising the moisture content of a tonne of grain with a moisture content of 12 % up to 22 % requires the absorption of approximately 128 L of water. However, up to three times as much water may be required to achieve this because of steam losses.

Photograph 4 – Typical steam flaker

3.3.1.3 Reconstitution

Originally, reconstitution came to the industry as a means of storing harvested grains containing excessive water that, under normal storage conditions, could not be stored due to qualitative, volume and performance losses. Reconstitution usually results in grain with a moisture content of 28% to 32% compared to dry stored grain, with a moisture content of about 12%. This higher moisture content can be achieved by harvesting at 28% to 32% moisture or by adding water (reconstituting). Typical reconstitution silos (‘Harvestore’ silos) are shown in PHOTOGRAPH 5.

Typically, water is added in a two-step process. Firstly, the grain is tempered using the same process as outlined in Section 3.3.1.1. This increases the moisture by approximately 6 percentage points. The remaining moisture is then added prior to the grain being transferred to the reconstitution silos.

Ideally, the high moisture grain must be stored in an air-tight facility for at least 10 days before feeding. The storage process is an ensilage process, which changes the nature of the endosperm thus improving digestibility. Ensiling high-moisture grain seems logical, because it gives the feedlot the option to feed a rapidly fermentable grain source that does not require steam flaking. After the grain is removed from the reconstitution silos, it is rolled prior to feeding. Rolling the grain involves passing the tempered grain between two rotating corrugated rollers that crack or crush the kernels (PHOTOGRAPH 3).

There is limited available data on water losses associated with reconstituting grain. Anecdotal evidence suggests that losses associated with reconstitution can be up to 25% of the water added to the grain.

Photograph 5 – Typical reconstitution silos

Increasing the moisture content of one tonne of grain from around 12% to an average 30 % moisture content requires approximately 257 kg of additional water. Hence, 257 kg of additional water is added for each tonne grain processed, or 0.257 kg (L) water per kg of grain.

Table 1 shows the estimated clean water use for reconstituting various grains. This information was compiled from 12 months of grain processing data provided by an Australian feedlot. This data, along with information provided on ration composition and feed intake, allowed average daily water use in terms of per head per day.

Table 1 – Estimated water use for reconstituting various grains (Davis & Watts 2006)

Grain Type		Barley	Corn	Sorghum
Initial moisture content, %		12.51	12.33	12.51
Final moisture content, %		29.81	29.22	29.32
Average Total Water used	(L/kg grain)	0.275	0.325	0.277
Average Total Water loss	(L/kg grain)	0.029	0.086	0.041
Maximum Water Loss	(L/kg grain)	0.119	0.258	0.200
Minimum Water Loss	(L/kg grain)	0.007	0.006	0.003
Water Used	(L/kg as fed)	0.169	0.163	0.162
Water Loss	(L/kg as fed)	0.020	0.059	0.028
Water Used	(L/head/day)	2.18	2.11	2.09
Water Loss	(L/head/day)	0.043	0.125	0.058
Percentage Water Loss	(%)	1.9	5.9	2.8

The average, maximum and minimum water loss was determined and presented in Table 1. Table 1 shows that the average water used for reconstituting sorghum was 277 L per tonne of grain. The water loss associated with this ranged from 3-200 L per tonne of grain with an average of 41 L per tonne. Therefore, based on information provided in TABLE 1, it is estimated that the percentage water loss for reconstituted sorghum was 2.8%.

TABLE 2 provides examples of estimated water use per head for various grain preparation processes.
These examples are based on the assumption that grain generally makes up 75% of a diet for feedlot cattle and that a 450 kg domestic class animal will consume approximately 13 kg of feed (as fed) per day. The wastage factor indicates the amount of water used above that added to the grain. Hence, a wastage factor of 1 indicates that the total water usage is equal to the water added to the grain. A wastage factor of 2 indicates that the total water usage is twice the mass of the water added to the grain.

TABLE 2 estimates that, depending on the treatment method and daily intake, water used to process grain could be in the range of 0.9 to 2.7 L per head per day.

Table 2 – Estimated water use per head for grain treatment

Processing Method		Tempering	Steam Flaking	Reconstitution
Final Moisture Content		20%	20%	30%
Water wastage factor		1	2.5	1.15
Water Used	(L/kg grain)	0.10	0.25	0.30
Water Used	(L/kg as-fed)	0.06	0.15	0.22
Water Used	(L/head/day)	0.98	2.44	2.9

Assumptions: Initial grain moisture content is 12% and ration is 75% grain. Daily intake (as-fed) is 13 kg/head/day.

Parker et al. (2000) monitored water usage at a 50,000 head feedlot. The average daily water use at the feed mill was measured separately. It was 55.8 m^3/day in April and 73.0 m^3/day in May. An average of 1.5 L/head/day was used in the feed mill based on 12 months of available feed mill water use data. Parker et al. (2000) in their studies measured an average water usage of 1.5 L/head/day for the feed mill or 3.4% of the total water usage in summer. In winter, over a three-day period, an average of 1.1 L/head/day was measured. This represented 2.2% of the total water usage. The feed processing method was steam flaking and it is reasonable to assume that, for a feedlot of this size, the grain would be flaked corn. The estimates in TABLE 2 are a little higher than the measurement of Parker et al. (2000).

3.4 Cattle Washing

Recent major outbreaks of food-borne illnesses have raised community interest in the food safety of meat. To prevent these outbreaks, it is important to control pathogen levels throughout the supply chain. Currently most controls over microbial contamination of meat occur in the abattoir through the adoption of Hazard Analysis and Critical Control Points (HACCP) and these measures have been effective in reducing carcass contamination (Elder et al. 2000). The pathogens causing these illnesses often originate during the pre-harvest stage on the farm. A quality systems approach to food safety suggests that the best approach is to reduce contamination to a safe level (consider this as an alternative to ‘during the pre-harvest stage’ - as early in the supply chain as practicable) during the pre-harvest stage, i.e. at the feedlot (Tucker & Klepper 2005).

Human illnesses from meat products are mainly caused by faecal contamination by bacteria such as *Salmonella*, *Campylobacter* and *Escherichia coli* 0157:H7. Animals carry these micro-organisms within their intestinal tracts and excrete them in faeces. Meat can be contaminated if some faeces are transferred to the meat (Tucker & Klepper 2005).

Faecal bacteria are resilient in a range of natural conditions. Microbial populations in faeces carried by cattle remain high even after cattle leave a feedlot (Wang & Makin 2001). If some faeces remain on the animals, meat contamination by these micro-organisms can occur during slaughter. Photograph 6 and Photograph 7 show how amounts of faeces can be present on feedlot cattle. Although a definitive causal relationship between reducing the pathogen load on-farm and reducing disease outbreaks has not been conclusively demonstrated for many pathogen-disease combinations (Isaacson et al. 2004), beef carcase contamination has been correlated with faecal pathogen shedding (Elder et al. 2000). However, Rowland et al. (1999) were unable to find a consistent association between dag loading and carcase microbiological levels.

Nevertheless, any reductions in pathogen numbers on the hides of cattle going to slaughter will be helpful in reducing the risk of meat contamination. Food safety is vital to consumer confidence and to protecting and growing markets for meat and meat products. It is important that meat and meat products from Australian feedlot cattle meet the highest possible food safety standards. Hence, it is important to ensure that the hides of cattle are visibly clean and also have low pathogen counts when presented for slaughter. There is a need to further investigate how this can be achieved by the use of suitable intervention strategies in the pre-harvest stage (Tucker & Klepper 2005).

The Australian standard covering this issue is the “Australian Standard for Hygienic Production and Transportation of Meat and Meat Products for Human Consumption” (Standards Australia 2002). AS 4696:2002 has a requirement that, at the abattoir, “reasonable steps are taken to present animals for inspection in a clean condition". The subjective nature of assessment means that cattle cleanliness standards vary between Australian processing works.

In response to these food safety concerns, cattle washing is now undertaken at many feedlots in Australia. Washing cattle prior to dispatch to processing works is carried out to prevent faecal contamination of carcasses. However, information and data on the amount of water used for this purpose in Australia is extremely limited. Debate is ongoing about its efficacy in removing dirt and dags from the animal. Some lot feeders believe that no amount of washing will remove all residues from the animal, leaving manual shearing as the only option.

PHOTOGRAPH 6 – DAGS ON FEEDLOT CATTLE

Photograph 7 – Close-up of dags on a feedlot steer

3.4.1 Current Industry Practices

Tucker & Klepper (2005) conducted a survey of ten feedlot operators, as well as a specialist feedlot nutritionist and a specialist feedlot veterinarian to gain information on pre-harvest pathogen intervention strategies used in the Australian lot feeding sector. Of the feedlots surveyed, between 1% and 40% of total cattle are subject to intervention strategies aimed at reducing hide contamination of cattle ready for dispatch to meat processing plants. Intervention strategies are generally carried out a short time (1 day – 1 week) prior to cattle dispatch and they include:

- Washing
- De-dagging by mechanical means
- Supplying additional bedding materials (rice hulls)

Factors that determine the necessity of implementing intervention strategies include:

- Varying inspection standards at different meat processing facilities
- Climatic conditions (wet conditions mean muddier pens)
- Pen cleaning management (clean pens mean cleaner cattle)
- Breed of animal; British (*Bos taurus*) cattle have longer coats and form more dags than shorter haired Brahman / Brahman cross (*Bos indicus*) type cattle

3.4.1.1 Cattle Washing

By far, the most common intervention strategy employed by lot feeders to reduce hide contamination is cattle washing. PHOTOGRAPH 8 shows the interior of a cattle wash. PHOTOGRAPH 9 is a close up of flooring, pipe work and the drain from a cattle wash. PHOTOGRAPH 10 shows the soaking stage of cattle washing. PHOTOGRAPH 11 shows a wastewater sump from a cattle wash.

Cattle washing systems can be automated or manual, or a combination of both. Washing typically involves a soaking phase followed by a high-pressure washing phase. During soaking, groups of 30-150 cattle are exposed to belly sprays for between ½ hour and 8 hours in soaking yards. This process softens dags and reportedly results in minimal stress to the animal. The cattle are then manually hosed with high-pressure hoses for up to 100 minutes, depending on the amount of soaking, or yarded into a high-pressure pen fitted with belly, and wall sprays delivering water at high pressure for 20-30 minutes. Sometimes cattle are washed first in the high-pressure pen and then manually with a high-pressure hose.

Using a high-pressure hose on cattle can cause bruising and stress to the animal. Several lot feeders are concerned that washing stresses the cattle and reported that it reduces meat quality (through increased dark cutting). One operator claimed that washing cattle in a race and crush resulted in 70% dark meat (Tucker & Klepper 2005).

A greater percentage of outgoing feedlot cattle need to be washed during the wet season when there is more wet manure to form dags. In southern Australia, the rainfall is winter dominant. The cold temperatures that occur during the peak washing season in southern Australia raise concerns about cattle welfare and stress. Some feedlots also wash cattle at night when temperatures may be even cooler.

Some lot feeders have the capacity to recycle cattle wash water. This reduces the total clean water requirement for washing. Some use treated effluent for cattle washing. The use of recycled wash water may promote cross contamination, however is predominantly used soaking with clean water used for final washdown.

Some lot feeders are proposing to invest in a system that allows water to be reused, as well as heated. This may reduce animal stress resulting in improved meat quality. Some operators have used or are considering using surfactants such as soap in wash water to assist in the softening of dags (Tucker & Klepper 2005).

The cattle most affected by hide contamination and dag formation are British breeds (*Bos taurus*) commonly found in areas with a winter dominant rainfall pattern. Short haired cattle (*Bos indicus*) typically found in northern Australia require less washing as dags form less readily on their short coats.

Currently there is research underway to assess the viability of applying an enzyme to cattle prior to dispatch. Preliminary work on hides is very promising in removing dags. However, tests are yet to be conducted on live cattle. As well, the cost and logistics of sourcing and applying the enzyme to ensure efficacy requires development (Tucker & Klepper 2005).

Photograph 8 – Interior of a feedlot cattle wash showing ground mounted belly sprays

Photograph 9 – Flooring, pipe work and drain of a feedlot cattle wash

Photograph 10 – Soaking stage of cattle washing

Photograph 11 – Cattle wash wastewater sump

The volume of water used to wash cattle will depend on the number of dags on the cattle, the cleanliness standard required at the processing plant, number of cattle washed and level of wastewater recycling implemented. No published literature was found giving information on the amount of water used to wash cattle. An estimate can be made using anecdotal evidence for lot feeders. One feedlot manager washes cattle in groups of about 32 x 700 kg head. The flow rate is 3.8 L/s (3000 GPH). This is a relatively low flow rate so he holds the cattle in the pen for 4 hours. This is a total volume of about 54,400 L or 1700 L per head. All of this water is clean water as no wastewater recycling is used. However, cattle washing is not required all year round. This feedlot manager estimates that he only washes 25% of outgoing cattle. For the number of cattle turned off from this feedlot per year, this is equivalent to 1.2 L/hd/day. Other managers use higher flow rates, shorter holding periods and wash different proportions of cattle turned off. All of these parameters affect the volume of water used for cattle washing. Another important variable is the ability to recycle wash water. If, say, 80% of the washing water is recycled back to the cattle wash, then this significantly reduces the demand for clean water (Davis & Watts 2006).

3.4.1.2 Other intervention strategies

Some lot feeders are, or have tried, scraping cattle in conjunction with hosing to remove dags. Both these methods may be dangerous to operators. A Western Australian feedlot undertakes shearing of cattle to remove dags a few days before dispatch. After shearing, cattle are returned to boggy pens but, with short hair, they don't collect further dags before shipment. The shearing process costs approximately $15/head, and also raises occupational health and safety issues (Tucker & Klepper 2005).

Rockdale Feedlot in south-western New South Wales uses the Rockdale Robotic Dag Removal System to pull dags from cattle. Dedagging takes about 60 minutes to do 40 head. This method only works on dry dags, otherwise washing is needed. Further details are provided in Rowland et al. (1999).

Photograph 12 – Cattle shears used for dag removal at a Western Australian feedlot

Another option to reduce the number of dags involves the inclusion of oils in feed to produce more oily coats which appears to reduce the hold that dags have on the hair, allowing them to be more readily removed (John Doyle pers. comm.). One feedlot in southern Australian uses bedding in pens holding cattle that will go out during the wet winter period. The bedding mixes with the manure keeping the dags soft, allowing for ready removal. This feedlot also holds washed cattle in bedded pens to prevent them from getting dirty prior to shipment (Tucker & Klepper 2005).

Taking cattle off feed or altering diets before dispatch is not commonly practiced as the stress affects meat quality. In addition, dietary changes to reduce faecal shedding are not supported by industry as these may not have the desired effect and may also reduce cattle performance (John Doyle pers. comm.). The use of feed additives to control pathogens does not commonly occur in Australian feedlots (Tucker & Klepper 2005).

3.5 Administration

Administration water usage has been defined as that used in staff amenities (office, staff accommodation, etc) and for maintaining lawns and gardens around the feedlot facility. The amount of water used in staff amenities and grounds maintenance is often negligible when compared to the major use activities such as cattle drinking water, feed preparation and cattle washing. However, on average, each member of staff may consume about 150 L of water per day through toilet flushing, washbasins and kitchen and laundry uses. A rule-of-thumb guide for the number of staff required for a feedlot is 1.2 persons per 1000 head of capacity. Hence, the water used by staff is equal to 0.18 L/head/day. When compared with drinking water estimates in the order of 65 L/head/day, this equates to less than one percent of the total water usage. Watering of lawns and gardens will be primarily be determined by the environmental conditions at the time, the available water supply and the visual amenity requirements of feedlot management.

3.6 Sundry Water Uses

Water is also used at cattle feedlots in a number of minor water use activities. These may include:

- Trough cleaning
- Evaporative Losses from holding storages (troughs, ring tanks, turkey's nests)
- Cleaning – Hospital, Receival/dispatch, Feed Processing
- Vehicle washing
- Dust control in pens on roads
- Drinking water for horses or other stock

Whilst categorised as minor uses, their value should not be ignored in assessing their effect on the total water supply and their usefulness in managing sustainable water usage.

Trough Cleaning
Water losses at troughs occur from water lost (dumped) during trough cleaning, evaporation from the air-water interface and sundry pipeline or float fault leakages.

Parker et al. (2000) measured water usage over a two-year period at a 50,000-head beef cattle feedlot in the Texas High Plains. Cattle types, mean liveweights and dry matter intakes were not reported. For a three-day period representing summer conditions, an average of 3.1 L/head/day was measured for trough leakage. This usage represented 6.98% of the total daily water use. In winter, over a three-day period, the measured water usage was 51.8 L/head/day, with trough overflow measured at 16.4 L/head/day (31.68%).

The high trough overflow usage is an intentional flow of water used to prevent freezing of the water troughs. Clearly, this would not apply in Australian feedlots.

There are no published data on similar measurements that have been made in Australia, but estimates could be made. Consider a 10,000 head feedlot near Dalby on the Darling Downs. As a general rule of thumb, 30 mm of water trough length is required per head of cattle in the pen (Skerman 2000). Hence, for a 150 head pen, it would be typical to have a single water trough that is 4.5 m long and 0.5 m wide (PHOTOGRAPH 13). The surface area of the water trough would be 2.7 m^2 and the volume would be approximately 390 L.

It can be assumed that the water troughs are cleaned at least once a week. During cleaning, the whole volume of the trough is dumped (~ 390 L) and the system flows vigorously (at 1.0 L/s) for 1 - 2 minutes. In this scenario, the estimated water loss is about 500 L for each trough per cleaning event. Over a whole year, this equates to 26,000 L per trough. At 100% occupancy, this is 0.47 L/head/day.

Data collected by Sanders et al. (1994) indicated that losses during trough cleaning were typically between 144–324 L with an average of 236 L per trough per cleaning for a 220 L trough. In this case, the troughs were cleaned twice per week and therefore losses over a whole year, equate to approximately 24,500 L per trough. The pen capacity was 240 head, therefore at 100% occupancy losses due to trough cleaning were 0.28 L/head/day.

Losses associated with trough cleaning are therefore primarily a function of trough capacity and cleaning frequency, with larger capacity troughs having higher annual losses than smaller troughs (Davis & Watts 2006).

Considering the literature and using the estimates described, water loss through trough cleaning is expected to range from 0.28-0.47 L/head/day. However, Parker et al. (2000) report a minimum loss of 3.1 L/head/day, which is more than six times higher than this estimate.

Photograph 13 – Typical water trough used at an Australian feedlot*

*Note: Overflow pipe to cater for faulty float valves and the brush beside the water trough used to clean algae and grain from the trough.

Evaporative Losses

Evaporation is the transfer of water, as water vapour, to the atmosphere from vegetated or non-vegetated sources. In the context of this report, it is the transfer of water from open storages and troughs. Evaporative losses could be a significant source of loss depending on the area of open storages, particularly in the summer months, corresponding to the period when demands for water are greatest.

It is usual practice at feedlots to deliver water from the source to a buffer storage adjacent to the feedlot. Typically, these storages will hold a few day's supply of drinking water and allow gravity flow of water throughout the facility. This provides security of supply should there be a major breakdown in a pump or pipeline coming from a bore, river or irrigation channel. Typically, some 5-20 days water supply is kept on hand. This is often stored above ground in a turkey's nest storage (PHOTOGRAPH 14) although enclosed steel or concrete tanks are sometimes used (Photograph 15) (Davis & Watts 2006).

Photograph 14 – Turkey's nest water storage

PHOTOGRAPH 15 – ENCLOSED CONCRETE WATER STORAGE TANK

For an open storage, some water is lost by evaporation. The net evaporation loss can be estimated as:

E = Open water pan coefficient (K_{OW}) x pan evaporation (E_P) less rainfall (P) *Eqn 8*

The evaporation loss for Dalby (for example) could be estimated as follows. Mean annual pan evaporation is approximately 2000 mm and mean annual rainfall is approximately 600 mm. Using the open water pan coefficient developed for several sites in Queensland by Weeks (1983), the K_{OW} value for Dalby would be 0.74 (Weeks 1983). Thus;

E = (0.74 x 2000 – 600) mm/yr
= 880 mm/yr

For a 10,000 head feedlot, 7 days of temporary storage is approximately 5 ML. A turkey's nest storage of this capacity would have a surface area of about 1600 m^2. Hence, with a net evaporation loss of 880 mm per year, this represents 1.40 ML/yr or 3850 L/day on average. This is about 0.4 L/head/day, which is a minor water loss compared to a drinking water intake in the order of 65 L/head/day.

Similarly, for water troughs, water is lost through evaporation from the air-water interface. Parker et al. (2000) found an average of 0.02 L/head/day for evaporation from troughs for a three-day period representing summer conditions at a 50,000 head feedlot in the Texas High Plains. This usage represented 0.05% of the total daily water use. In winter, over a three-day period, the measured water usage was 51.8 L/head/day, with evaporation contributing 0.02 L/head/day or 0.04% of the total water usage.

No similar measurements have been made in Australia but estimates could be made. Using the same example of a 10,000 head feedlot near Dalby on the Darling Downs with water troughs measuring 4.5 m long and 0.5 m wide, giving a surface area of 2.7 m^2. A conservative assessment of the evaporation loss would be to assume that the loss is equal to pan evaporation – the water trough being of similar volume and depth to a Class ‘A’ pan – and that there is no net replenishment from rainfall (rainfall overtops the water trough). Hence, the annual evaporation loss would be 2000 mm/year or 5400 L from the trough. This is equivalent to 0.10 L/head/day assuming that the pen is full all year round. This loss is five times higher than that presented by Parker et al. (2000) but, as discussed in Section 4.2.2, water troughs in the US are often smaller in surface area to reduce the likelihood of freezing.

Cleaning

A number of facilities within the feedlot are cleaned down on an as-needed basis as part of hygiene management strategies. These include feed processing areas, hospital, induction and dispatch areas. These areas are cleaned to control pests and vermin, disease and workplace health and safety issues. The feed processing area is cleaned of spilt and spoilt grain as-needed. The hospital is cleaned daily to remove manure and other wastes in order to minimise disease spread and provide a clean working environment for staff. Induction and dispatch facilities are generally cleaned once per week or on an as-needed basis depending on throughput.

Cleaning is a manual process that generally involves one to two staff members with a pressurised hand-held hose. Cleaning time depends on area to be cleaned, cleanliness to be achieved and number of staff/hoses available. Hence, the volume of water used is dependent on hose flow rate, number of hoses and cleaning time.

Vehicle Washing

Vehicle washing is another important hygiene and maintenance management practice. Feed trucks, mobile machinery and vehicles are cleaned on as-needed basis. Typically, dust/dirt, grease and oil are removed.

Cleaning is a manual process that usually involves only the machinery operator with a pressurised high-pressure low-volume (Gerni) or low-pressure high-volume hand-held hose. Cleaning time depends on the size and dirtiness of equipment and level of cleanliness to be achieved. Hence, the volume of water used is dependent on hose flow rate and cleaning time.

Dust control

Dust from feedlots can be a nuisance during hot, dry periods. Dust from pens, alleys, and roads can annoy neighbours, possibly impair cattle performance, irritate feedlot employees and become a workplace health and safety issue with respect to the movement of mobile plant and equipment (Sweeten 1982).

Dust can be generated from a number of sources in the feedlot. The feed mill, feed and access roads and the cattle pens are the primary and most significant sources of dust. Secondary sources such as collection, storage and spreading of manure on utilisation areas can also result in dust problems. In Australia, dust from the pen areas is controlled by cattle and manure management techniques (i.e. stocking density, removal of manure at optimum moisture) rather than application of water to the pen surface.

The most common and effective method of dust control on roads is the application of water. Typically, application is carried out with mobile units such as water tankers or water trucks in Australia (See PHOTOGRAPH 16). The application of water also aids in maintaining the integrity of the road surface and minimises potholes.

Dust suppression is undertaken on an as-required basis depending on climatic conditions. The majority of feedlots use clean water. However, effluent is sometimes used if available. A Queensland feedlot is known to capture stale trough water during trough cleaning into a tanker and utilise this for dust suppression on roads.

Mobile units used for dust suppression vary from two and half tonne trucks outfitted with 2,500 L tanks up to dedicated tankers with 25,000 to 40,000 L capacity. Typically, mobile units are fitted with pumps discharging water through a series of nozzles or a single spray nozzle at the rear of the tanker.

Photograph 16 – Dust suppression using a water tanker

4 Materials and Methods

4.1 Overview – Experimental Work

The objective of the project was to collect good-quality data on water usage and relate this to production parameters in feedlots so that the information could be used across Australia. To that end, it was necessary to ensure that the feedlots involved were representative and that reliable data could be obtained. The steps in the project were:

1. Select a range of feedlots across Australia that were representative of climatic zones, feeding regimes, management styles and cattle markets.
2. Review the design and management of these feedlots to select those where reliable data could be collected at a reasonable cost.
3. Select the preferred feedlots and complete negotiations at each site.
4. Design an instrumentation system for each feedlot.
5. Design a data collection system for each feedlot.
6. Undertake regular (monthly or fortnightly) data collection.
7. Undertake short-term detailed data collection for specific aspects of water usage.
8. Analyse and review the data.

4.2 Selected Feedlots

Following a lengthy process, eight feedlots were selected to provide a representative sample. TABLE 3 summarises the key characteristics of the selected feedlots. To maintain confidentiality, none of the feedlots are identified by name and will be referred to as Feedlots A to H.

The selected feedlots provide a range of climatic conditions from a northern feedlot in a hot, humid summer-dominant rainfall to southern feedlots in cooler, winter-dominant rainfall zones. FIGURE 4 and FIGURE 5 shows the mean monthly temperatures and monthly rainfall probabilities for Feedlot A respectively.

Feedlot A has a strongly summer-dominant rainfall with a reasonable probability of high rainfall in some months. It has warm to hot summers and mild winters. In summer, the maximum monthly temperatures range from 33 to 35°C. During winter, average maximum monthly temperatures range from 22 to 26°C with monthly minimum temperature around 8 to 9°C.

FIGURE 6 and FIGURE 7 shows the mean monthly temperatures and monthly rainfall probabilities for Feedlot H respectively. Feedlot H has a much lower and winter-dominant rainfall than Feedlot A. It has mild to warm summers and cool to cold winters. In summer, the maximum monthly temperatures range from 27 to 30°C. During winter, average maximum monthly temperatures range from 13 to 15°C with monthly minimum temperature around 4 to 6°C.

Grain processing methods vary from simple tempering to reconstitution and steam flaking. Some feedlots wash cattle (mainly in winter) while other feedlots do not undertake any cattle washing.

Feedlot D was not included in the water studies and Feedlot C was not included in the energy studies.

Table 3 – Characteristics of selected feedlots

Feedlot Name		A	B	C	D	E	F	G	H
Climate									
Mean Annual Rainfall	mm	577	582	403	641	679	831	640	716
Rainfall Pattern		Summer dominant	Winter dominant	Winter dominant	Summer dominant	Summer dominant	Uniform	Summer dominant	Summer dominant
Mean Annual Class A Pan Evaporation	mm	2372	1825	1788	1934	1934	1423	1934	1715
Mean Max Temp – January	°C	34.1	31.2	29.6	31.6	31.6	25.9	31.6	29.7
Mean Min Temp – June	°C	8.9	2.7	4.3	5.7	5.7	2.0	5.7	4.6
Feedlot Capacity and Design									
Licensed Capacity	head	>15000	>15000	>15000	>15000	>15000	>15000	>5000	>1000
Cattle Washing	% of turnoff	0	30	40	0	10	40	0	65
Feed Processing									
Grain Processing Method		Steam Flaked	Steam Flaked	Steam Flaked	Reconstitution	Reconstitution	Steam Flaked	Steam Flaked	Tempering
Main Energy Source		LPG	Natural Gas	LPG	Electricity	Electricity	Butane	LPG	Electricity

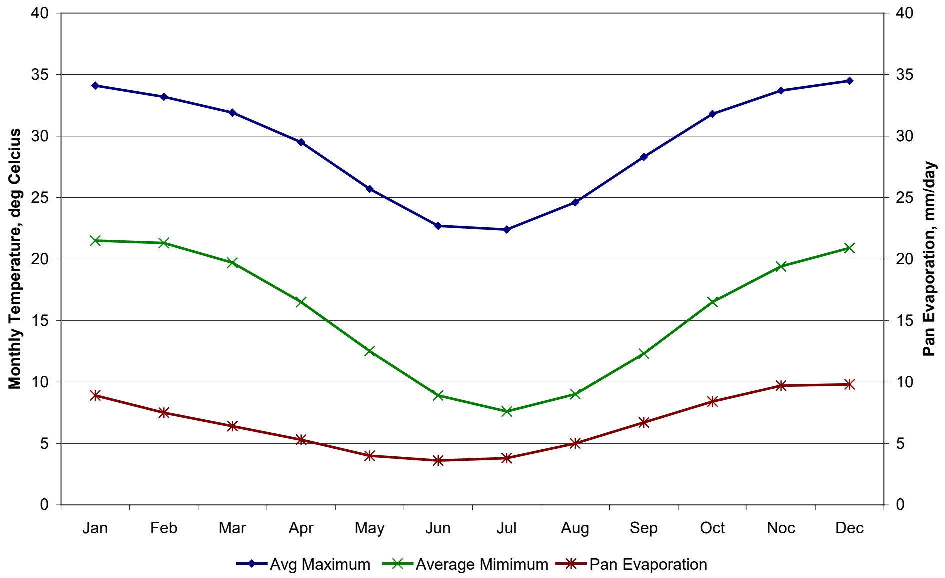
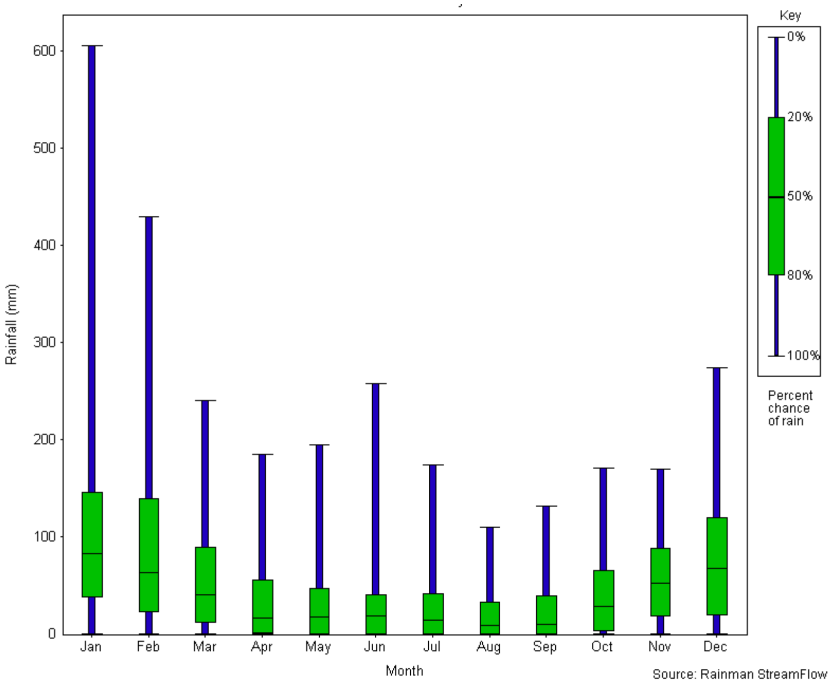


Figure 4 – Average monthly temperatures and pan evaporation for Feedlot A



Source: Rainman StreamFlow

Figure 5 – Monthly rainfall probabilities for Feedlot A

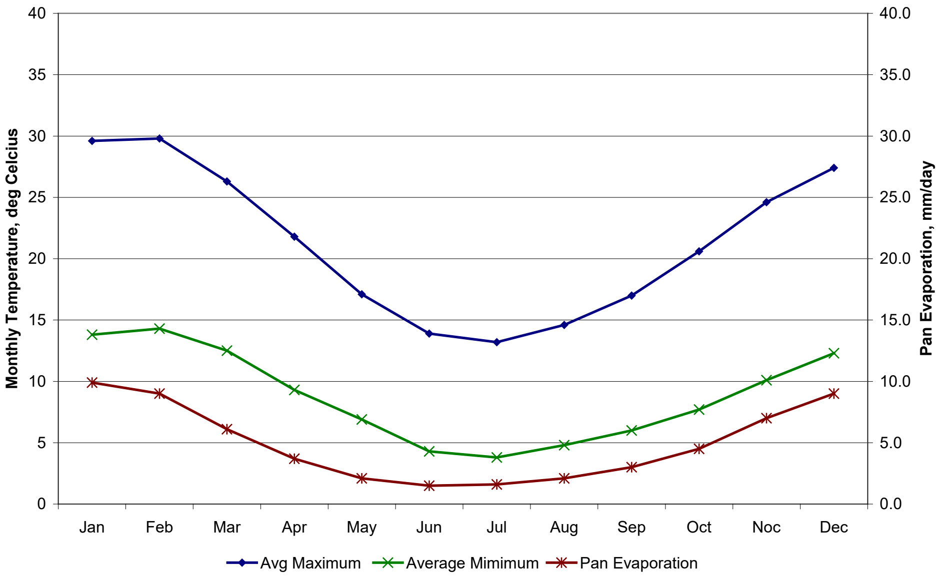


Figure 6 – Average monthly temperatures and pan evaporation for Feedlot H

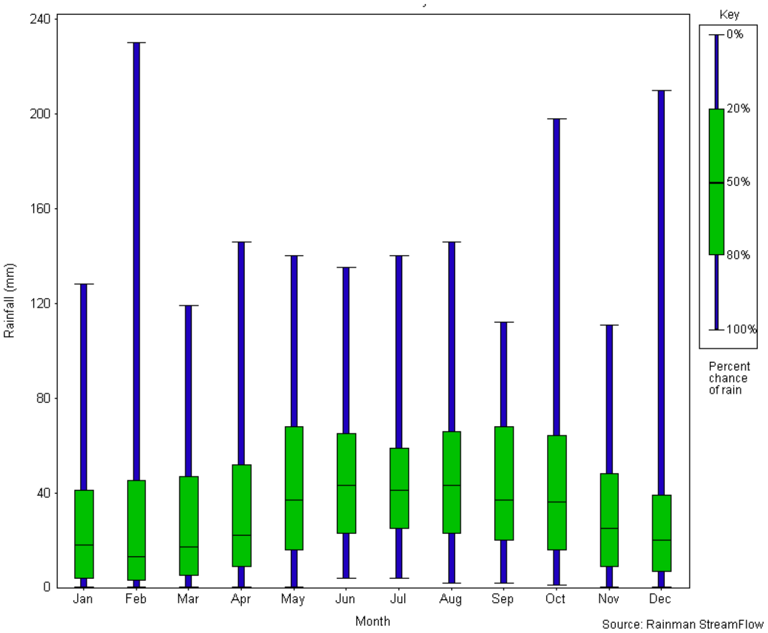


Figure 7 – Monthly rainfall probabilities for Feedlot H

4.3 Water Supply and Reticulation System Layouts

As part of the selection process, the water reticulation system layout at each feedlot was inspected and a flow chart prepared. FIGURE 8, FIGURE 9, FIGURE 10, FIGURE 11, FIGURE 12, FIGURE 13 and FIGURE 14 show the water reticulation systems for Feedlots A, B, C, E, F, G and H respectively. Feedlot D did not participate in the water usage studies.

The project needed to be able to measure total clean water usage at each feedlot (Focus Area 1 on each Water Reticulation System Layout) as well as the water usage in the main feedlot activities. The main areas of interest were:

1. Focus Area 2 - Pen Area
2. Focus Area 3 - Feed Processing
3. Focus Area 4 - Cattle Washing
4. Focus Area 5 – Administration

Water usage in the pen area is primarily cattle drinking water but can include other uses of water within the pen area. This could include:

- Trough cleaning
- Trough evaporation losses
- Hospital wash down
- Receival / dispatch facility washdown
- Vehicle washing
- Dust control
- Stables

Site-specific measurements were undertaken at each feedlot to quantify these additional water uses within the drinking water sector (see Section 4.8).

Any existing water meters were located and the required positioning of additional water meters was determined.

A gap analysis was undertaken to determine the quantity and type of water measurement instrumentation required to allow direct or indirect measurement of these major activities. This was undertaken in collaboration with the Condamine Electric Company (CEC), a company that specialises in irrigation installations.

In most cases, the water reticulation system at each feedlot was a complex layout. This is due to a number of factors including evolutionary design as the feedlot has expanded and developed over of time and a built-in redundancy factor. The redundancy factor allows water to flow to pens from more than one direction. Drinking water supply lines are usually ring line systems, making direct measurement very difficult.

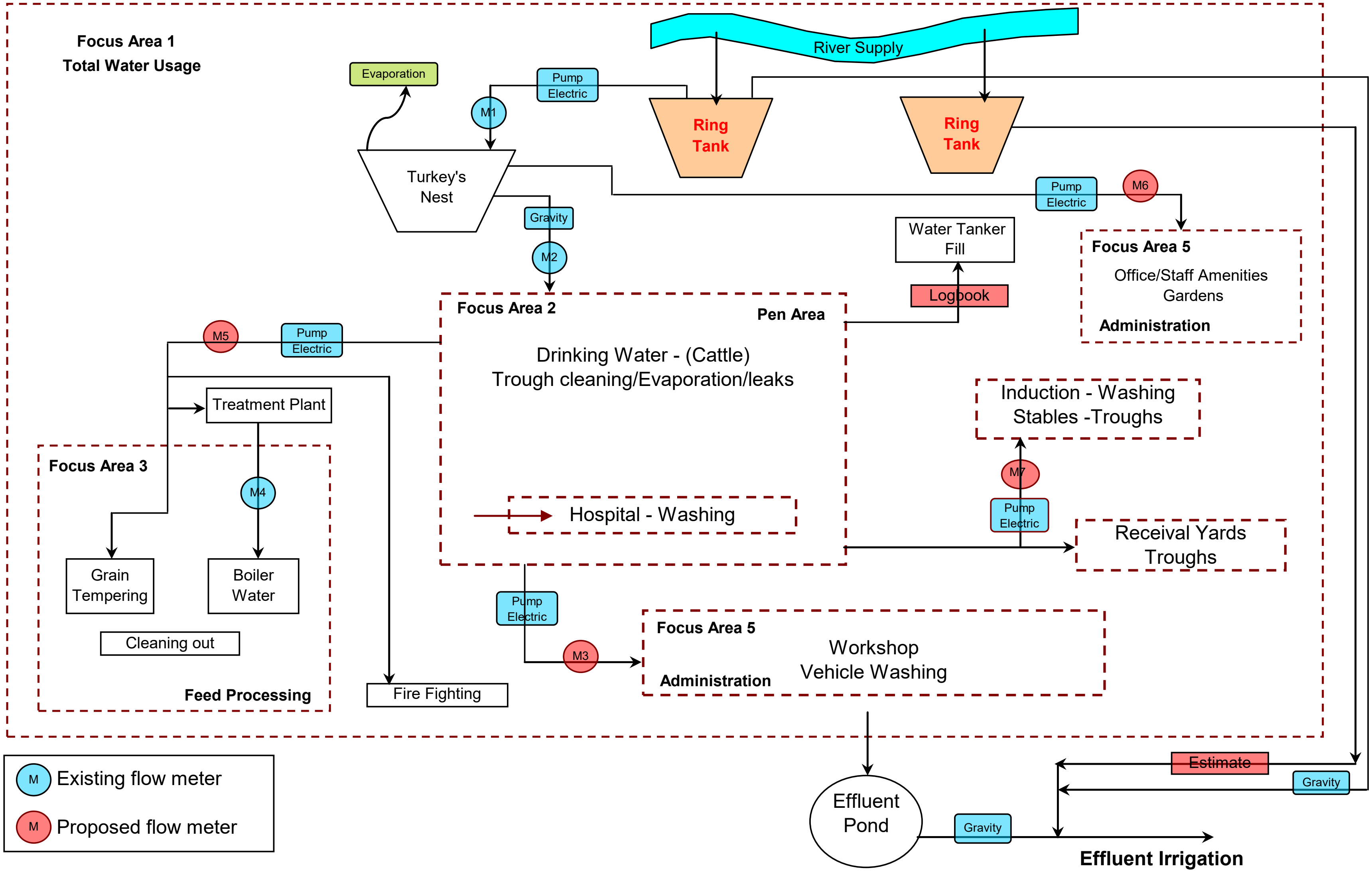


Figure 8 – Water system reticulation layout – Feedlot A

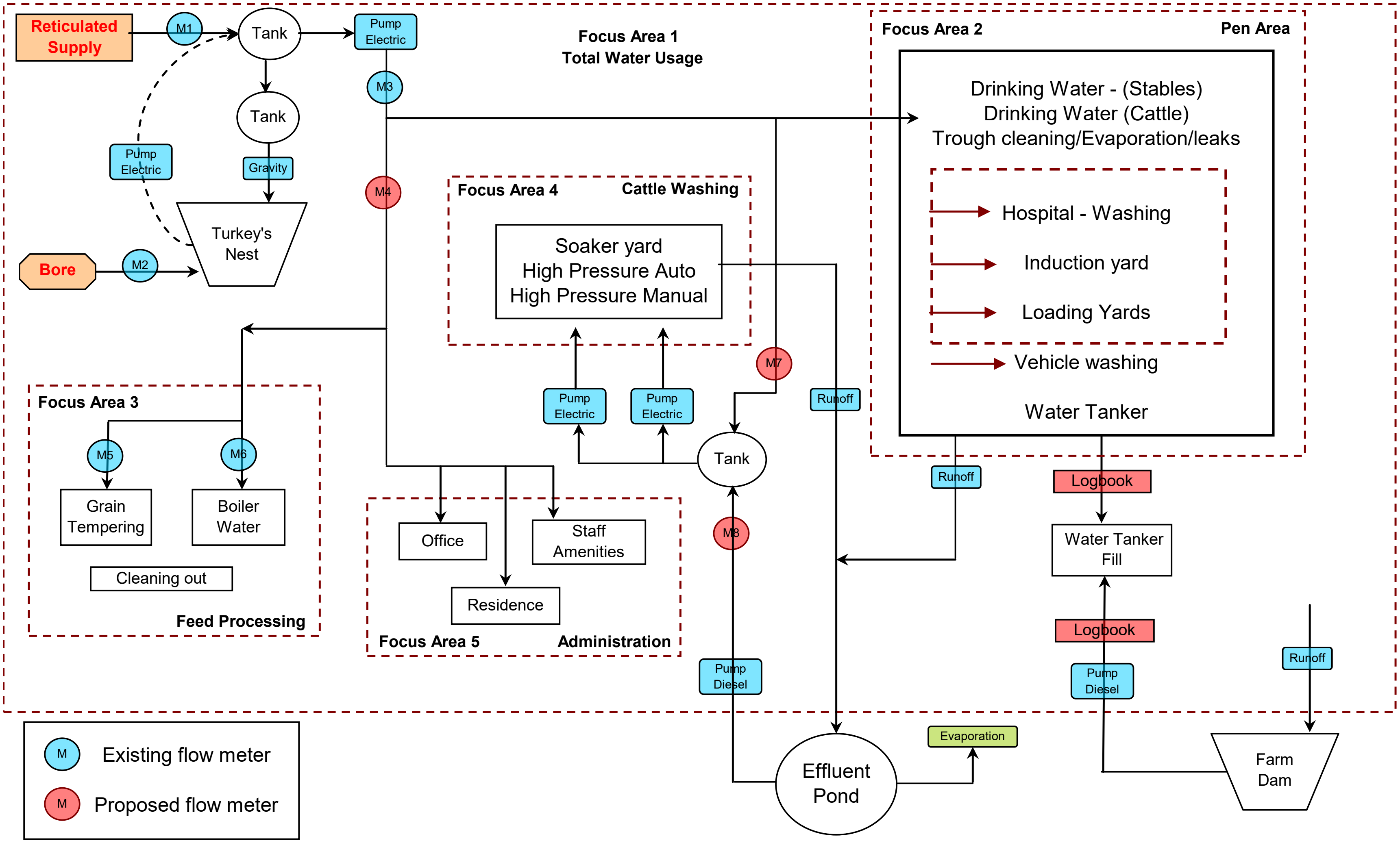


Figure 9 – Water system reticulation layout – Feedlot B

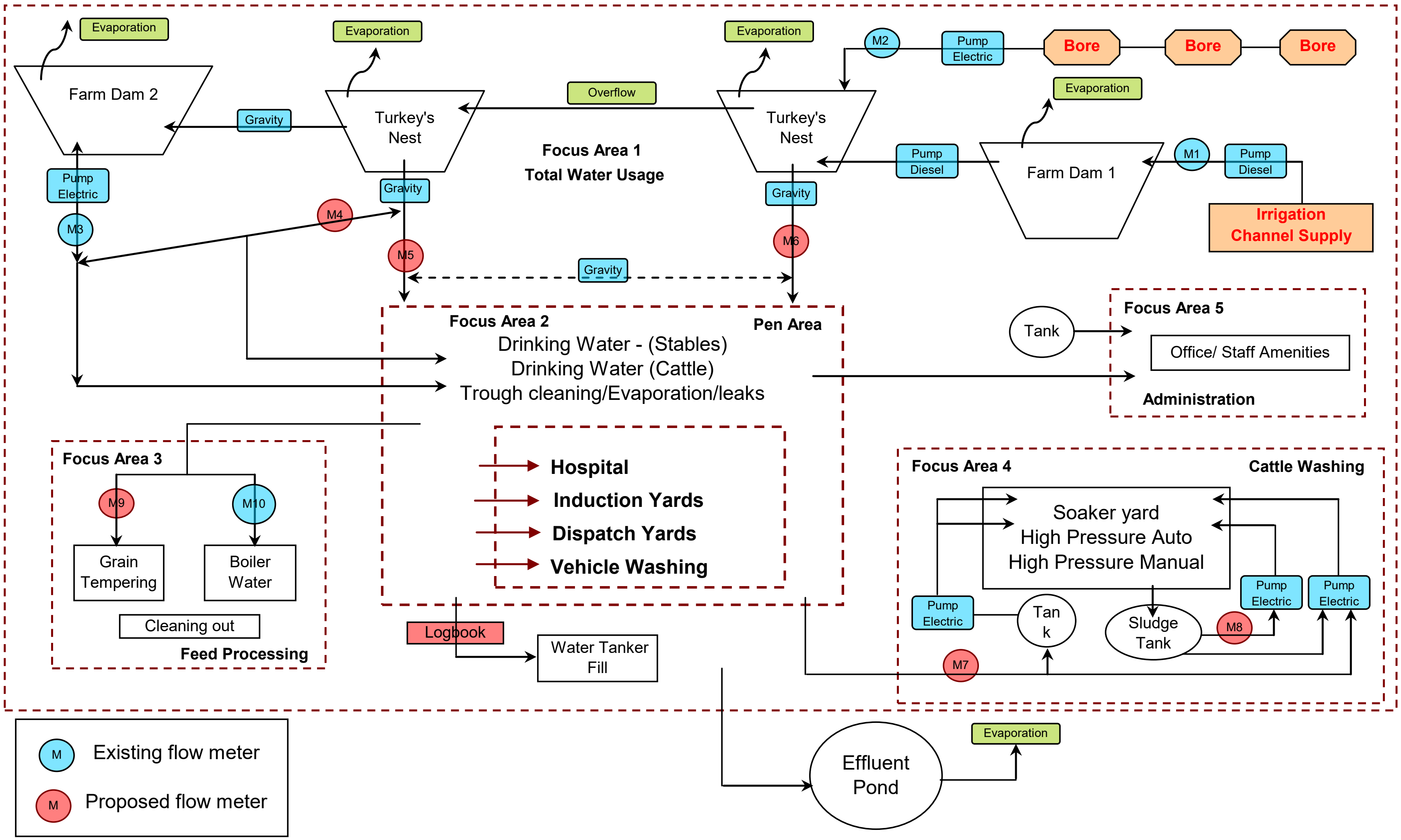


Figure 10 – Water system reticulation layout – Feedlot C

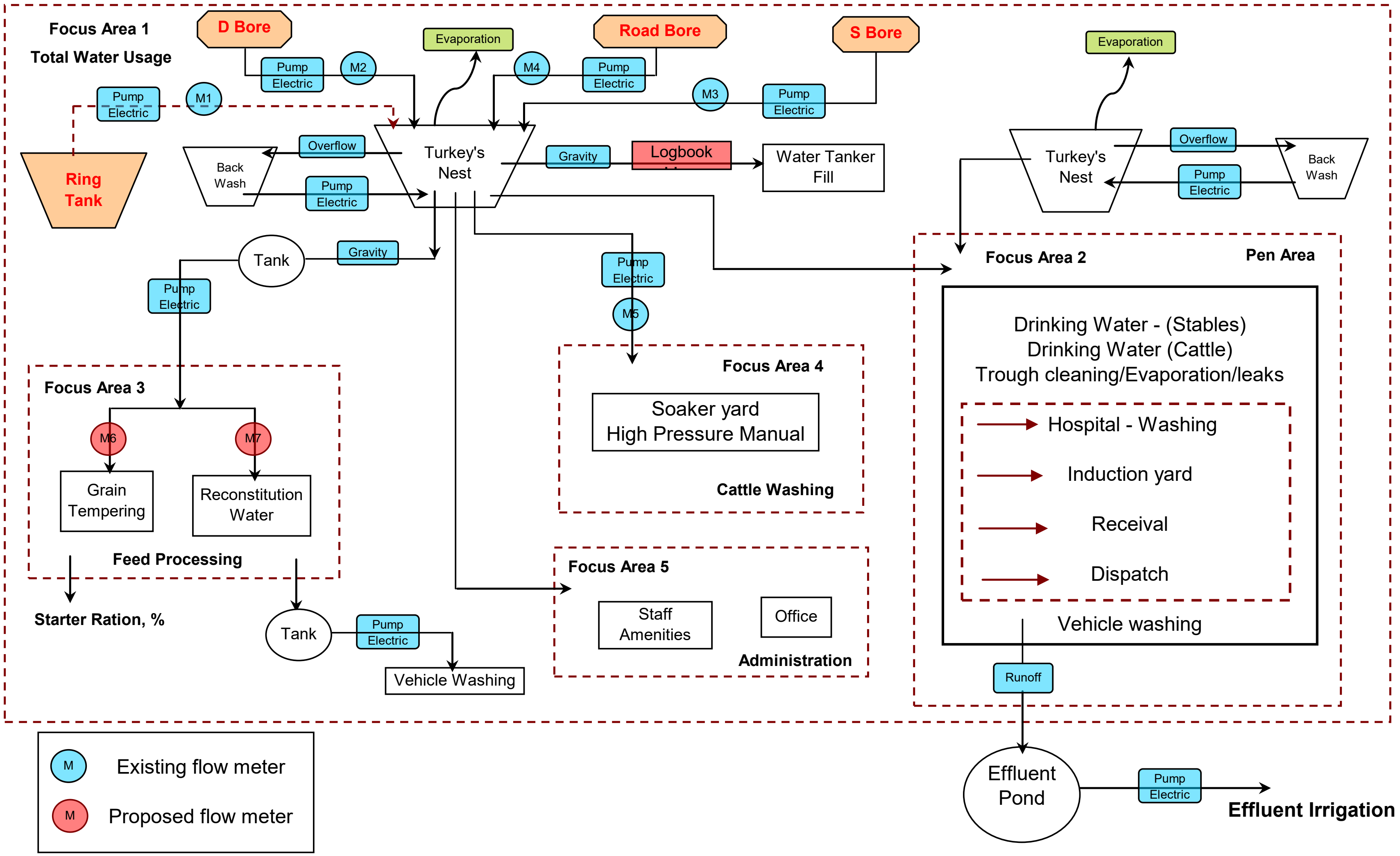


Figure 11 – Water system reticulation layout – Feedlot E

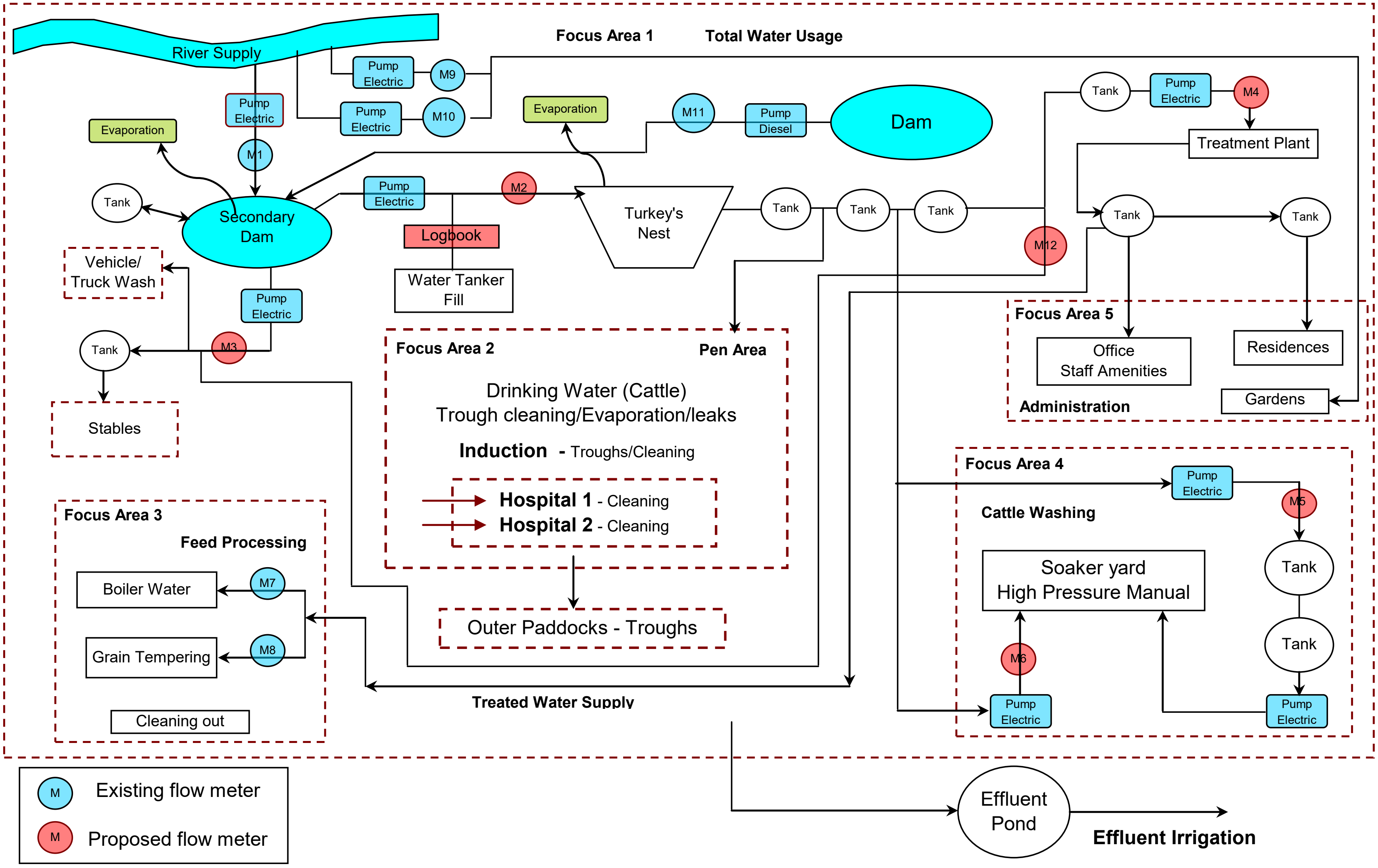


Figure 12 – Water system reticulation layout – Feedlot F

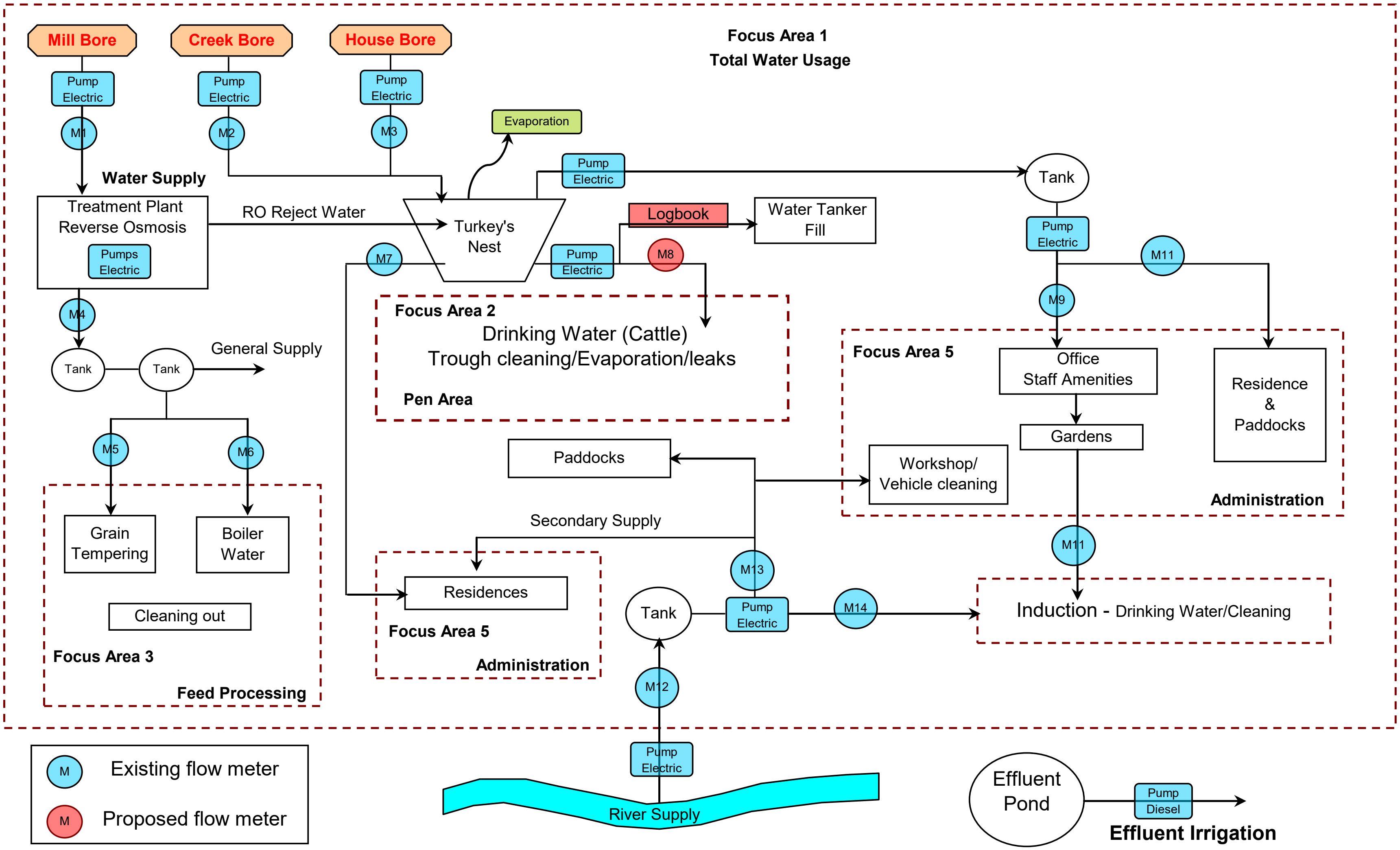


Figure 13 – Water system reticulation layout – Feedlot G

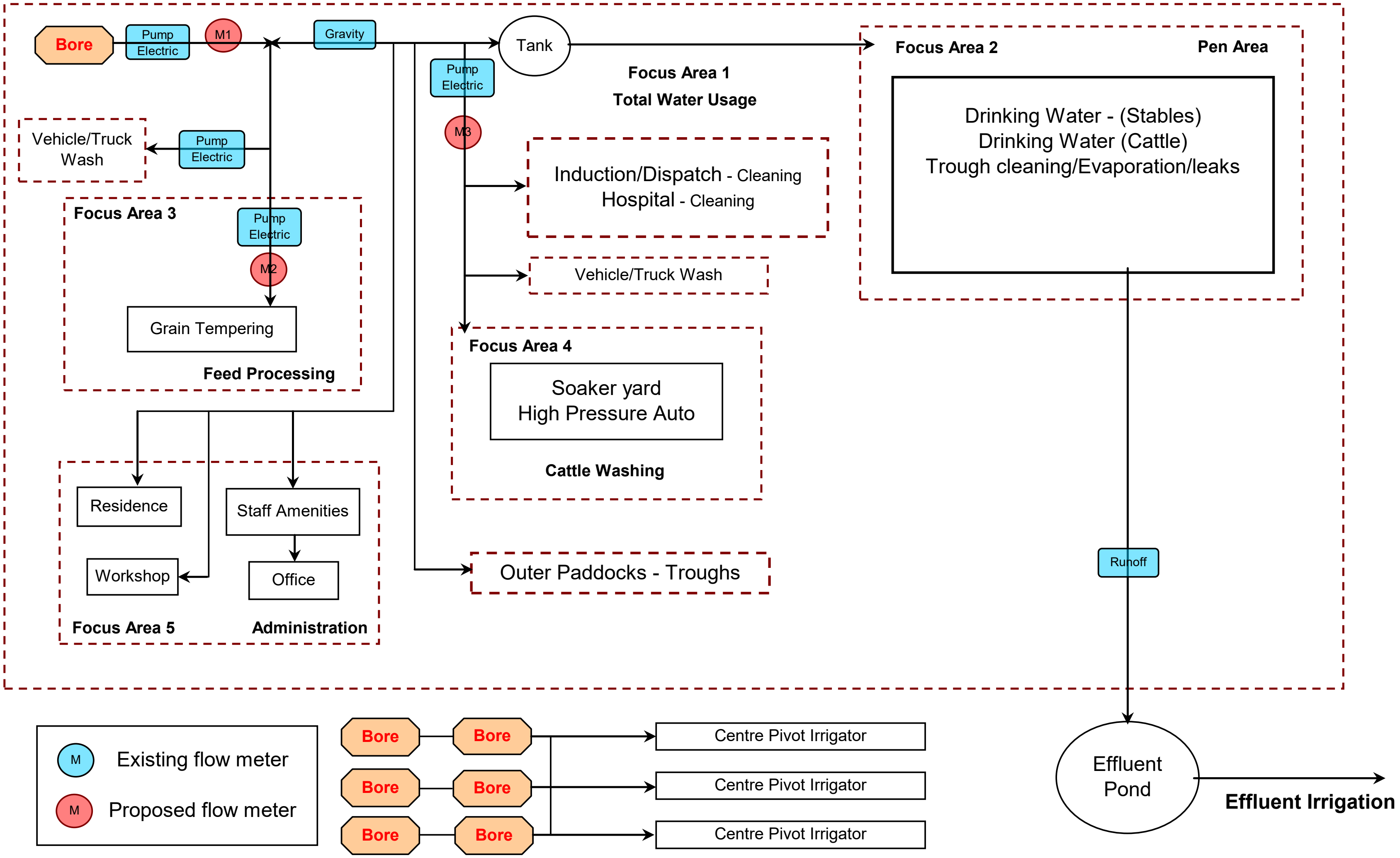


Figure 14 – Water system reticulation layout – Feedlot H

4.4 Water System Instrumentation

A local company, Condamine Electric Company (CEC), in consultation with FSA Consulting, selected a number of water meters suit the type of installation. The selection parameters included the size (diameter) and type of pipe work (poly, PVC, galvanised), pressurised or gravity flow, maximum, minimum and average flow rates and ease of installation. Water meters that best suited the individual installation and that were widely in use were selected.

CEC undertook a site visit to each feedlot and installed the water meters. This ensured a coordinated, standardised and timely installation of the instrumentation. Six types of water meters were selected. These included the ManuFlo AQUAMASTER^{TM}, ManuFlo MEH Multi-Jet, ManuFlo FRT, ManuFlo SW, MACE Rotaflo and ELSTER Helix. The following sections provide a brief overview of the specifications and capabilities of each type of water meter.

4.4.1 ManuFlo AQUAMASTER^{TM}

The AquaMaster™ is an electromagnetic flow meter capable of operating over a very wide flow range. The ManuFlo Aquamaster has fully bi-directional operation, that is forward and reverse pulses. Hence, forward and reverse flow along with net flow can be recorded. It offers reference meter quality performance with ± 0.4% of reading, being ideal for measurement of contaminated water (where conventional mechanical meters would block) in remote applications. With no moving parts, and an obstruction-less bore, this type of flow meter guarantees the highest level of performance, unaffected by specific gravity or viscosity variations, or the most contaminated of fluids, whilst maintaining a high degree of accuracy.

The ManuFlo Aquamaster meter is available for a pipe size range of 40, 50, 80, 100, 150, 200 and 250 mm and has flange mounting. The ManuFlo Aquamaster can operate reliably between minimum flowrates of between 318-5000 L/hr (q_{min}) and maximum continuous flowrates of 78000-1249800 L/hr (q_{max}) depending on the size of the meter. The maximum working pressure is 1600 kPa and accuracy of the meter at q_{min} is ±2% and at q_{max} is ±0.4%.

The ManuFlo Aquamaster LCD display is either integral head mounted to the sensor tube, or remote connected by a low voltage 2-metre signal cable. The ManuFlo Aquamaster is powered by two field replaceable internal Lithium batteries (2 x 3.6v) which have a life of up to 3 years and are provided in a compact IP65 Polycarbonate enclosure with moulded mounts.

The ManuFlo Aquamaster LCD display provides an instantaneous flowrate reading with a total display and resettable total display (PHOTOGRAPH 17).

Photograph 17 - ManuFlo Aquamaster water meter

4.4.2 ManuFlo MEH Multi-Jet

The ManuFlo MEH Multi-Jet flowmeters are suited to low and medium flows and ideally for measurement of gravitational flows or low-pressure applications (PHOTOGRAPH 18). They are a mechanical display meter. The meters are made with a brass/gunmetal casing and thermo-plastic working chambers. The meters are not approved for human drinking water applications.

The meters have a strainer on the inlet. Measurement is in the forward direction only. The register system operates by means of magnetic drive, and is sealed and separated from the water measurement system. Small impurities are able to be passed without blockage.

The ManuFlo MEH meter is available for a pipe size range of 15, 20, 25, 32 and 40mm and has brass coupling connectors. The ManuFlo MEH can operate reliably between minimum flowrates of between 42-300 L/hr (q_{min}) and maximum continuous flowrates of 3000 to 19800 L/hr (q_{max}) depending on the size of the meter. The maximum working pressure is 1000 kPa and accuracy of the meter between q_{min} and q_{max} is ±2.5%.

The MEH versions do not have the capability of a pulse output and have a mechanical display only. They measure flow in one direction only. Hence, the arrow on the meter body is to be in the same direction as the water flow when installed. For best results, the meter must be installed in a horizontal upright position only.

Photograph 18 – ManuFlo MEH Multijet water meter

4.4.3 ManuFlo FRT

The Manu FRT water meter incorporates a Rota Pulse Flow Sensor (RPFS) paddlewheel insertion type flowmeter and a FRT303 flowrate totaliser display.

With only one moving part and limited intrusion into the pipe and with its flow-through design, the RPFS allows accurate measurement of liquid flows with virtually no head loss.

Each of the four blades of the rotor (paddlewheel) extends approximately one centimetre into the flowing liquid. The sensor generates a square wave pulse with the frequency output proportional to flow velocity and proportional to pipe diameter. Magnets are not used in the RPFS models, thereby eliminating iron particles jamming the rotor. The alloy rotor used also makes the RPFS less susceptible to interference from turbulence and particles hitting the rotor, thereby giving superior flow results.

The ManuFlo RPFS is available for a pipe size range of 15, 20, 25, 32, 40, 50, 65, 80, 100 and 150 mm and inserts directly into a large range of pipe adapter fittings available in PVC, galvanised iron, brass, stainless steel or polypipe materials. The ManuFlo RPFS can operate reliably between minimum flowrates of between 330-32100 L/hr (q_{min}) and maximum continuous flowrates of 5400 to 540600 L/hr (q_{max}) depending on the size of the meter. The maximum working pressure is 1034 kPa and accuracy of the meter is ±1% for velocities between 0.7 to 7.0 m/s and ± 2.5% for velocities between 0.5 to 8.5 m/s.

The ManuFlo RPFS has a 2-metre lead that is connected to a ManuFlo FRT303 Flowrate Totaliser. The RPFS incorporates internal amplification, allows a pulse transmission up to 1000 metres to the receiver device.

The ManuFlo FRT303 provides an instantaneous flowrate reading with a resettable total display and grand total display (PHOTOGRAPH 19). The ManuFlo FRT303 is powered by a internal Lithium battery which has a life of up to 10 years and is provided in a compact IP65 Polycarbonate enclosure with moulded mounts.

Photograph 19 – ManuFlo FRT water meter and display

4.4.4 ManuFlo SW

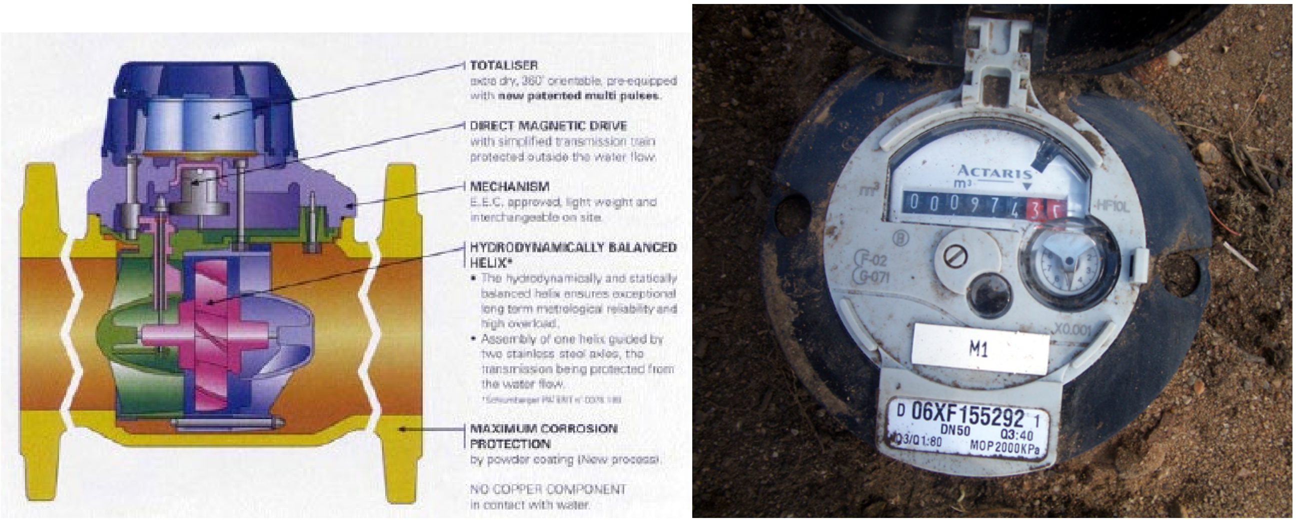
The ManuFlo SW is a medium capacity in-line turbine type meter suitable for moderate and sustained flows associated with bulk metering (PHOTOGRAPH 20).

The ManuFlo SW Woltex Turbine water meter operates on the velocity principle, where water enters the meter and drives the inner Woltex turbine rotor. A direct magnetic drive operates the counter register.

The ManuFlo SW is available for a pipe size range of 50, 65, 80, 100, 125, 150 and 200mm and has flange mounting. The ManuFlo SW can operate reliably between minimum flowrates of between 500-2500 L/hr (q_{min}) and maximum continuous flowrates of 48000 to 798000 L/hr (q_{max}) depending on the size of the meter. The maximum working pressure is 2000 kPa and accuracy of the meter at q_{min} is ±5% and at q_{max} is ±2%.

The ManuFlo SW also has an optional volt-free reed switch pulse output module with a 2 m lead that can be retro-fitted to the mechanical counter display. The pulse output can be connected to a range of external displays or electronic reading and recording by a logger.

The mechanical register can be rotated 360°, and is waterproof and vacuum-sealed to avoid condensation. The meters are pre-calibrated for a horizontal position. Installation of a strainer upstream of the meter is recommended to protect the hydraulics against raw particles. Straight pipe sections upstream (of length equal to 10x pipe diameter) and downstream (of length equal to 5x pipe diameter) are recommended to cancel the effects of any hydraulic perturbations.



Photograph 20 – ManuFlo SW Turbine type water meter

4.4.5 MACE Rotaflo

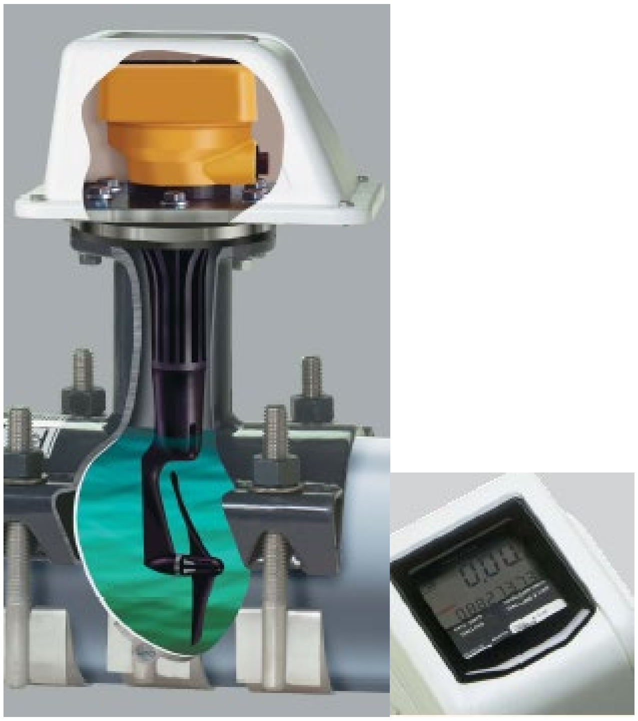
The MACE RotaFlo is a high-capacity in-line rotor type meter suitable for high and sustained flows associated with bulk metering (PHOTOGRAPH 21).

The Mace RotaFlo is suitable for a pipe size range of 150, 200, 250 and 300mm and mounts directly onto the pipe with the aid of dedicated saddle. The Mace RotaFlo can operate reliably between minimum flowrates of between 18000-72000 L/hr (q_{min}) and maximum continuous flowrates of 360000 to 1620000 L/hr (q_{max}) depending on the size of the meter. The maximum working pressure is 1034 kPa and accuracy of the meter between q_{min} and q_{max} is ±2%.

The Rotaflo provides accurate, repeatable data with a simple, single moving part design. As the rotor passes the base of the unit, an electromagnetic signal is transmitted from the rotor tip directly to the sealed pickup within the sensor. Based on this data, the Rotaflo calculates and displays, flow rate and total flow.

The design incorporates a ceramic bearing on the rotor for greater linear accuracy and longer wear life. The Rotaflo features innovative rotor design, snap-on rotor replacement, tamper-proof mounting, pulse output and only a single moving part. These qualities combine to create the RotaFlo's remarkably low cost of ownership.

The installation of a Mace RotaFlo is fast and simple and incorporates a ready and reliable calibration.



Photograph 21 – Mace Rotaflo water meter

4.4.6 ELSTER Helix H4000

The Helix H4000 is a high capacity in-line Woltmann helical rotary type meter with a precision injection moulded measurement mechanism suitable for high and sustained flows associated with bulk metering. The meter can be installed in horizontal, vertical or inclined pipelines.

The Helix H4000 is available in sizes from 40 to 300 mm and has flange mounting. The Helix H4000 can operate reliably between minimum flowrates of between 1-15 L/hr (q_{min}) and maximum continuous flowrates of 50 to 1500 L/hr (q_{max}) depending on the size of the meter. The maximum working pressure is 1400 kPa and accuracy of the meter between q_{min} and q_{max} is ±2%.

This meter has inherently low-pressure loss characteristics due to minimum restriction and no change in flow direction as water flows through the meter. In addition, generous length integral flow straightening vanes to negate the effect of non-ideal upstream flow conditions.

The measurement mechanism incorporates state-of-the-art features to give optimum long-term accuracy, extended wear life and reduced maintenance. The balanced rotor has a specific gravity of 1.0 to minimise bearing loads and reduce friction. This ensures that even the slightest movement of water will be translated to the rotor, giving improved flow sensitivity at low flows. The measurement mechanism has been specially designed to give the rotor a “thrust relief” effect as water passes through the meter. This, together with the use of jewelled rotor bearings plus tungsten carbide thrust pads and stub shafts, result in greater linear accuracy and longer wear life.

The Helix H4000 has a hermetically sealed register with kilolitres shown in a bold straight reading drum and pointers indicating litres. The “copper can” outer barrier and mineral glass lens ensure moisture is kept out to give clear, condensation free readings over the life of the meter, even in the most severe environments. The counter is protected by a robust housing and lid.

The Helix H400 has an opto-electronic pulse output which gives one pulse per litre for electronic reading. The pulse output is recorded by a Mace FloLog single channel logger.

The Mace FloLog has as standard 512k flash memory that is sufficient memory for two years data storage at 10 minute logging intervals. The logger includes a 3.6Volt lithium battery that is designed to last over 5 years. The logger records the data/time and counts the pulses between a user defined logging period. The data is then translated into user definable units.

The Mace FloLog is low cost, easy to use, robust and comes with free MACE FloCom software for downloading data.

Photograph 22 – Elster Helix H4000 water meter and Mace FloLog logger.

4.5 Feedlot Instrumentation

The following sections describe the installation of water meters at each feedlot.

4.5.1 Feedlot A Instrumentation

FIGURE 8 shows the water supply system layout and location of the water meters installed at Feedlot A.

4.5.1.1 Meter No – M3

This meter was located to measure the water usage for the workshop and vehicle washing. This 50 mm diameter polythene pipe is pressurised, with a flowrate in the order of 12500 L/hr. A Manu FRT meter was selected. The meter was installed directly into a horizontal section of pipe with 50 mm saddle clamp mounted on the pipe. The display remotely mounted onto the side of the workshop. Flowrate in L/min and total flow in kL are shown on the display.

Photograph 23 – Installed water meter M3 at Feedlot A

4.5.1.2 Meter No – M5

This meter was located to measure the water usage for feed processing. This 50 mm diameter polythene pipe is pressurised, with a flowrate in the order of 12500 L/hr. A Manu FRT meter was selected. The meter was installed directly into a horizontal section of pipe using a 50 mm saddle clamp. The display remotely mounted onto the wall of the commodity shed. Flowrate in L/min and total flow in ML are shown on the display.

Photograph 24 – Installed water meter M5 at Feedlot A

4.5.1.3 Meter No – M6

This meter was located to measure the water usage for the main office, staff amenities and gardens. This 50 mm diameter polythene pipe is pressurised, with a flowrate in the order of 9500 L/hr. A Manu FRT meter was selected. The meter was installed directly into an inclined section of pipe using a 50 mm saddle clamp. The display is remotely mounted onto the wall of the pump shed. Flowrate in L/min and total flow in kL are shown on the display.

Photograph 25 – Installed water meter M6 at Feedlot A

4.5.1.4 Meter No – M7

This meter was located to measure the water usage for the induction facility and the stables. This 50 mm diameter polythene pipe is pressurised, with a flowrate in the order of 6000 L/hr. A Manu FRT meter was selected. The meter was installed directly into a horizontal section of pipe using a 50 mm saddle clamp. The display is remotely mounted onto a post of the induction facility. Flowrate in L/min and total flow in ML are shown on the display.

Photograph 26 – Installed water meter M7 at Feedlot A

4.5.2 Feedlot B Instrumentation

FIGURE 9 shows the water supply system layout and location of the water meters installed at Feedlot B.

4.5.2.1 Meter No – M4

This meter was located to measure the water usage for feed processing and administration. This 50 mm diameter polythene pipe is pressurised, with a flowrate in the order of 8000 L/hr. A Manu FRT meter was selected. The meter was installed directly into a 50 mm saddle clamp mounted on a horizontal section of pipe. The display is remotely mounted onto the wall of the main pump shed. Flowrate in L/min and total flow in ML are shown on the display.

4.5.2.2 Meter No – M7

This meter was located to measure the clean water usage for cattle washing. This 80mm diameter PVC pipe is pressurised, with a flowrate in the order of 8000 L/hr. A Manu FRT meter was selected as the most appropriate meter for this application. The meter was installed directly into an 80mm saddle clamp mounted on a vertical section of pipe. The display is remotely mounted wall of the supply tank. Flowrate in L/min and total flow in kL are shown on the display.

PHOTOGRAPH 27 – INSTALLED WATER METER M4 AT FEEDLOT B

Photograph 28 – Installed water meter M7 at Feedlot B

4.5.2.3 Meter No – M8

This meter was located to measure the recycled effluent water usage for cattle washing. This 80 mm diameter PVC pipe is pressurised, with a flowrate in the order of 5000 L/hr. A Manu FRT meter was selected as the most appropriate meter for this application. The meter was installed directly into a 80mm saddle clamp mounted on a vertical section of pipe. The display is remotely mounted onto the wall of the supply tank. Flowrate in L/min and total flow in kL are shown on the display.

Photograph 29 – Installed water meter M8 at Feedlot B

4.5.3 Feedlot C Instrumentation

FIGURE 10 shows the water supply system layout and location of the water meters installed at Feedlot C.

4.5.3.1 Meter No – M4

This meter was located to measure the feedlot water supply. This 150 mm diameter PVC pipe is gravity fed. A Manu Aquamaster meter was selected. The meter was installed directly into a horizontal section of pipe with flanged mounts. This meter is fully bi-directional, that is forward and reverse flow along with net flow are measured. Flowrate in L/min and total positive, negative and net flow in kL are shown on the display.

Photograph 30 – Installed water meter M4 at Feedlot C

4.5.3.2 Meter No – M5

This meter was located to measure the feedlot water supply. This 150 mm diameter PVC pipe is pressurised, with a flowrate in the order of 12500 L/hr. A Manu Aquamaster meter was selected. The meter was installed directly into a horizontal section of pipe using flanged mounts. This meter is fully bi-directional, i.e. forward and reverse flow along with net flow are measured. Flowrate in L/min and total positive, negative and net flow in kL are shown on the display.

Photograph 31 – Installed water meter M5 at Feedlot C

4.5.3.3 Meter No – M6

This meter was located to measure the feedlot water supply. This 150mm diameter galvanised pipe is gravity fed. A Mace RotaFlo meter was selected. The meter was installed directly into a horizontal section of pipe using a 150 mm saddle clamp. Flowrate in L/min and total flow in kL are shown on the display.

PHOTOGRAPH 32 – INSTALLED WATER METER M6 AT FEEDLOT C

4.5.3.4 Meter No – M7

This meter was located to measure the clean water usage for the cattle wash. This 100mm diameter PVC pipe is pressurised, with a flowrate range between 80,000-230,000 L/hr. A Manu Aquamaster meter was selected. The meter was installed directly into a vertical section of pipe using flanged mounts. Flowrate in L/min and total flow in m^3 are shown on the display.

Photograph 33 – Installed water meter M7 at Feedlot C

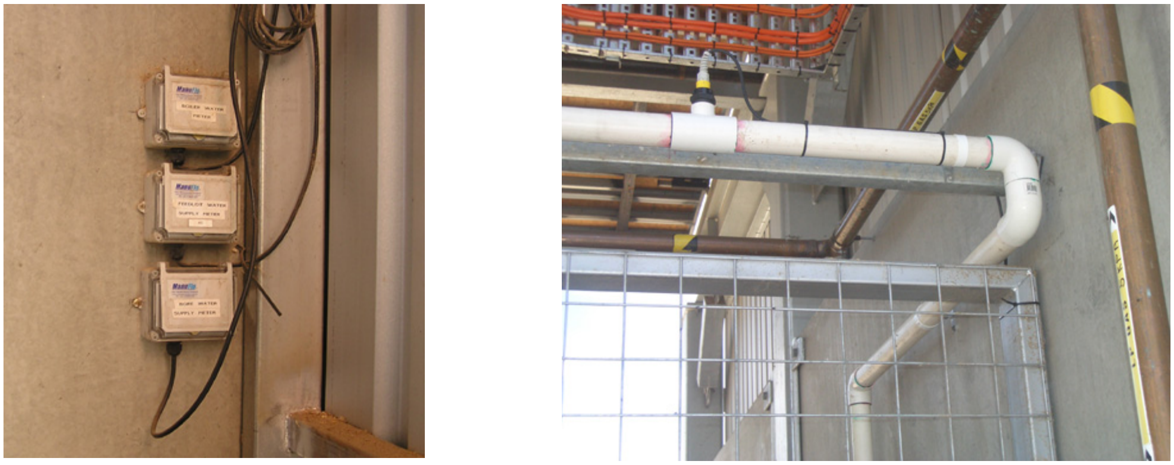
4.5.3.5 Meter No – M8

This meter was located to measure the recycled water usage for the cattle wash. This 100 mm diameter PVC pipe is pressurised, with a flowrate in the order of 80,000-100,000 L/hr. A Manu Aquamaster meter was selected as the most appropriate meter for this application. The meter was installed directly into a vertical section of pipe using flanged mounts. Flowrate in L/min and total flow in kL are shown on the display.

Photograph 34 – Installed water meter M8 at Feedlot C

4.5.3.6 Meter No – M9

This meter was located to measure the water usage for feed processing, specifically grain tempering water. This 50 mm diameter PVC pipe is pressurised, with a flowrate in the order of 9500 L/hr. A Manu FRT meter was selected as the most appropriate meter for this application. The meter was installed directly into a 50 mm PVC socket connection that was installed onto a horizontal section of existing pipe work. The display is remotely mounted onto the wall of the feed processing facility. Flowrate in L/min and total flow in kL are shown on the display.



Photograph 35 – Installed water meter M9 at Feedlot C

4.5.4 Feedlot E Instrumentation

FIGURE 11 shows the water supply system layout and location of the water meters installed at Feedlot E.

4.5.4.1 Meter No – M6

This meter was located to measure the water usage for feed processing specifically grain tempering water. This 50 mm diameter PVC pipe is pressurised, with a flowrate in the order of 35000 L/hr. A Manu FRT meter was selected. The meter was installed directly into a 50 mm PVC socket connection which was installed onto a horizontal section of existing pipe work. The display is remotely mounted onto existing steel framework. Flowrate in L/min and total flow in kL are shown on the display.

Photograph 36 – Installed water meter M6 at Feedlot E

4.5.4.2 Meter No – M7

This meter was located to measure the clean water usage for feed processing specifically grain reconstituting water. This 50 mm diameter PVC pipe is pressurised, with a flowrate in the order of 35000 L/hr. A Manu FRT meter was selected as the most appropriate meter for this application. The meter was installed directly into a 50 mm PVC socket connection that was installed onto a horizontal section of existing pipe work. The display is remotely mounted onto existing steel framework. Flowrate in L/min and total flow in kL are shown on the display.

Photograph 37 – Installed water meter M7 at Feedlot E

4.5.5 Feedlot F Instrumentation

FIGURE 12 shows the water supply system layout and location of the water meters installed at Feedlot F.

4.5.5.1 Meter No – M2

This meter was located to measure the water usage for the main feedlot supply. This 150 mm diameter galvanised pipe is pressurised, with a flowrate range in the order of 80000-230000 L/hr. A 150 mm Mace RotaFlo meter was selected. The meter was installed directly onto a horizontal section of pipe via a 150mm saddle clamp mounted on the pipe. Flowrate in L/min and total flow in ML are shown on the display.

Photograph 38 – Installed water meter M2 and data logger at Feedlot F

4.5.5.2 Meter No – M3

This meter was located to measure the water usage for the stables, vehicle/truck wash and treatment plant. This 50 mm diameter polythene pipe is pressurised, with a flowrate in the order of 12500 L/hr. A Manu FRT meter was selected. The meter was installed directly onto a horizontal section of pipe using a 50 mm saddle clamp. The display is remotely mounted onto the wall of the pump shed. Flowrate in L/min and total flow in kL are shown on the display.

Photograph 39 – Installed water meter M3 at Feedlot F

4.5.5.3 Meter No – M4

This meter was located to measure the water usage for the treatment plant. This 40 mm diameter PVC pipe is pressurised, with a flowrate in the order of 5500 L/hr. A Manu FRT meter was selected. The meter was installed directly into a 40 mm PVC socket connection that was installed onto a vertical section of existing pipe work. The display is remotely mounted onto the wall of the treatment plant shed. Flowrate in L/min and total flow in kL are shown on the display.

Photograph 40 – Installed water meter M4 at Feedlot F

4.5.5.4 Meter No – M5

This meter was located to measure the water usage during cattle washing. This location is the primary water supply for the cattle wash. This 50 mm diameter galvanised pipe is pressurised, with a flowrate in the order of 16000 L/hr. A Manu FRT meter was selected. The meter was installed directly into a 50 mm galvanised socket connection that was installed onto a vertical section of the existing pipe work. The display is remotely mounted onto the wall of the pump enclosure. Flowrate in L/min and total flow in kL are shown on the display.

Photograph 41 – Installed water meter M5 at Feedlot F

4.5.5.5 Meter No – M6

This meter was located to measure the water usage during cattle washing. This location is the secondary water supply for the cattle wash and is a 150 mm diameter PVC gravity fed pipe. A Mace RotaFlo meter was selected. The meter was installed directly into a horizontal section of pipe using a 150 mm saddle clamp. Flowrate in L/min and total flow in kL are shown on the display.

Photograph 42 – Installed water meter M6 at Feedlot F

4.5.5.6 Meter No – M12

This meter was located to measure the water usage of the treatment plant. This 25 mm diameter galvanised pipe is pressurised, with a flowrate in the order of 6000 L/hr. A Manu FRT meter was selected. The meter was installed directly into a 25 mm galvanised socket connection that was installed onto an existing vertical section of pipe work. The display is remotely mounted above the water meter on the same pipeline. Flowrate in L/min and total flow in kL are shown on the display.

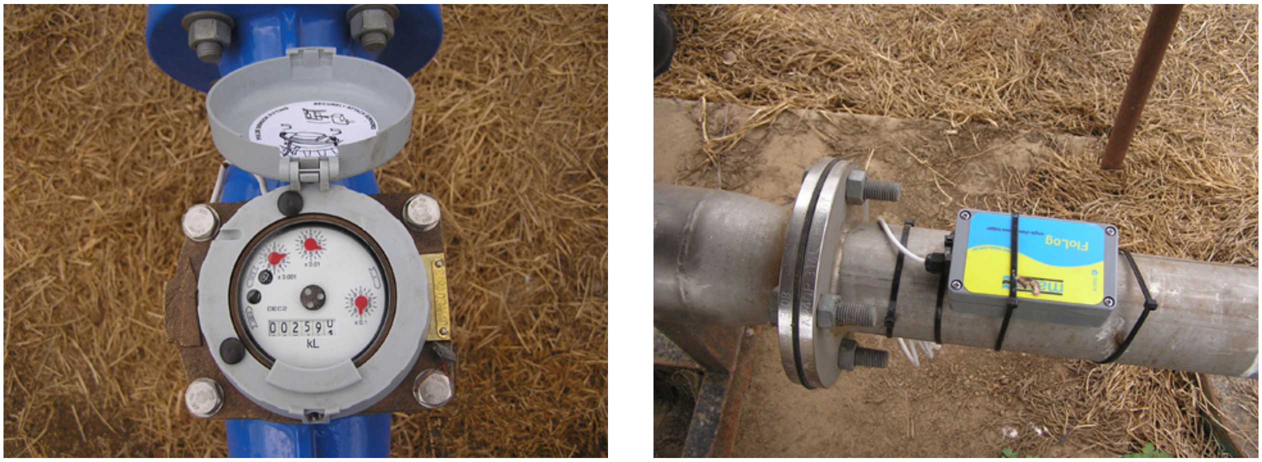
Photograph 43 – Installed water meter M12 at Feedlot F

4.5.6 Feedlot G Instrumentation

FIGURE 13 shows the water supply system layout and location of the water meters installed at Feedlot G.

4.5.6.1 Meter No – M7

This meter was located to measure the clean water usage within the pen area. This directly measures cattle drinking water consumption and associated losses with trough cleaning/evaporation etc. This 75mm diameter galvanised pipe is pressurised, with a flowrate in the order of 22500 L/hr. A Elster Helix H4000 meter was selected. The meter is mounted horizontally. The meter was installed with flange mounts into the existing pipe work and has electronic logging capabilities. The logger recorded the date, time and counted the pulses between a user defined logging period. It then translated the data into a flow rate and total flow per minute. The logger unit was remotely mounted onto the galvanised pipe within the pump house approximately 2 m from the meter. Total flow in kL is shown on the display.



Photograph 44 – Installed water meter M8 and data logger at Feedlot G

4.5.7 Feedlot H Instrumentation

FIGURE 14 shows the water supply system layout and location of the water meters installed at Feedlot H.

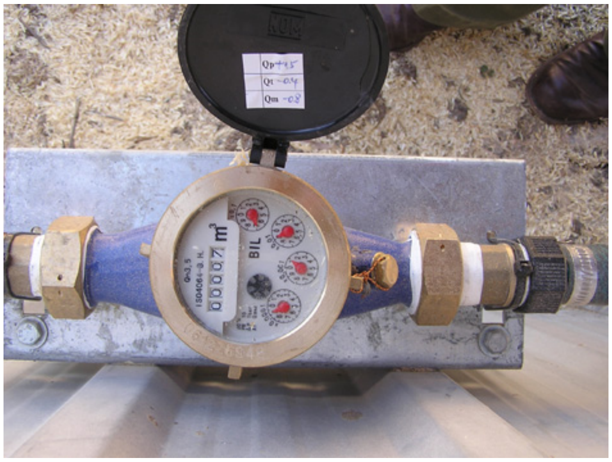
4.5.7.1 Meter No – M1

This meter was located to measure the total water usage for the feedlot. This 50 mm diameter polythene pipe is pressurised, with a flowrate in the order of 5500 L/hr. A Manu SW50 meter was selected as the most appropriate meter for this application. The meter is mounted horizontally with flange mounting directly into the pipe. The display shows total flow in m^3.

Photograph 45 – Installed water meter M1 at Feedlot H

4.5.7.2 Meter No – M2

This meter was located to measure the clean water usage for feed processing, specifically grain tempering. This 25 mm diameter PVC pipe is pressurised, with a flowrate in the order of 10000 L/hr. A Manu MEH25 meter was selected as the most appropriate meter for this application. The meter is mounted horizontally directly into the pipe. The display shows total flow in m^3.



Photograph 46 – Installed water meter M2 at Feedlot H

4.5.7.3 Meter No – M3

This meter was located to measure the water usage for cattle washing. This 50 mm diameter polythene pipe is pressurised, with a flowrate in the order of 15000 L/hr. A Manu FRT meter was selected as the most appropriate meter for this application. The meter is mounted in a vertical section of pipe. The meter was installed directly into a 50mm saddle clamp mounted on the pipe, with the display remotely mounted onto the processing shed corner post. Flowrate in L/min and total flow in kL are shown on the display.

Photograph 47 – Installed water meter M3 at Feedlot H

4.6 Monthly Water Usage Recording

As most of the water meters did not have any digital recording capability, each meter had to be read manually at the end of each period. The nominal period was monthly, however if the last day of the month fell on a weekend then the meters were read either prior too or at the earliest convenience after the last day of the month. Therefore, the nominal period varied from a minimum of 27 to a maximum of 33 days.

Each feedlot was given a recording sheet which detailed the meter number and location. The feedlot manager or a nominated staff member read the water meters. The reading along with the respective units either megalitres (ML), kilolitres (kL) or cubic metres (m^3) were recorded on the recording sheet and faxed or emailed to FSA Consulting at the end of each month.

The M8 water meter installed at Feedlot G had a single channel logger installed to log a pulse signal from the meter. The logger recorded the date, time and counted the pulses between a user defined logging period. It then translated the data into a flow rate and total flow per minute. In this case, the data from the meter was downloaded via computer every month and the resulting dataset emailed to FSA Consulting.

4.7 Monthly Herd Performance and Feed Consumption Recording

Due to the potentially sensitive nature of the information produced by this research, the reported information will be presented in such a way that individual feedlots cannot be identified. Therefore, water use is presented as a function of a number of feedlot indices to protect the anonymity of the feedlot. The feedlot indices corresponded to the activity measured and included usage on a per head basis, per tonne grain processed and per kilogram of hot standard carcase weight gain (kg HSCW gain).

In this context, HSCW gain is the difference between total dressed carcase weight of cattle leaving the feedlot less the estimated total dressed carcase weight of cattle entering the feedlot.

To enable the respective indices to be estimated, herd performance and feed consumption data was provided. Herd performance data was provided on a market type basis and included liveweight of incoming and shipped cattle, days on feed, average daily gain, dressing percentage, number of cattle entering the feedlot along with number shipped. Commodity usage for the period was provided, broken into categories of major grains, protein sources, roughages/silages, liquids and supplements.

The herd performance and feed consumption data was obtained directly from the respective feedlots in-house feedlot management software (e.g. Bunk Management System, Possum Gully, Feedlot 3000). These systems are dedicated cattle feeding software systems to assist operations in better managing assets, inventories, commodities and maintenance of financial records.

4.8 Sundry Water Uses

Sundry water usage was assessed at all feedlots between February and August 2007. These assessments involved discussion with feedlot managers and staff together with on-ground measurements and observations for various operations. Activities investigated included trough cleaning, hospital cleaning, induction yard cleaning and vehicle washing. These minor activities are too numerous to monitor economically using in-line water meters. An assessment of evaporation loss at each feedlot used field measurements and climate data. These losses occur from troughs and open storages, and consequently, evaporation losses vary greatly between feedlots.

4.8.1 Evaporation losses

Evaporation losses from storages and troughs could not be measured directly. These losses were estimated using climate data and water surface areas.

Evaporation from water troughs was estimated by assuming that the annual loss is equivalent to the mean annual evaporation from a Class A pan. This approach is conservative as it assumes that there was no net replenishment due to rainfall. The volumetric loss was estimated from the surface area of the exposed water in the water troughs.

TABLE 4 gives the water trough dimensions for each feedlot. Using the mean annual Class A pan evaporation given in TABLE 3, mean annual water trough evaporation loss can be estimated. Exposed trough area varies from 1.1 m^2 to 7.2 m^2, with an associated variation in the annual evaporation (see TABLE 4). Troughs within production pens were less variable with surface areas ranging from 1.8 m^2 to 3.0 m^2.

Most feedlots in the study have buffer storages with an exposed surface. Storages directly related to feedlot water supply were measured to ascertain the average surface area and annual evaporation. These calculations excluded other on-farm dams. Net evaporation was calculated after Weeks (1983):

Net evaporation = Open water pan coefficient (K_{OW}) x pan evaporation (E_P) less rainfall (P)

Net evaporation was multiplied by the total surface water area of the buffer storages at each feedlot to derive an evaporation loss in kL/yr. This figure was referenced to an average number of head/day for comparison across feedlots. TABLE 5 gives the details of feedlot storages and associated evaporation losses.

TABLE 6 presents the overall evaporation losses for all feedlots from both troughs and storages together with evaporation referenced to the average number of head/day for comparison.

Evaporation loss is one of the most variable losses between feedlots. This is due to the variation in the size, number of open water storages and net evaporation at individual feedlots.

Table 4 – Typical water trough dimensions (by feedlot)

Dimension	Units	Trough Type	A	B	C	E	F	G	H
Length*	m	TO 1	-	2.89(30%)	1.38[r] (12%)	-	1.52[r](15%)	9.0 (9%)	2.01[r](23%)
		TP 2	2.85 (35%)	4.88(61%)	4.82 (72%)	2.42(81%)	4.9 (8%)	3.01 (85%)	4.90 (62%)
		TP 3	5.35 (65%)	1.76[r](9%)	2.79 (13%)	2.92(19%)	4.9 (57%)		
		TP 4					4.91 (12%)		
		TP 5					4.77 (8%)		
Width	m	TO 1	-	-	-	-	-	0.80	-
		TP 2	0.56	0.57	0.46	0.47	0.45	0.49	0.45
		TP 3	0.55	0.46	1.0	0.50	0.45		
		TP 4					0.45		
		TP 5					0.50		
Volume	L	TO 1	-	246	616	-	852	1790	1900
		TP 2	352	495	378	191	221	280	334
		TP 3	752	948	653	345	282		
		TP 4					357		
		TP 5					415		
Surface Area**	m^2	TO 1		1.4	1.5	-	1.8	7.2	3.5
		TP 2	1.1	2.0	2.0	1.1	1.8	1.2	1.5
		TP 3	3.0	2.4	2.8	1.5	1.8		
		TP 4					1.8		
		TP 5					2.0		
Total Feedlot Trough Surface Area	m^2		220	207	287	126	249	79	24

TO 1 are troughs used in hospital and induction pens. The troughs recorded are the most common trough for this category

TP 2, 3, 4 are troughs used in production pens [r] Denotes a round trough * Proportion of total troughs used in the feedlot

Table 5 – Typical buffer storage dimensions (by feedlot)

		units	A	B	C	E	F	G	H
Open Surface Area	Storage 1	m^2	5252	-	7530	2575	2552	1530	-
	Storage 2	m^2	-	-	4960	706	-		-
	Storage 3	m^2	-	-	-	5815	-		-
	Storage 4	m^2	-	-	-	1745	-		-
Combined Open Storage Surface Area		m^2	5252	0	12490	10841	2552	1530	

Table 6 – Estimated total evaporation loss (by feedlot)

		A	B	C	E	F	G	H
Estimated net evaporation	mm/yr	775	948	1217	792	78	796	565
Estimated trough evaporation loss	kL/yr	119	155	758	65	95	32	7
Estimated storage evaporation loss	kL/yr	4,072	0	15,204	8,583	121	1,218	0
Estimated total evaporation loss	kL/yr	4,191	155	15,962	8,648	216	1,250	7
Estimated total evaporation loss	L/head/day	0.63	0.002	3.99	2.50	0.01	0.44	0.001

4.8.2 Water Losses during Trough Cleaning

Water troughs need to be cleaned regularly as they accumulate grain and other feed stuffs that quickly ferment. Algal growth can occur quickly and this may taint the flavour of the water, reducing intake by cattle. The amount of water used in trough cleaning is determined by three main parameters;

- cleaning frequency,
- water volume of the troughs, and
- clean water inflow during cleaning.

Site-specific measurements and observations were made at each feedlot to gauge trough cleaning procedures and to estimate water losses during trough cleaning.

The frequency of cleaning generally has the largest influence on the overall amount of water used, followed by trough volume and clean water used during cleaning. At the feedlots studied, cleaning frequency varied from twice per week to once per fortnight.

All feedlots in the study emptied the water from the trough during the cleaning process, leading to an initial water loss equal to the volume of the trough (trough volume loss). Overall trough volume varied greatly within and between feedlots from approximately 191 L to almost 950 L (TABLE 4). Troughs used in hospital pens and holding paddocks tend to be round troughs of greater volume. However, the average trough size at all feedlots (taken as the average volume of each trough type used multiplied by the proportion of this type used in the feedlot) showed less variation from 178 – 614 L (Table 7).

In addition to the trough volume, additional water is used at most feedlots to flush out waste material (flushing volume loss). This flushing volume varied widely from 0 to 350 L/trough (see TABLE 7). Most feedlots stop water flow during the trough cleaning process to minimise flushing losses and these feedlots used approximately 50-100 L of clean water during the cleaning process. One feedlot allowed clean water to flow for the whole time while cleaning was being carried out, resulting in a larger clean water loss. Another method for trough cleaning was to pump out the trough with a small pump mounted on a four-wheel motor bike (see PHOTOGRAPH 58). This feedlot does not have a sewered trough system and the process is used to prevent the formation of a water patch immediately behind each water trough. Generally, where this method was employed, the whole trough was not completely emptied during the cleaning process and this reduced the clean water loss to a negligible amount.

The overall volume of water used for trough cleaning per month varied greatly, depending on frequency of trough cleaning and the method used for cleaning.

Table 7 – Typical water trough cleaning data (by feedlot)

Feedlot	Units	**A**	**B**	**C**	**E**	**F**	**G**	**H**
No of trough cleanings per month	No/mth	14	4-5	2	8-9	2	8-9	6-7
Flushing volume loss[a]	L	10	357	71	0	56	0	55
Trough volume loss[b]	L	614	461	411	178	341	277	305
Est. Average cleaning volume used per month[c]	kL	598	418	200	135	107	9	22
Estimated cleaning volume	L/head/day	0.10	0.07	0.04	0.03	0.01	0.003	0.04

[a] Clean water is excess water that flows during the trough cleaning process in addition to the trough water that is released from the trough.

[b] Average trough size is calculated from the volume of each different trough size multiplied by the proportion of these troughs used in the feedlot.

[c] Represents water emptied from the trough, additional clean water flow during cleaning and sewer flow if applicable. Trough cleaning measurements were taken for troughs in production pens.

4.8.3 Sundry Water Uses – Feedlot A

Sundry water uses at Feedlot A include trough washing, evaporation, leakages and hospital cleaning. These minor losses were estimated using data collected during an intensive study at the feedlot in April 2007. Most of these losses are from the drinking water supply.

Troughs

Feedlot A uses two different water trough configurations with a large 5-m concrete trough used in each of the production pens (see PHOTOGRAPH 48) and a smaller 3-m concrete trough used in the hospital pens and receival/dispatch pens (see PHOTOGRAPH 49). About 65% of troughs are the large size whole 35% are the small size. TABLE 4 gives trough dimensions and evaporation losses. The small troughs have a sheeted float cover, while the larger troughs have a wire-mesh float cover which leaves a larger evaporative area from this trough.

Photograph 48 – Large 5-m trough in production pens (Feedlot A)

Photograph 49 – Small 3-m trough type showing steel float cover (Feedlot A)

Trough cleaning

Troughs are cleaned at Feedlot A every second day (15 times per month). An underground sewer system is connected to each trough. The removal of a bung in the base of the trough allows the trough to be drained fully without dumping water in the pen. The cleaning process begins with draining the water from the trough. As the trough empties, the bung is wedged under the float to prevent flushing water inflow. The trough walls and base are scrubbed while the water drains from the trough, and once the scrubbing is complete, the float is allowed to open and the trough is flushed before the bung is replaced allowing the trough to refill.

It takes about 1.5 minutes to drain the trough while the time taken to scrub the trough depends on the amount of residue present. Flushing (with the bung removed) takes approximately 30 seconds, and the trough takes a further 1.5 - 2.5 minutes to fill after the bung is replaced. TABLE 7 gives an estimate of the water used during trough washing.

Other water uses

Minor water uses also include cleaning at the hospital complex, which is washed on a regular basis, with two hoses being used as needed. Hosing is done with one or two hoses, and on average takes approximately 1 hour with 1 hose. The flow rate of this hose averages 0.7 L/second. Water used for vehicle washing and at the workshop was measured by Meter M3 and water used in the induction facility was measured by Meter M7.

Hoses are used for cleaning a number of sections in the feed processing area. The main processing area is cleaned twice weekly for 1 hour, with the hose supplying 1 L/sec. A second hose is used once weekly for 1 hour, cleaning the area around the feed office. The flow rate is about 0.9 L/sec. A third hose is used to wash the feed truck loading area, using 0.4 L/sec for 30 minutes three times weekly.

The sundry water uses for Feedlot A represent about 0.9 L/head/day (see TABLE 9).

4.8.4 Sundry Water Uses – Feedlot B

Sundry water uses at Feedlot B include trough washing, trough evaporation, hospital cleaning, induction yard cleaning, water supply to stables and vehicle washing together with leakages. These minor water uses were assessed by conducting an intensive study of the processes involved.

Troughs

There are three types of trough used in the production pens at Feedlot B. These include round troughs used in the old pens, long 5-m troughs on fence lines of all new large pens and short 3-m troughs on fence lines of hospital and induction pens. The long troughs represent about 60% of the feedlot. All long and short troughs are sewered, and have a flat steel cover over the float valve end that reduces the evaporative surface area of the trough. TABLE 4 gives detailed trough dimensions and evaporation data.

Photograph 50 – Round trough in production pen (Feedlot B)

Trough washing

Trough washing is done weekly at Feedlot B (4 times per month). The first step in the washing process involves opening a valve at the top end of the sewer line (see PHOTOGRAPH 52) to start a flushing flow down the sewer (which prevents grain / scum clogging up the sewer line). This is left on while each row of troughs are cleaned. Unfortunately, the flow rate for this sewer line was not able to be measured.

After the sewer flow starts, troughs are scrubbed using a brush to remove algae and get the sludge in suspension. When this is done, the sewer stand pipe is removed and the trough empties. There is no facility to shut off clean water flow while the trough empties, and clean water flow during trough washing is approximately 2 minutes at a flow rate of 1.7 L/second. After the trough is flushed, the standpipe is replaced and the trough refills. The whole process takes approximately 3.5 minutes to complete. There are 10 round troughs used in the feedlot production pens, and these are cleaned by removing a bung and allowing the water to flow into the pen (see PHOTOGRAPH 50). Additional clean water used during cleaning is similar to other large troughs used.

Some troughs, particularly those located slightly inside the pen (not under the fence), take longer to clean because cattle can stand in these troughs and foul the water with manure.

Water valves in the troughs at Feedlot B are operated by a float on the end of a short rope (not a float ball – see PHOTOGRAPH 51), with the outlet of the valve shooting upward under the steel cap. During cleaning, this causes water to spray out from under the cap onto the concrete apron for about 2 minutes during trough cleaning. This additional water loss was not able to be measured. TABLE 7 gives water used during trough washing for this feedlot.

Photograph 51 – Float valve – plastic float on a rope – valve sprays upwards (Feedlot B)

Photograph 52 – Pipe & valves used to flush sewer line (Feedlot B)

Other water uses

Apart from road watering, it was not possible to measure the other sundry water losses at Feedlot B. The sundry water uses for Feedlot B represent about 0.1 L/head/day (see Table 9) but do not include sewer flushing, hospital cleaning and vehicle washing.

4.8.5 Sundry Water Uses – Feedlot C

Feedlot C uses a small amount of water to carry out various cleaning and convenience practices that could not be monitored using water meters. These practices include trough washing, induction and hospital yard cleaning and vehicle washing. These minor water uses were assessed in August 2007 with an intensive water use study at the feedlot.

Troughs

Feedlot C uses two main trough types in production pens at the feedlot (PHOTOGRAPH 53 and PHOTOGRAPH 54). These troughs are constructed from concrete and have a semi circular (Type 1) or trapezoidal (Type 3) internal shape. The receival / dispatch yards use a round poly trough (Type 4) which is shown in Photograph 55. Troughs are located on the fence lines between pens (each trough services 2 pens) with troughs located on all pen end rows.

Photograph 53 – “Type 1” large standard trough (Feedlot C)

Photograph 54 – “Type 3” large trough used in old pens (Feedlot C)

Photograph 55 – Round trough used in arrival / dispatch yards (Feedlot C)

Trough washing

Trough washing is done on a fortnightly basis in winter and less frequently in summer (2 times per month). All troughs in the production pens are linked to a sewer system to reduce the amount of water flowing into the pens. The washing process begins by starting a flow of clean water through the sewer line to avoid any blockages, then proceeding to wash a row of troughs. During observations, the sewer line was running for a total of 43 minutes while a row of 13 troughs were washed, at a measured flow rate of 0.4 L/second.

The individual trough washing process begins by removing a stand pipe at the end of the trough and scrubbing the walls as the water empties into the sewer line (see PHOTOGRAPH 56). There is no attempt made to stop clean water flow during the washing process, and flow time averaged 45 seconds. The flushing water flow rate of the troughs measured 1.5 L/second. The whole trough washing process takes an average of 1.4 minutes from the time the stand pipe is removed to when it is replaced.

Photograph 56 – Trough washing (Feedlot C)

Other water uses

Other water uses include cleaning at the hospital and induction yards. These facilities are washed daily with a single pressurised hose. The hose used at the hospital facility had a measured flow rate of 0.9 L/second and the cleaning process takes approximately 20 minutes. At the induction facility, cleaning takes approximately 7 minutes with a single hose that has a measured flow rate of 2.4 L/second.

Sundry water uses used from the cattle washing water supply include vehicle washing and filling of the water truck. Vehicle washing is carried out daily for between 30 and 45 minutes, using a single hose with a flow rate of 3.3 L/second. The water truck is used several times per month depending on need. The water truck holds 14,000 L and this water use is recorded with a log each month. Cleaning at the feed processing area is carried out with the water tanker truck. The process is done on a weekly / biweekly basis for approximately 1 hour. This uses approximately 3500 L.

The sundry water uses for Feedlot C represent about 4.1 L/head/day (see Table 9). This is the largest loss at any of the studied feedlots due to the large surface area of the buffer storages.

4.8.6 Sundry Water Uses – Feedlot E

Sundry water uses at Feedlot E include trough washing, cleaning of the induction/dispatch and hospital yards, feed processing areas and other losses from leakages. These practices were assessed by conducting an intensive study of minor water losses at the feedlot in February 2007.

Troughs

Feedlot E uses two trough types in the production pens. These troughs are constructed from fibreglass and are a semi circular shape. A third, smaller trough is used in the holding pens at the livestock receival/dispatch area, though these troughs are only likely to supply a small amount of water. Troughs in the production pens are housed in a cement bunk with steel railing to prevent damage from the cattle (see Photograph 57). There are 99 troughs used in the production pens. Of these, 20 are the larger trough and 79 are the smaller trough. Table 4 gives trough dimensions and evaporation losses.

Photograph 57 – Fibreglass water trough (Feedlot E)

Trough washing

All troughs are washed every 3-4 days year round (8-9 times per month) to ensure a supply of clean water is available for cattle at all times. This cleaning schedule has proved successful in maintaining water quality and is considered an improvement on the previous management plan. The feedlot considers trough cleaning an important practice and instructs workers to do a thorough job while maintaining efficiency. The process involves initial thorough scrubbing of the trough to remove scum that has built up on the internal walls of the trough and around the float valve. While this is being done, the worker starts a pump (which is mounted on a four-wheel motorbike) which rapidly empties the trough (see Photograph 58). This feedlot does not have a sewer system and this process prevents the formation of wet patch where the trough water is dumped. The worker continues to clean the trough as water is pumped out, completing the job when approximately 50 mm of water remains in the bottom. The worker then adds approximately half a cup of copper sulphate ($CuSO_4$) to the trough which inhibits algal growth in the trough. TABLE 7 gives water used during trough washing for this feedlot.

Photograph 58 – Trough cleaning process showing motorbike mounted pump (Feedlot E)

Other water uses

Further cleaning water is used at the hospital, receival/dispatch and induction yards for regular cleaning. The receival/dispatch yards are cleaned on a weekly basis. This process takes approximately 45 minutes using a 25 mm hose, with a measured operating flow rate of 0.9 L/s.

The induction yards are cleaned twice per week for a variable amount of time depending on available of staff and other operations (approximately 45 min). The process is carried out with a single 25 mm hose operating at a flow rate measured at 1.5 L/s.

The hospital area is cleaned weekly, using a 25 mm high-pressure hose. The cleaning operation takes approximately 45 minutes and the average flow rate measured was 0.5 L/s. This feedlot also has a horse wash down bay that is used daily for approximately 1 hour. The wash down uses a 25mm hose with a measured flow rate of 0.6 L/s.

The feed processing area is cleaned primarily with air, however each fortnight the lines are cleaned with water. This process takes approximately 30 minutes and is carried out with a fire hydrant hose (38 mm) operating at a measured flow rate of 3.1 L/s.

TABLE 9 gives the sundry water losses for Feedlot E. They represent 2.7 L/head/day.

4.8.7 Sundry Water Uses – Feedlot F

Sundry water uses at Feedlot F include trough washing, hospital cleaning, induction cleaning and feed processing area cleaning. These minor uses were assessed by conducting an intensive study of the processes involved in February 2007.

Troughs

Feedlot F uses five trough types in production pens, three of which are shown in Photograph 59, Photograph 60 and PHOTOGRAPH 61. All troughs are constructed from concrete. They are either semi circular (Type 3) or trapezoidal (Type 1, 2, 4) in cross-section. The horse paddocks, hospital and induction yards predominantly use round troughs (Photograph 62) with a small number of rectangular troughs in some pens. A separate section of the lot where cattle are housed in sheds uses a different type of trough (trough 5), which is a small basin approximately 300mm in diameter. Type 5 troughs are not discussed further as the expected loss is minimal because of low evaporation rates and the minimal water losses during cleaning. Troughs are located on the fence lines between pens (each trough services 2 pens) with troughs located on all pen end rows. Detailed trough dimensions and evaporation losses are reported in TABLE 4.

Photograph 59 – Old Type-1 style trough with trapezoidal cross-section and concrete float valve cover (Feedlot F)

Trough washing

Trough washing at Feedlot F is carried out approximately twice a month, depending on staff availability. The process involves initial scrubbing the trough walls and stirring the trough water before empting the trough (this water flows into a pipe sewer system to avoid wetting pens). During the emptying process, the float valve is held up manually to avoid unnecessary flushing water loss. A small amount of flushing water is allowed to flow in the final stages of the process in order to clean the bottom of the trough. The whole process takes approximately 3 minutes, with a fresh water flow time averaging 37 seconds. Water used during trough washing for this feedlot is reported in TABLE 7.

Photograph 60 – Standard large Type-2 trough with trapezoidal cross-section (Feedlot F)

Photograph 61 – Type 3 trough with semi-circular cross-section (Feedlot F)

Photograph 62 – Round trough used in horse paddocks, hospital pens and induction yards (Feedlot F)

Other water uses

Feedlot F has two hospitals on the eastern and western side of the feedlot. The hospital on the eastern side is the larger of the two and this is used on a regular (daily) basis. This hospital has two gravity fed 25 mm cleaning hoses, while the smaller hospital has no cleaning facilities. The flow rate of hoses at the main hospital is 2.4 L/s and cleaning operations are undertaken at approximately 6-week intervals for 10-15 minutes. A hose is used for cleaning the post mortem area that is used weekly as needed. This cleaning operation takes approximately 5 minutes.

Induction area cleaning losses are accounted for in the cattle-washing component as the water is metered from the cattle wash inflow.

Water use in the cattle washing area at Feedlot F also includes a small amount of water used for washing the induction yards and cattle washing area. This washing is done on an as-needed basis (approximately once per month) and takes between 1.5-2 hours. Cleaning is done with a single high-pressure hose with a measured flow rate of 4.5 L/second.

TABLE 9 gives the sundry water losses at Feedlot F. They represent about 0.03 L/head/day.

4.8.8 Sundry Water Uses – Feedlot G

Feedlot G has minor losses associated with trough cleaning, induction yard cleaning, feed processing area cleaning and leakages. At this feedlot, minor water use at the induction facility was measured using a water meter and this information is presented in the results section. An intensive study was undertaken to assess water use practices at the feedlot by observation. This intensive study was carried out in March 2007.

Troughs

Feedlot G uses four trough types in and around the feedlot, and one type as standard for all production pens. PHOTOGRAPH 63 shows the trough used in production pens. Troughs are generally located in the middle of the pens (1 trough per pen). TABLE 4 reports detailed trough dimensions and evaporation losses for this feedlot.

Photograph 63 – Standard production pen trough (Feedlot G)

Trough washing

Feedlot G operates a regular schedule for trough washing, with all troughs being washed twice per week (8-9 times per month). For similar reasons to Feedlot E, trough washing is done with a pump out system (see PHOTOGRAPH 64). The first step is to attach the hose to an outlet of the trough and begin pumping the water from the trough. Immediately following this action, a tap is turned off, preventing clean water flow into the trough during the process. As the water is pumped out, the trough walls are scrubbed. The last operation is to turn on the tap allowing clean water to flow into the trough and to turn off the pump. The whole process takes approximately 2 minutes, with the fresh water flow time averaging only a few seconds. In estimating the water used during trough washing, it has been assumed (on advice from the feedlot manager) that on average, only 37 troughs would be cleaned per week as two pens remain empty and these troughs are not cleaned until required. TABLE 7 gives water used during trough washing.

Photograph 64 – Trough cleaning process showing trailer mounted pump (Feedlot G)

Other water uses

The induction yards are cleaned every week for a variable amount of time, using two 25 mm hoses. Cleaning operations take approximately 1 – 1.5 hours with two hoses to clean the main working area. If a single hose is used or if there is multiple days build up of manure, the cleaning process can take up to 3 hours. There is no hospital facility at this feedlot. Water use in the induction facility at this feedlot was metered separately.

Thorough cleaning at the feed mill is undertaken every 10 days, with an additional minor clean conducted every 5 days. This process is carried out with a single hose and takes approximately 1.5 – 2 hours for the major cleaning and 0.5 – 1 hour for the minor cleaning. The hose is a 25 mm high-pressure hose with a relatively low flow rate of 0.6 L/s.

TABLE 9 gives the sundry water losses at Feedlot G. They represent about 0.5 L/head/day.

4.8.9 Sundry Water Uses – Feedlot H

Sundry water uses at Feedlot H include trough washing, cleaning at the feed processing and induction facilities, vehicle washing and leakages. All other water uses were monitored with water meters and are not reported here. Minor water uses were assessed by FSA Consulting staff in March 2007.

Troughs

Feedlot H uses four trough types in and around the feedlot, and one type as standard for all production pens (PHOTOGRAPH 65). All troughs are constructed from concrete, two have a trapezoidal cross-section (Type 1, 2) and the remaining troughs used in the induction pens and holding paddocks are round.

Photograph 65 – Type 1 standard production pen trough (Feedlot H)

There are eight "Type 1" troughs used in the production pens. The troughs are located on the fence line, with one trough serving two pens, and there are no troughs on the end of rows. Detailed trough dimensions and evaporation losses are reported in TABLE 4.

Trough washing

Feedlot H operates a regular schedule for trough washing, with all troughs cleaned twice per week on Monday and Thursday (8 times per month). The process begins by removing a bung from the trough, which allows water to drain freely into a sewer system. As the trough empties, the walls and bottom of the trough are scrubbed. There is no system for preventing clean water flushing flow from occurring during the cleaning process, and the clean water flow time is approximately 45 seconds for each trough. The whole process takes approximately 2 minutes. Water used during trough washing for this feedlot is reported in TABLE 7.

Photograph 66 – The trough cleaning process (Feedlot H)

Other water uses

Water used for washing at the induction facility and some vehicle / truck washing is taken from the cattle wash water supply and has been accounted for there. The induction yards are cleaned approximately once per week for approximately 20 minutes using one hose. This hose is 25 mm in diameter and water is pressurised by a pump located at the induction area. The average flow rate measured was 1.1 L/s.

Truck and machinery washing is carried out at this area, using a 25 mm hose from the same pump. The measured flow rate for this hose is 2.9 L/s. This hose is used for approximately 10 minutes per week.

Cleaning at the feed processing facility is carried out on an as needed basis, averaging about 10 minutes cleaning per week. This cleaning is carried out with a 25 mm hose under pressure, operating at a flow rate of 1.5 L/s. Other cleaning at this facility is done using an air compressor.

TABLE 9 gives the sundry water losses at Feedlot H. They represent about 0.1 L/head/day.

4.9 Data Collection Period

Monthly data were collected over a 12-month period from March 2007 to February 2008. This period allowed for the annual variation in total water usage to be quantified.

Intensive measurements of trough cleaning and other minor water uses were undertaken between February and August 2007 by FSA Consulting staff (Stephen Wiedemann, Rod Davis, Nathan Heinrich and Peter Watts).

4.10 Data Analysis

Monthly water meter readings were imported into a large Excel spreadsheet and cross checked with previous month's readings. Where anomalous data were detected, the participating feedlot was contacted and the data were examined in more detail. Anomalous data may have included a reduction in meter reading from previous or unexplained extraordinarily large increases in water usage.

Herd performance and feed consumption data were imported into the same spreadsheet. Similarly, data quality checks were undertaken. For example, the mean number of cattle-on-hand were compared with licensed capacity to ensure market types were not counted twice or missed. Where anomalous data were detected, the participating feedlot was contacted and the data were examined in more detail. The total HSCW gain per month was calculated from the data for estimated liveweight in lot at the start of the month, total liveweight in, total liveweight out and estimated liveweight in lot at the end of the month.

The spreadsheet then calculated the water usage of the major feedlot activities as a function of their respective indices including on a per head basis, per tonne grain processed and per kilogram of hot standard weight gain (kg HSCW gain).

5 Results and Discussion

Total water usage and activity water usage are presented in the following sections. It is important to note that the feedlot numbering system in the methodology section does not align with the number system in the results and discussion sections. That is, Feedlot B in Section 4.2 is not Feedlot B in Section 5.1. This provides anonymity for the participating feedlots.

5.1 Total Water Usage

FIGURE 15 to FIGURE 21 inclusive present the monthly results for the period March 2007 to February 2008 of the total clean water use for the seven feedlots. Total clean water usage is the combination of drinking water, feed processing, cattle washing (where this practice is undertaken), administration and direct sundry uses such as trough cleaning, dust control, vehicle and facility cleaning and indirect sundry 'uses' such as evaporation. There was no clean water usage reported for effluent dilution. For cattle washing, only the clean water usage is presented in this section. At a number of feedlots, recycled water is also used for cattle washing. These data will be presented in Section 5.4. The usage for the respective activities was standardised per kg HSCW gain for the respective month.

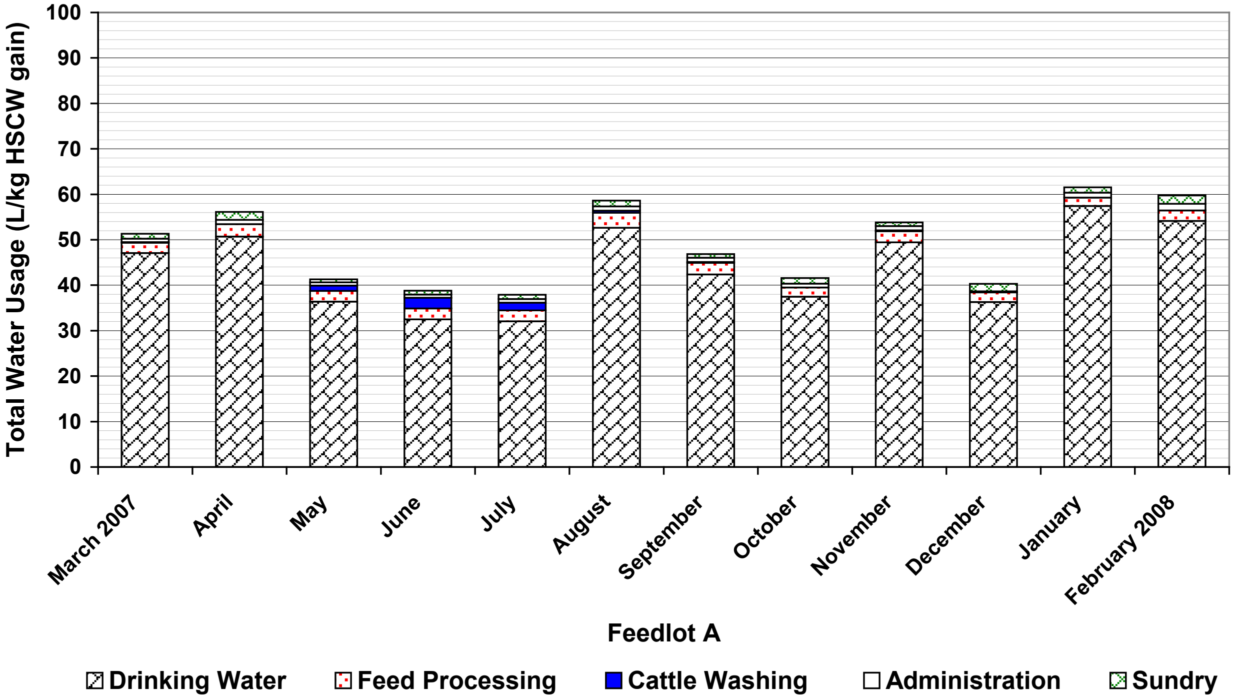


Figure 15 – Monthly total water usage at Feedlot A (L/kg HSCW gain)

FIGURE 15 shows the total monthly clean water usage at Feedlot A for the period March 2007 to February 2008. This shows that the total monthly clean water use ranges from 38 to 62 L/kg HSCW gain. The lowest water usage was measured in winter (July) and the highest in summer (January).

Drinking water is the single largest consumer of water in the feedlot as expected and contributed 33 to 58 L/kg HSCW gain or in the order of 92 % of total usage. In June and July, cattle washing water usage contributed 2.4 L/kg HSCW gain (6 %) and 1.7 L/kg HSCW gain (5 %) of total water usage respectively. Feed processing contributed an average of 2.4 L/kg HSCW gain or around 5 % of total usage. Administration (2 %) and sundry uses (1 %) contribute the remaining usage. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

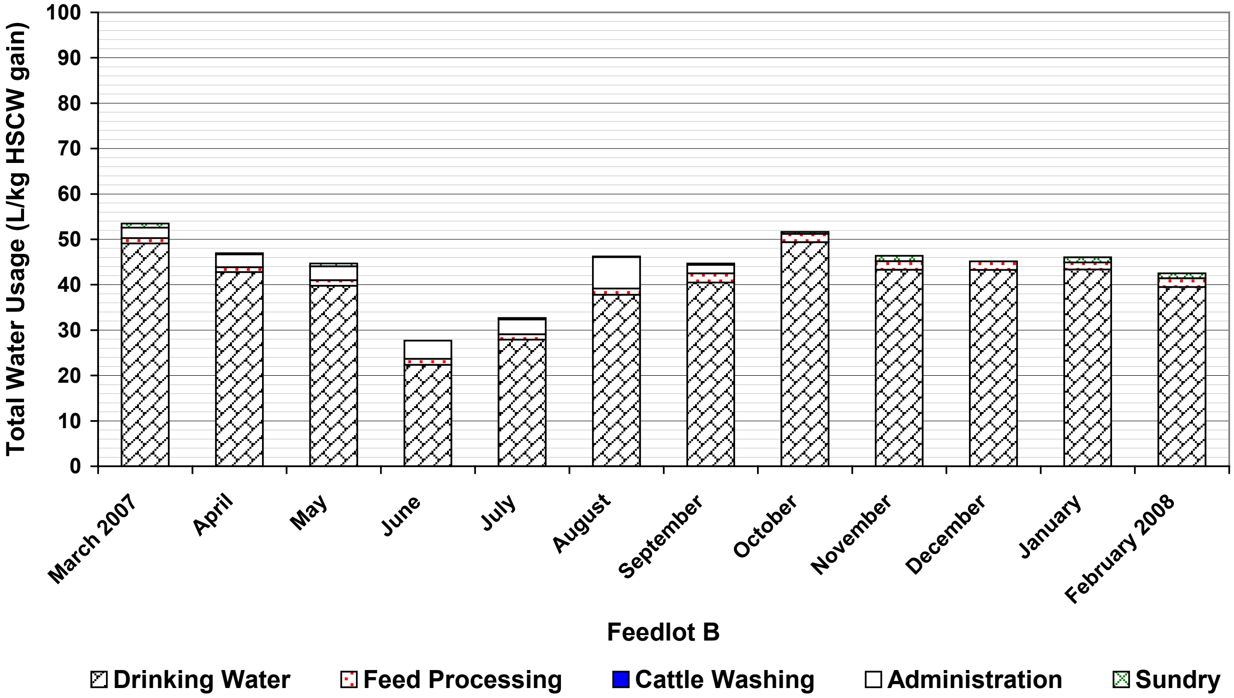


Figure 16 – Monthly total water usage at Feedlot B (L/kg HSCW gain)

FIGURE 16 shows the total monthly clean water usage at Feedlot B for the period March 2007 to February 2008. Total monthly clean water use ranges from 28 to 54 L/kg HSCW gain. The lowest water usage was measured in winter (June) and the highest in summer (March). Drinking water is the single largest consumer of water in the feedlot as expected and contributed 22 to 49 L/kg HSCW gain or an average of 90 % of total usage. Feedlot B does not wash cattle and administration water usage was not recorded from September to February due to a broken water meter. Feed processing contributed an average of 1.5 L/kg HSCW gain or around 4 % of total usage. Administration (5 %) and sundry uses (1 %) contributed the remaining usage. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

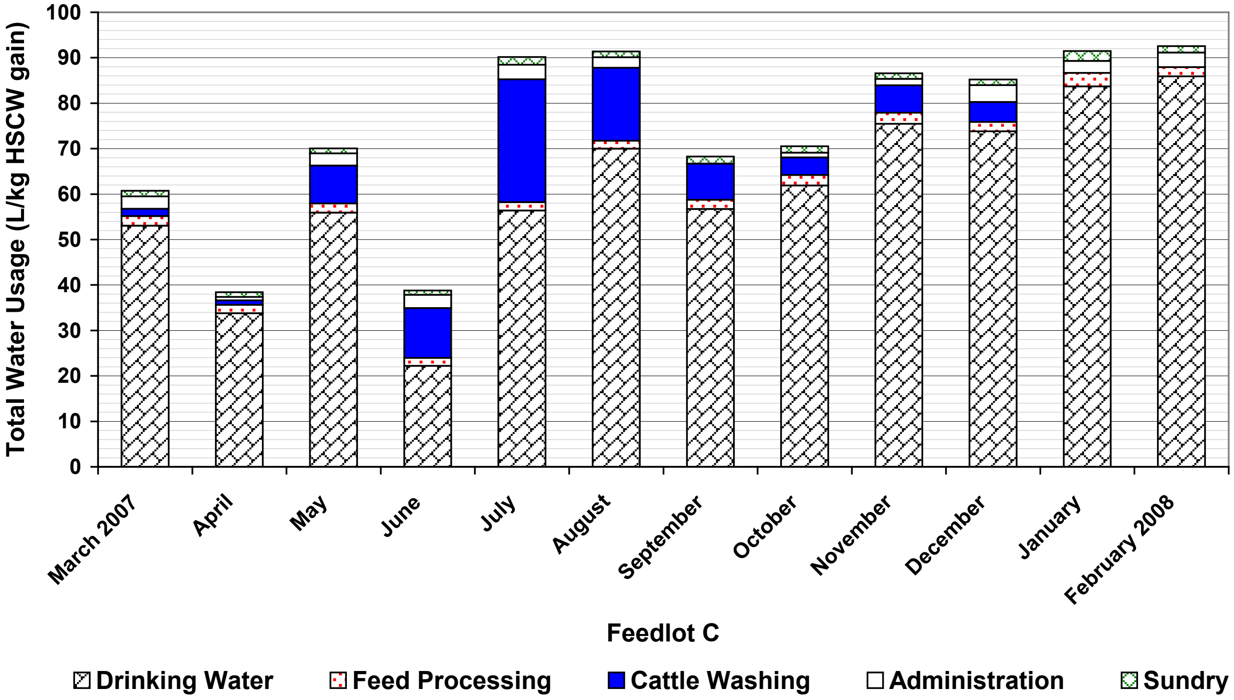


Figure 17 – Monthly total water usage at Feedlot C (L/kg HSCW gain)

FIGURE 17 shows the total monthly clean water usage at Feedlot C for the period March 2007 to February 2008. Total monthly clean water use ranges from 38 to 92 L/kg HSCW gain. The lowest water usage was measured in winter (June) and the highest in summer (January). Drinking water is the single largest consumer of water in the feedlot as expected and contributed 22 to 86 L/kg HSCW gain or an average of 89 % of total usage in months with no cattle washing and an average 72 % in months when cattle were washed. Feed processing contributed an average of 2.1 L/kg HSCW gain or around 3 % of total usage. From May to December, cattle washing water usage contributed an average of 10.5 L/kg HSCW gain (15 %) of total water usage. Administration (4 %) and sundry uses (2 %) contributed the remaining usage. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

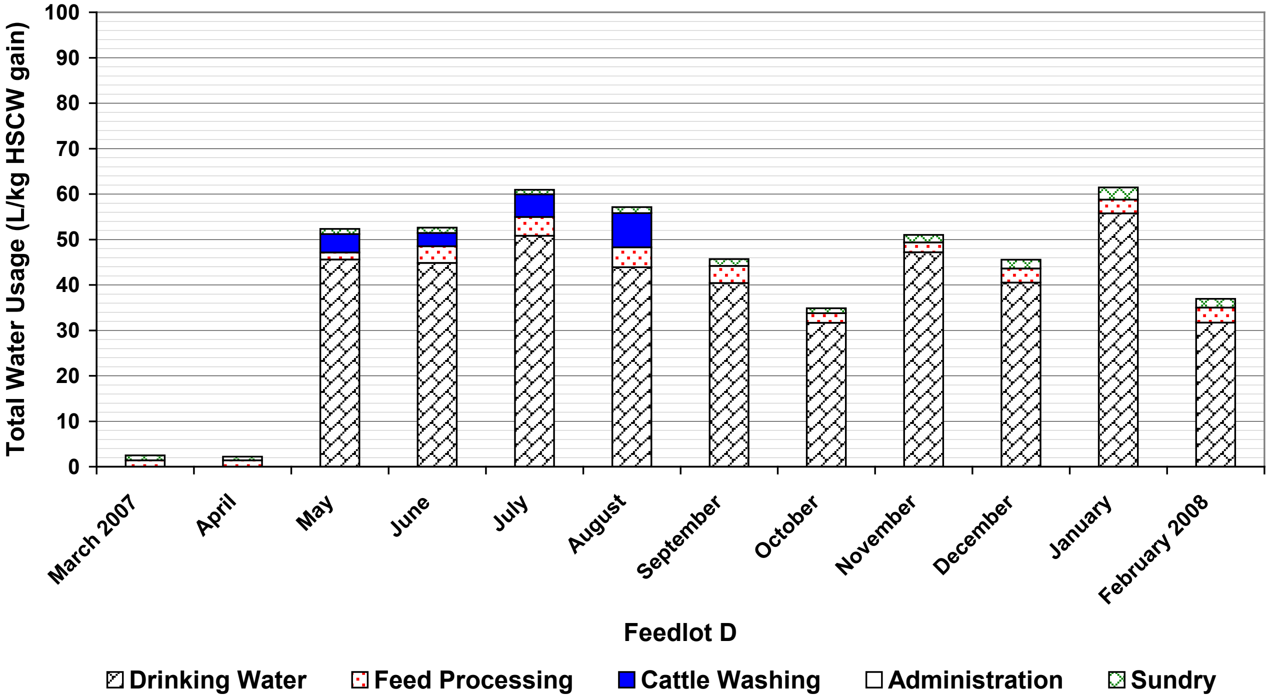


Figure 18 – Monthly total water usage at Feedlot D (L/kg HSCW gain)

FIGURE 18 shows the total monthly clean water usage at Feedlot D for the period March 2007 to February 2008. Drinking water was not measured in March and April 2007. Total monthly clean water use ranges from 35 to 62 L/kg HSCW gain. The lowest water usage was measured in October and the highest in summer (January). At this feedlot, office water usage could not be measured directly and therefore is included in the drinking water total. Drinking water is the single largest consumer of water in the feedlot as expected and contributed 32 to 55 L/kg HSCW gain or an average of 93 % of total usage in months with no cattle washing and an average 85 % in months when cattle were washed. At this feedlot, a steam flaking feed processing system was commissioned in June. Prior to this, grain was tempered only. Feed processing contributed an average of 1.5 L/kg HSCW gain or around 3 % of total usage when tempered only compared with 3.3 L/HSCW gain (7%) when steam flaked. From May to August, cattle washing water usage contributed an average of 5 L/kg HSCW gain (9 %) of total water usage. Sundry uses (2 %) contributed the remaining usage. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

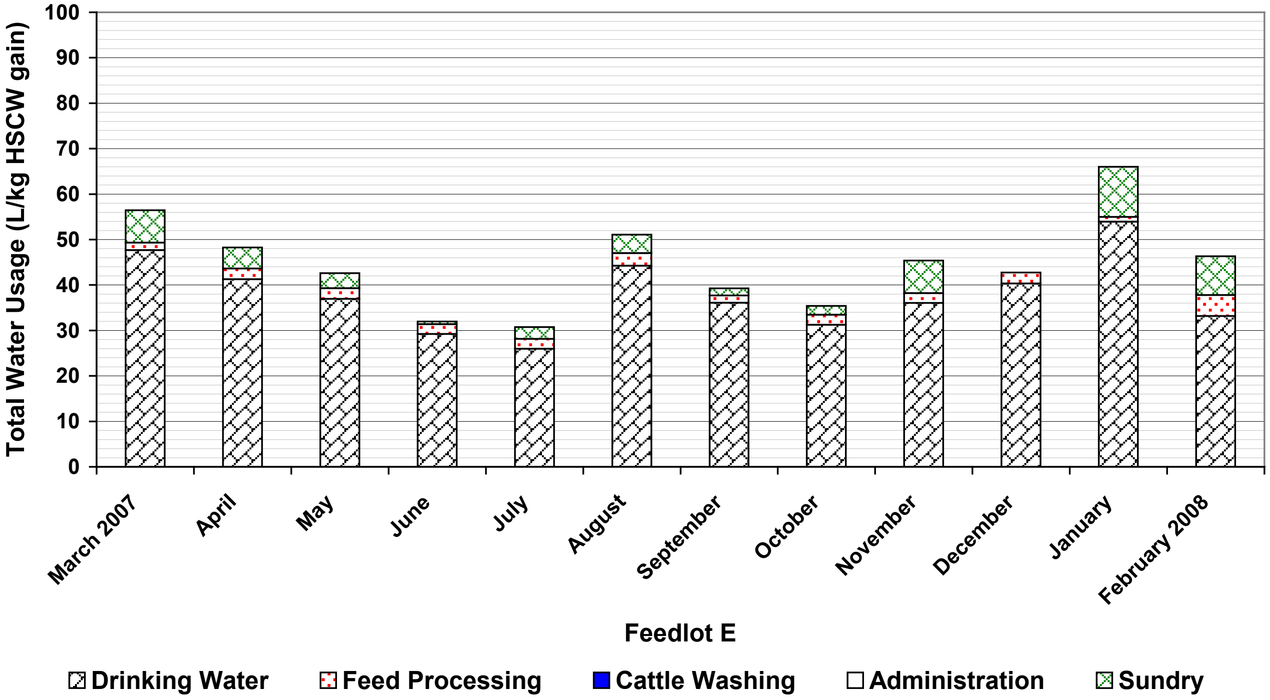


Figure 19 – Monthly total water usage at Feedlot E (L/kg HSCW gain)

FIGURE 19 shows the total monthly clean water usage at Feedlot E for the period March 2007 to February 2008. Total monthly clean water use ranges from 31 to 66 L/kg HSCW gain. The lowest water usage was measured in winter (July) and the highest in summer (January). At this feedlot, office water usage could not be measured directly and therefore is included in the drinking water total. Drinking water is the single largest consumer of water in the feedlot as expected and contributed 27 to 64 L/kg HSCW gain or an average of 91 % of total usage. This two fold variation in drinking water consumption can be explained through climatic variation throughout the study period. Feedlot E did not wash any cattle during the reporting period. Feed processing contributed an average of 2.3 L/kg HSCW gain or around 5 % of total usage. Sundry uses (3 %), in particular dust control contributed the remaining usage. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

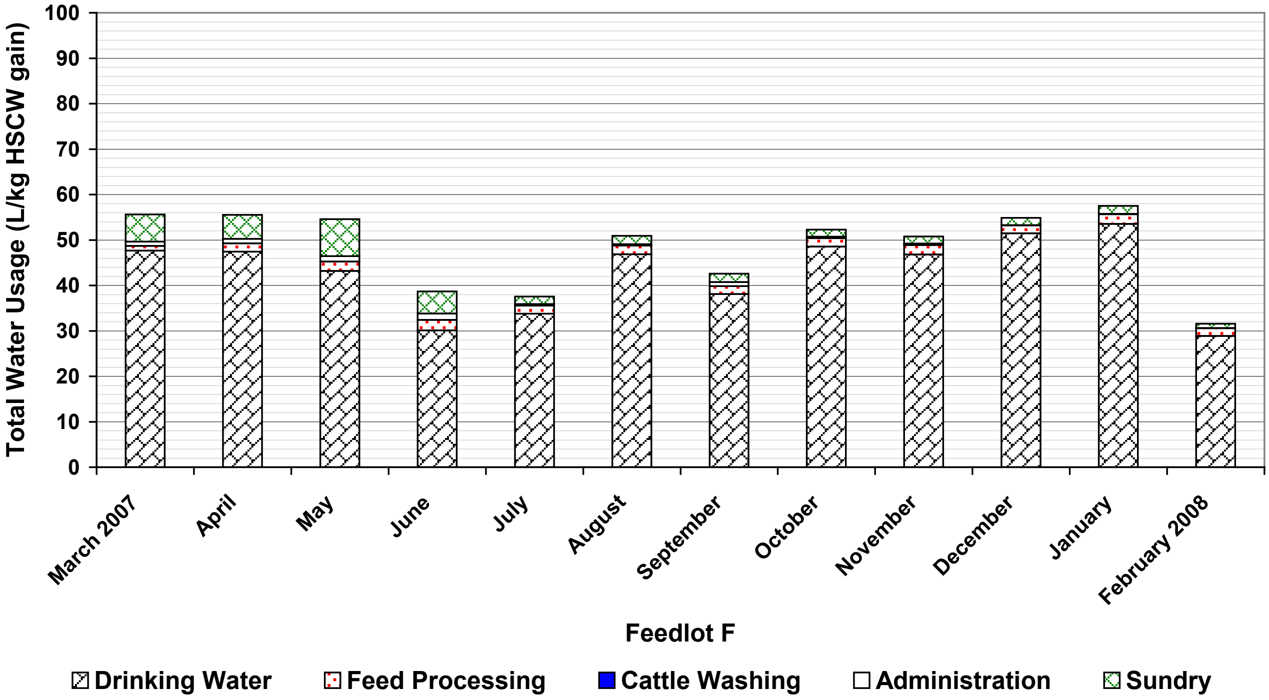


Figure 20 – Monthly total water usage at Feedlot F (L/kg HSCW gain)

FIGURE 20 shows the total monthly clean water usage at Feedlot F for the period March 2007 to February 2008. Total monthly clean water use ranges from 32 to 58 L/kg HSCW gain. The highest water usage was measured in January 2008 and the lowest in February 2008, a high rainfall month. Drinking water is the single largest consumer of water in the feedlot as expected and contributed 30 to 55 L/kg HSCW gain or an average of 91 % of total usage in months. Feed processing contributed an average of 1.8 L/kg HSCW gain or around 4 % of total usage. Administration contributed an average of 0.6 L/kg HSCW gain (1 %) predominantly in garden maintenance. Sundry uses, in particular dust control contributed an average of 2.0 L/kg HSCW gain or 4 % usage. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

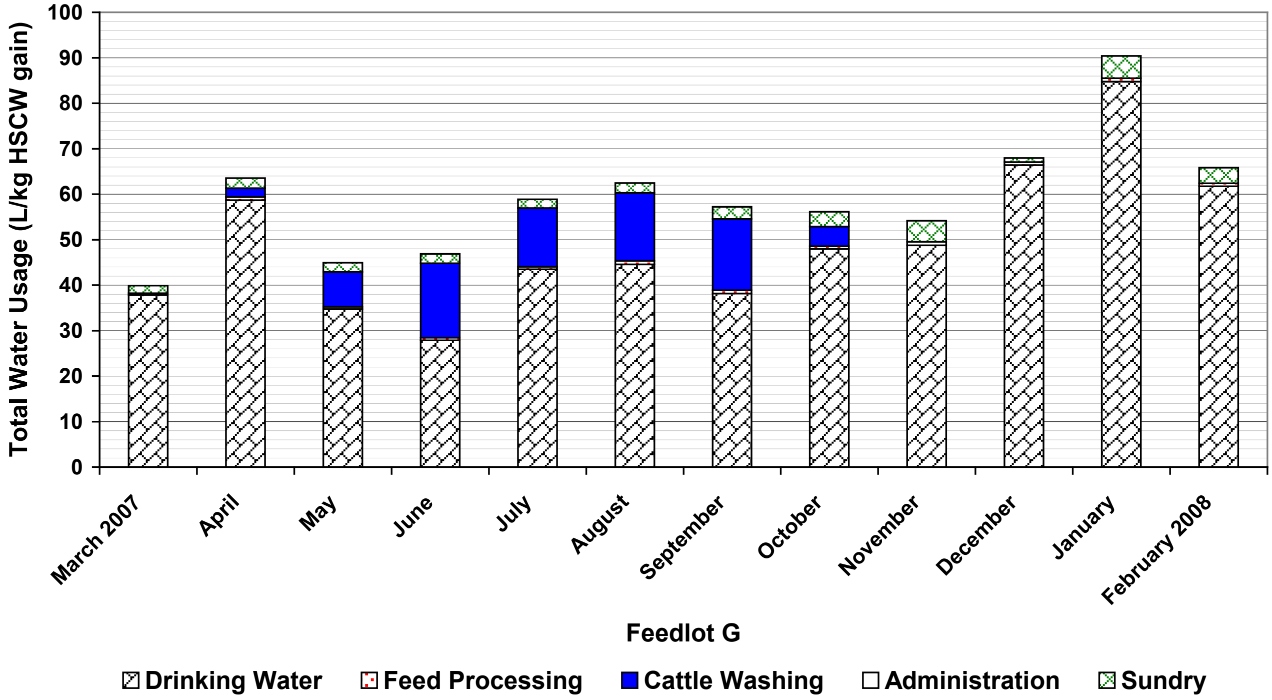


Figure 21 – Monthly total water usage at Feedlot G (L/kg HSCW gain)

FIGURE 21 shows the total monthly clean water usage at Feedlot G for the period March 2007 to February 2008. Total monthly clean water use ranges from 40 to 90 L/kg HSCW gain. The lowest water usage was measured in March and the highest in summer (January). At this feedlot, office water usage could not be measured directly and therefore is included in the drinking water total. Drinking water is the single largest consumer of water in the feedlot as expected and contributed 28 to 85 L/kg HSCW gain or an average of 95 % of total usage in months with no cattle washing and an average 75 % in months when cattle were washed. Feed processing contributed an average of 0.6 L/kg HSCW gain or around 1 % of total usage. From May to October, cattle washing water usage contributed an average of 11.3 L/kg HSCW gain (21 %) of total water usage. Sundry uses contributed the remaining usage representing an average of 2.0 L/kg HSCW gain (4 %). Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

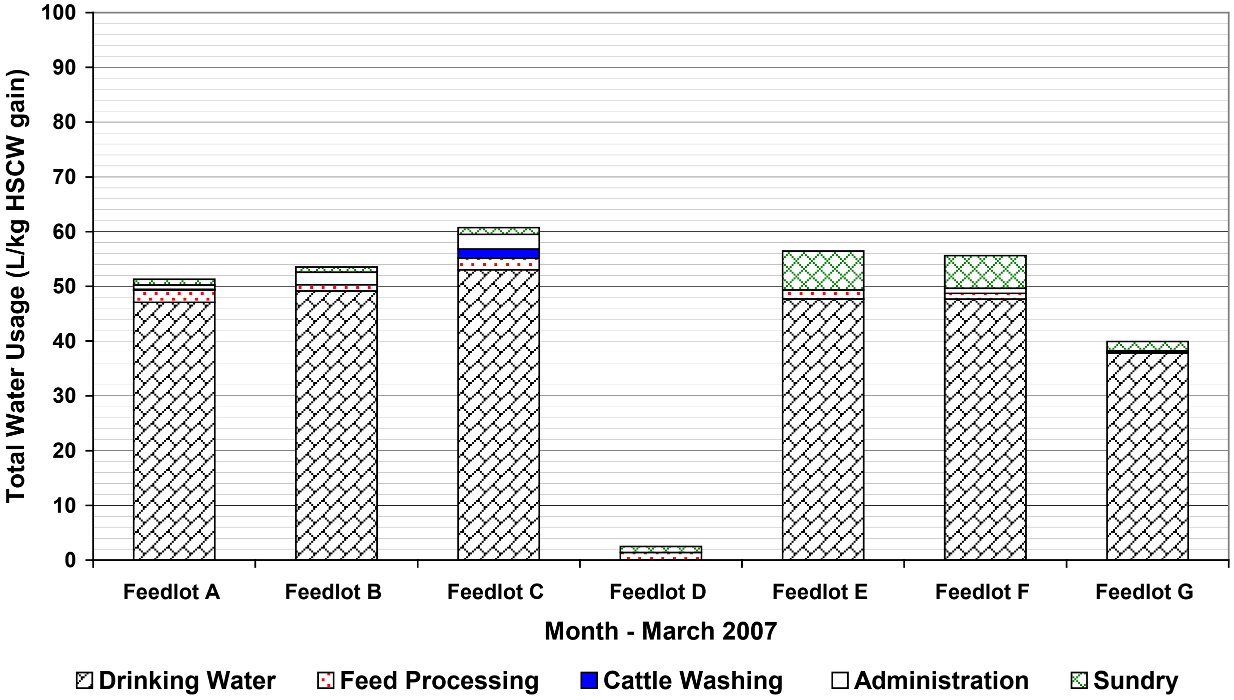


Figure 22 – Total water usage for March 2007 (L/kg HSCW gain)

FIGURE 22 shows the total clean water usage across all feedlots for March 2007. Total monthly clean water use ranges from 40 to 60 L/kg HSCW gain. The lowest water usage was measured at Feedlot G and the highest at Feedlot C. Drinking water was not recorded at Feedlot D during March 2007. Drinking water consumption ranged from 38 to 53 L/kg HSCW gain for all feedlots. Feed processing water usage ranged from 0.4 to 2.3 L/kg HSCW gain. Administration water usage was directly measured at Feedlots A, B, C and F and was found to range from 0.8 to 2.7 L/kg HSCW gain. Sundry water uses contributed 0.3 to 7 L/kg HSCW gain. Dust control and evaporative losses are the primary drivers of sundry water usage. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

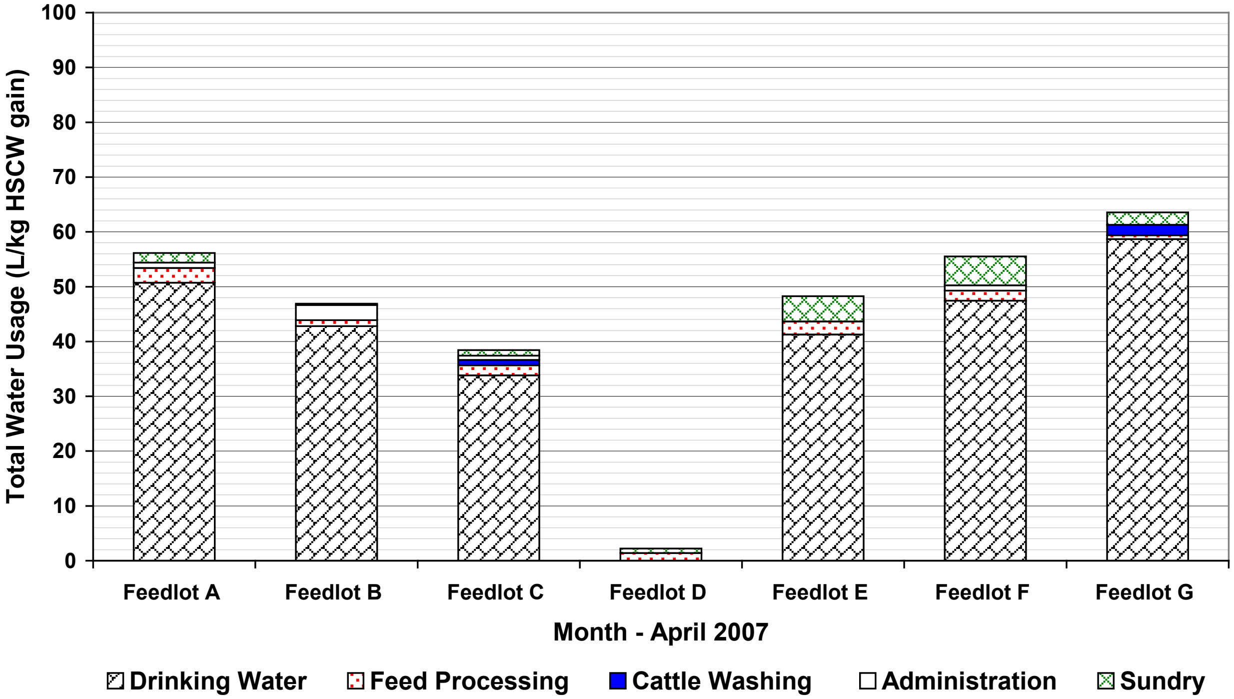


Figure 23 – Total water usage for April 2007 (L/kg HSCW gain)

FIGURE 23 shows the total clean water usage across all feedlots for April 2007. Total monthly clean water use ranges from 38 to 64 L/kg HSCW gain. The lowest water usage was measured at Feedlot C and the highest at Feedlot G. Drinking water was not recorded at Feedlot D during April 2007. Drinking water consumption ranged from 33 to 58 L/kg HSCW gain across all feedlots. Total water usage has increased in all feedlots by approximately 20 L/kg HSCW gain when compared with March levels, whilst Feedlot C recorded a reduction in its usage by a similar amount. Feed processing water usage ranged from 0.7 to 2.7 L/kg HSCW gain, similar levels to March. Administration water usage are similar to that measured in March at Feedlots A, B, C and F, ranging from 0.8 to 2.8 L/kg HSCW gain. Sundry water uses contributed 0.2 to 5.3 L/kg HSCW gain. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

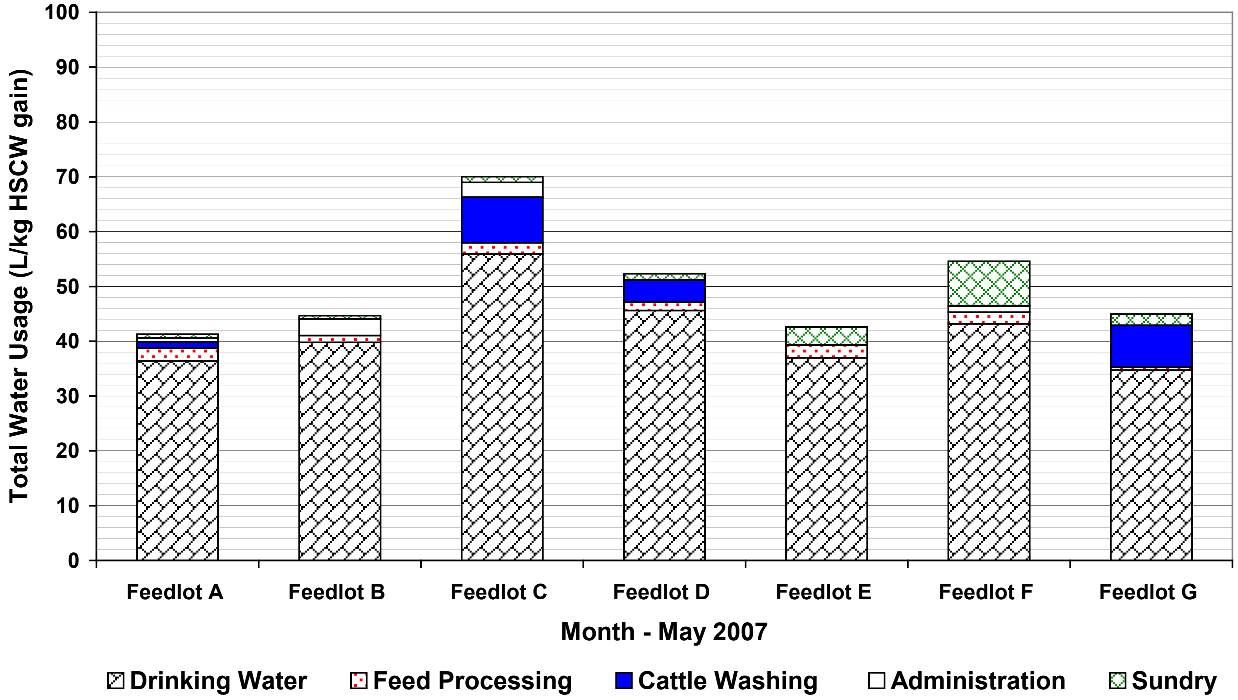


Figure 24 – Total water usage for May 2007 (L/kg HSCW gain)

FIGURE 24 shows the total clean water usage across all feedlots for May 2007. Total monthly clean water usage levels range from 41 to 70 L/kg HSCW gain, a similar range to April but the pattern is different. The main driver of total monthly clean water use is drinking water consumption level, which is determined by prevailing climatic conditions. Hence there is greater variability. Consider Feedlot C, which has increased its drinking water consumption considerably and has commenced washing cattle. Feedlot F has a similar level to previous months, whilst Feedlot G has recorded a lower drinking water consumption than previous. Drinking water consumption ranged from 35 to 54 L/kg HSCW gain a similar range when compared to April but with a dissimilar pattern. Feed processing water usage ranged from 0.5 to 2.4 L/kg HSCW gain, similar levels to April. Cattle washing water usage ranged from 1.2 to 8.3 L/kg HSCW gain. Administration water usage are similar to that measured in April at Feedlots A, B, C and F, ranging from 0.7 to 3.0 L/kg HSCW gain. Sundry water uses contributed 0.6 to 8.2 L/kg HSCW gain. At Feedlot F, the increased sundry water usage is due to irrigation of gardens. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

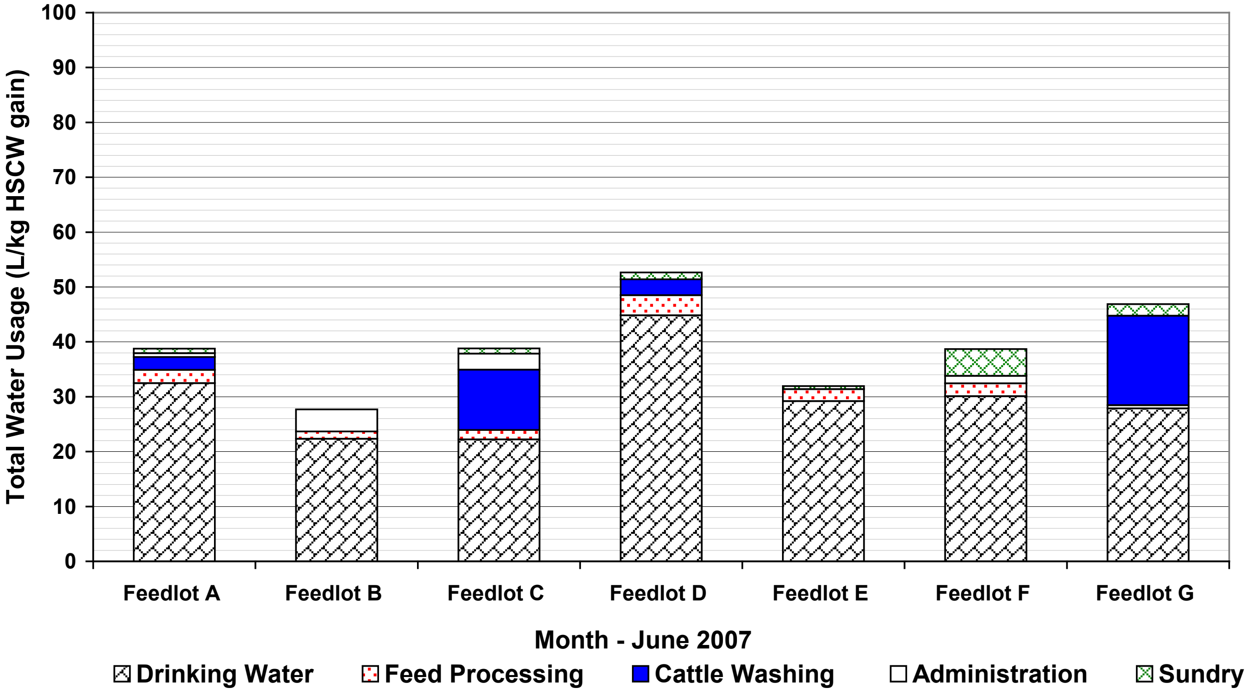


Figure 25 – Total water usage for June 2007 (L/kg HSCW gain)

FIGURE 25 shows the total clean water usage across all feedlots for June 2007. Total monthly clean water usage levels have reduced from 28 to 52 L/kg HSCW gain. The greatest reduction was at Feedlot C, where levels reduced from 70 to 38 L/kg HSCW gain, and this was driven by a reduction drinking water consumption level, a result of prevailing climatic conditions. However, Feedlots A, D and E recorded similar levels in total water usage when compared with May. Drinking water consumption ranged from 22 to 44 L/kg HSCW gain. Feed processing water usage ranged from 0.6 to 3.7 L/kg HSCW gain, a slightly greater range when compared to May, due primarily to Feedlot D moving from tempering to a steam flaking system. Cattle washing water usage ranged from 2.4 to 15.4 L/kg HSCW gain. Administration water usage are similar to that measured in May at Feedlots A, B, C and F, ranging from 0.7 to 4.0 L/kg HSCW gain. Sundry water uses contributed 0.4 to 4.9 L/kg HSCW gain. The reduction in sundry water use for Feedlot F, driven by reduced irrigation of gardens. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

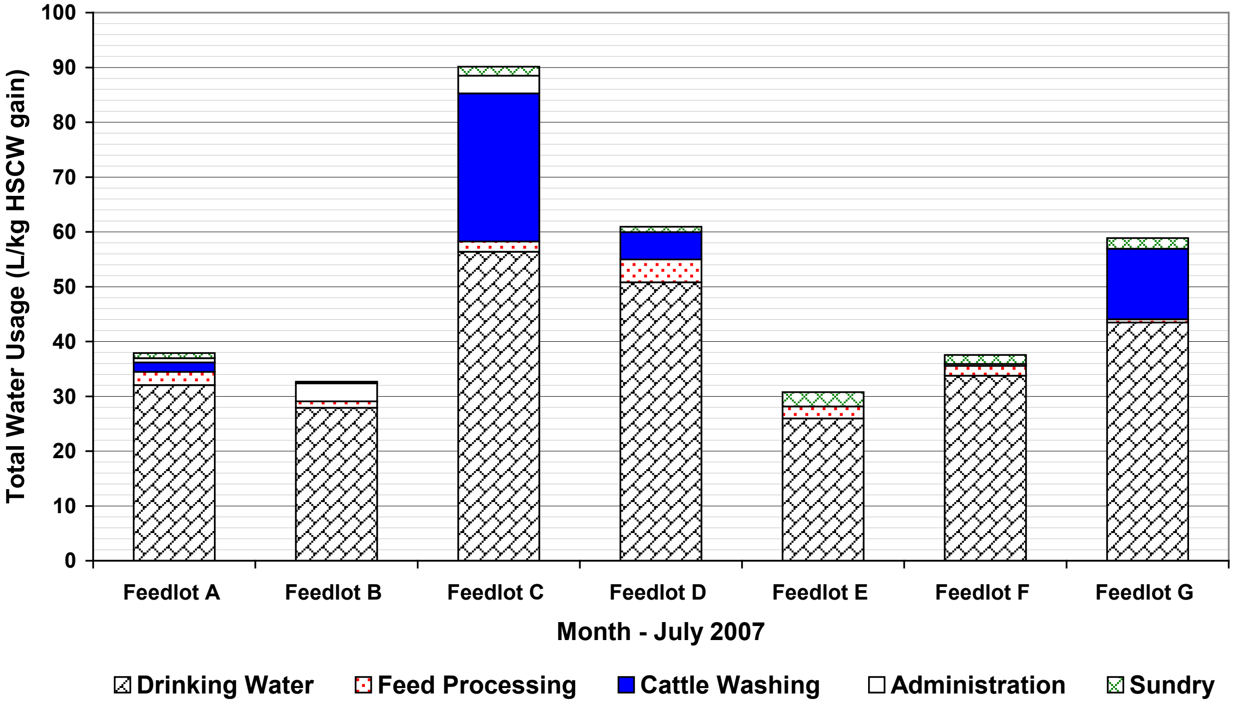


Figure 26 – Total water usage for July 2007 (L/kg HSCW)

FIGURE 26 shows the total clean water usage across all feedlots for July 2007. Total monthly clean water usage levels have increased and range from 30 to 90 L/kg HSCW gain. This range is similar to the range found in total water usage by Davis and Watts (2006) (38 to 90 L/kg HSCW gain). Feedlots C, D and G have increased total usage levels when compared with June, with the greatest increase at Feedlot C. At Feedlot C, the total usage level has increased from 38 to 90 L/kg HSCW gain, driven by an increase drinking water consumption and cattle washing usage levels. Drinking water consumption ranged from 26 to 56 L/kg HSCW gain. Feed processing water usage ranged from 0.6 to 4.2 L/kg HSCW gain, a similar range when compared to June. Cattle washing water usage ranged from 1.7 to 27.0 L/kg HSCW gain, a two-fold increase when compared with June. Administration water usage are similar to that measured in June at Feedlots A, B, C and F, ranging from 0.3 to 3.3 L/kg HSCW gain. Sundry water uses contributed 0.3 to 2.6 L/kg HSCW gain. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

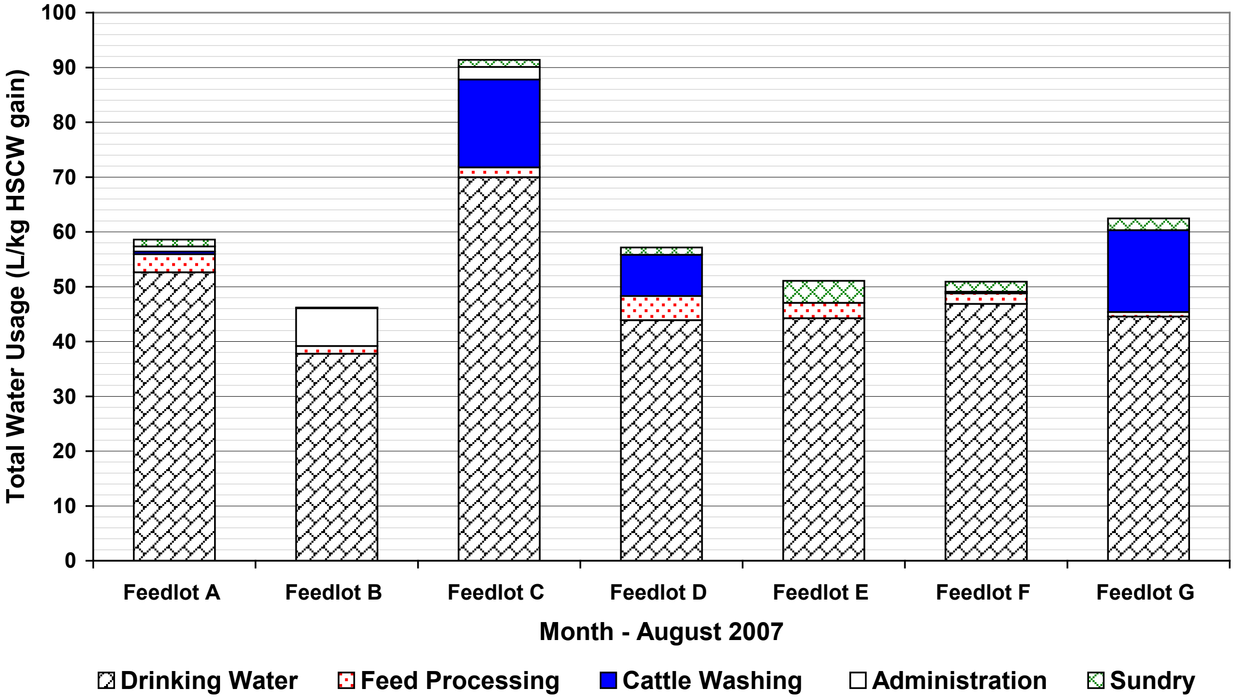


Figure 27 – Total water usage for August 2007 (L/kg HSCW)

FIGURE 27 shows the total clean water usage across all feedlots for August 2007. Total monthly clean water usage levels have increased when compared to July and range from 46 to 90 L/kg HSCW gain. Drinking water consumption ranged from 38 to 70 L/kg HSCW gain. Feed processing water usage ranged from 0.8 to 4.4 L/kg HSCW gain, a similar range when compared to July. Cattle washing water usage ranged from 0.5 to 16.1 L/kg HSCW gain, a similar range when compared with June. Administration water usage has increased from July levels at Feedlots A, B, C and F and ranges from 0.3 to 6.9 L/kg HSCW gain. Sundry water uses contributed 0.3 to 4.0 L/kg HSCW gain. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

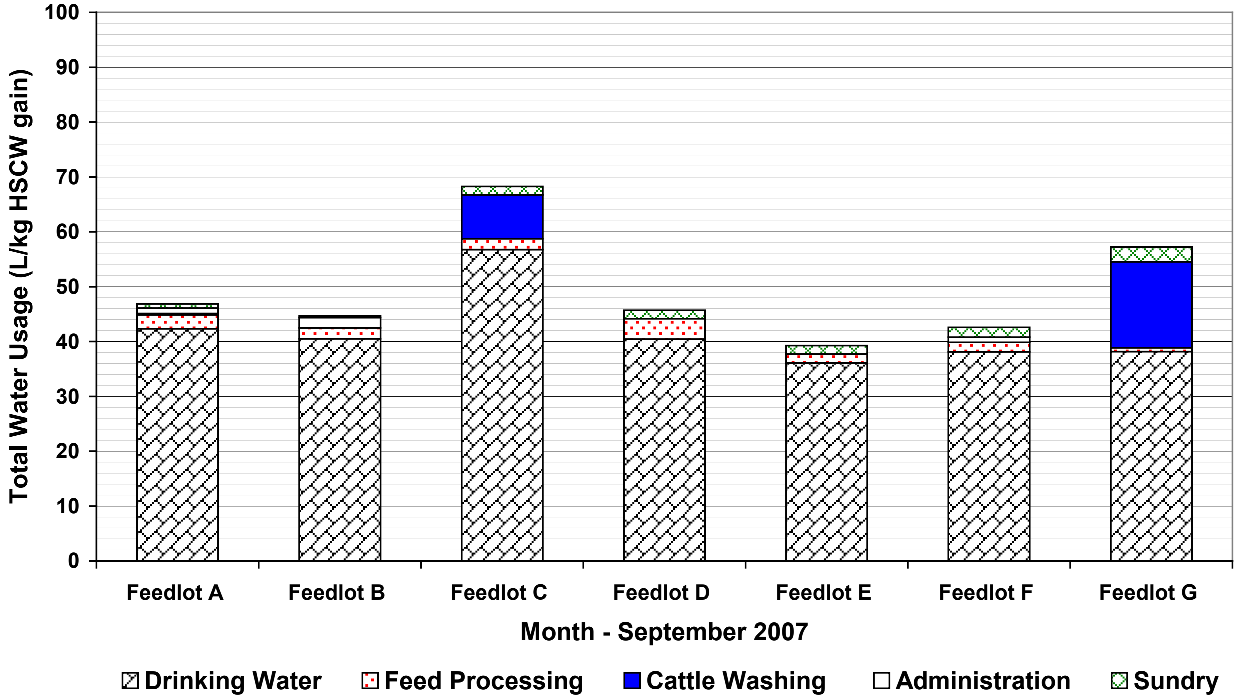


Figure 28 – Total water usage for September 2007 (L/kg HSCW)

FIGURE 28 shows the total clean water usage across all feedlots for September 2007. Total monthly clean water usage levels have reduced when compared to July and range from 40 to 68 L/kg HSCW gain. Drinking water consumption levels averaged 40 L/kg HSCW gain and are similar across all feedlots with the exception of Feedlot C, which recorded 57 L/kg HSCW gain. Feed processing water usage ranged from 0.7 to 3.7 L/kg HSCW gain, a slight reduction when compared to August. Cattle washing water usage ranged from 8 to 14.6 L/kg HSCW gain, a similar range when compared with June. Administration water usage has reduced from August levels at Feedlots A, B, C and F and ranges from 0.9 to 1.9 L/kg HSCW gain. Sundry water uses contributed 0.3 to 2.7 L/kg HSCW gain. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

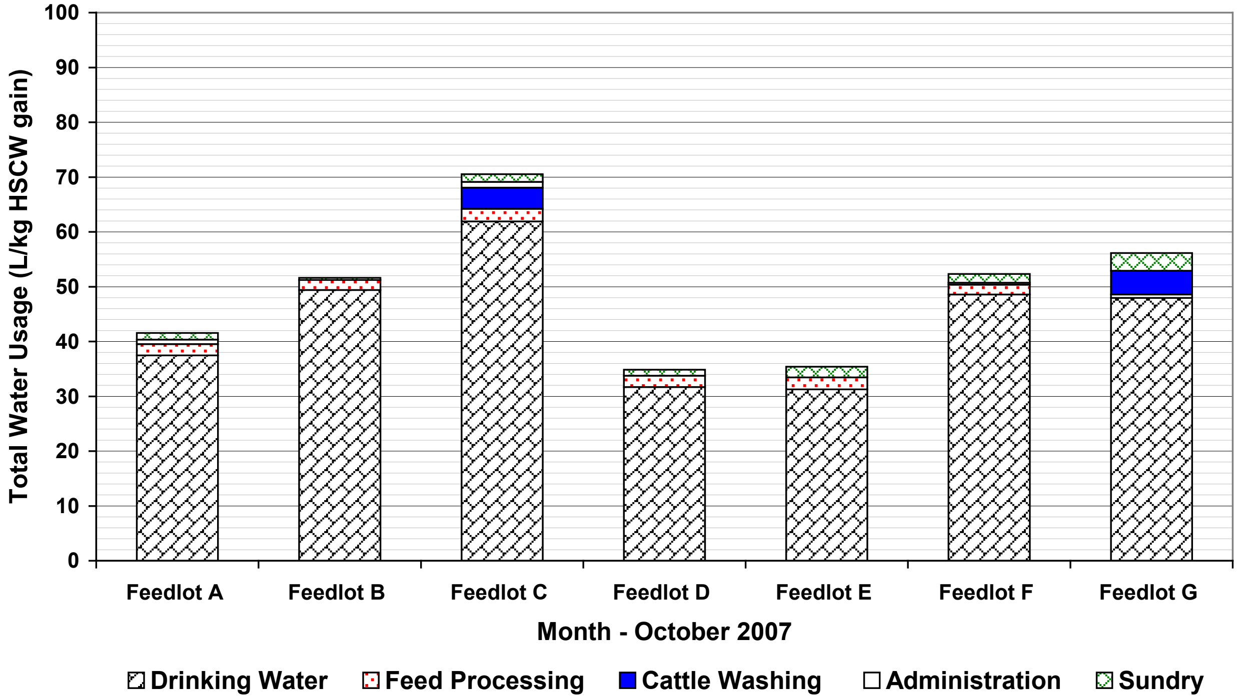


Figure 29 – Total water usage for October 2007 (L/kg HSCW gain)

FIGURE 29 shows the total clean water usage across all feedlots for October 2007. Total monthly clean water usage levels have reduced in Feedlots D, E, increased in Feedlots B, F and G, whilst Feedlots A and C have similar usage levels when compared to August. The total water usage level ranges from 36 to 70 L/kg HSCW gain. Drinking water consumption levels ranged between 32 and 61 L/kg HSCW gain. Feed processing water usage ranged from 0.6 to 2.3 L/kg HSCW gain, a similar range when compared to August. Cattle washing water usage ranged from 3.9 to 4.9 L/kg HSCW gain, a reduction from September levels. Administration water usage levels at Feedlots A, B, C and F have reduced when compared to September and range from 0.3 to 1.0 L/kg HSCW gain. Sundry water uses are similar when compared to September levels and contributed 0.4 to 3.2 L/kg HSCW gain. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

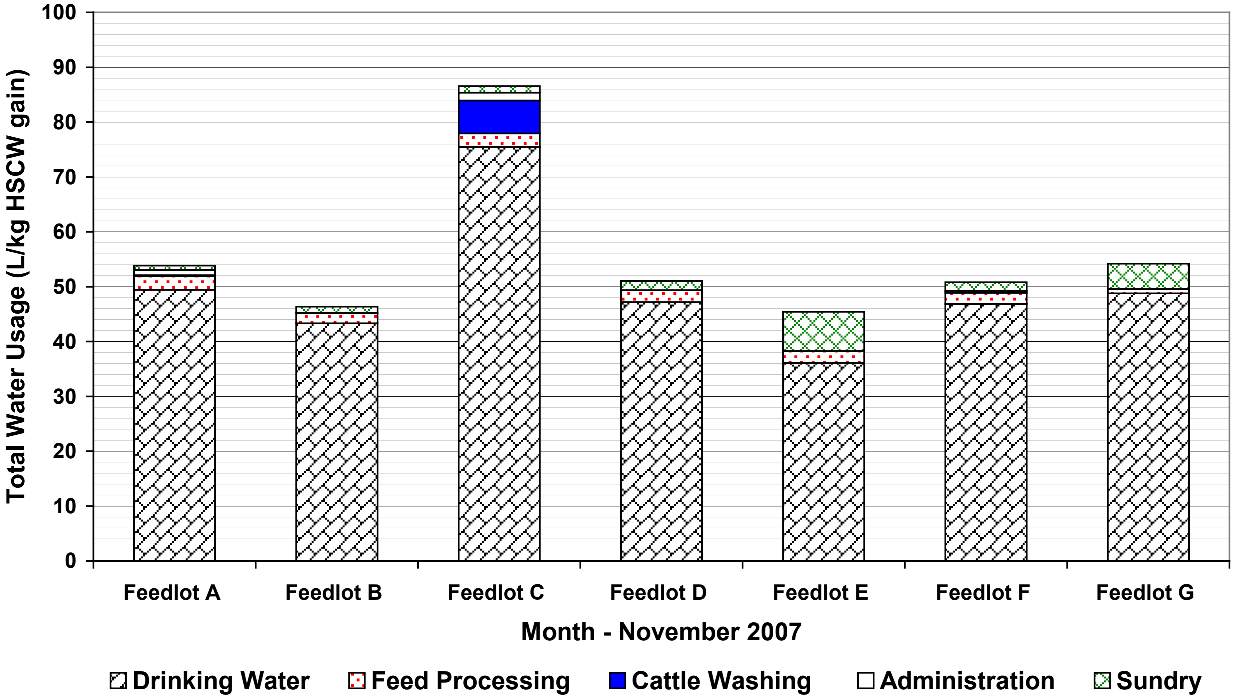


Figure 30 – Total water usage for November 2007 (L/kg HSCW gain)

FIGURE 30 shows the total clean water usage across all feedlots for November 2007. Total monthly clean water usage levels are similar between feedlots ranging from 46 to 54 L/kg HSCW gain, whilst Feedlot C recorded a usage level of 87 L/kg HSCW gain. Drinking water consumption levels have increased and ranged between 36 and 75 L/kg HSCW gain. Feed processing water usage ranged from 0.8 to 2.5 L/kg HSCW gain, a similar range when compared to October. Feedlot C was the only feedlot still washing cattle and this contributed 6.0 L/kg HSCW gain to the total water usage level. Administration water usage levels at Feedlots A, B, C and F are similar to October levels and range from 0.3 to 1.4 L/kg HSCW gain. Sundry water uses have increased slightly when compared to October levels and contributed between 0.4 to 7.2 L/kg HSCW gain. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

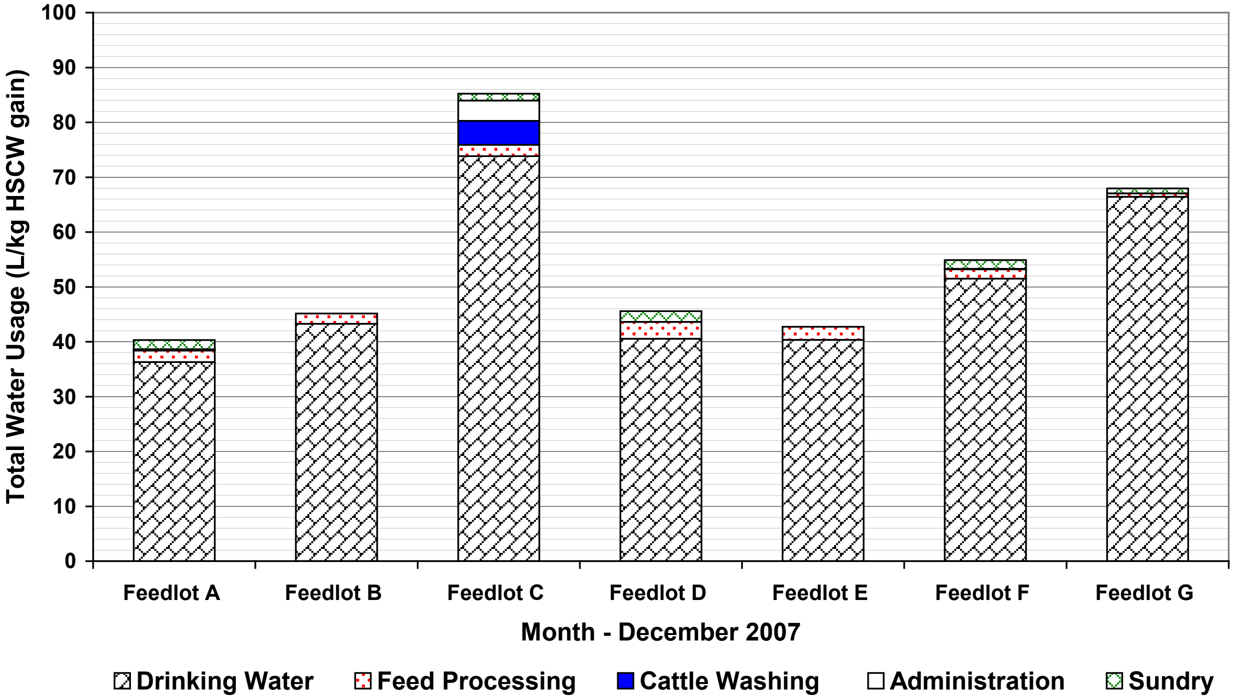


Figure 31 – Total water usage for December 2007 (L/kg HSCW gain)

FIGURE 31 shows the total clean water usage across all feedlots for December 2007. Total monthly clean water usage levels at Feedlots B, C, D and E are similar whilst F and G have increased and Feedlot A decreased when compared with November levels. Total water usage ranges from 40 to 86 L/kg HSCW gain. Drinking water consumption levels ranged between 36 and 73 L/kg HSCW gain. Feed processing water usage ranged from 0.6 to 3.1 L/kg HSCW gain, a similar range when compared to November. Feedlot C was the only feedlot still washing cattle and this contributed 4.4 L/kg HSCW gain to the total water usage level. Administration water usage levels at Feedlots A, B and F have reduced, whilst Feedlot C has increased when compared to November levels and range from 0.2 to 3.7 L/kg HSCW gain. Sundry water uses have increased slightly when compared to November levels and contributed between 0.4 to 2.0 L/kg HSCW gain. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

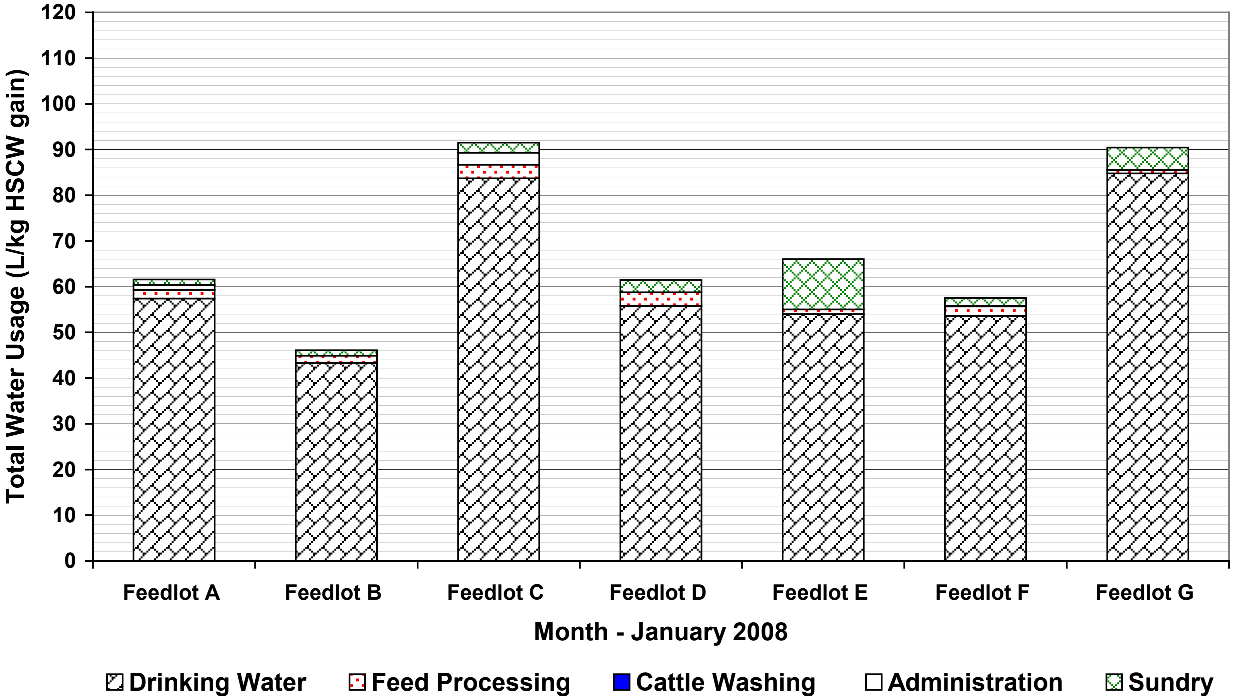


Figure 32 – Total water usage for January 2008 (L/kg HSCW gain)

FIGURE 32 shows the total clean water usage across all feedlots for January 2008. Total monthly clean water usage levels at Feedlots A, C, D, E and G has increased whilst B and F are similar when compared with December levels. Total water usage ranges from 46 to 92 L/kg HSCW gain. Drinking water consumption levels ranged between 43 and 85 L/kg HSCW gain. Feed processing water usage ranged from 0.8 to 3.0 L/kg HSCW gain, a similar range when compared to December. All feedlots had ceased cattle washing. Administration water usage levels at Feedlots A, B, C and F have reduced, when compared to December levels and range from 0.1 to 2.7 L/kg HSCW gain. Sundry water uses have increased slightly when compared to December levels and contributed between 0.4 to 11 L/kg HSCW gain. This is due to increased evaporative losses. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

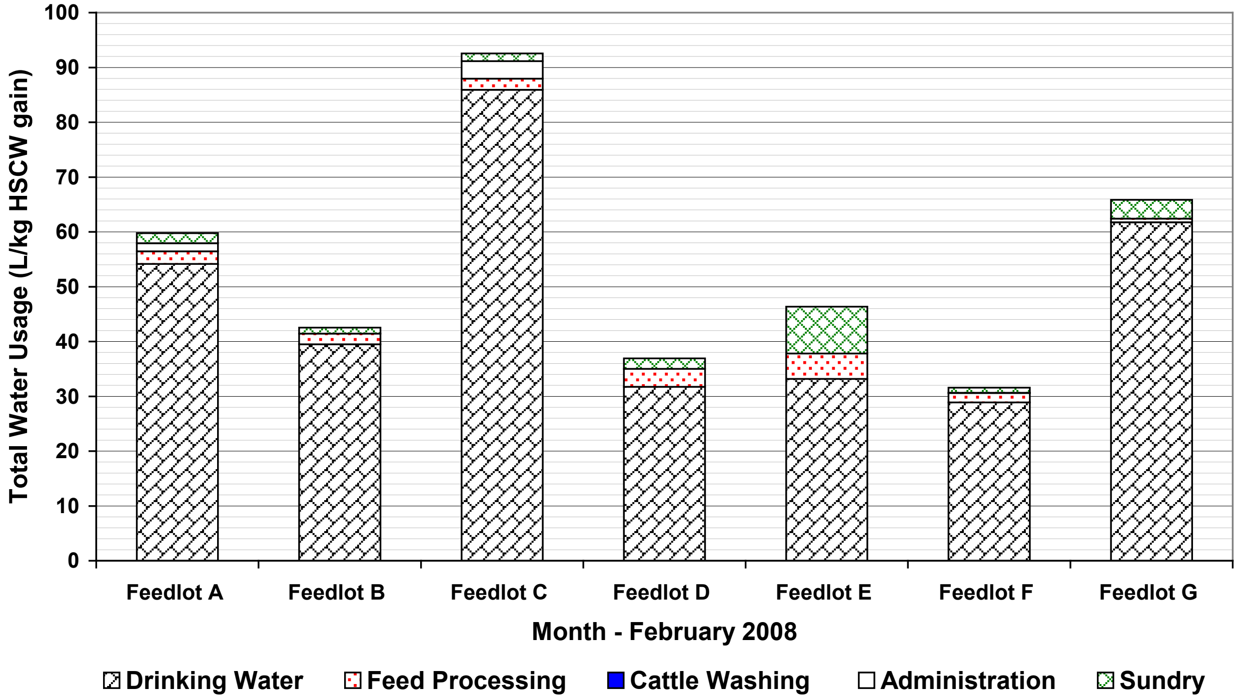


Figure 33 – Total water usage for February 2008 (L/kg HSCW gain)

FIGURE 33 shows the total clean water usage across all feedlots for February 2008. Total monthly clean water usage levels at Feedlots A, B, C and D are similar, Feedlot F has reduced, whilst E and G are similar when compared with January levels. Total water usage ranges from 32 to 92 L/kg HSCW gain. Drinking water consumption levels ranged between 29 and 86 L/kg HSCW gain. Feed processing water usage ranged from 0.7 to 4.6 L/kg HSCW gain, an increase when compared to January. All feedlots had ceased cattle washing. Administration water usage levels at Feedlots A, B, C and F have increased, when compared to January levels and range from 1.5 to 3.2 L/kg HSCW gain. Sundry water uses have increased slightly when compared to January levels and contributed between 0.4 to 8.5 L/kg HSCW gain. Further discussion on activity water usage is presented in Sections 5.2 to 5.6.

The monthly variation and variation between feedlots, when standardised to a per kg of HSCW gain, can be attributed to a number of factors. These include climatic variation, cattle genotype, cattle market types and management operations including frequency of trough cleaning, cattle washing, dust control and feed processing. Further discussion on individual activity water usage is presented in the following sections.

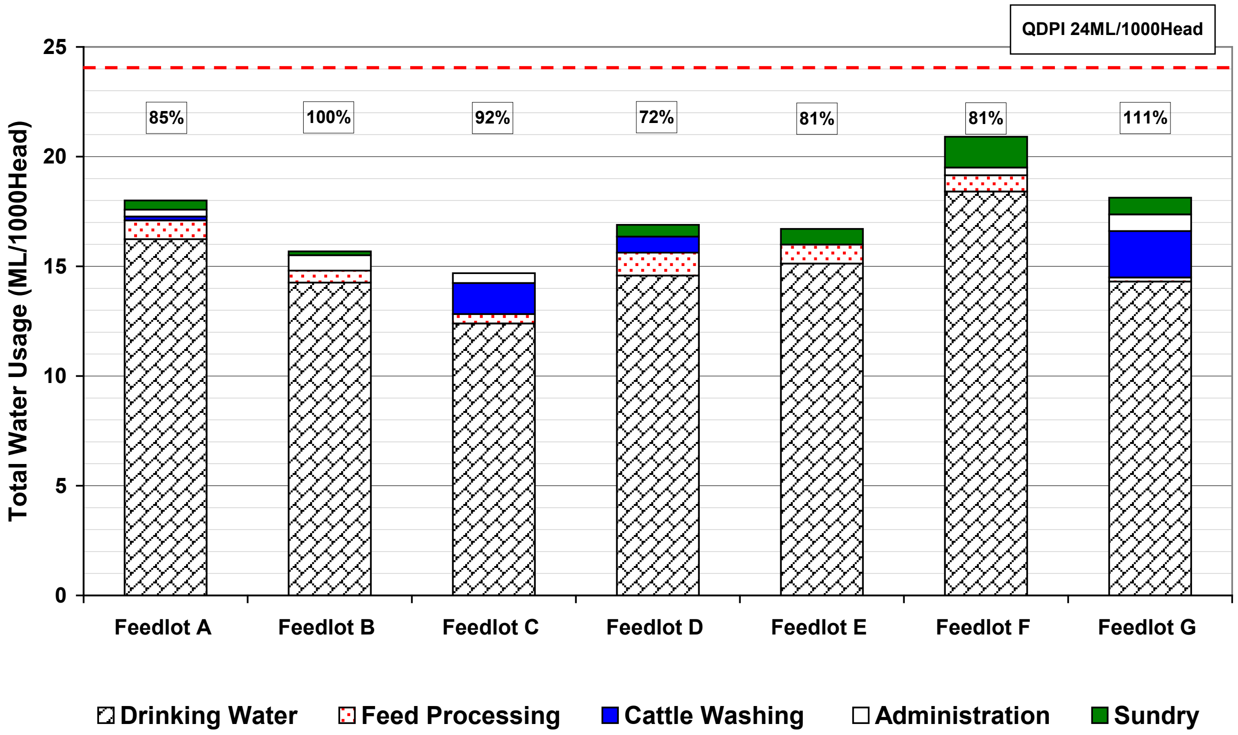


Figure 34 – Total water usage (ML/1000 head on feed) and occupancy

When issuing a licence for a feedlot in Queensland, Queensland Department of Primary Industries and Fisheries (QDPI&F) requires that the feedlot has a correctly licensed, high-reliability water supply equivalent to 24 ML per year for each 1000 SCU of licensed capacity. FIGURE 34 illustrates the total water usage on a megalitre per head on feed basis (Head is used rather than SCU for those states where SCU does not apply) for the seven feedlots that participated in the water usage investigation. The average occupancy, defined as mean number of cattle on hand divided by the licensed pen capacity) and the QDPI water supply licensing requirement of 24 ML/1000 head (DPI, 2000) are also shown. For Feedlot G, the head on feed also incorporates background and starter cattle and therefore, occupancy is apparently greater than 100%.

The QDPI requirement makes a small allowance for other uses such as trough cleaning, minor leakages but does not allow for significant usage for the purposes of dust control, feed processing or evaporation from open storages. From FIGURE 34, the total water usage for the period March 2007 to February 2008 ranged from 14.5 to 20.5 ML/1000 head and is below that required by the QDPI&F.

5.2 Drinking Water Consumption

5.2.1 Monthly Variation in Drinking Water Consumption

Drinking water is the single largest consumer of water in the feedlot and contributed 22 to 86 L/kg HSCW gain across all feedlots. The differences between feedlot drinking water consumption on a kg HSCW gain basis can be attributed to the differences between market types (long fed - low daily gain v domestic - higher daily gain). However, the primary driver of drinking water consumption is climatic variation.

FIGURE 35 illustrates the average drinking water consumption on a per head per day basis for the seven feedlots that participated in the water usage investigation. The minimum and maximum drinking water consumption per head per day for any one month is also presented. Note that feedlot numbering in this section does not match the numbering in previous sections to maintain anonymity for the participating feedlots. Whilst a summary is provided in this section, complete individual feedlot monthly drinking water consumption figures on a per head per day basis are presented in Appendix A.

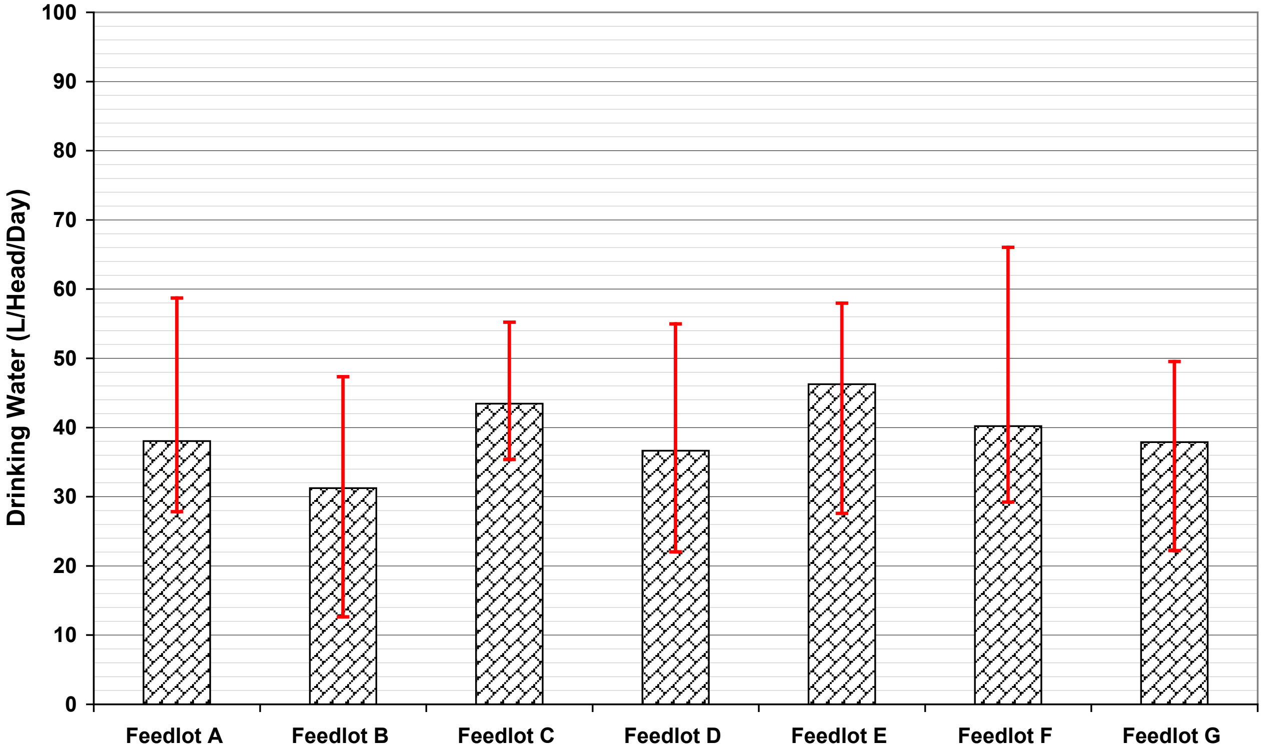


Figure 35 – Average / maximum / minimum drinking water for March 2007 to February 2008 (L/head/day)

The average drinking water consumption across all feedlots for March 2007 to February 2008 ranged from 31 L/head/day at Feedlot B to 46 L/head/day at Feedlot E, with an average in the order of 40 L/head/day. Feedlot E located in a sub-tropical environment had the highest average drinking water consumption of 46 L/head/day, whilst Feedlot B, which experiences cold winters, mild summers and high rainfall when compared with other feedlot locations, had the lowest drinking water consumption of 31 L/head/day.

These levels are less than the often quoted figure within the industry of an average of 65 L/head/day. It is believed that the 65 L/head/day figure is based on the maximum daily requirement of 5 L per 50 kg LWT, hence representing the water requirements of a 650 kg beast. Parker et al. (2000) in their US study found drinking water consumption to average 34.1 and 43.9 L/head/day in winter and summer respectively, comparable to the figures found in this study.

The maximum monthly drinking water consumption recorded was 66 L/head/day at Feedlot E during January 2008 and the minimum of 12 L/head/day was recorded at Feedlot B in June 2007. This difference can be attributed to differences in climatic conditions between these two feedlots including temperature and rainfall. Feedlot B experienced a very cold and wet June 2007, whilst Feedlot E experienced a hot and dry January 2008.

An indication of the monthly variability in drinking water consumption levels can be gained through comparison of the maximum, minimum and average consumption levels. Feedlots A and F have a consistent usage with only one or two months of high usage. Conversely, Feedlot C has less variability.

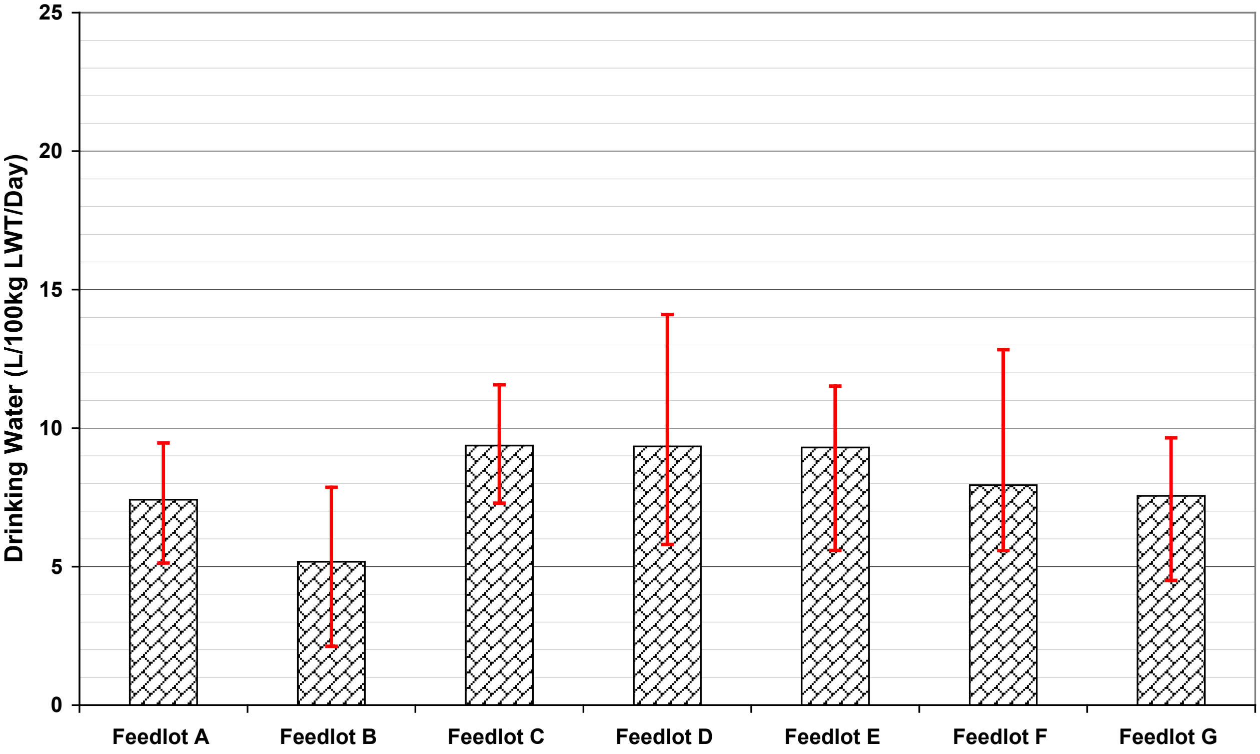


Figure 36 – Average / maximum / minimum drinking water for March 2007 to February 2008 (L/100 kg LWT/day)

FIGURE 36 illustrates the average drinking water consumption standardised on a per 100 kg LWT per day basis for the seven feedlots that participated in the water usage investigation. The minimum and maximum drinking water consumption per 100 kg per day for any one month is also presented.

The average drinking water consumption across all feedlots for March 2007 to February 2008 ranged from 5 L/100 kg LWT/day at Feedlot B to 9.5 L/100 kg LWT/day at Feedlots C, D and E, with an average in the order of 8 L/100 kg LWT/day. For Feedlots C, D and E, this is similar to the daily requirement for stock watering of 5 L per 50 kg LWT (DPI Site Selection Farm Note 1995). Whilst for Feedlots A, F and G and, in particular Feedlot B, it is less than the quoted daily requirement.

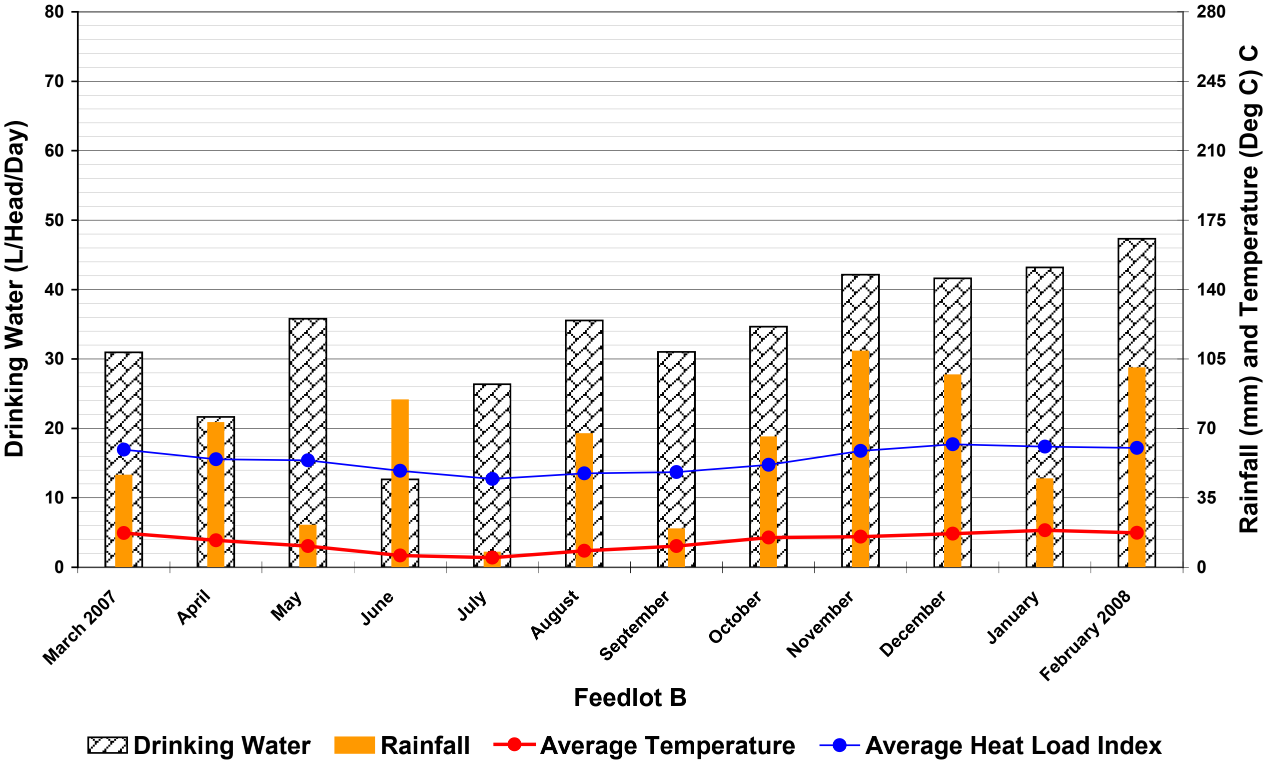


Figure 37 – Drinking water consumption March 2007 to February 2008 - Feedlot B (L/head/day)

FIGURE 37 illustrates the average drinking water consumption on a per head per day basis for Feedlot B. Monthly rainfall, average daily temperature and average heat load index are also presented. This feedlot experienced a cold winter, mild summer and over 50 mm of rainfall in all but 3 months of the year. Heat load index and rainfall are the primary drivers of drinking water consumption. Typically as heat load index increases, drinking water intake increases. Conversely, drinking water intake decreases with cool wet weather and rainfall. The monthly averages tend to mask the direct reduction in drinking water consumption. However, trends are still evident. In periods of hotter weather, the average monthly drinking water consumption is reduced with periods of rainfall. This can be seen when comparing months from November 2007 through February 2008. During this period, the heat load index is of the same magnitude but rainfall is causing the variability in drinking water consumption. In periods of rainfall, it would be expected that some water intake is from water captured in feed bunks, this may be a plausible explanation for some of the reduction in drinking water.

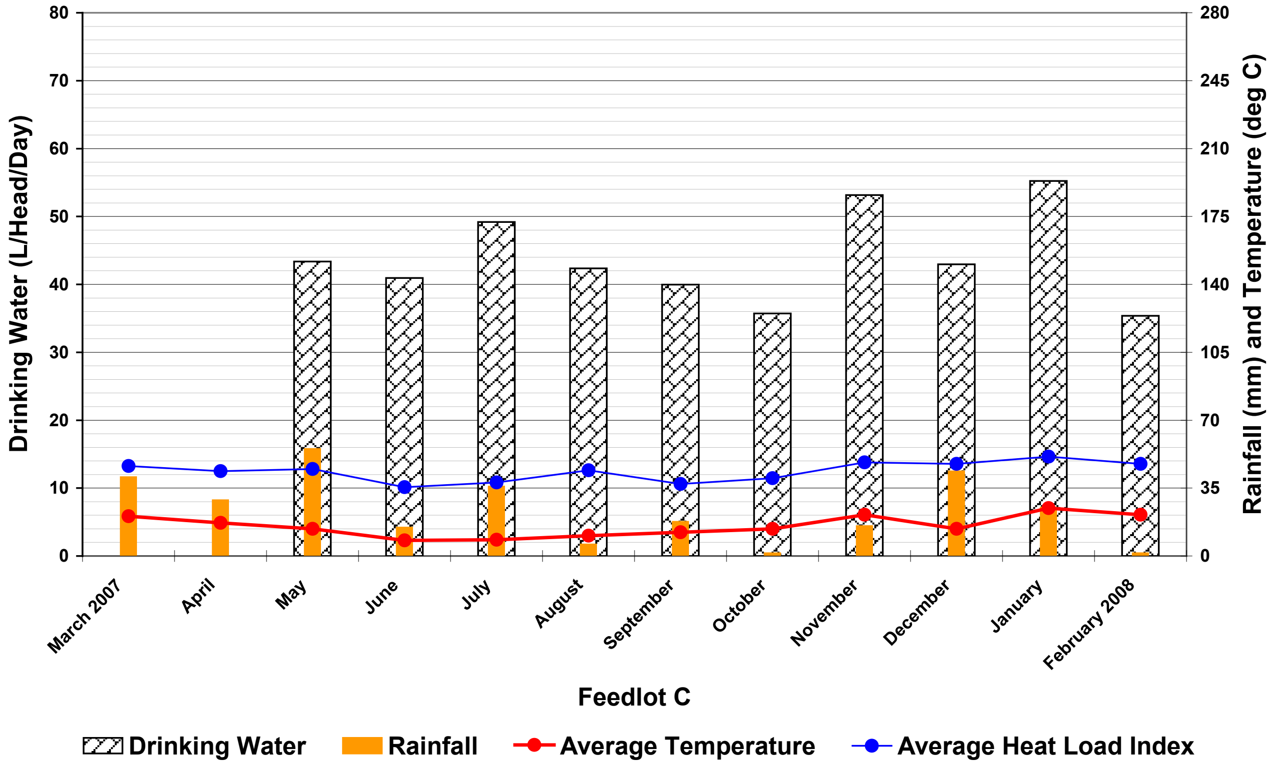


Figure 38 – Drinking water consumption for March 2007 to February 2008 – Feedlot C (L/head/day)

FIGURE 38 illustrates the average drinking water consumption on a per head per day basis for Feedlot C. Monthly rainfall, average daily temperature and average heat load index are also presented. This feedlot experienced a cold winter, mild summer and below average rainfall.

For the majority of months, a trend of increased drinking water with increased heat load index is apparent at this feedlot. However, there are some months, for example September, October and February 2008, in which other factors are also influencing consumption levels. October has a higher heat load index and less rainfall than September but drinking water is less. October and February have similar drinking water levels and no rainfall. However, average temperature and heat load index is less in October.

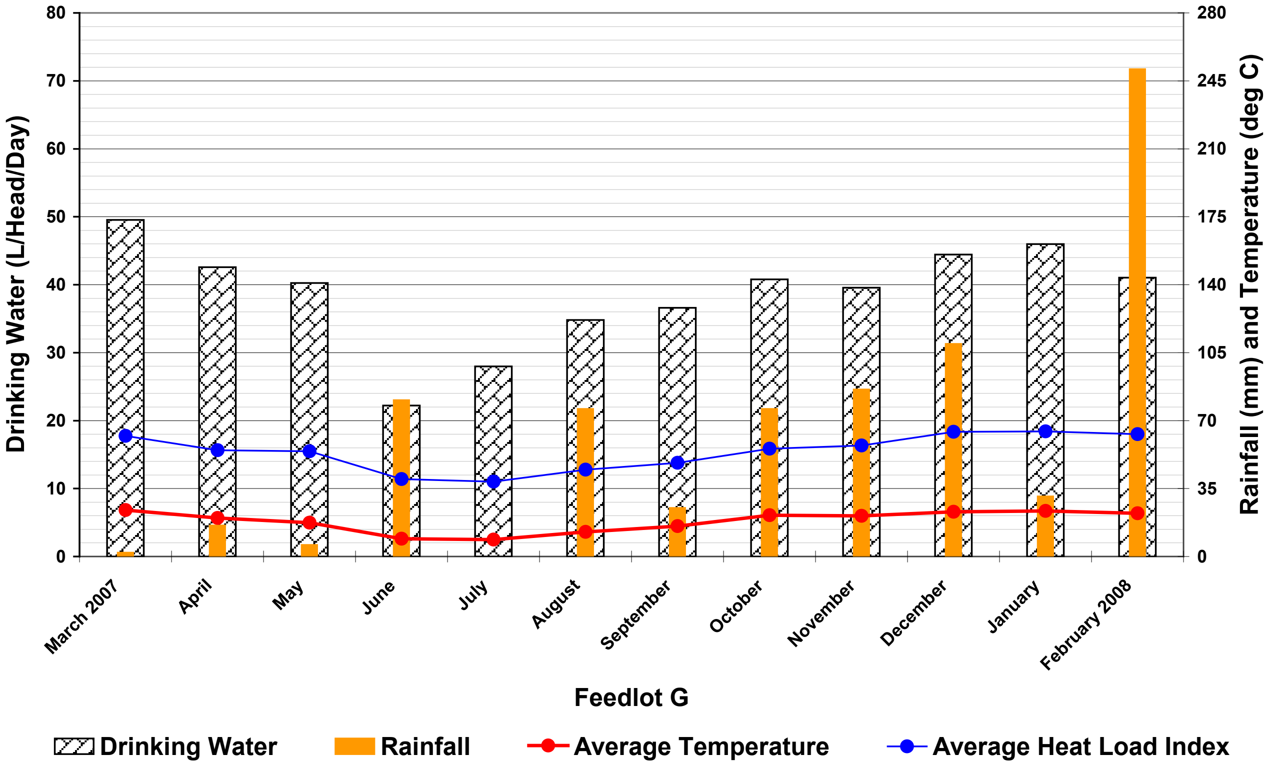


Figure 39 – Drinking water consumption March 2007 to February 2008 – Feedlot G (L/head/day)

Figure 39 illustrates the average drinking water consumption on a per head per day basis for Feedlot G. Monthly rainfall, average daily temperature and average heat load index are also presented. This feedlot experienced a cool winter, mild summer and summer dominant rainfall. At this feedlot, there is a strong trend between heat load index, rainfall and drinking water consumption. Typically, as heat load index increases, then drinking water intake increases. Conversely, drinking water decreases with cool wet weather (June) and periods of rainfall even when heat load index level remain elevated. This is evident when comparing March 2007, January and February 2008 data. March 2007, December 2007, January 2008 and February 2008 experienced similar heat load index levels, however March 2007 and January 2008 recorded less rainfall and correspondingly the drinking water consumption is reduced.

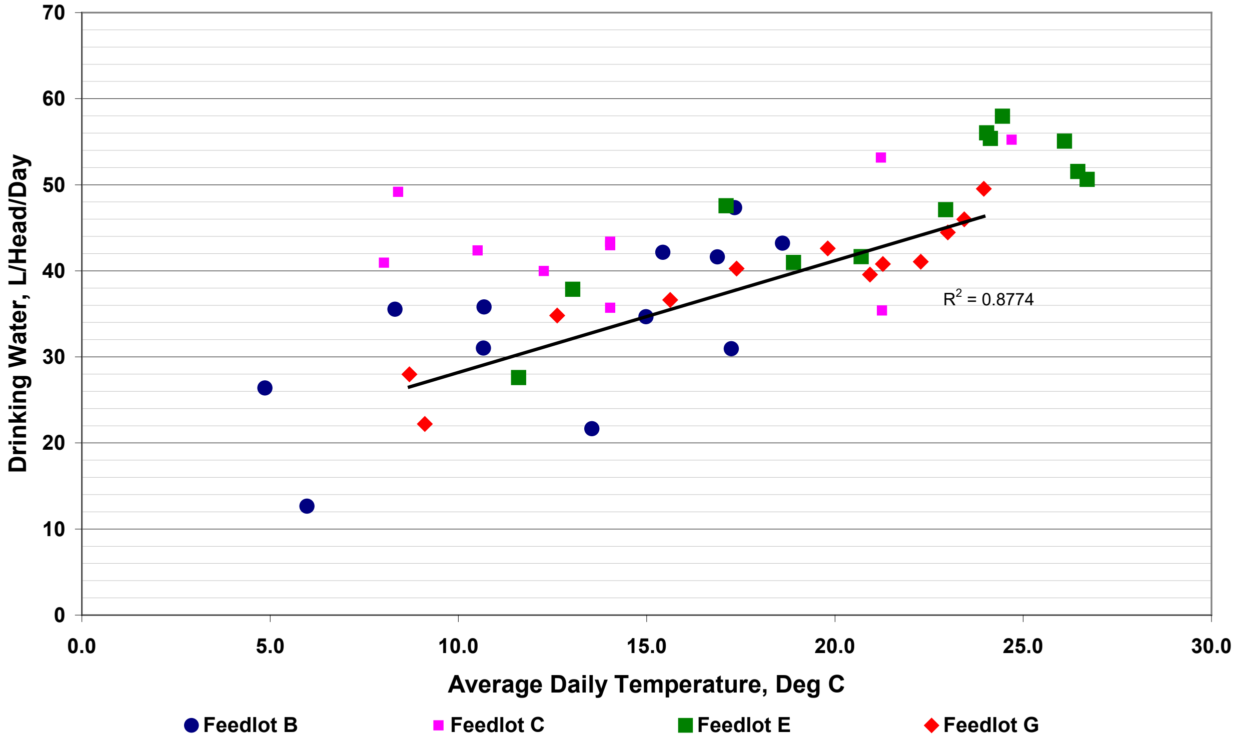


Figure 40 – Drinking water consumption (L/head/day) versus average monthly temperature for Feedlots B, C, E and G

FIGURE 41 illustrates the average drinking water consumption on a per head per day basis versus the average temperature for the corresponding month. Data from Feedlot B, C, E and G are presented. The trend line is based on Feedlot G data set. This figure shows the relationship between drinking water consumption and temperature. As temperature increases so does drinking water consumption.

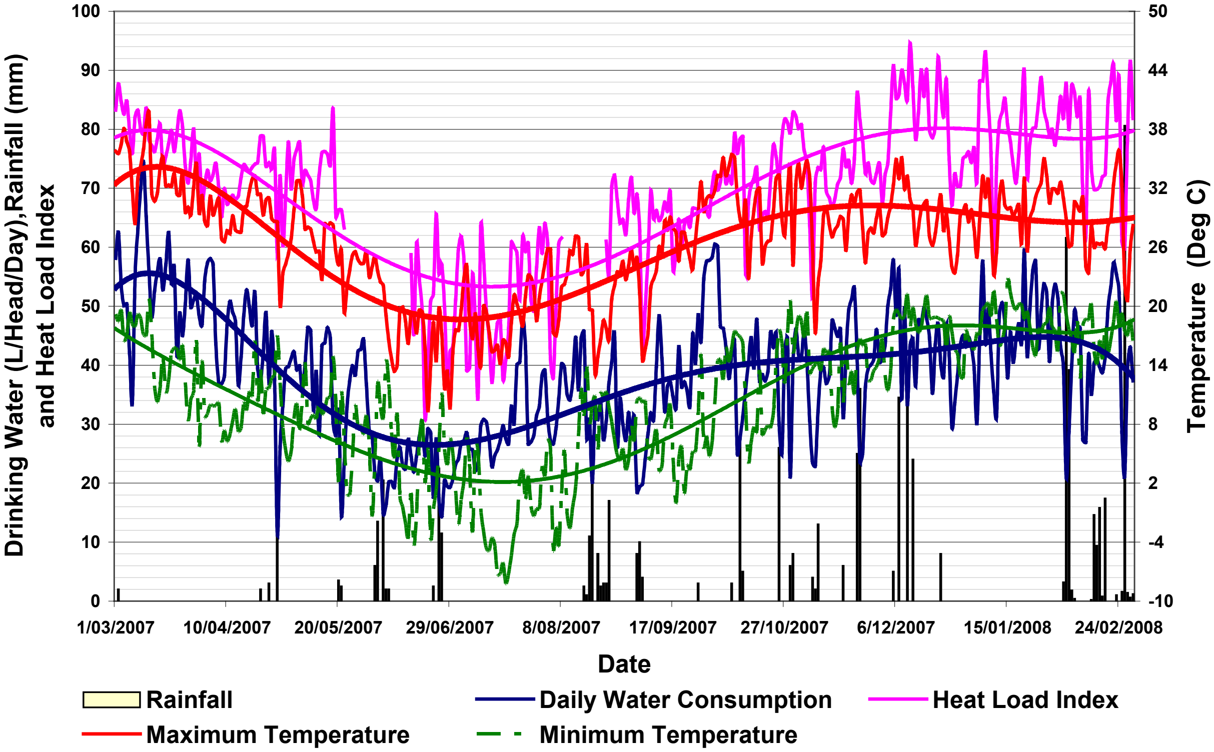


Figure 41 –Daily variation in drinking water consumption March 2007 to February 2008 – Feedlot G (L/head/day)

FIGURE 41 illustrates the drinking water consumption on a per head per day basis for Feedlot G. Daily rainfall, heat load index, minimum and maximum temperatures are also presented. A polynomial regression trend line averaging the daily data for the respective indices is also presented. At this feedlot, daily drinking water consumption was logged every three minutes so that hourly and daily total flows were recorded. This, in combination with climatic data, allows a more detailed examination of the drivers of drinking water consumption.

The daily drinking water consumption for the period March 2007 to February 2008 ranged from 11 L/head/day in April to 75 L/head/day in March. Throughout late autumn and early winter, drinking water consumption levels were at their lowest in the order of 24 L/head/day. Drinking water consumption levels start to increase as temperature increases and where at their highest in March 2007 when consumption levels in the order of 55 L/head/day were recorded. The relationship between drinking water consumption, heat load index and rainfall is clearly evident on a daily basis. During periods of rainfall, drinking water consumption is suppressed, whilst during periods of high heat load, drinking water is at its highest.

5.2.2 Diurnal Variation in Drinking Water Consumption

The diurnal variation in water consumption has been investigated across three one-week periods in summer, in which heat load index was at its greatest and demand for drinking water was at its greatest. The diurnal variation influences the demand throughout the day, and is an important design component of the feedlot water supply and reticulation system. Diurnal water consumption patterns were assessed by plotting water consumption flow rates throughout the day.

FIGURE 42 to FIGURE 44 illustrates the drinking water consumption on a per head per hour basis for three seven-day periods during December/January and February 2008. Hourly heat load index, ambient temperature and rainfall are presented.

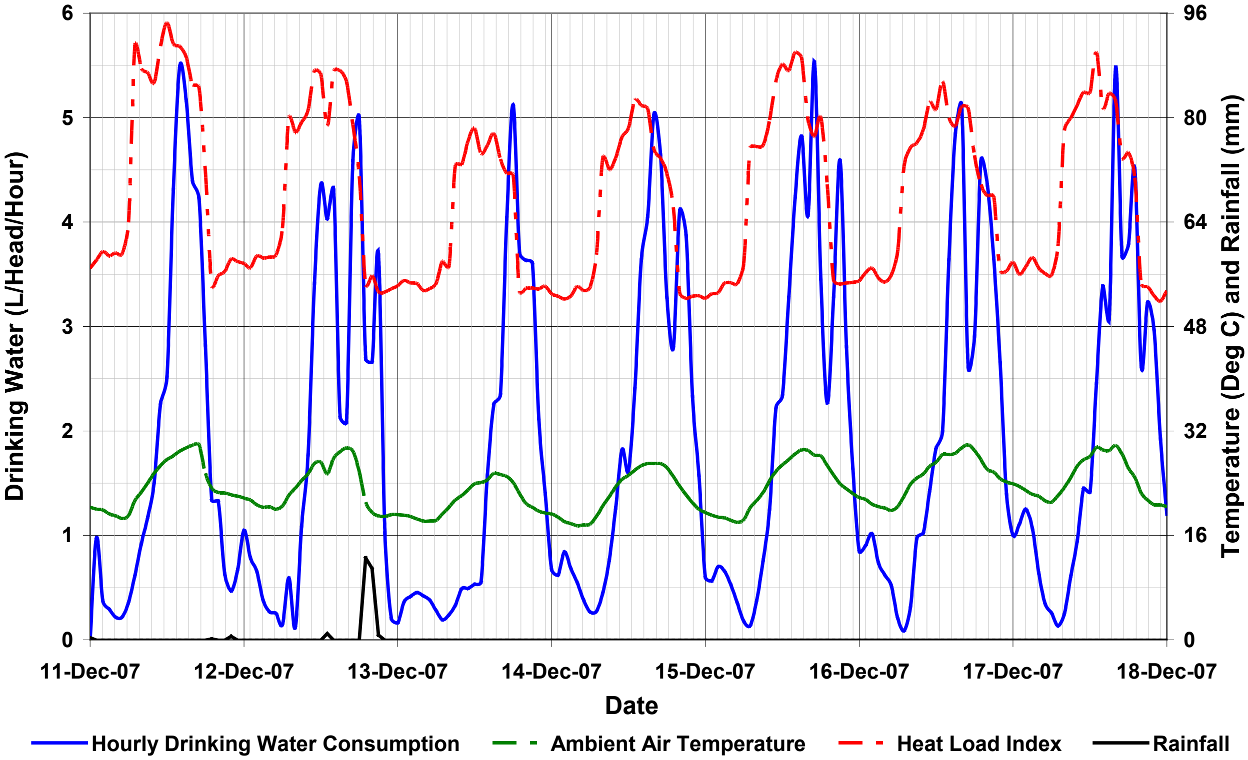


Figure 42 – Daily variation in drinking water consumption 11th December 2007 to 18th December 2007 - Feedlot G (L/head/hour)

FIGURE 42 shows drinking water consumption (L/head/hr) for Feedlot G for the period 11th December to 18th December 2007. Drinking water consumption clearly increases with increasing heat load. During this period, the peak drinking water requirement measured was in the order of 5.5L/head/hour. This represents a maximum flow rate required of approximately 660 L/min. This figure also shows that there is a lag of around 2 hours between peak heat load and peak drinking water consumption. Hence, it is at this time that the reticulation system must be capable of supplying the necessary water to the cattle.

The peak daily demand can be compared with the pumping capacity of the water reticulation system to determine if sufficient capacity is available to deliver water. The pumping capacity of the reticulation system is designed to be 1800 L/min. Peak flow rates in the order of 660 L/min were measured. During this time, the feedlot manager advised that the water supply could not keep up with consumption. Therefore, the delivery lines must be a limiting factor within the water reticulation system at this feedlot. Peak flow rates are an important criteria when planning and designing reticulation systems.

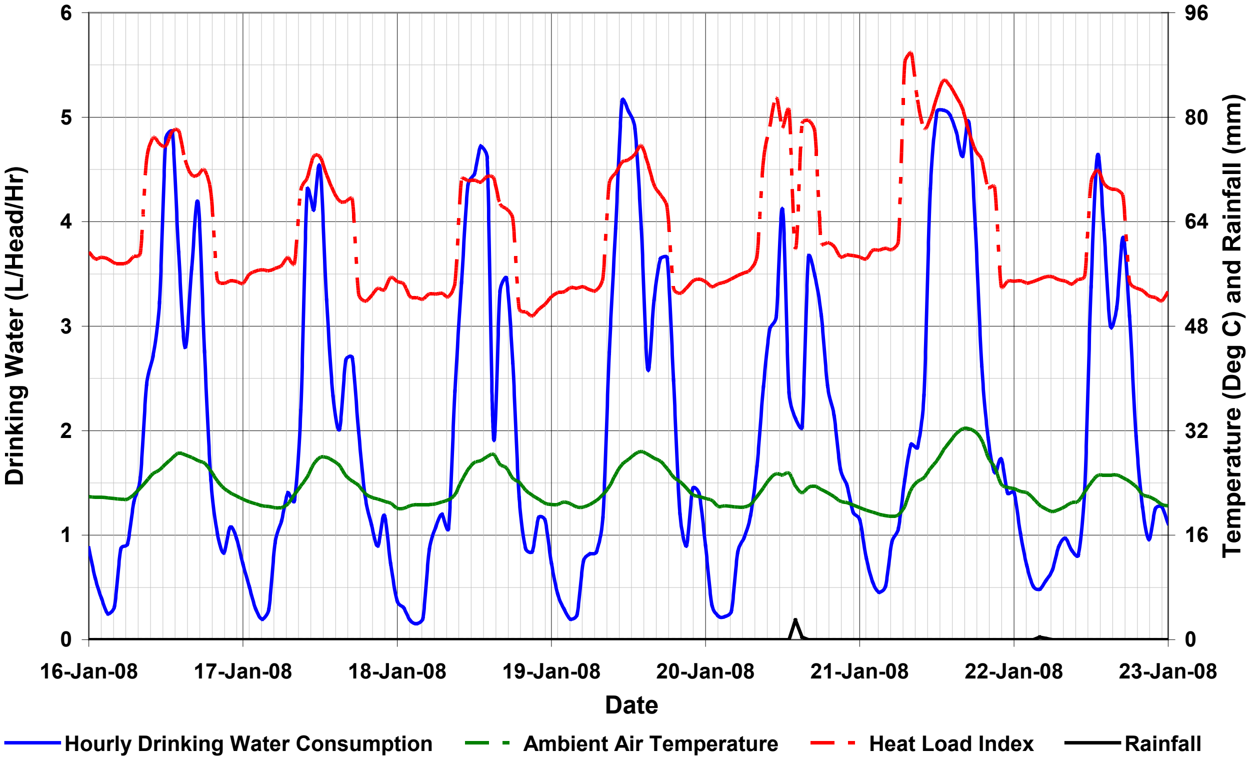


Figure 43 – Daily variation in drinking water consumption 16th January 2008 to 23rd January 2008 - Feedlot G (L/head/hour)

FIGURE 43 shows drinking water consumption (L/head/hr) for Feedlot G for the period 16th January to 23rd January 2008. The heat load index is lower and correspondingly, the drinking water requirement is lower than when compared with the December period. During this period, the peak drinking water requirement measured was in the order of 4.5 L/head/hour. There is a lag of around 2 hours between peak heat load and peak drinking water consumption, two distinct drinking periods throughout each day and the effect of rainfall on consumption.

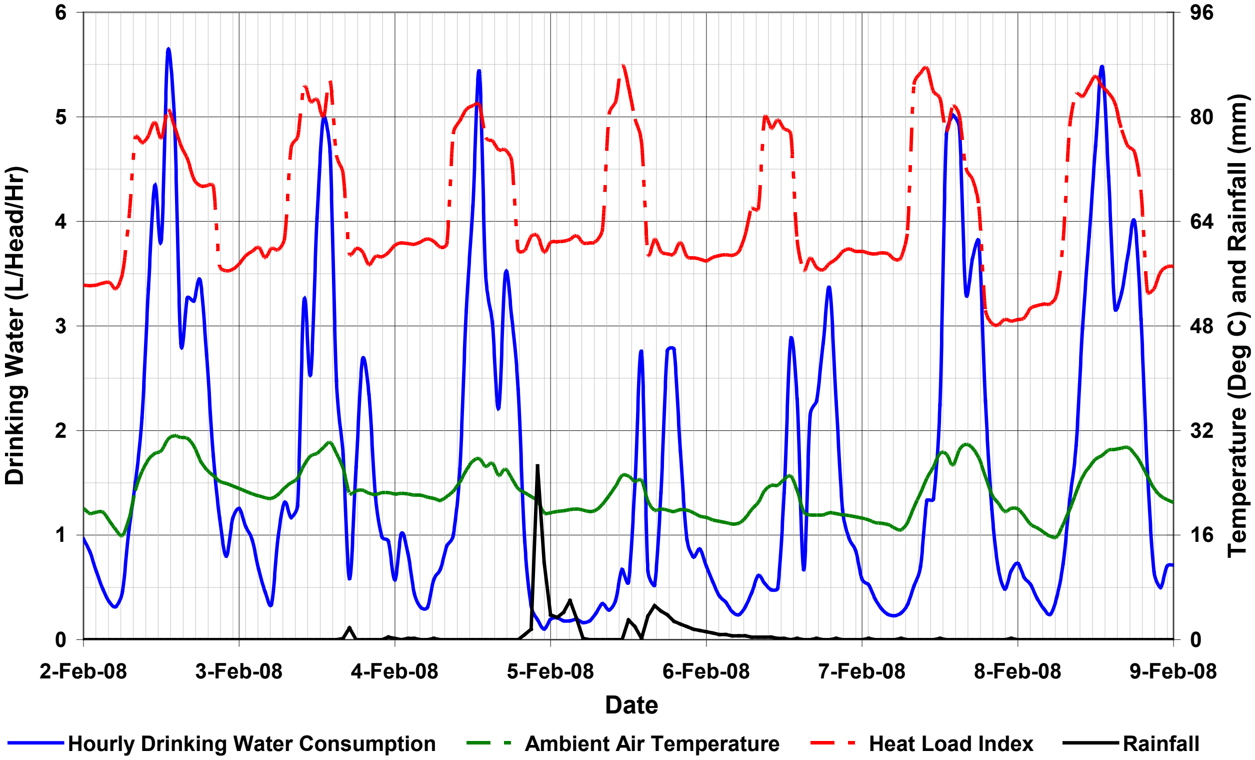


Figure 44 – Daily variation in drinking water consumption 2nd February 2008 to 9th February 2008 - Feedlot G (L/head/hour)

FIGURE 44 shows drinking water consumption (L/head/hr) for Feedlot G for the period 2nd February to 9th February 2008. This period clearly shows the effect of rainfall on drinking water consumption. Rainfall on the 5th and 6th of February suppresses consumption even whilst the heat load index remains high. In this case, relative humidity is the driver of heat load, not temperature. During this period, the peak drinking water requirement measured ranged from 3.0 to 5.5 L/head/hour. Similarly, to the FIGURE 42 and FIGURE 43, a lag of around 2 hours between peak heat load and peak drinking water consumption is also evident.

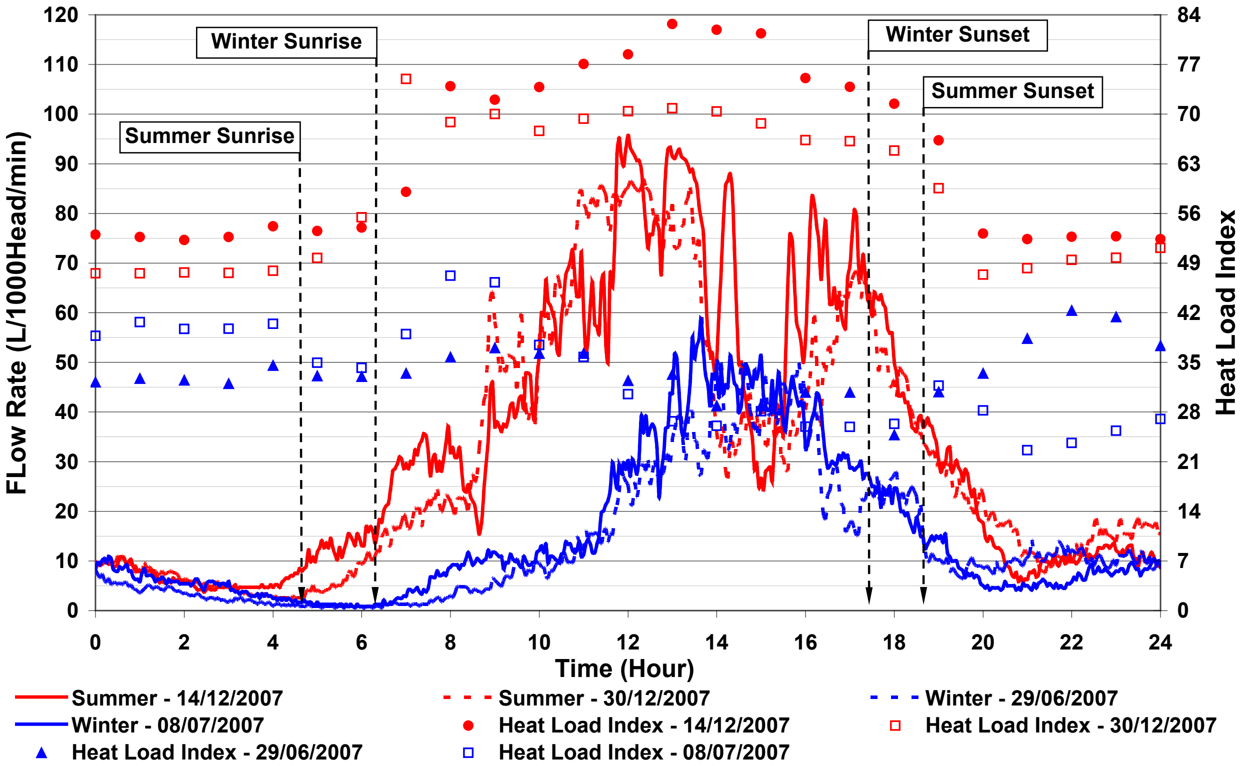


Figure 45 – Daily variation in drinking water consumption - Summer and Winter - Feedlot G (L/1000 head/min)

Figure 45 illustrates the drinking water diurnal variation between two non-consecutive days from summer and winter. The flow rate recorded was standardised on a 1000 head on feed per hour basis and there was no rainfall on either of the days. Hourly heat load index is also presented.

The 29th of June and the 8th of July were selected as the winter days as the temperature on these days represented the average winter temperatures for this feedlot. During winter, the drinking water diurnal variation is characterised by a continuous consumption period between 1 and 4 pm, with no distinct single peak. The cattle commence drinking at sunrise, consume the majority of water during the course of the day and consume another small volume just after sunset observed as a slight rise at 18:00 hrs on FIGURE 45. Consumption then drops and remains relatively constant from 19:00 to 01:00 hours, then declines to almost zero, just prior to sunrise.

The 14th and 30th of December were selected as the summer days for this comparison as the temperature on these days were representative of average summer temperatures. During summer, the total volume of water is higher as expected but also the consumption times throughout the day differ when compared to the winter pattern. The summer patterns are characterised by two distinct peaks, one between 10:00-14:00 hours, and the other between 16:00-18:00 hours. The cattle commence drinking at sunrise, consume the majority of water during the middle of the day and finally consume another volume prior to sunset. Note that during the peak midday consumption, there are two distinct periods of continuous drinking and this may indicate the cattle have run low on water. Consumption then drops and remains relatively constant from 19:00 to 01:00 hours, then declines to almost zero, just prior to sunrise.

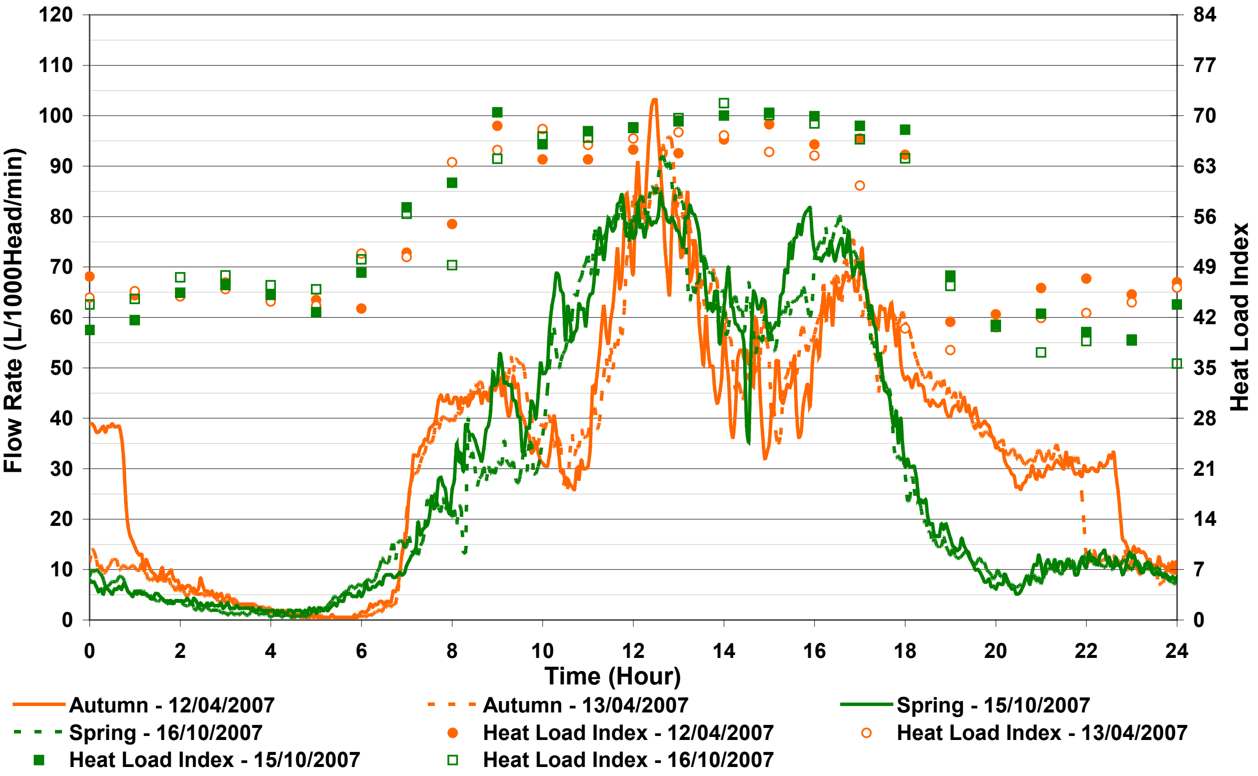


Figure 46 – Daily variation in drinking water consumption - Autumn and Spring - Feedlot G (L/1000 head/min)

FIGURE 46 illustrates the drinking water diurnal variation between two consecutive days from Autumn and Spring. The flow rate recorded was standardised on a 1000 head on feed per hour basis and there was no rainfall on either of the days.

The 12th and 13th of April were selected as the Autumn days as the temperature on these days represented the average Autumn temperatures for this feedlot. On these days, the drinking water diurnal variation is characterised by three peak consumption periods throughout the day. The cattle commence drinking at sunrise with an initial volume consumed around 09:00 hours, the greatest peak occurs in the middle of the day followed by another period of consumption around 16:00 just prior to sunset. Consumption then reduces, remains constant until 02:00 hours then drops to zero, just prior to sunrise. The patterns on these days are consistent with the summer consumption patterns.

The 15th and 16th of October were selected as the Spring days as the temperature on these days represented the average monthly Spring temperatures for this feedlot. On these days, the drinking water diurnal variation is characterised by three peak consumption periods throughout the day. The cattle commence drinking at sunrise with the greatest peak occurring in the middle of the day followed by another period of consumption around 17:00 just prior to sunset. Consumption is occurring well into the night prior to sharply dropping off at 23:00 hours and dropping to zero, just prior to sunrise. The patterns on these days are consistent with the summer consumption patterns.

5.3 Feed Processing Water Usage

FIGURE 47 illustrates the average feed processing water usage on a tonne of grain processed basis for the seven feedlots that participated in the water usage investigation. The minimum and maximum feed processing water usage, on a tonne of grain processed basis, for any one month is also presented. The feedlot numbering in this section does not match the numbering in previous sections to maintain anonymity for the participating feedlots. Whilst a summary is provided in this section, complete individual feedlot monthly feed processing water usage is presented in Appendix B.

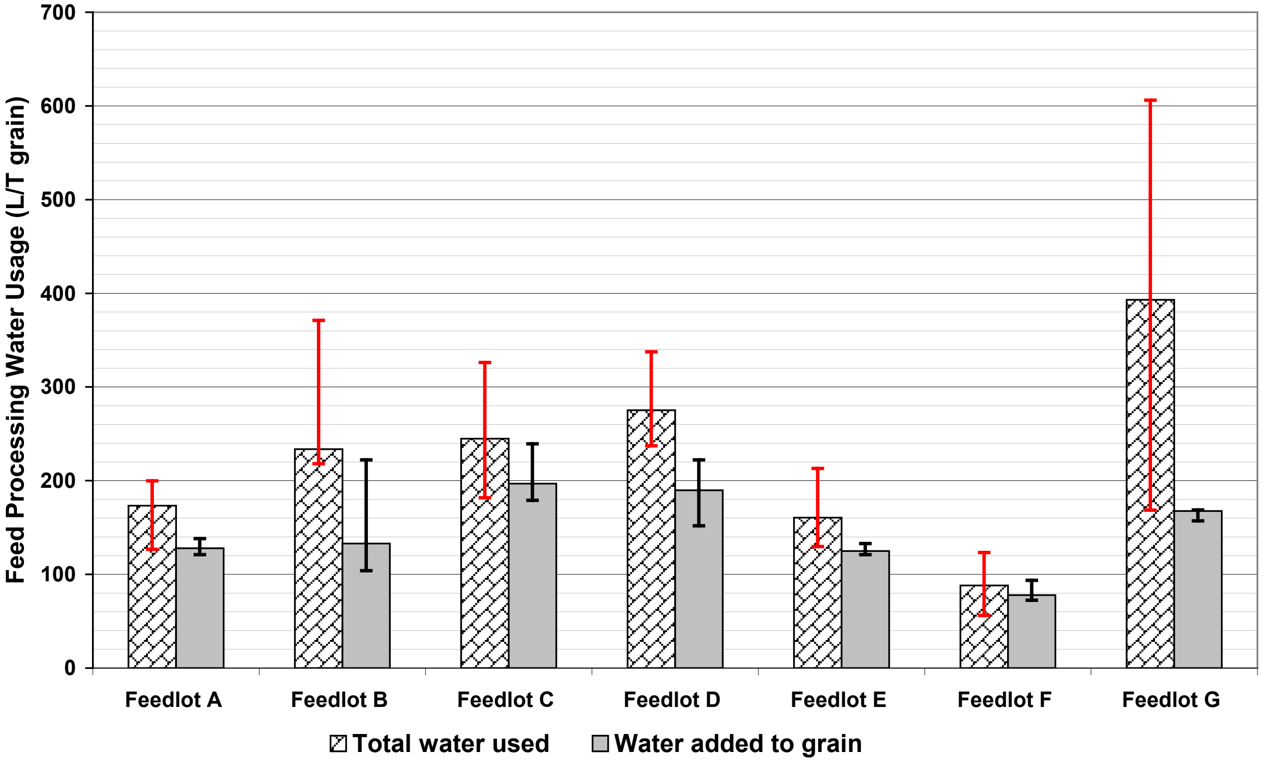


Figure 47 – Total feed processing water usage (L/t grain)

Feed processing water usage is the second highest consumer of water in feedlots where no cattle washing is undertaken. Figure 47 illustrates the average total feed processing water usage on a tonne of grain processed basis for the seven feedlots. Feed processing water has two components. They are:

- water stored in the moistened grain (moisture difference between dry and wet grain), and
- unaccounted-for losses, which are a function of the feed processing method.

The average water stored in the grain was calculated from the moisture content of incoming and processed grain and the quantity processed for each month. These data were supplied by each feedlot. Unaccounted-for water is the measured total feed processing water less the water stored in grain.

The average feed processing water usage ranges from 90 to 390 L/t grain processed. The total water added to the grain ranges from 45 to 90% of the total water used. Three different feed processing systems are represented within the seven feedlots. Feedlot F tempers grain only, Feedlot C tempers and reconstitutes grain whilst the remaining feedlots temper and steam flake grain. For Feedlot F, the water stored in the grain is similar to the total water used. Hence, it has a very low volume of unaccounted-for water. At Feedlot C, an average of 40 L/t grain is unaccounted-for whilst water usage and unaccounted-for water within steam flaked systems is variable. Therefore, in steam flaking, if the tempering component water usage is reflected in the water stored in the grain, then the majority of unaccounted-for water can be attributed to the process of steam generation and delivery. Feedlots A and E have lower unaccounted-for water than Feedlot B, D and G. A number of factors will influence feed processing water usage include system employed, grain type, target moisture and management of the system.

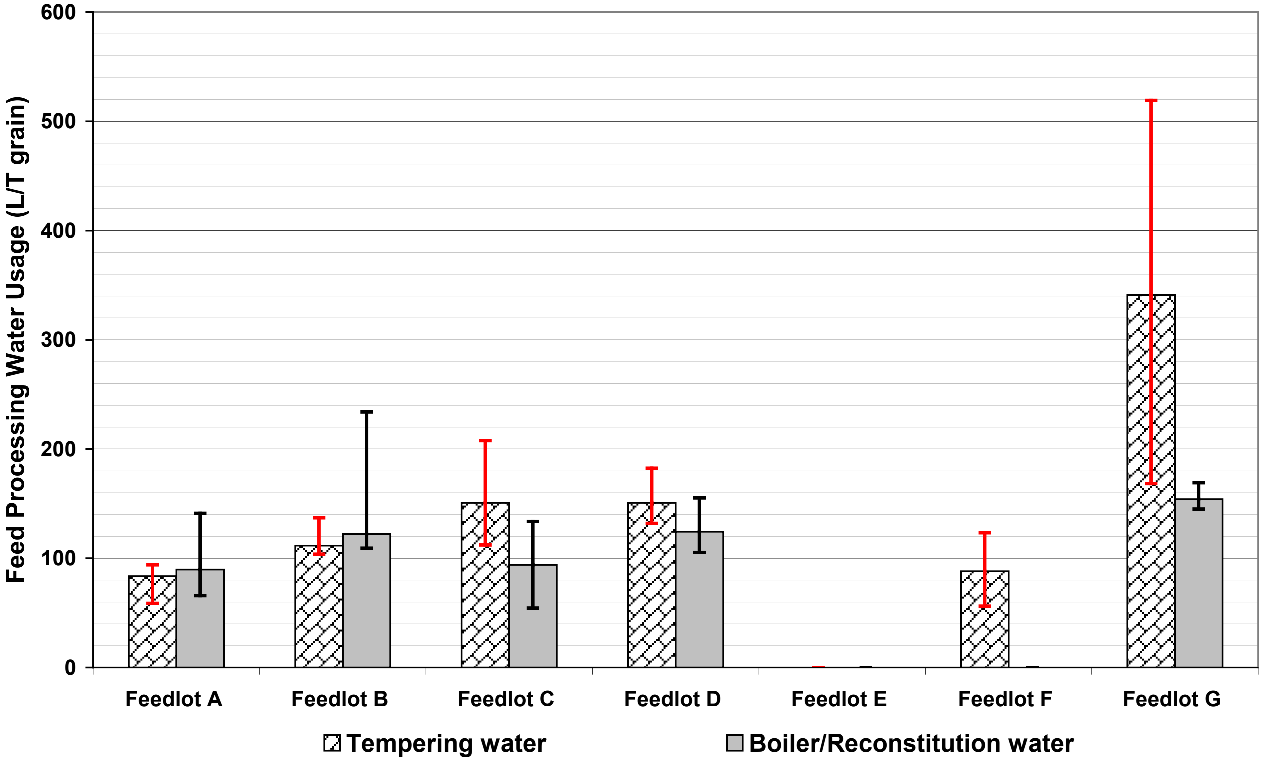


Figure 48 – Feed processing water usage (L/t grain)

At the majority of feedlots, the feed processing water was able to be divided into tempering, boiler and reconstitution water usage. FIGURE 48 illustrates the average feed processing component water usage on a tonne of grain processed basis for the seven feedlots. The minimum and maximum water usage for each component for any one month is also presented. Feedlot E was not able to supply individual usage for tempering and boiler water use. Feedlot F tempers grain only, Feedlot C tempers and reconstitutes grain whilst the remaining feedlots temper and steam flake grain.

The measured tempering water usage ranges from 80 to 150 L/t grain processed for all feedlots with the exception of feedlot G which has an average tempering water usage of 340 L/t grain processed. Steam flaking boiler water usage ranges from 80 to 150 L/t grain processed. Hence, there is a large variation between and within feedlots. Feedlot G has a narrow water usage range, whilst feedlot A has a wider range. Feedlot B has two months where boiler water usage per tonne of grain processed is higher than the average. Management of the various systems appears to be the principal driver of the respective feed processing system.

5.4 Cattle Washing

FIGURE 49 illustrates the average total water usage for washing cattle (L/head) for the seven feedlots. The total water usage in some feedlots comprises clean and recycled water. FIGURE 50 shows the break-down between clean and recycled washing water. Feedlot C and Feedlot E do not wash cattle. Feedlot D did not wash any cattle during the study period. The minimum and maximum water usage per head washed for any one month is also presented. The feedlot numbering in this section does not match the numbering in previous sections to maintain anonymity for the participating feedlots. Appendix C gives more complete individual feedlot monthly cattle washing water usage.

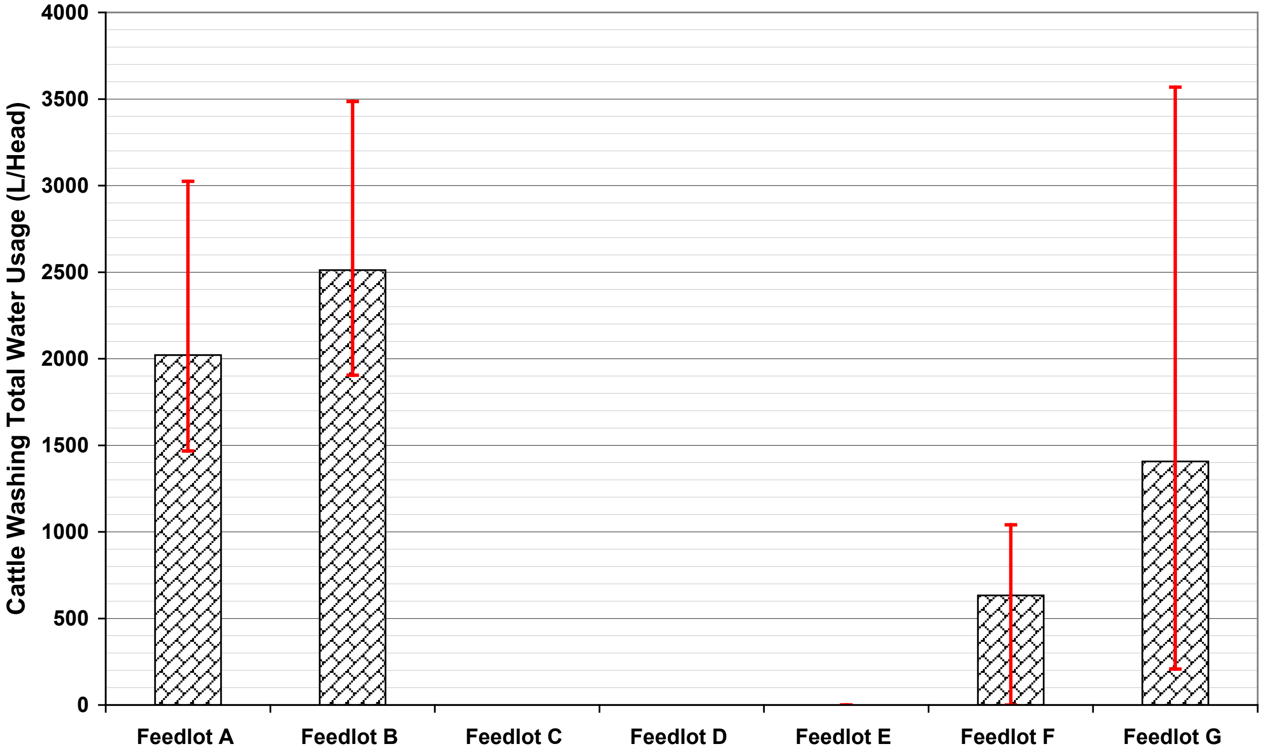


Figure 49 – Average / maximum / minimum cattle washing water usage (L/head)

The total cattle washing water usage ranges from an annual average per feedlot of 700 L/head to 2500 L/head. However, a monthly average water usage up to 3500 L/head has been recorded at Feedlots A and G. The water required for cattle washing is dependent on the dirtiness of the cattle and the cleaning requirements. Feedlot A experienced high rainfall whilst Feedlot F experienced lower than average rainfall during the cattle washing period.

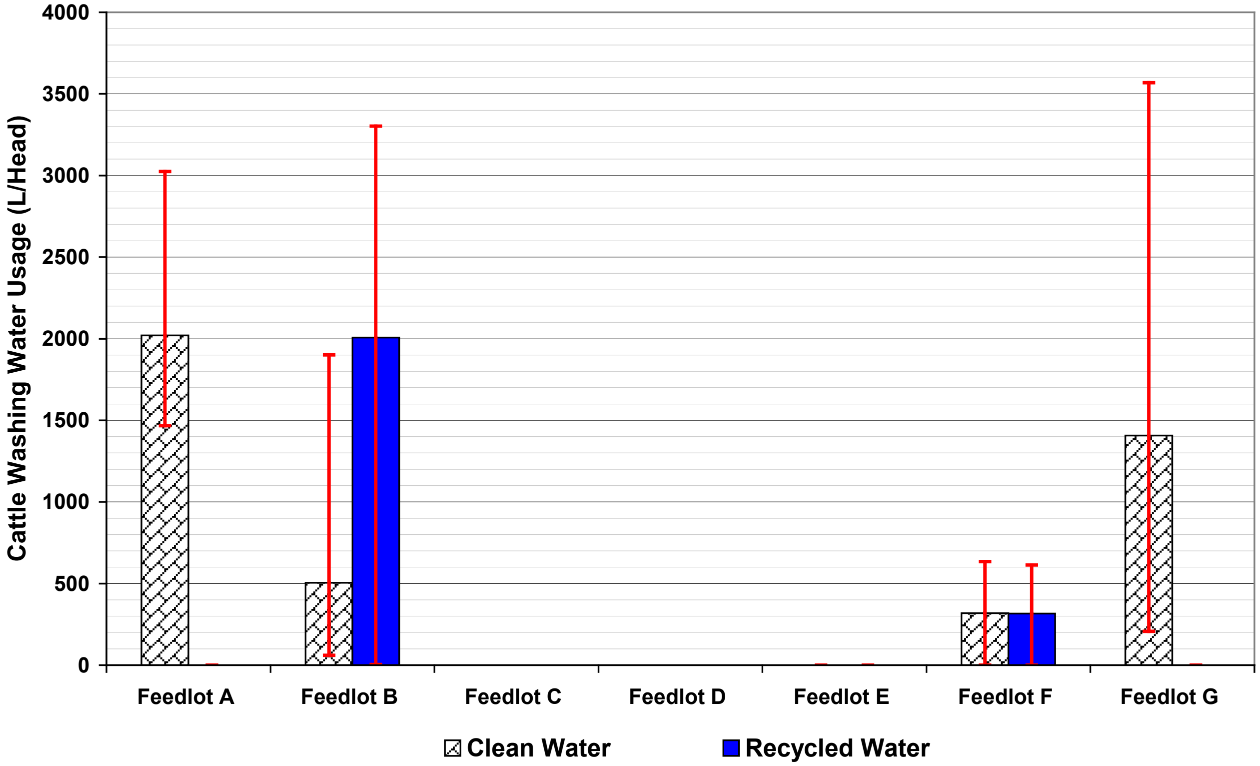


Figure 50 – Components of cattle washing water usage (L/head)

FIGURE 50 illustrates the average clean water and recycled water usage for washing cattle (L/head) for the seven feedlots. Whilst Feedlot B has recorded the highest average monthly total water usage, it is noted that the majority of this water is recycled water from washing cattle. Feedlot A and Feedlot G do not recycle water.

5.5 Administration

FIGURE 51 gives the average total water usage for administration (L/kg HSCW gain basis). The minimum and maximum water usage for any one month is also presented. Administration water usage was only able to be directly measured at Feedlot D, E, F and G. In addition, feedlot numbering in this section does not match the numbering in previous sections to maintain anonymity for the participating feedlots. Whilst a summary is provided in this section, complete individual feedlot monthly administration water usage is presented in Section 5.1.

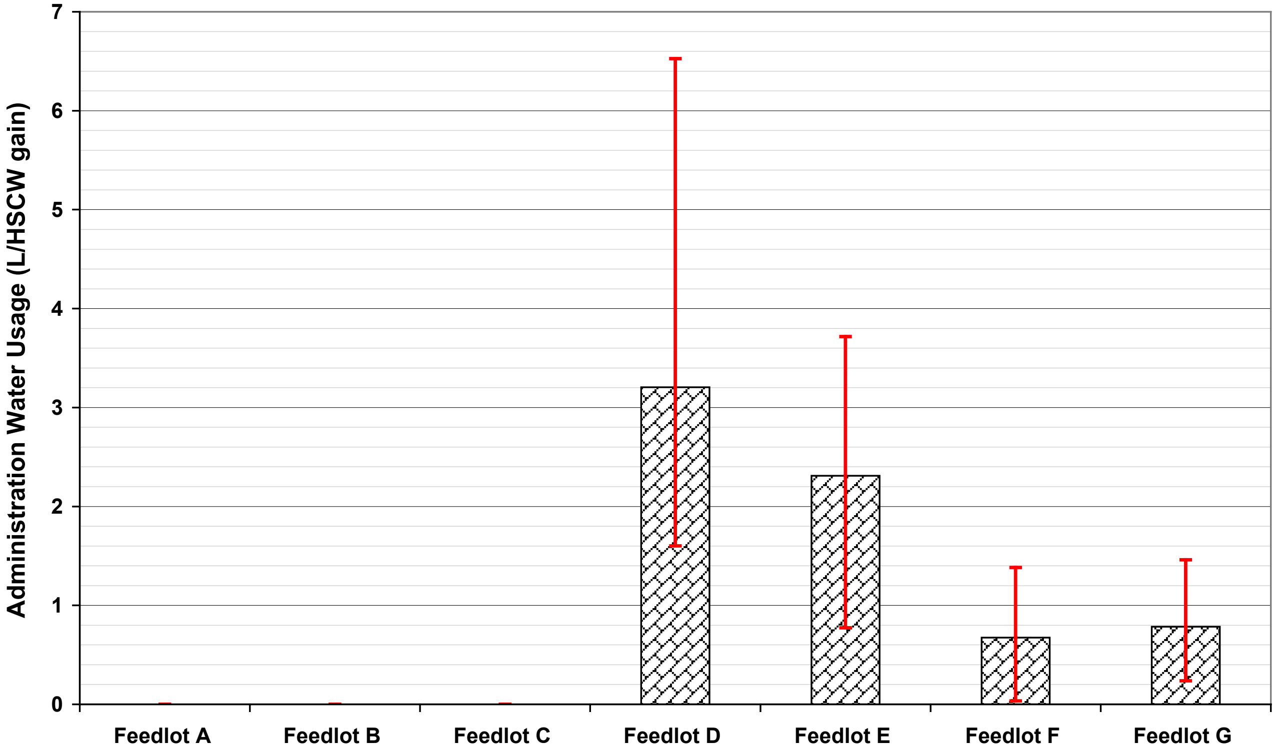


Figure 51 – Average administration water usage (L/kg HSCW gain)

Administration water usage comprises that used in office and staff amenities and for watering of lawns and gardens. Average administration water usage ranged from 0.6 to 3.2 L/kg HSCW gain over the period March 2007 to February 2008. Administration represents a small proportion of the total water usage, representing in the order of 2% and is driven primarily by the volume of water irrigated onto lawns and gardens.

5.6 Sundry Water Uses

TABLE 8 gives a summary of the measured and estimated sundry water uses at each feedlot in L/kg HSCW gain whilst TABLE 9 presents these sundry water uses per head on feed basis. The feedlot numbering is consistent with Section 4.8. Where appropriate, these data were deducted from the total water use data to gain a better estimate of drinking water use.

Table 8 – Sundry water uses for each feedlot (L/kg HSCW gain)

Feedlot	A	B	C	E	F	G	H
Water trough evaporation	0.08	0.03	0.17	0.01	0.02	0.01	0.02
Water trough cleaning	4.60	0.84	0.53	0.34	0.23	0.04	0.65
Hospital/Induction Cleaning	2.03	0*	0.25	0.42	0.13	0.28	0.29
Vehicle washing	0.64	0*	0.48	0.02	0*	0.00	0.23
Road Watering	5.73	0.33	0.10	1.28	0*	0.00	0.00
Water Storage evaporation	2.61	0.00	3.34	1.82	0.02	0.45	0.00
TOTAL (L/kg HSCW gain)	15.69	1.20	4.86	3.90	0.39	0.78	1.18

* Data unavailable

Table 9 – Sundry water uses for each feedlot (L/head/day)

Feedlot	A	B	C	E	F	G	H
Water trough evaporation	0.6	0.7	5.1	0.4	0.3	0.3	0.4
Water trough cleaning	35.2	24.2	16.1	10.8	3.9	1.2	15.9
Hospital/Induction Cleaning	15.5	0.0	7.7	13.4	2.2	8.4	7.0
Vehicle washing	4.9	0.0	14.5	0.6	0*	0.0	5.5
Road Watering	43.8	9.5	3.1	40.6	0*	0.0	0.0
Water Storage evaporation	230.3	0.0	1450.0	910.6	4.3	161.1	0.0
TOTAL L/head/year	330.3	34.5	1497.0	977.0	10.7	171.0	28.9
TOTAL L/head/day	0.9	0.1	4.1	2.7	0.03	0.5	0.1

* Data unavailable

The sundry water losses ranged from 0.03 L/head/day to 4.1 L/head/day. Water storage evaporation contributed the largest use in those feedlots with open water storages. Water trough cleaning is the second largest use in those feedlots with no road watering. Road watering can contribute up to 44L/head. Hence, the three largest sundry water uses viz. water storage evaporation, trough cleaning and road watering are dependent on the total open water surface area, net evaporative losses, trough size and frequency of cleaning and cleaning method and road maintenance. Hence, sundry losses are dependent on feedlot design, location (climate) and operational management.

6 Opportunities for Water Use Efficiency Improvements

The majority (75-90%) of clean water usage at Australian feedlots is cattle drinking water and there is little scope to reduce this component. However, there is scope to minimise losses in the remaining 10-25% of water usage.

This study has estimated the magnitude of evaporative losses from open water storages during March 2007 and February 2008. The magnitude of these losses can be up to 4.1 L/head/day dependent on total surface area and net evaporation. At this feedlot, this represents up to 10% of the total water usage. Hence, this is a significant loss of valuable water.

Evaporation from open water storages has always been known to be large but the cost of the solution has always been considered far higher than the value of the water saved. However, over the last few years new materials and inventive solutions for applying those materials, have come along which have reduced the costs of potential solutions. At the same time, the value of water has risen considerably and it is possible that a balancing point has now been reached. Lining storages to prevent seepage losses may also be a consideration.

One feedlot has already lined (with HDPE) and covered one of its drinking water buffer storages with a cover to control evaporation. Whilst obviously reducing evaporative losses, this solution also has provided additional benefits such as cleaner (effective barrier to light therefore less algal growth) and cooler water (reflection of solar radiation). This has resulted in more water consumed, translating into increased performance. Hence, it is recommended that is one area that could be considered by feedlots with open water storages.

However, the total cost is very site specific and depends upon the remoteness of the site and other issues such as whether the top edge of the storage has been graded for easy vehicular access.

As a guide, the covers have a base costing in the order of $6.50 per square metre (plus GST). These covers has an estimated lifespan of 10 years and probably can be depreciated over 5 years. It has a 5-year pro rata warranty.

The water required for cattle washing is dependent on the dirtiness of the cattle a result of prevailing climatic conditions and genotype and the cleaning requirements.

The average water required for cattle washing can be up to 2500 L/head. However a maximum usage of 3500 L/head over one month was recorded. If there is no recycling, then this must be sourced from clean water. Therefore, recycling of washing water for soaking should also be an important consideration for those feedlots that are required to wash cattle.

There are also efficiency gains to be made from an operational perspective such as overflowing cattle wash storage tanks, cleaning hoses remaining on during breaks, attention to storage and trough leakages and float shut off.

7 Conclusions and Recommendations

7.1 Conclusions

Little work has been undertaken to evaluate total water consumption by feedlots. The amount of water used at feedlots has been studied in North America in the 1980's. To date, only a limited study on drinking water requirements has been undertaken in Australia. Water is both the most important feed component fed to cattle and the most valuable natural resource (after land) in Australia. Hence, it is of critical importance to lot feeders.

Little information exists on the water usage of individual components of the feedlot system, viz drinking water, feed processing, cattle washing, administration and dilution of effluent irrigation. Factual information on water usage was collected on individual feedlot sector operations where possible.

Results from the seven feedlots studied showed that total annual clean water use (without dilution of effluent) ranged from 30-104 L/kg HSCW gain over the period March 2007 to February 2008. This is a similar range to that found in earlier work (34-90 kg/HSCW gain) by Davis & Watts (2006). Drinking water contributed in the order of 90% of the total water usage in the months when no cattle where washed. This reduces to a figure in the order of 75% during months when cattle washing is undertaken. Drinking water consumption is driven by rainfall and heat load as expected. During rainfall, drinking water consumption is suppressed and increases to maximum levels during periods of high heat loading.

The average drinking water consumption across all feedlots for March 2007 to February 2008 ranged from 31 L/head/day to 46 L/head/day, with an average in the order of 40 L/head/day. Feedlot E located in a subtropical environment had the highest average drinking water consumption of 46 L/head/day, whilst Feedlot B which experiences cold winters, mild summers and high rainfall when compared with other feedlot locations had the lowest drinking water consumption of 31 L/head/day.

These levels are less than the often quoted figure within the industry of an average of 65 L/head/day. It is believed that the 65 L/head/day figure is based on the maximum daily requirement of 5 L per 50 kg LWT, hence representing the water requirements of a 650 kg beast.

The maximum monthly drinking water consumption recorded was 70 L/head/day during January 2008 and the minimum of 4 L/head/day was recorded in June 2007.

The relationship between drinking water consumption, heat load index and rainfall is clearly evident on a daily basis. During periods of rainfall, drinking water consumption is suppressed, whilst during periods of high heat load, drinking water is at its highest.

Where no cattle washing is undertaken, feed processing water usage is the second highest consumer of water in feedlots. Three different feed processing systems are represented within the seven feedlots and included tempering, reconstitution and steam flaking. Feed processing contributes in the order of 4% as a function of HSCW gain and is dependent on the grain processing system employed at the feedlot. This figure can vary from month to month depending on the management of the various systems.

The measured average feed processing water usage ranges from 90 to 390 L/t grain processed. The total water added to the grain ranges from 45 to 90% of the total water used. For tempering only systems, the water added to the grain is similar to the total water used, hence has a very low volume of unaccounted-for water. For reconstitution, an average of 40 L/t grain is unaccounted-for whilst water usage and unaccounted-for water within steam flaked systems is variable with an average unaccounted-for loss of 225L/t grain. Therefore, in steam flaking, if the tempering component water usage is reflected in additional water in the grain, then the majority of unaccounted-for water can be attributed to the process of steam generation and delivery. A number of factors will influence feed processing water usage include system employed, grain type, target moisture and management of the system.

Cattle washing is the second highest consumer of water in feedlots in months when it is undertaken. The total water usage in some feedlots comprises clean and recycled water. Cattle washing can contribute up to 25% as a function of HSCW gain of the total water usage.

The average total cattle washing water usage ranges from 800 L/head to 2600 L/head. However, a monthly average water usage up to 3900 L/head was recorded at one feedlot. Recycled water can account for 50 to 75% of the total washing water usage. The water required for cattle washing is dependent on the dirtiness of the cattle and the cleaning requirements. Feedlot A experienced high rainfall whilst Feedlot F experienced lower than average rainfall during the cattle washing period.

Administration water usage comprises that used in office and staff amenities and for watering of lawns and gardens. Average administration water usage ranged from 0.6 to 3.2 L/kg HSCW gain over the period March 2007 to February 2008. Administration represents a small proportion of the total usage, representing in the order of 2% and is driven primarily by the volume of water irrigated onto lawns and gardens.

The sundry water losses ranged from 0.03 L/head/day to 4.1 L/head/day. Water storage evaporation water trough cleaning and road watering are the three largest sundry water uses. Variation between feedlots may be explained by feedlot design (surface area open water storages, size of troughs), location (climate) and management operations including frequency of trough cleaning and road maintenance (dust control).

Actual water usage levels within individual activities have been recorded in seven feedlots representative of the Australian Feedlot Industry. These included drinking water, feed processing, cattle washing, administration and sundry uses. The selected feedlots provide a range of climatic conditions from a northern feedlot in a hot, humid summer-dominant rainfall to southern feedlots in cooler, winter-dominant rainfall zones. Grain processing methods vary from simple tempering to reconstitution and steam flaking. Some feedlots wash cattle (mainly in winter) while other feedlots do not undertake any cattle washing.

The outcomes of this study will allow the feedlot industry to start benchmarking total water usage, hence addressing the public misconceptions associated with the water used in the production of one kilogram of grained beef. In addition, this information is invaluable for participating feedlots in understanding the drivers of drinking water consumption and targeting high water use areas for efficiency gains and for future design and management considerations.

7.2 Recommendations

The data collected to date have indicated a large variation in total water usage between participating feedlots. This variation can be attributed to location (climatic variation), operation and management of the respective activities.

Benchmarking of this information has raised awareness of water usage within the participating feedlots. This project has also provided industry with a set of industry statistics on water and energy usage over a 12-month period.

The current study period has not experienced excessively high temperatures during summer and therefore continuation would enhance the likelihood of collecting data within periods of higher temperatures and heat loading. This would provide a more robust baseline data set. In addition, this process would also quantify any efficiency gains resulting from changes to activities that may have been implemented.

This is important both at an industry and feedyard level. This will establish a baseline for industry on water and energy usage within individual activities. Demonstrating a history of use and quantifying usage levels may be important if regulatory authorities reduce water supply allocations or impose mandatory implementation of resource efficiency measures. Reduced water supply allocations may also impact on current cattle licensing arrangements etc.

To consolidate and build on the work already undertaken it is recommended that the data collection and collation of water and energy usage within all of the existing participating feedlots continue for a further 12 months. The rationale for this option is that all of the equipment is installed and recording well, hence is a cost-effective activity. This option would require the development, implementation and use of a simplified electronic reporting system to ensure ease and consistency in reporting.

Firstly, this will allow the industry to establish a more robust baseline for water usage. Secondly, this will allow individual feedlots to benchmark their operation and identify areas to target for improved water efficiency. Thirdly, the impact on changes to management practices to demonstrate water efficiency gains from changes to activities will be documented.

In addition, it is important that this information is extended to industry and industry research community.

Therefore, it is recommended that a series of information sheets and case studies to assist lot feeders in understanding, planning and organising, implementing and monitoring a water and energy efficiency program based on the outcomes of this work be prepared.

This would include an ‘Understanding’, ‘Benchmarking’ and ‘Case study’ series of information sheets. The ‘understanding’ series would outline the protocols on how to develop a system to measure, collate, analyse and report water use data, assess their water consumption for benchmarking purposes and identify water impacts and opportunities. Examples of information sheets within this series include, but not limited to – ‘Commitment - Establishing the drivers for resource management’, ‘Understanding your system – Mapping water distribution networks’, ‘Designing a water usage monitoring system’, ‘Measuring water usage’, ‘Reading water meters’, ‘Defining functional units’ etc.

In the current study, drinking water consumption is measured indirectly in all but one of the participating feedlots. In one feedlot it is able to be measured directly and this allows an accurate recording of consumption and daily variations in consumption at a feedyard level.

These data can be used by the industry to establish drinking water consumption levels and also as a base for the development of predictive models. However, using these data for the development predictive modelling was outside the scope of this work. In addition, this dataset is limited to the Darling Downs area and does not contain extended periods of hot, dry weather or extremely cool and wet wintertime conditions. These data also highlight the diurnal variation in drinking water consumption and shows that are distinct winter and summer patterns.

Therefore, it is recommended to obtain additional drinking water consumption patterns within a hot and humid environment and further detailed analysis of drinking water consumption. The detailed work could be undertaken as part of a PhD study.

The detailed study may include drinking water consumption of cattle in shaded and unshaded pens may differ, covered water supply etc.

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Appendix A –Drinking Water Consumption

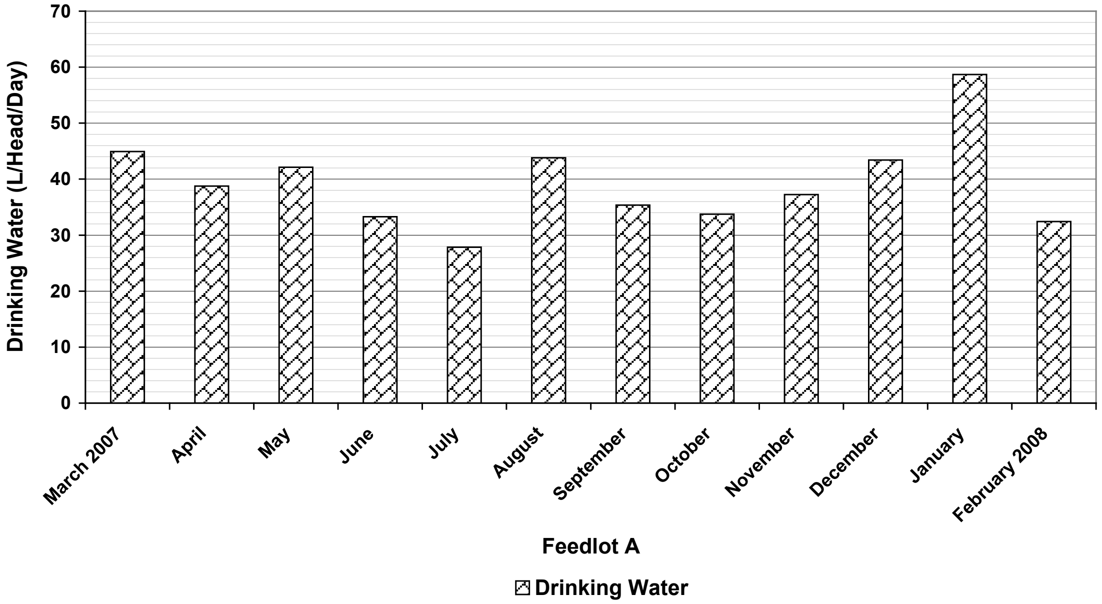

Figure 52 – Drinking water consumption for Feedlot A (L/head/day)

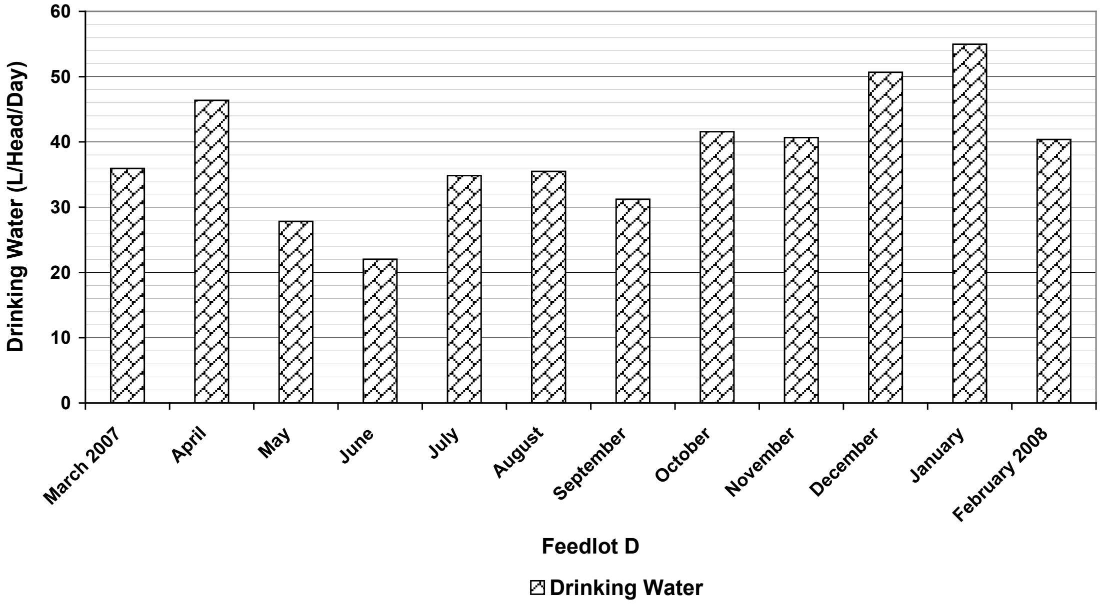

Figure 53 – Drinking water consumption for Feedlot D (L/head/day)

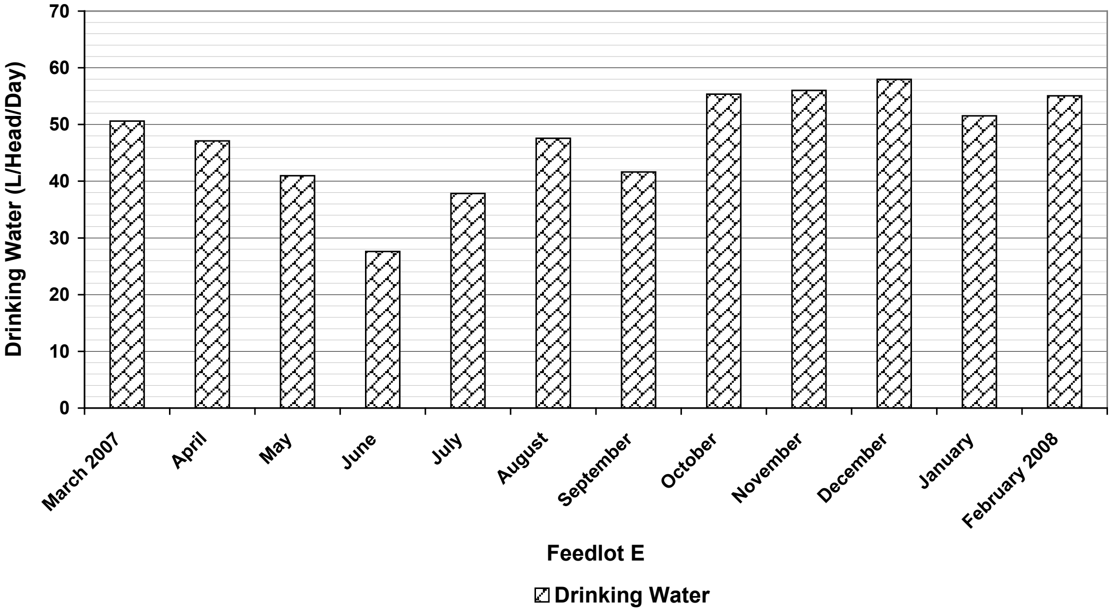

Figure 54 – Drinking water consumption for Feedlot E (L/head/day)

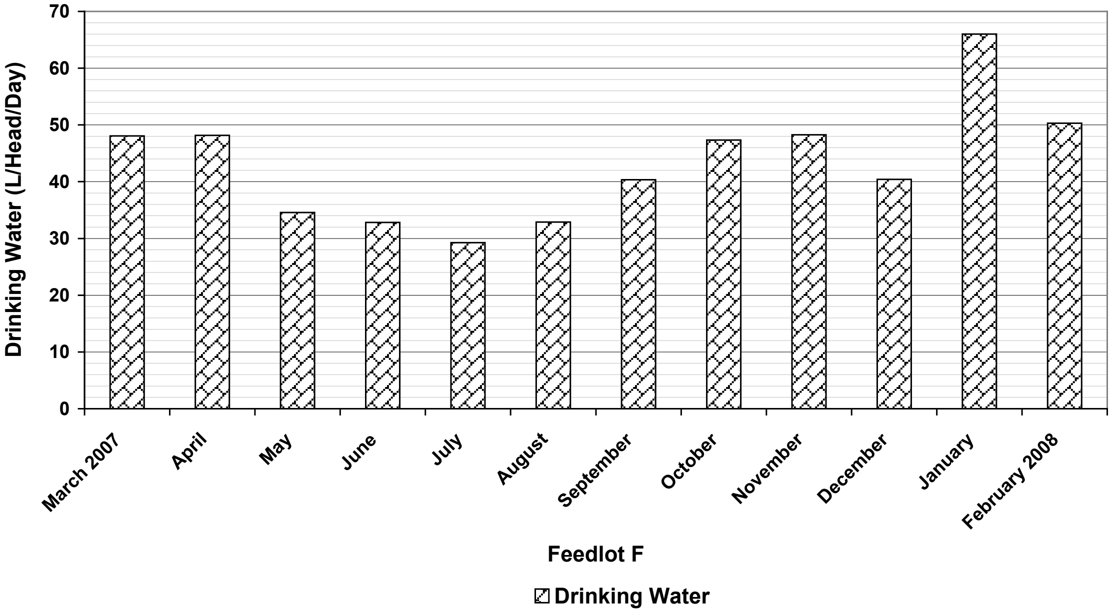

Figure 55 – Drinking water consumption for Feedlot F (L/head/day)

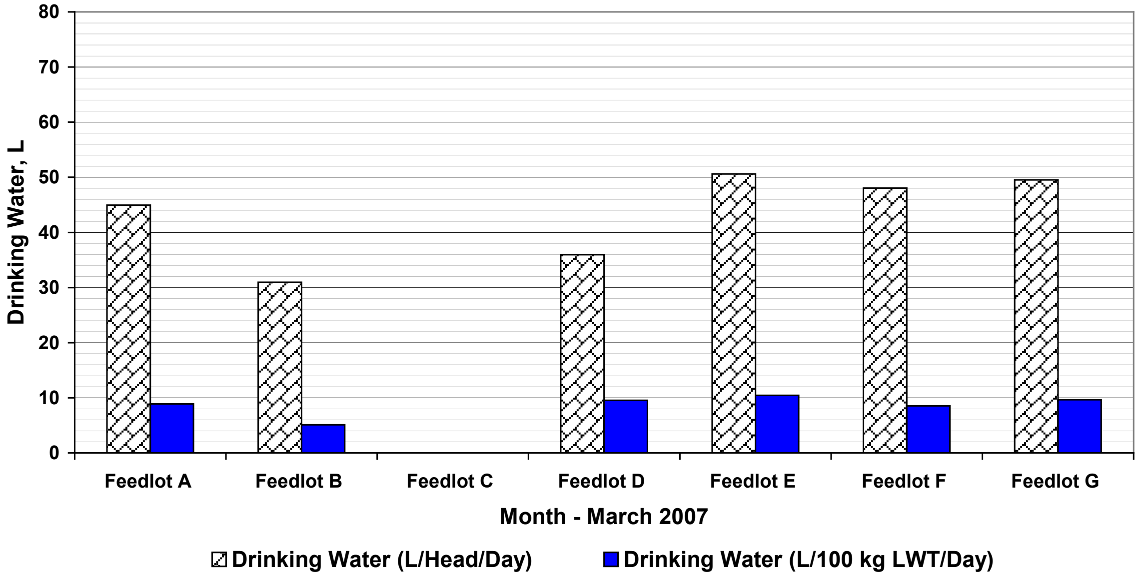

Figure 56 – Drinking water consumption for March 2007 (L/head/day & L/100 kg LWT/day)

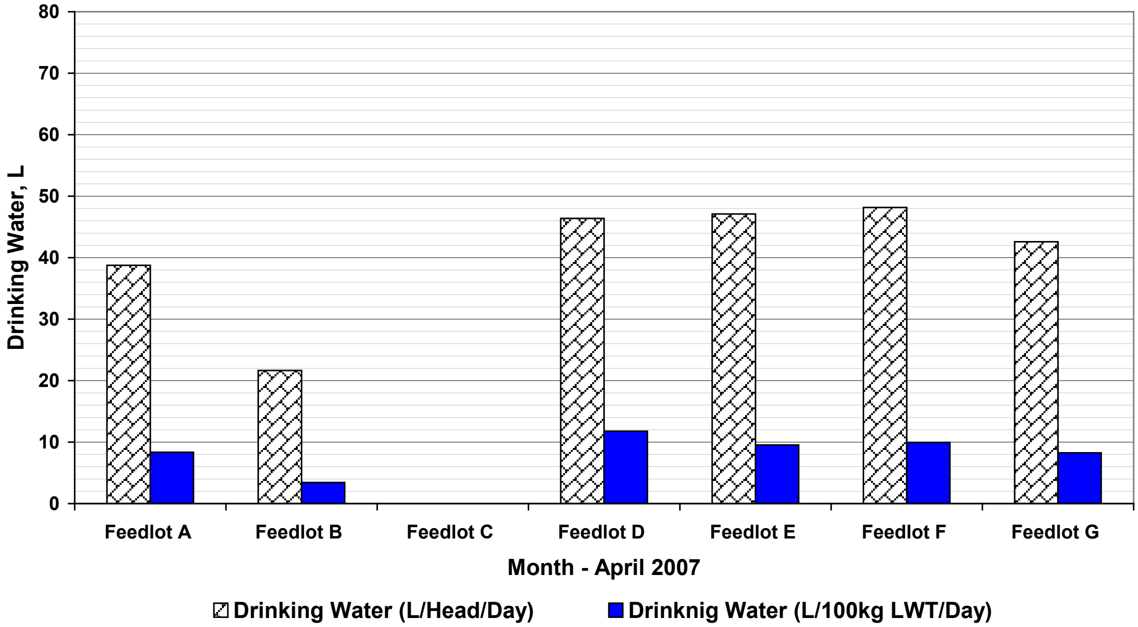

Figure 57 – Drinking water consumption for April 2007 (L/head/day & L/100 kg LWT/day)

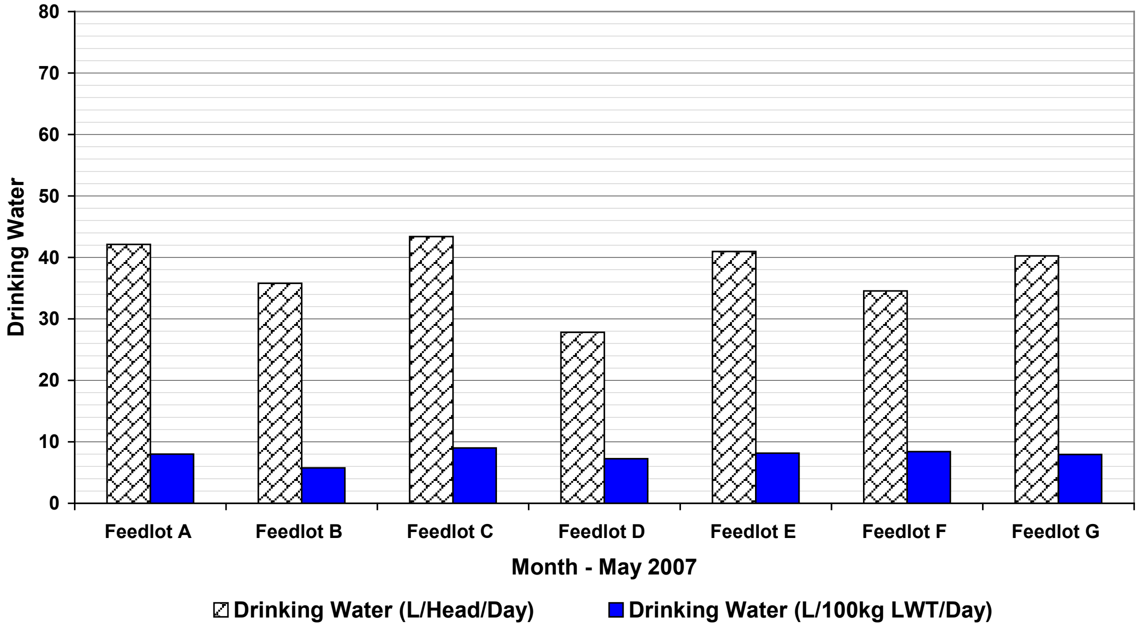

Figure 58 – Drinking water consumption for May 2007 (L/head/day & L/100 kg LWT/day)

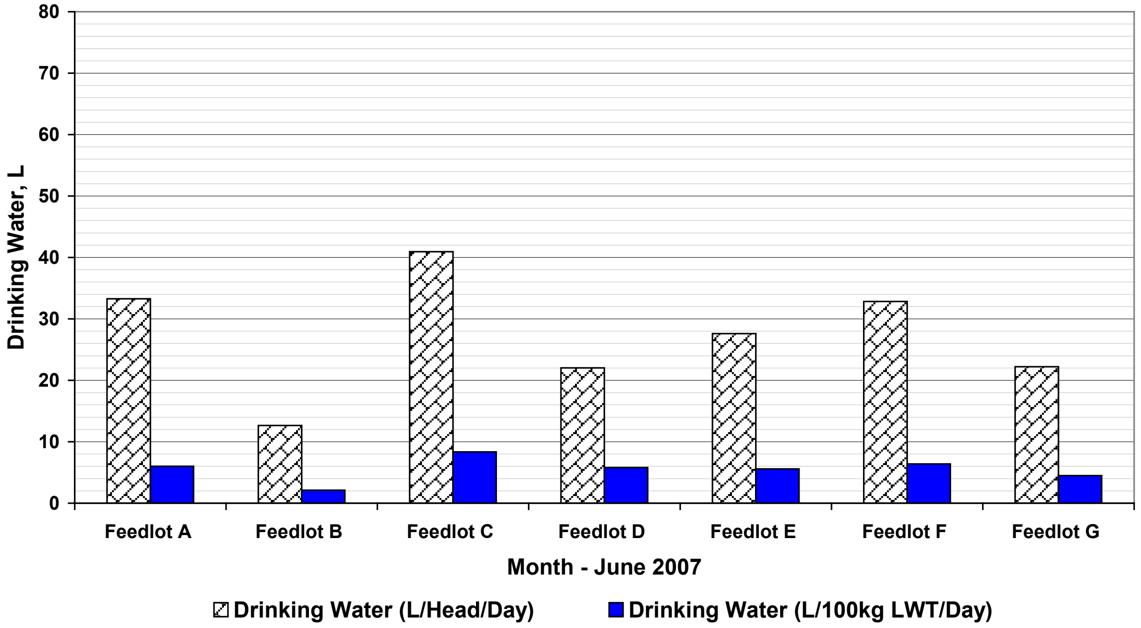

Figure 59 – Drinking water consumption for June 2007 (L/head/day & L/100 kg LWT/day)

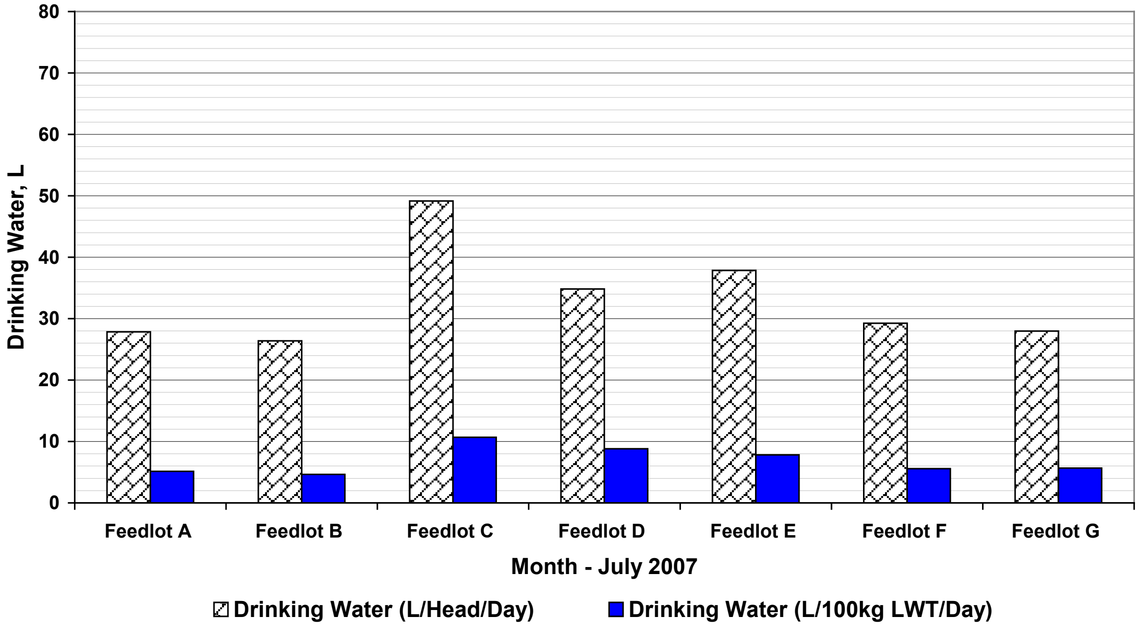

Figure 60 – Drinking water consumption for July 2007 (L/head/day & L/100 kg LWT/day)

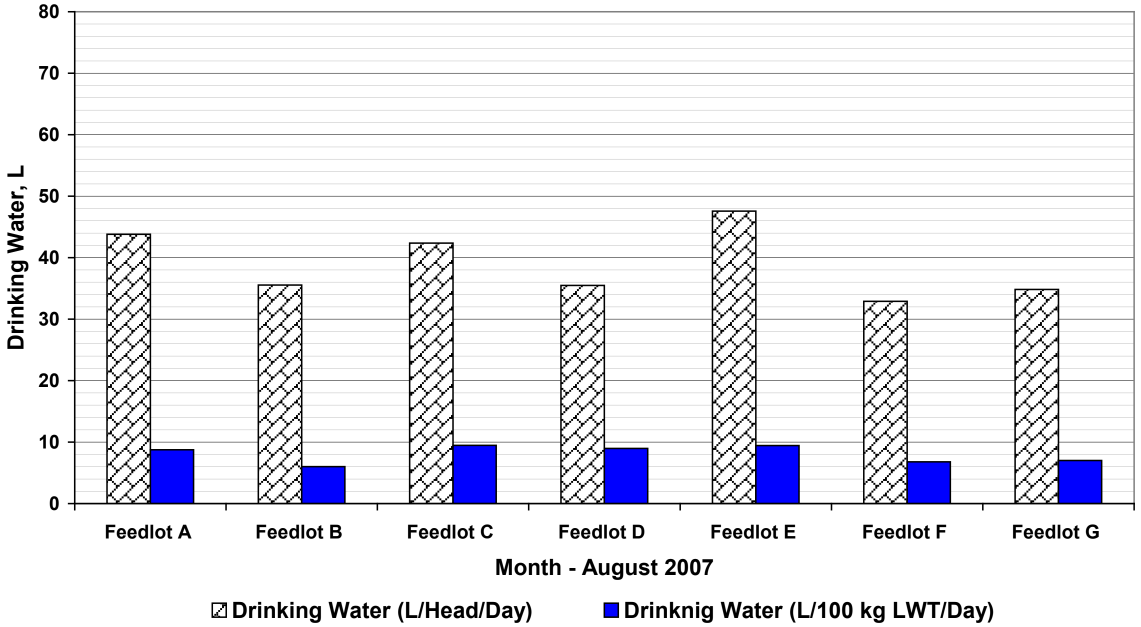

Figure 61 – Drinking water consumption for August 2007 (L/head/day & L/100 kg LWT/day)

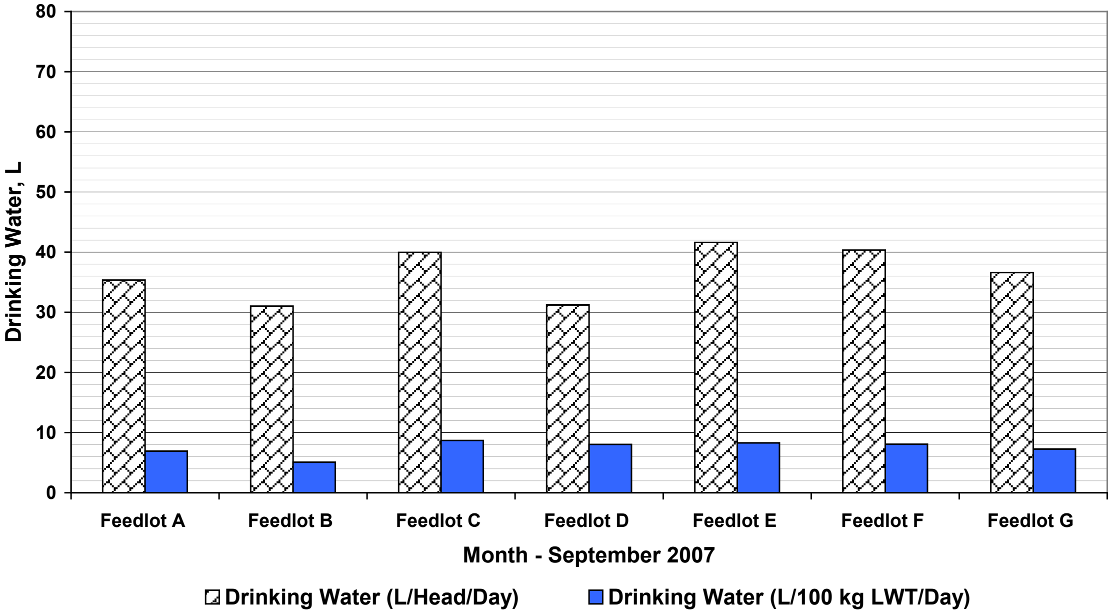

Figure 62 – Drinking water consumption for September 2007 (L/head/day & L/100 kg LWT/day)

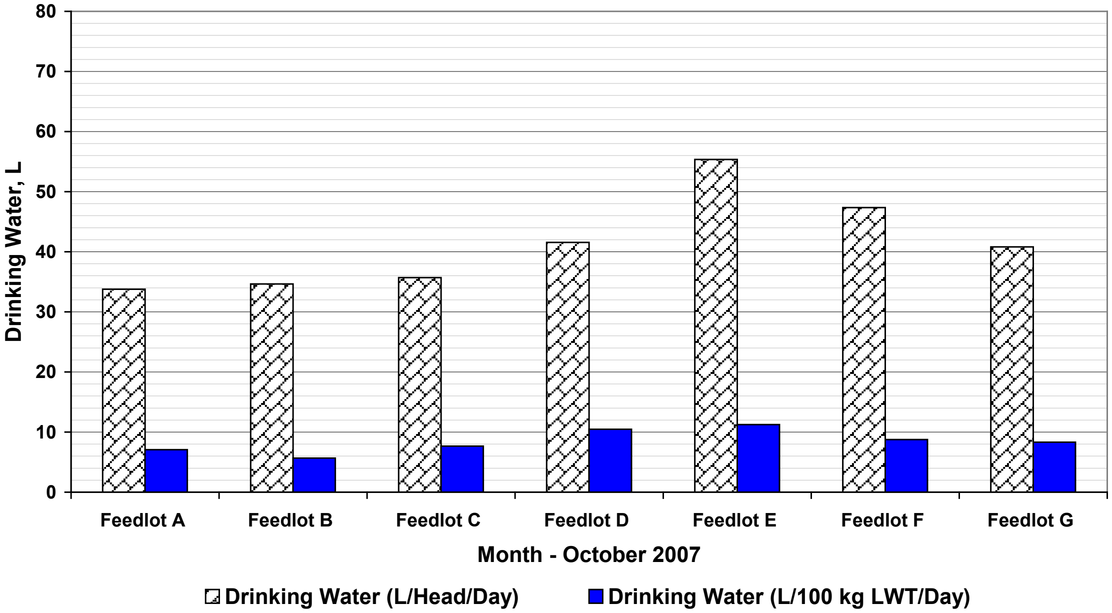

Figure 63 – Drinking water consumption for October 2007 (L/head/day & L/100 kg LWT/day)

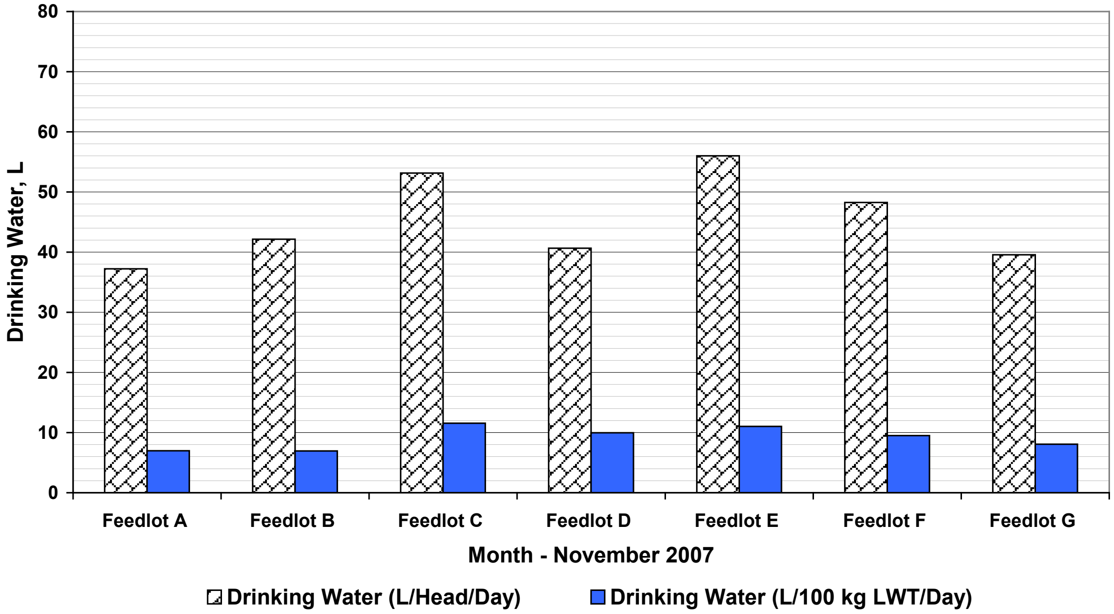

Figure 64 – Drinking water consumption for November 2007 (L/head/day & L/100 kg LWT/day)

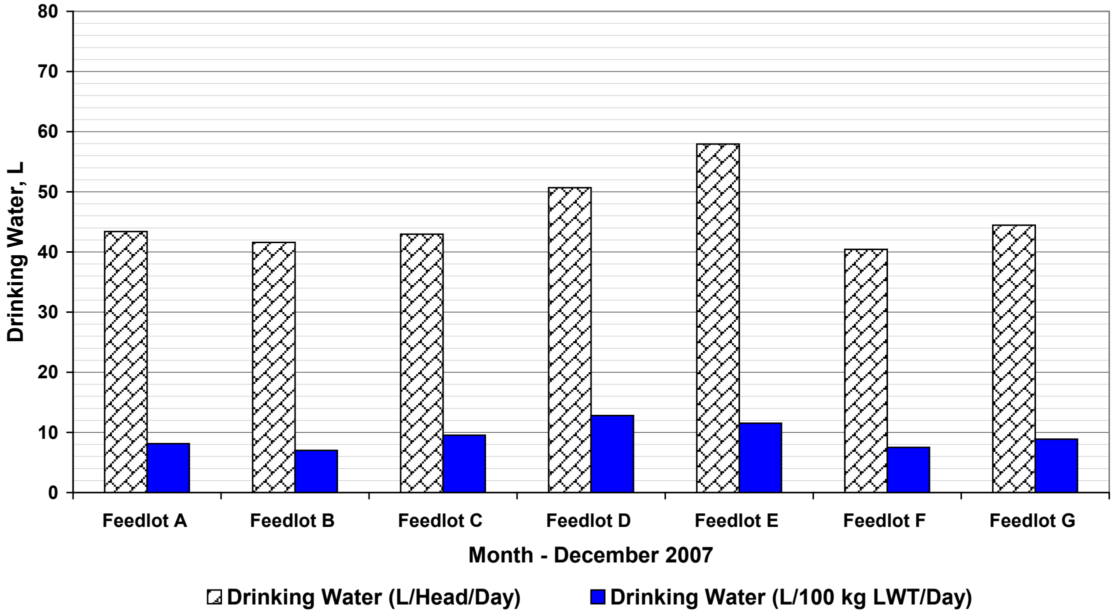

Figure 65 – Drinking water consumption for December 2007 (L/head/day & L/100 kg LWT/day)

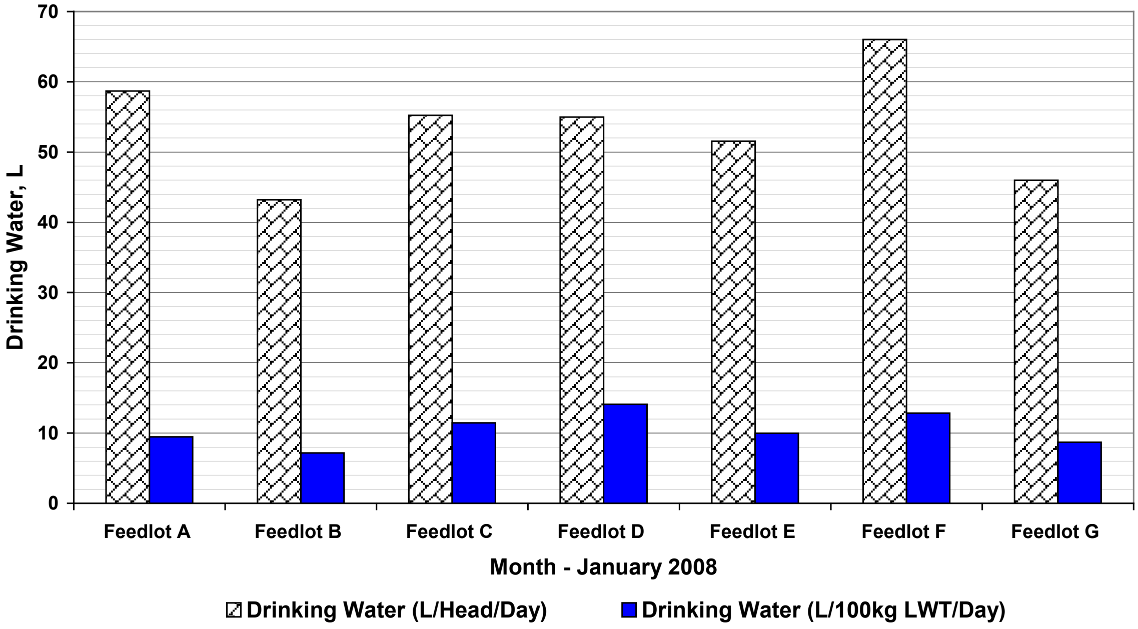

Figure 66 – Drinking water consumption for January 2008 (L/head/day & L/100 kg LWT/day)

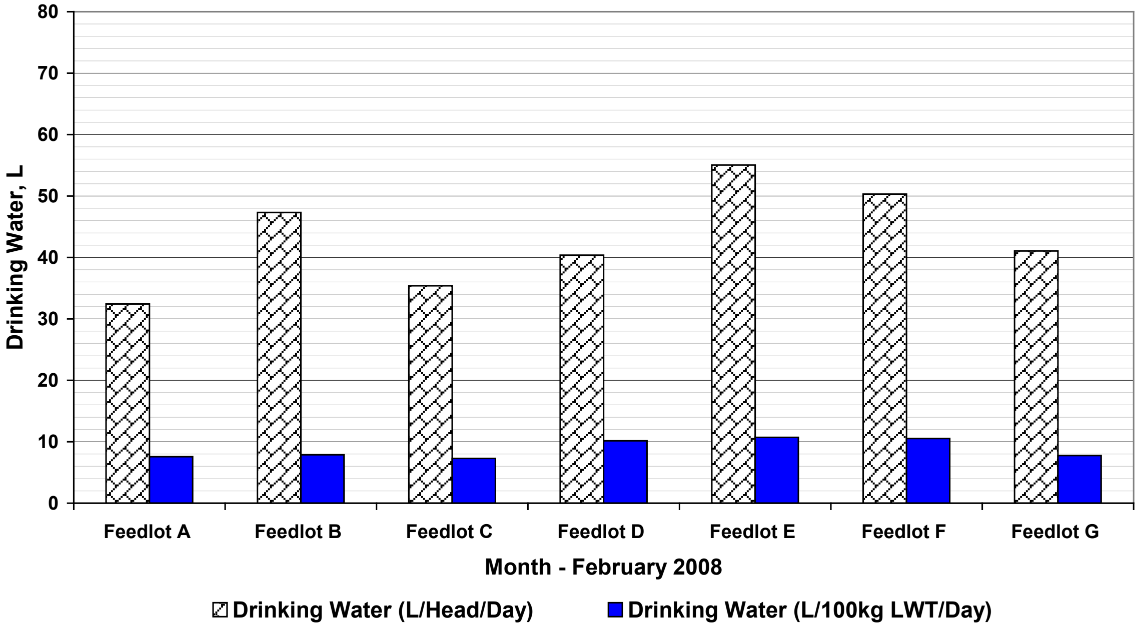

Figure 67 – Drinking water consumption for February 2008 (L/head/day & L/100 kg LWT/day)

Appendix B – Feed Processing Water Usage

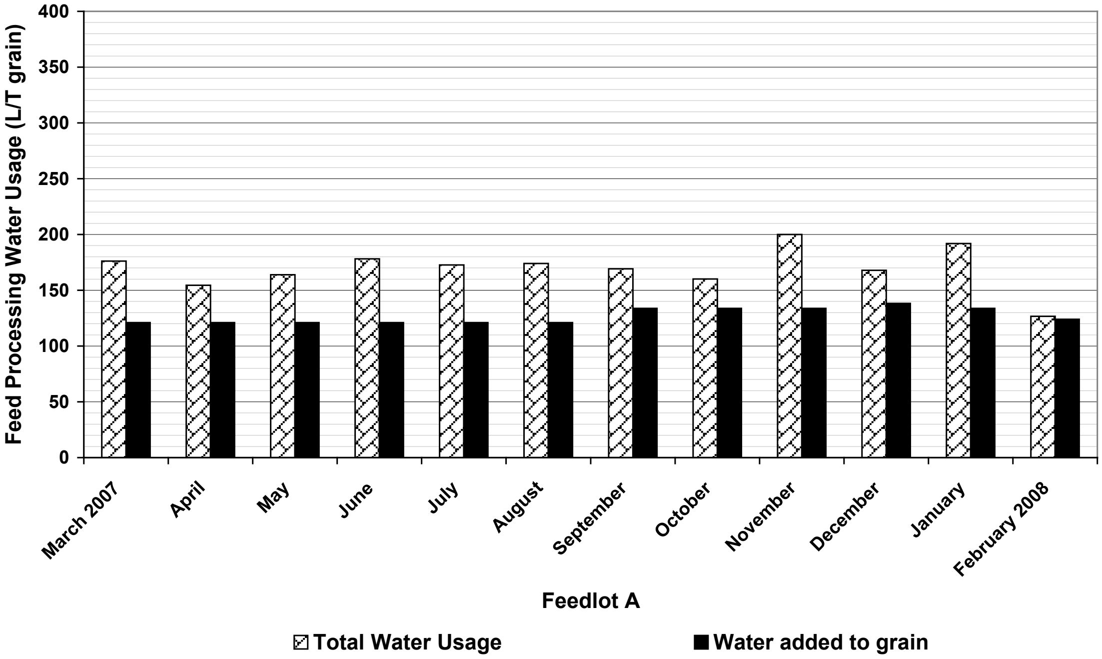

Figure 68 – Feed processing water usage for Feedlot A (L/t grain)

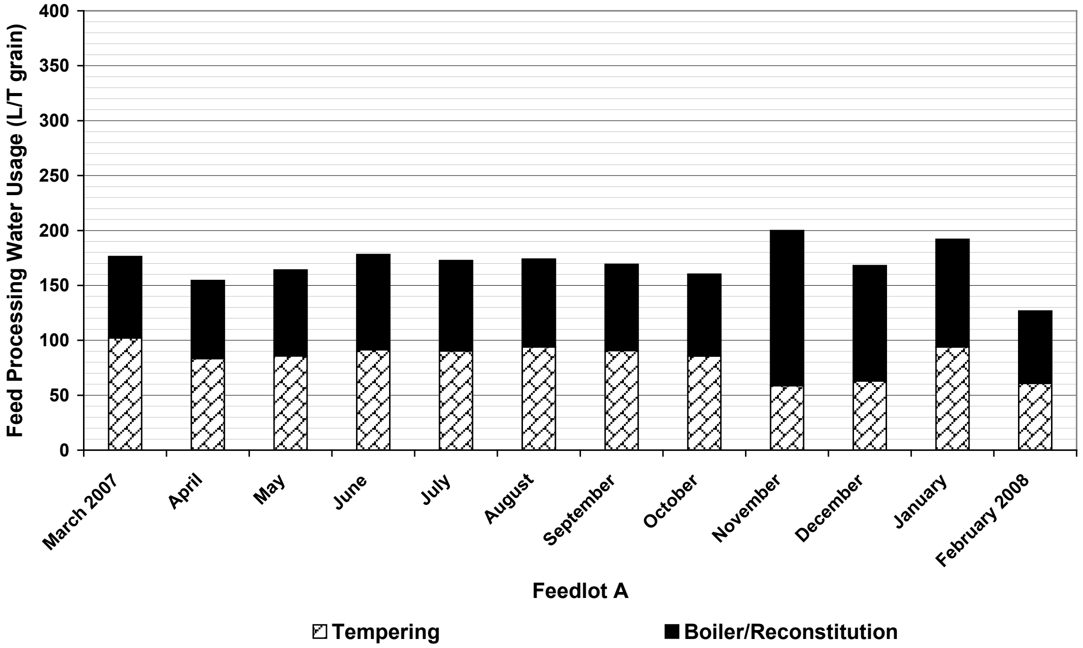

Figure 69 – Feed processing component water usage for Feedlot A (L/t grain)

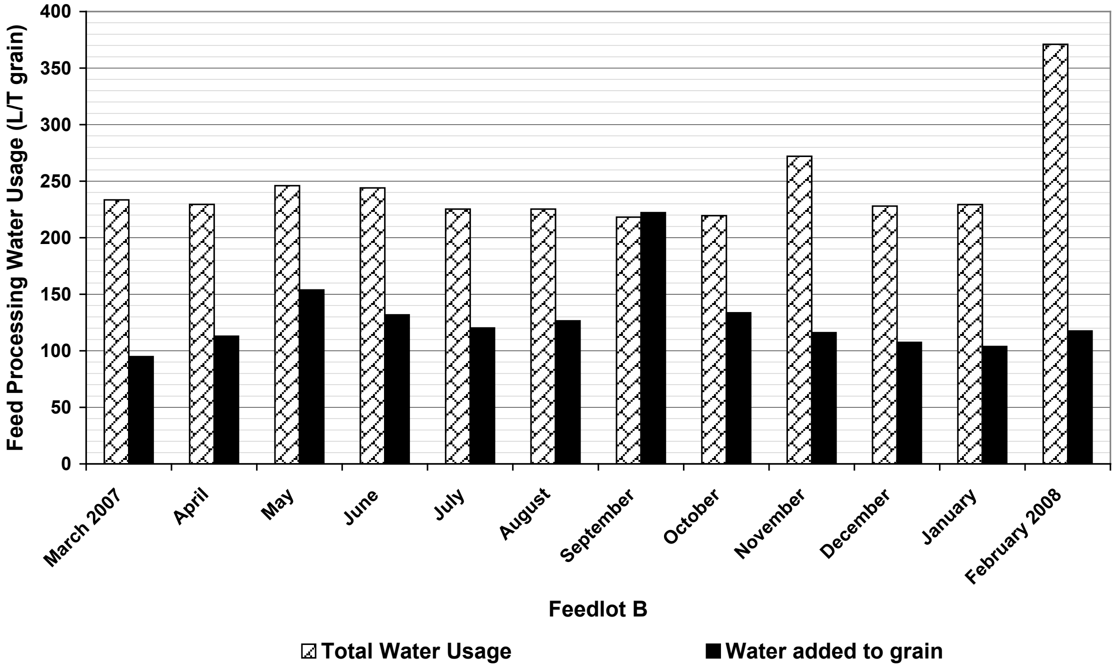

Figure 70 – Feed processing water usage for Feedlot B (L/t grain)

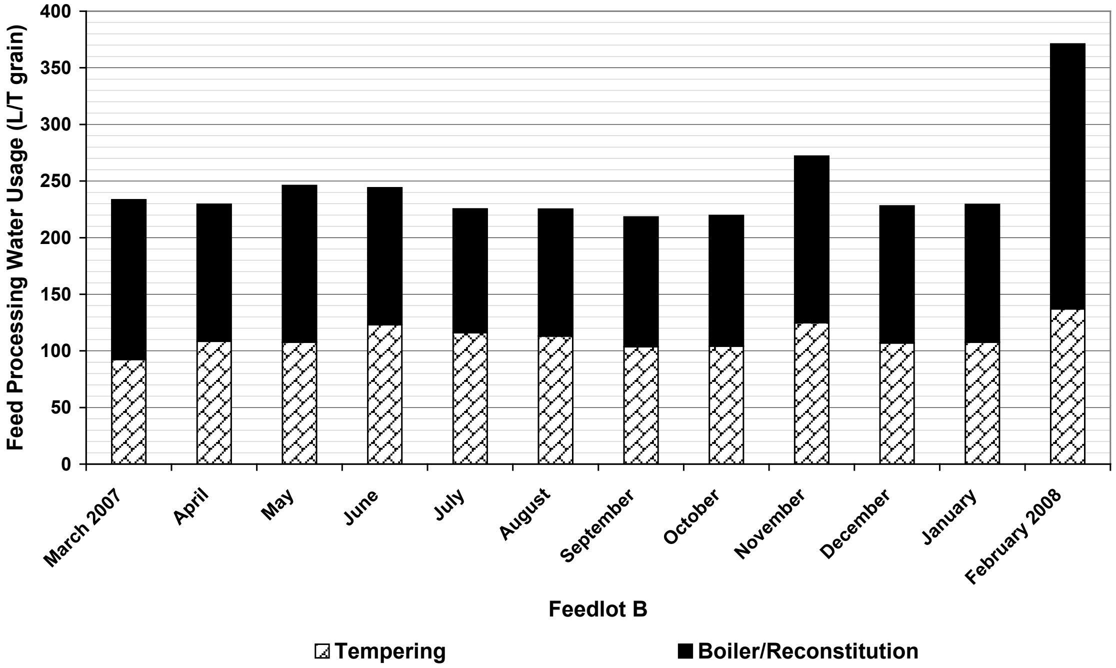

Figure 71 – Feed processing component water usage for Feedlot B (L/t grain)

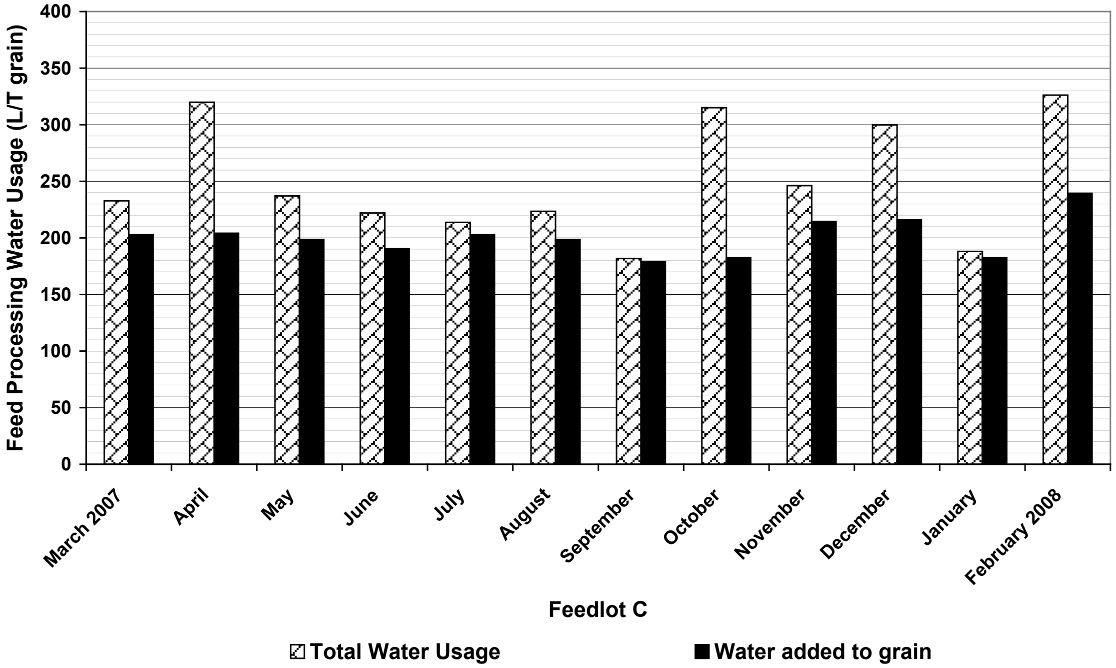

Figure 72 – Feed processing water usage for Feedlot C (L/t grain)

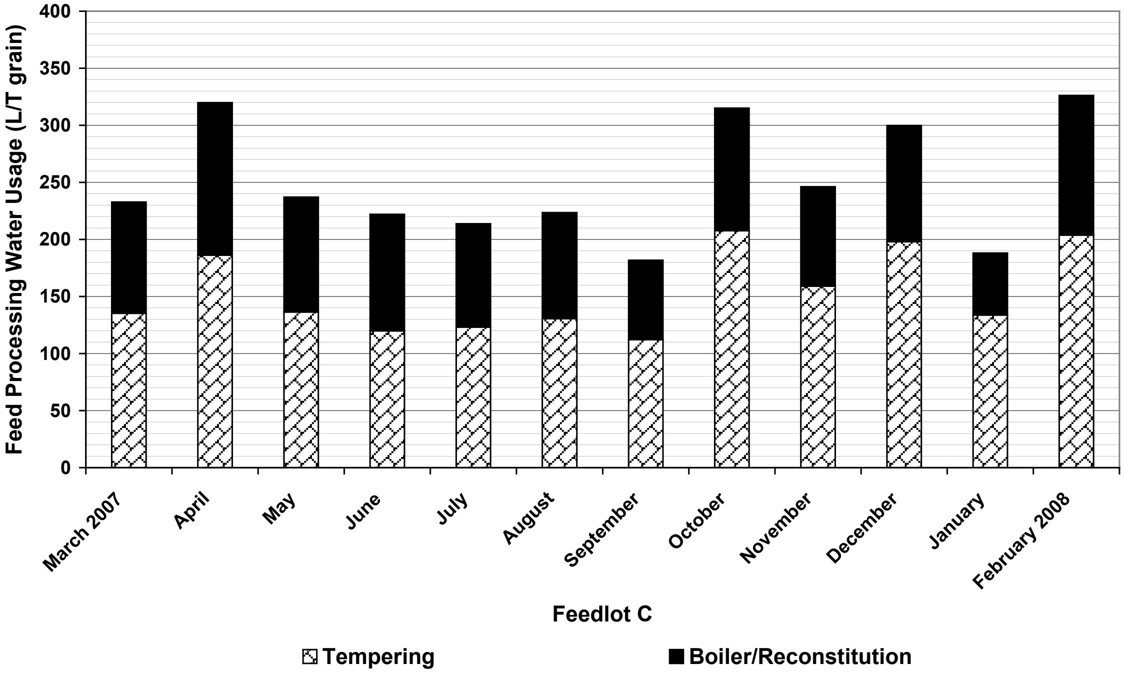

Figure 73 – Feed processing component water usage for Feedlot C (L/t grain)

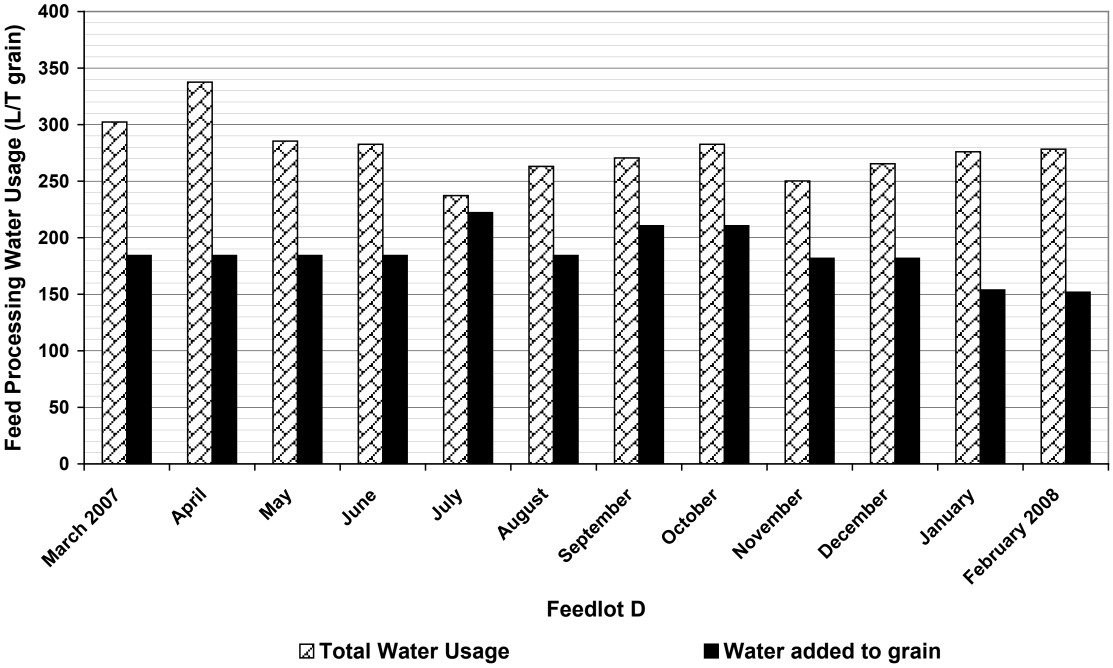

Figure 74 – Feed processing water usage for Feedlot D (L/t grain)

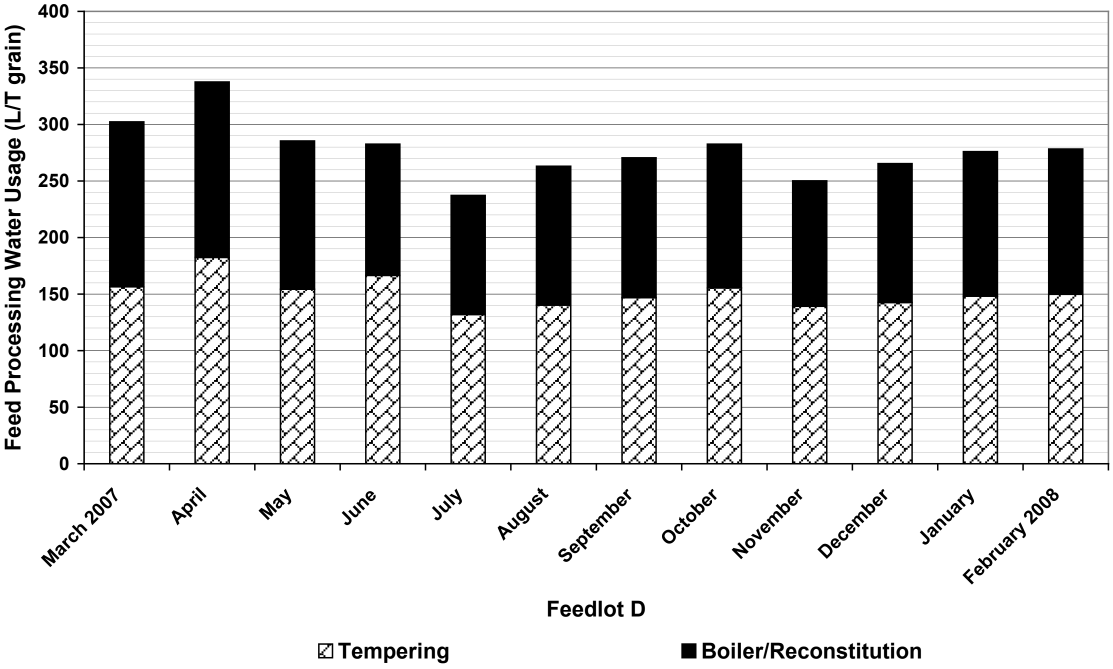

Figure 75 – Feed processing component water usage for Feedlot D (L/t grain)

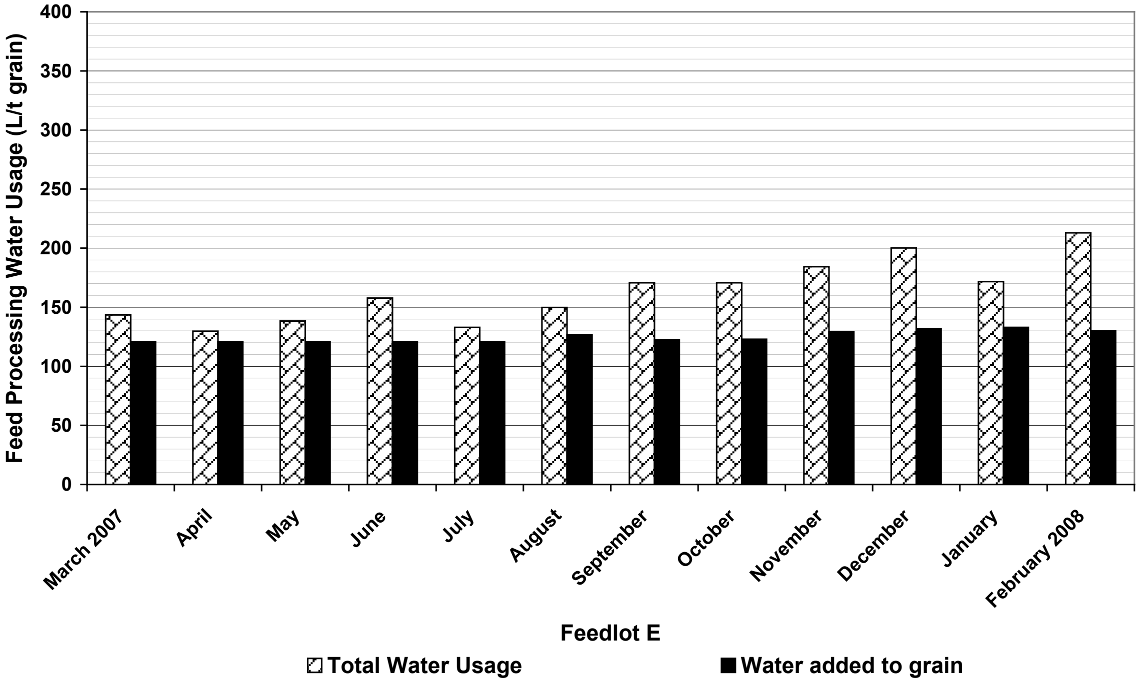

Figure 76 – Feed processing water usage for Feedlot E (L/t grain)

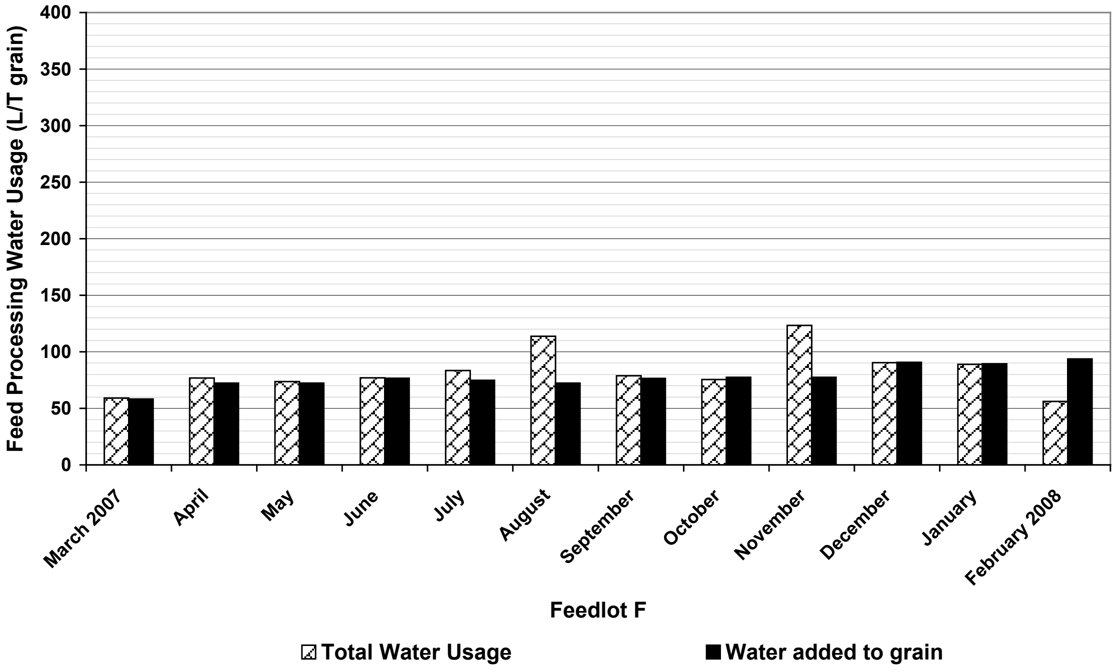

Figure 77 – Feed processing water usage for Feedlot F (L/t grain)

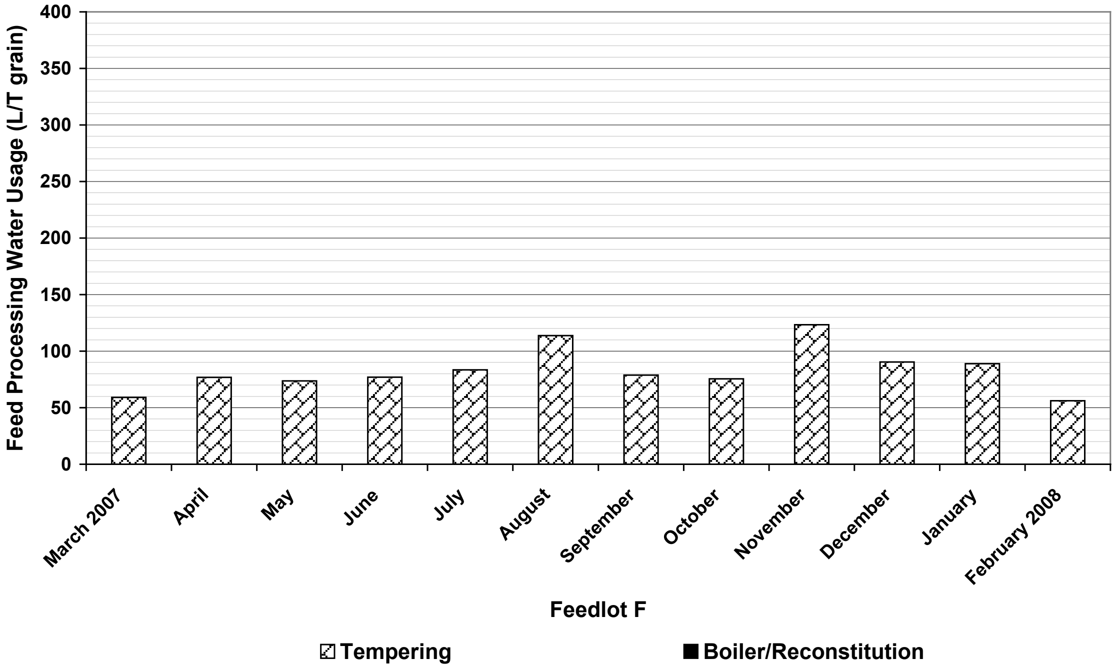

Figure 78 – Feed processing component water usage for Feedlot F (L/t grain)

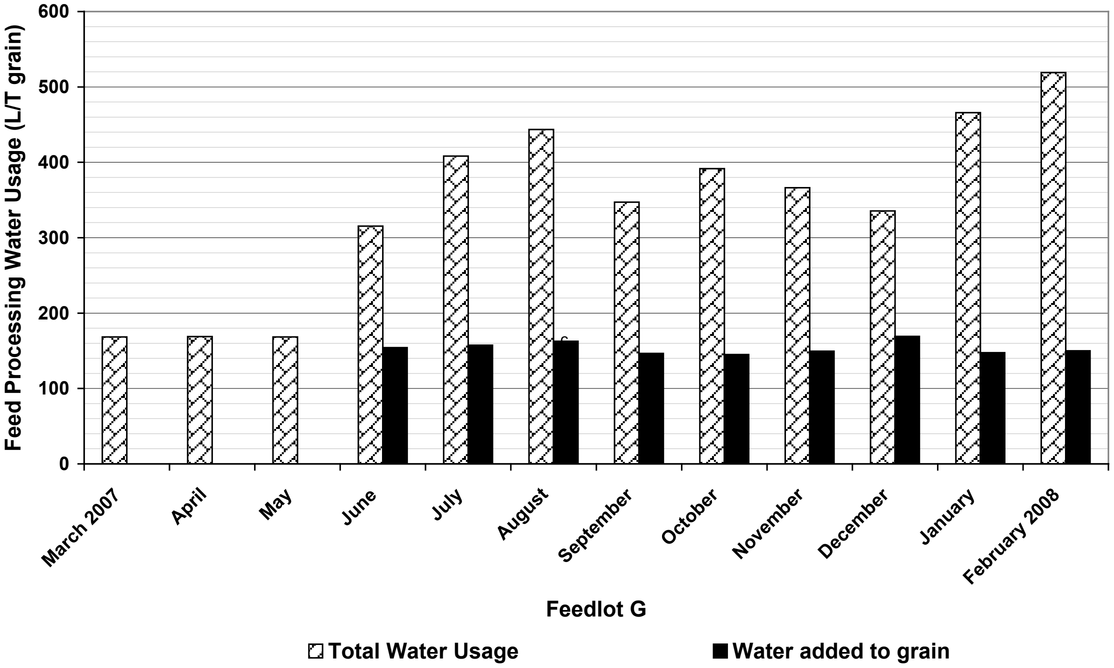

Figure 79 – Feed processing water usage for Feedlot D (L/t grain)

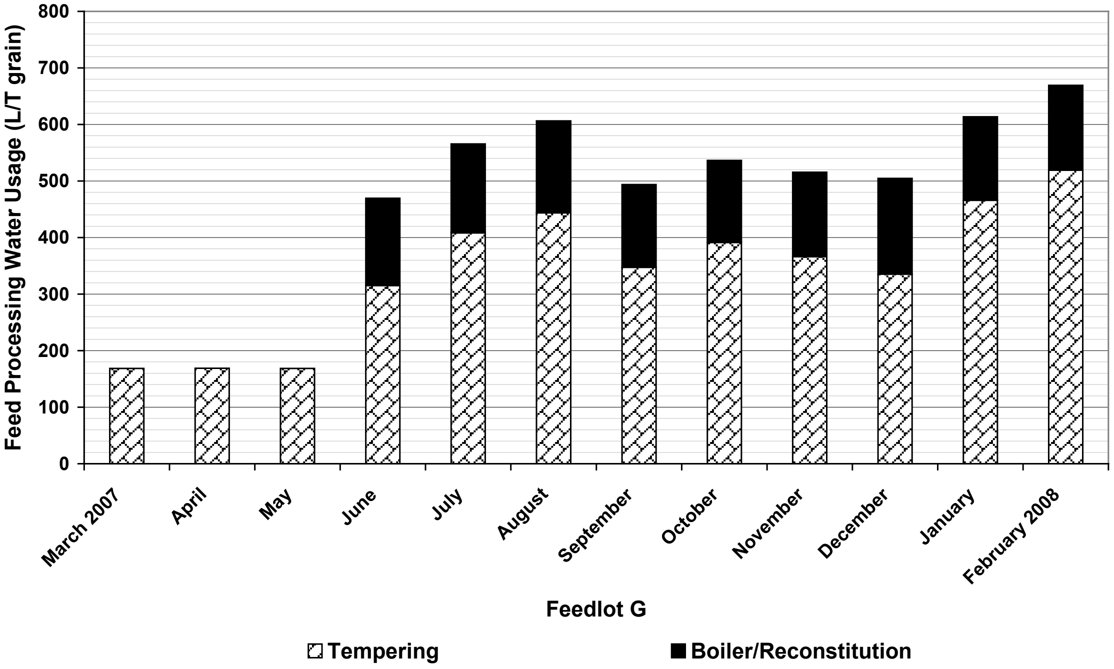

Figure 80 – Feed processing component water usage for Feedlot F (L/t grain)

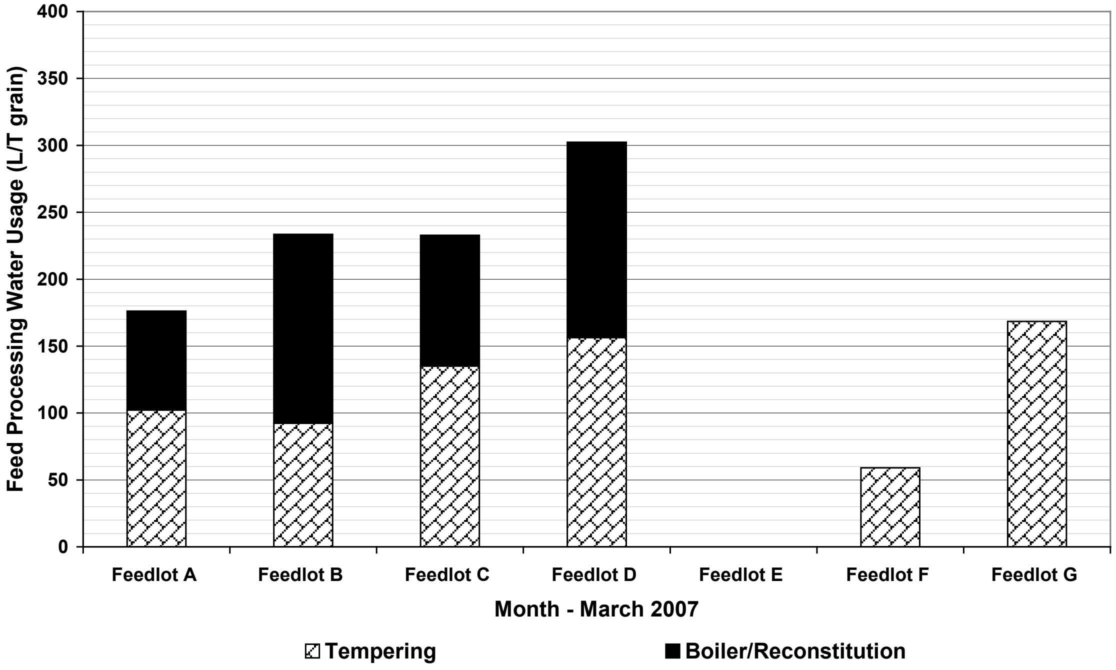

Figure 81 – Feed processing component water usage for March 2007 (L/t grain)

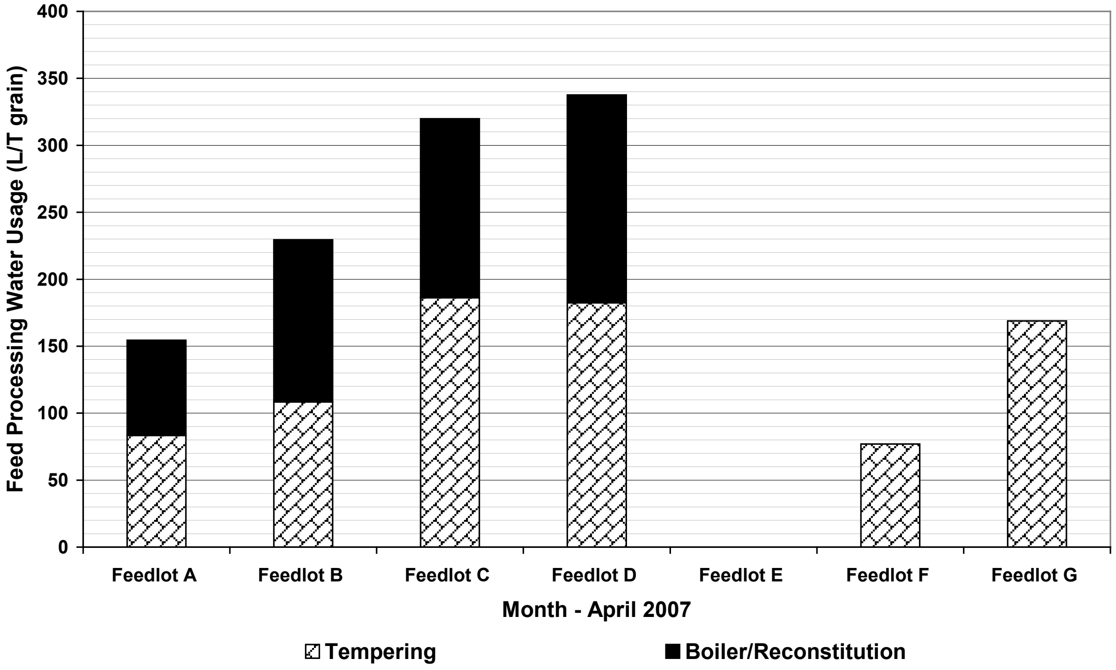

Figure 82 – Feed processing component water usage for April 2007 (L/t grain)

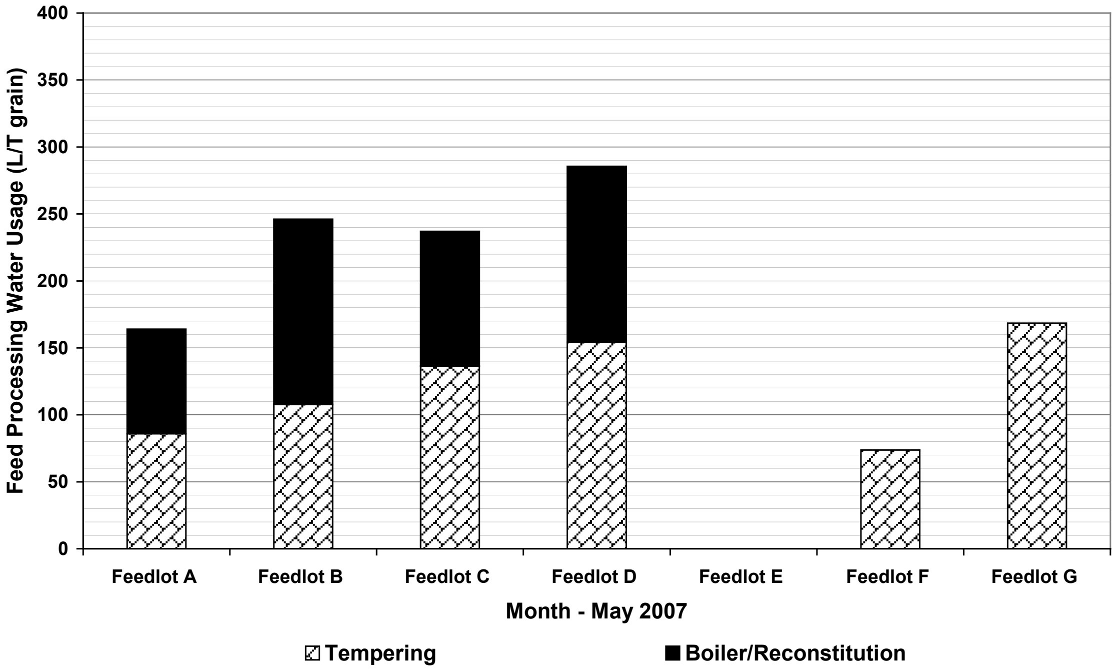

Figure 83 – Feed processing component water usage for May 2007 (L/t grain)

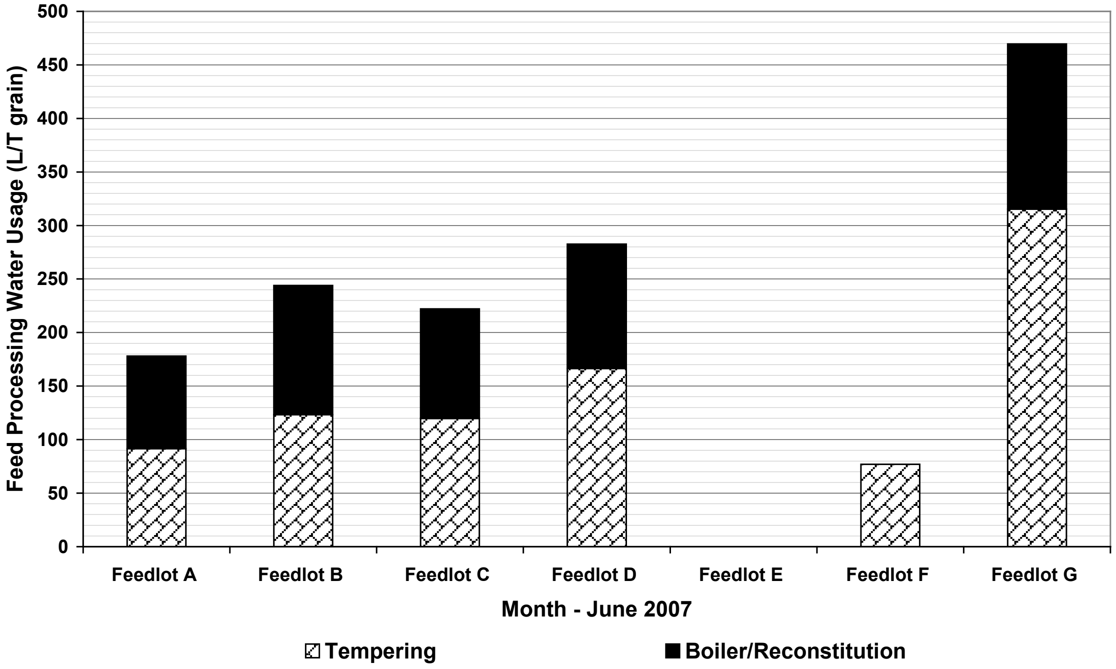

Figure 84 – Feed processing component water usage for June 2007 (L/t grain)

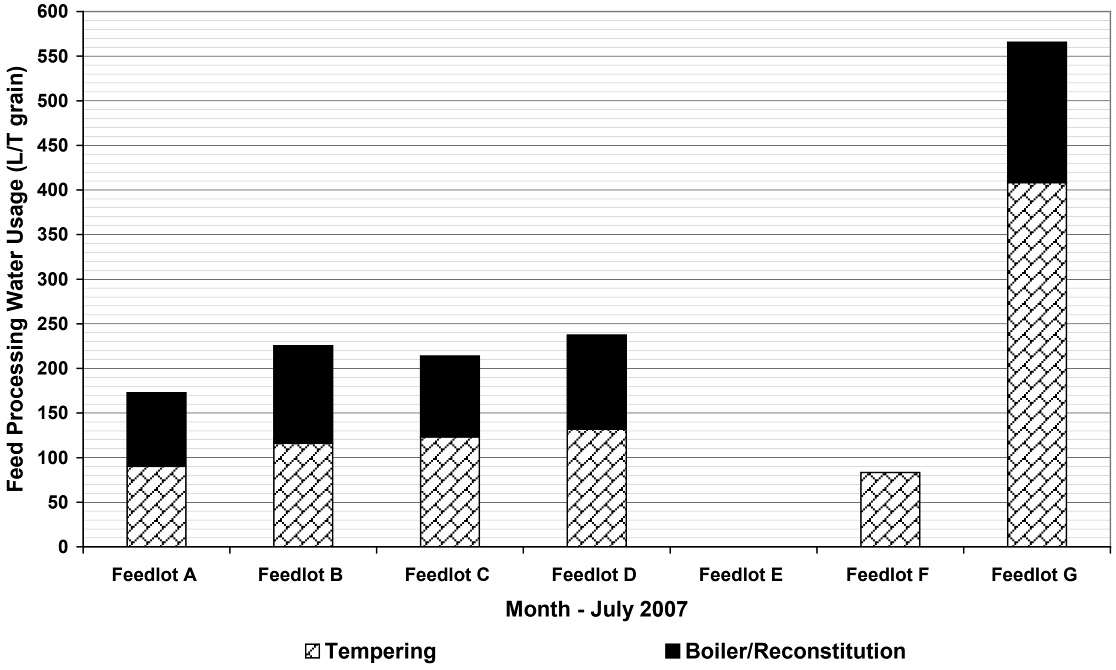

Figure 85 – Feed processing component water usage for July 2007 (L/t grain)

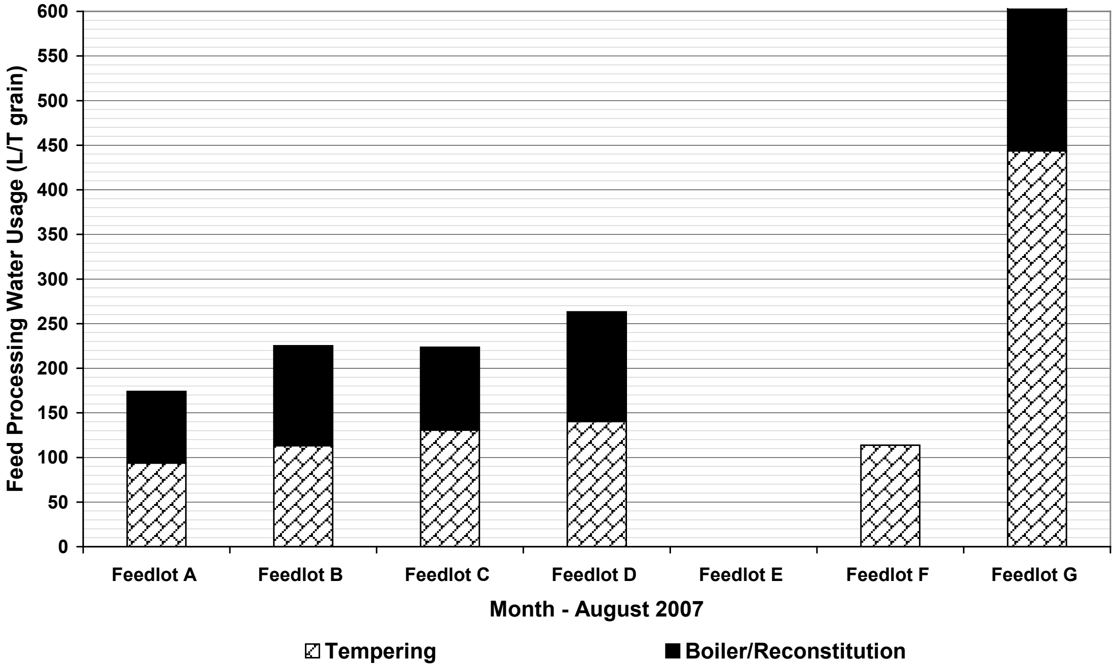

Figure 86 – Feed processing component water usage for August 2007 (L/t grain)

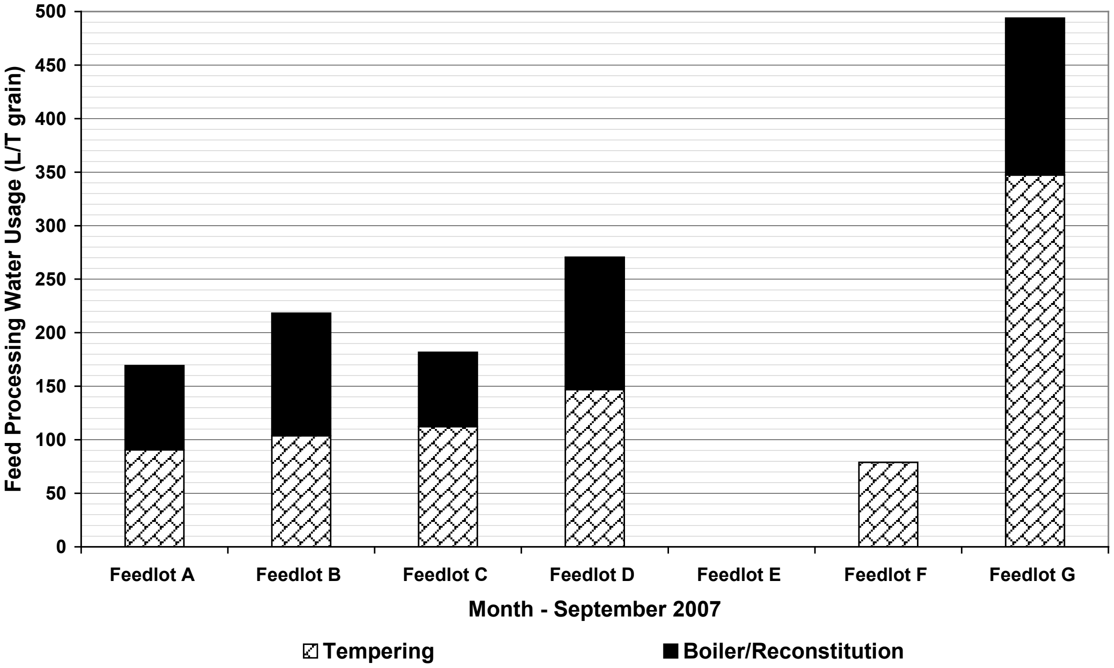

Figure 87 – Feed processing component water usage for September 2007 (L/t grain)

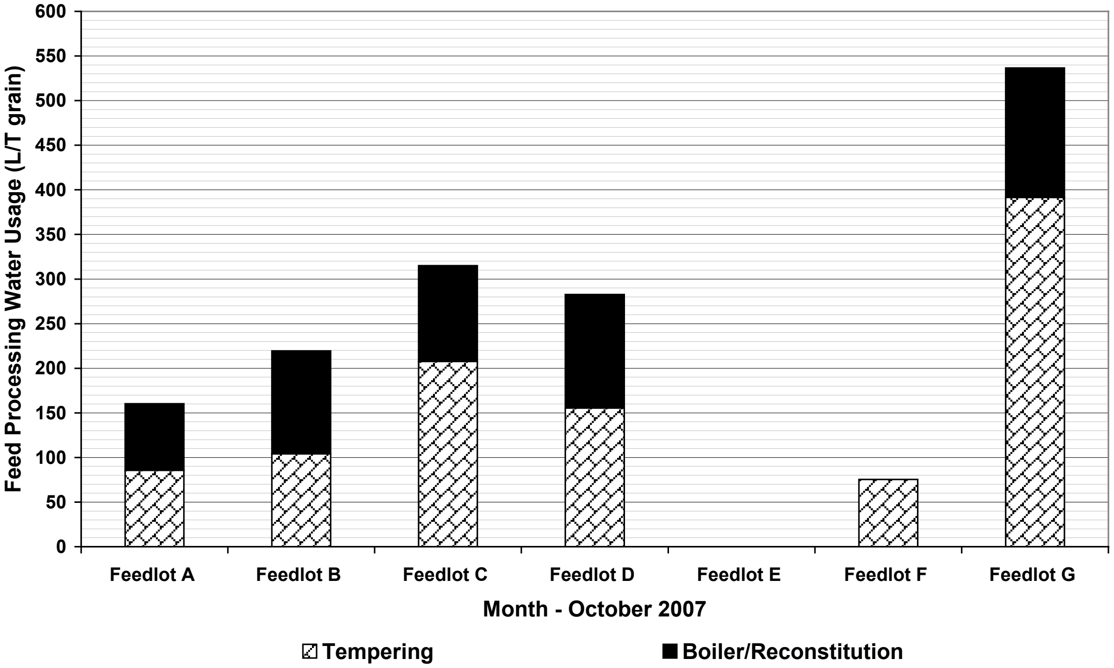

Figure 88 – Feed processing component water usage for October 2007 (L/t grain)

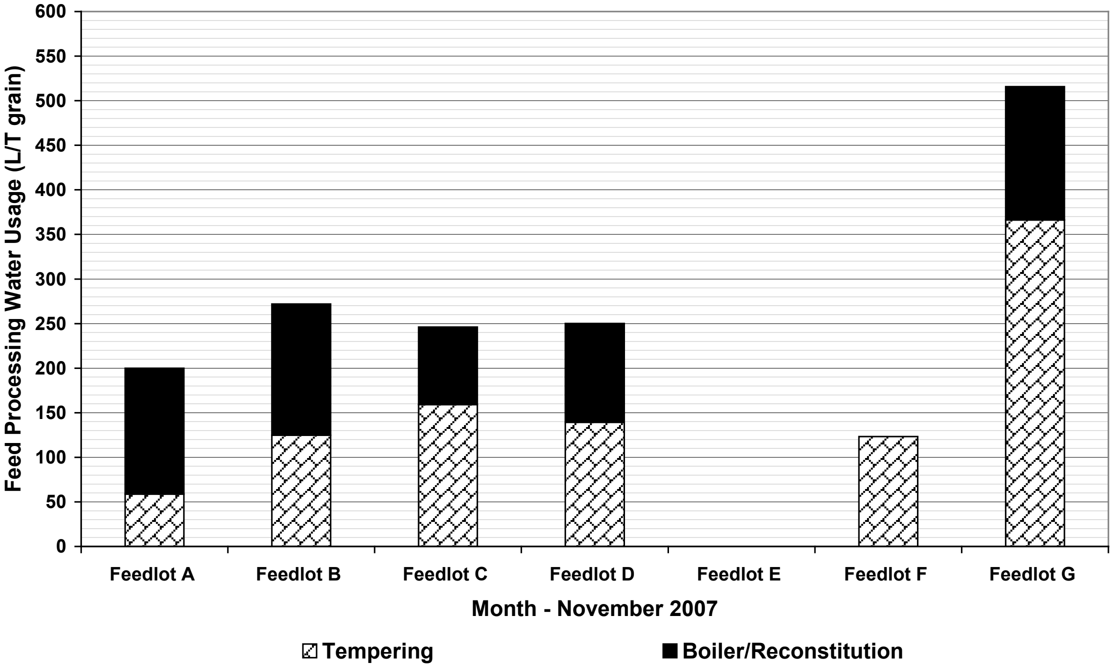

Figure 89 – Feed processing component water usage for November 2007 (L/t grain)

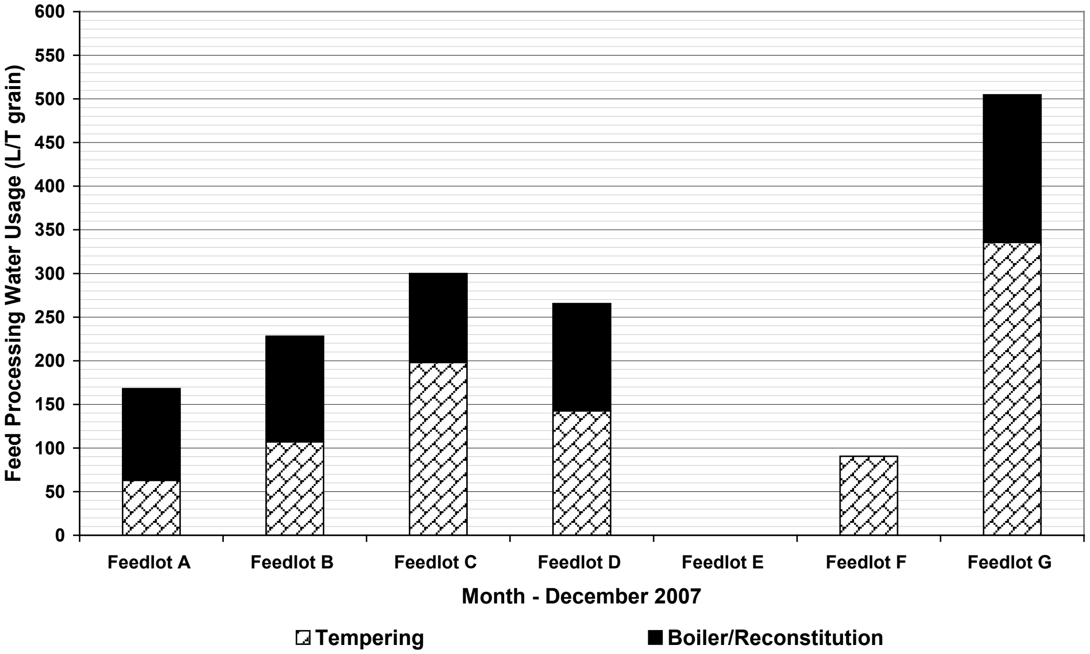

Figure 90 – Feed processing component water usage for December 2007 (L/t grain)

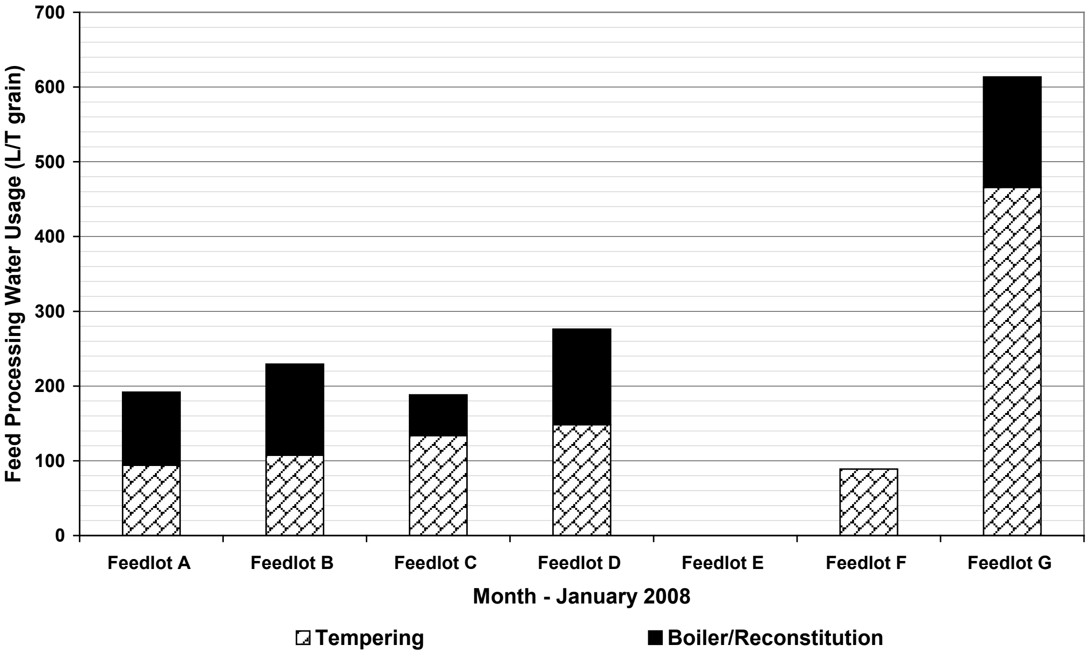

Figure 91 – Feed processing component water usage for January 2008 (L/t grain)

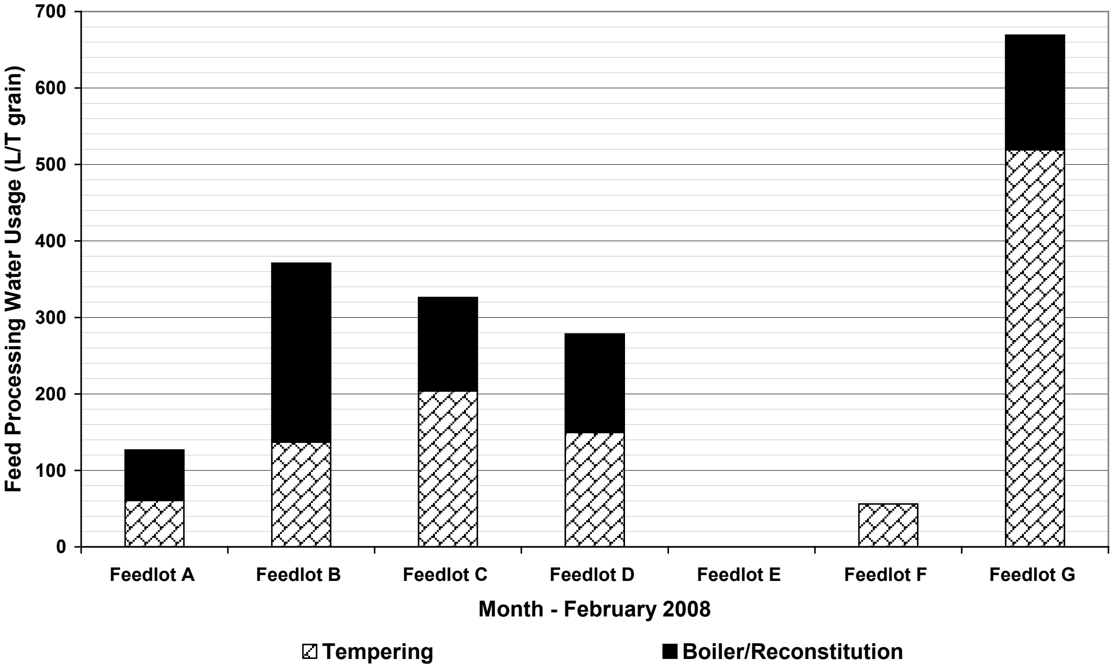

Figure 92 – Feed processing component water usage for February 2008 (L/t grain)

Appendix C – Cattle Washing Water Usage

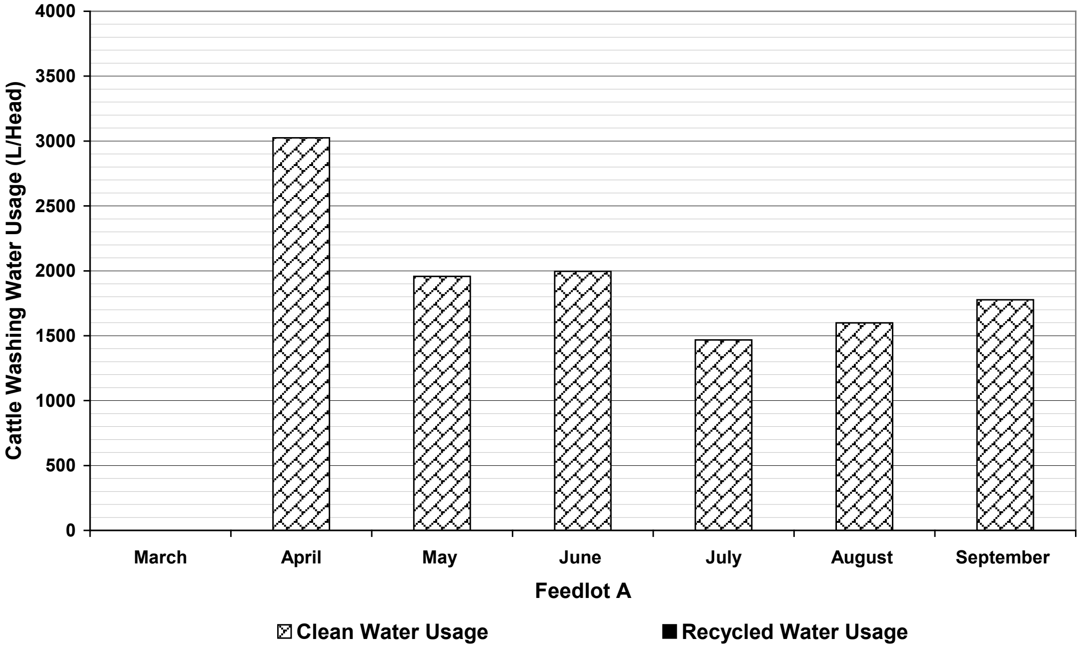

Figure 93 – Cattle washing water usage for Feedlot A (L/head)

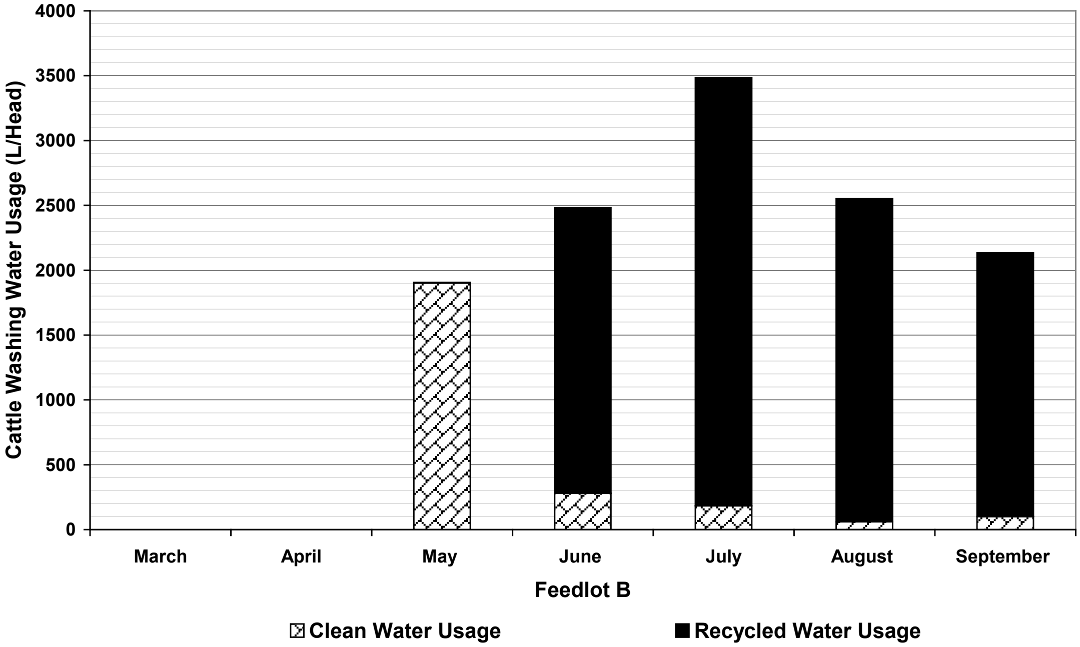

Figure 94 – Cattle washing water usage for Feedlot B (L/head)

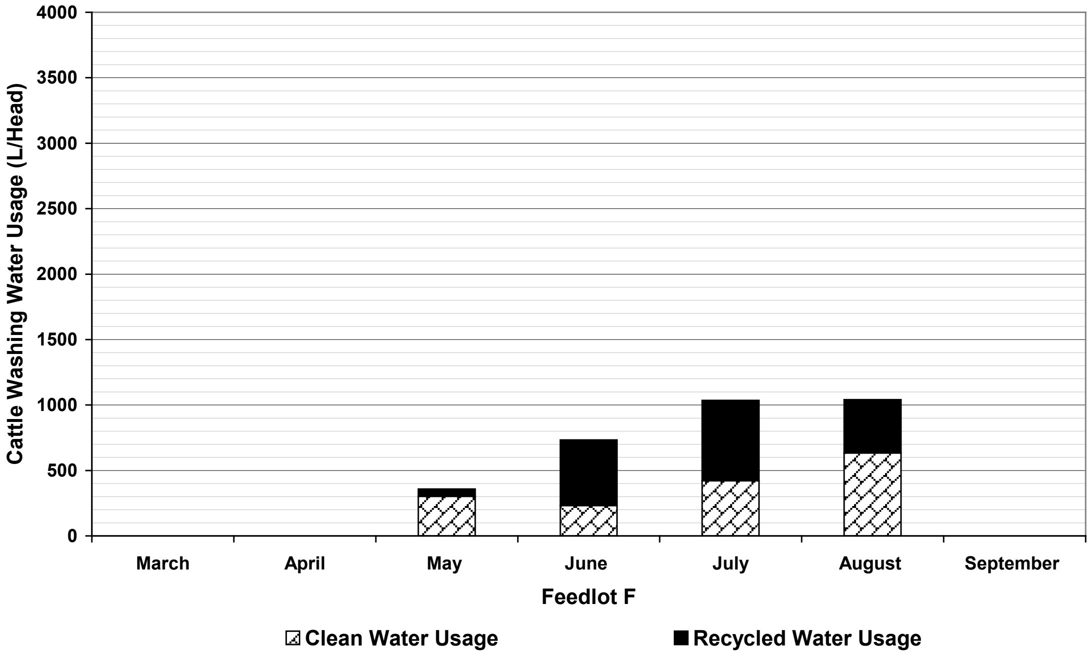

Figure 95 – Cattle washing water usage for Feedlot F (L/head)

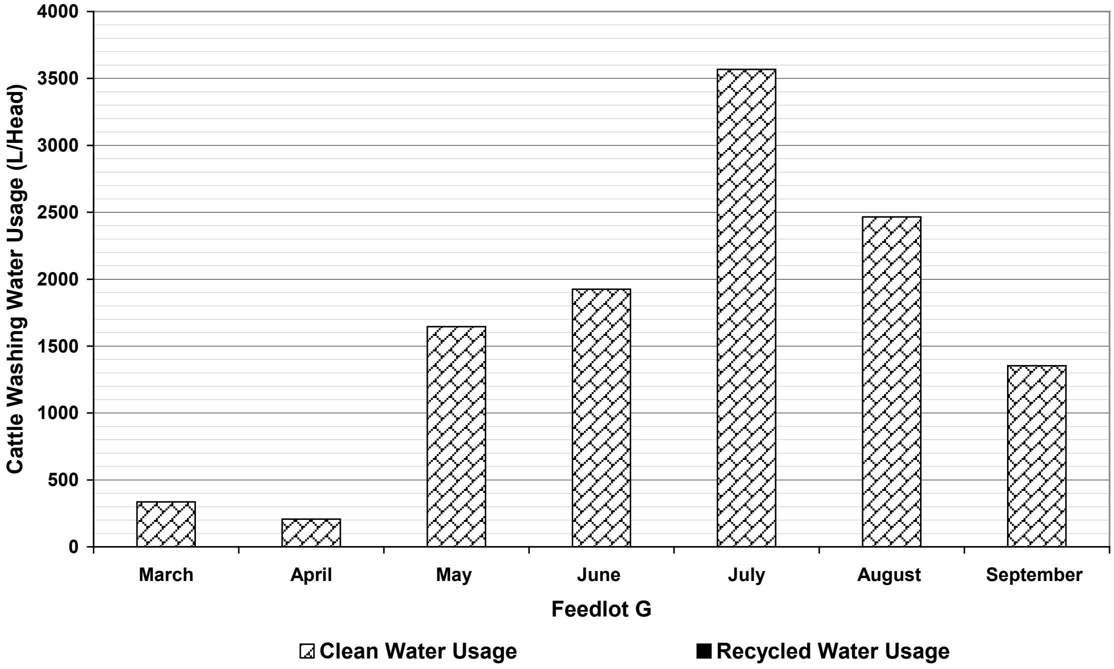

Figure 96 – Cattle washing water usage for Feedlot G (L/head)

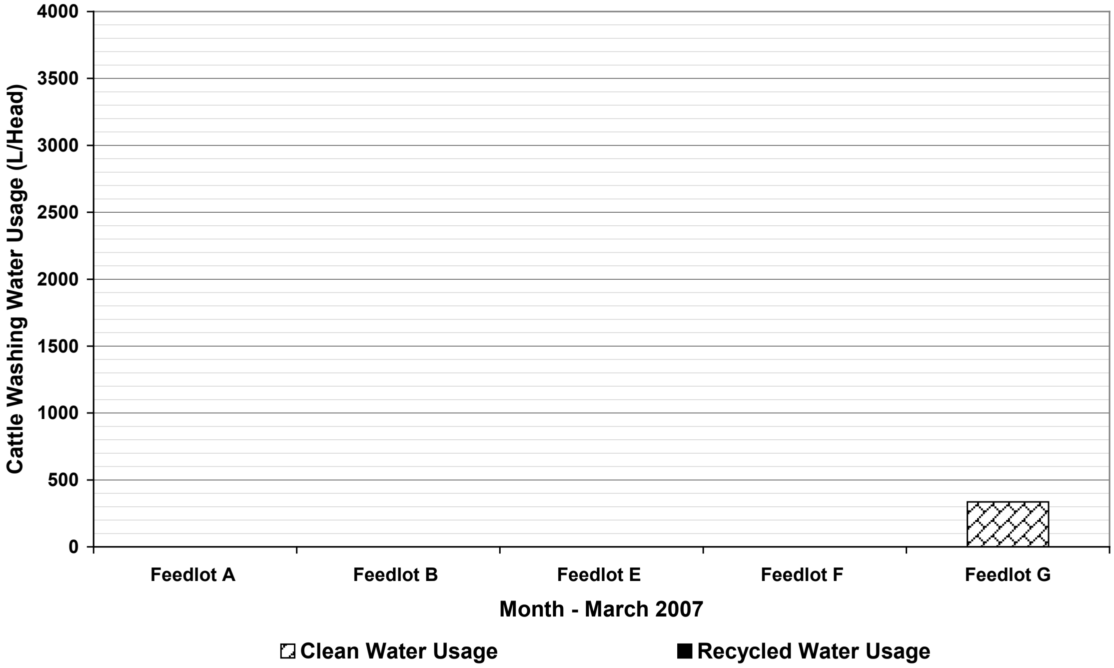

Figure 97 – Cattle washing water usage for March 2007 (L/head)

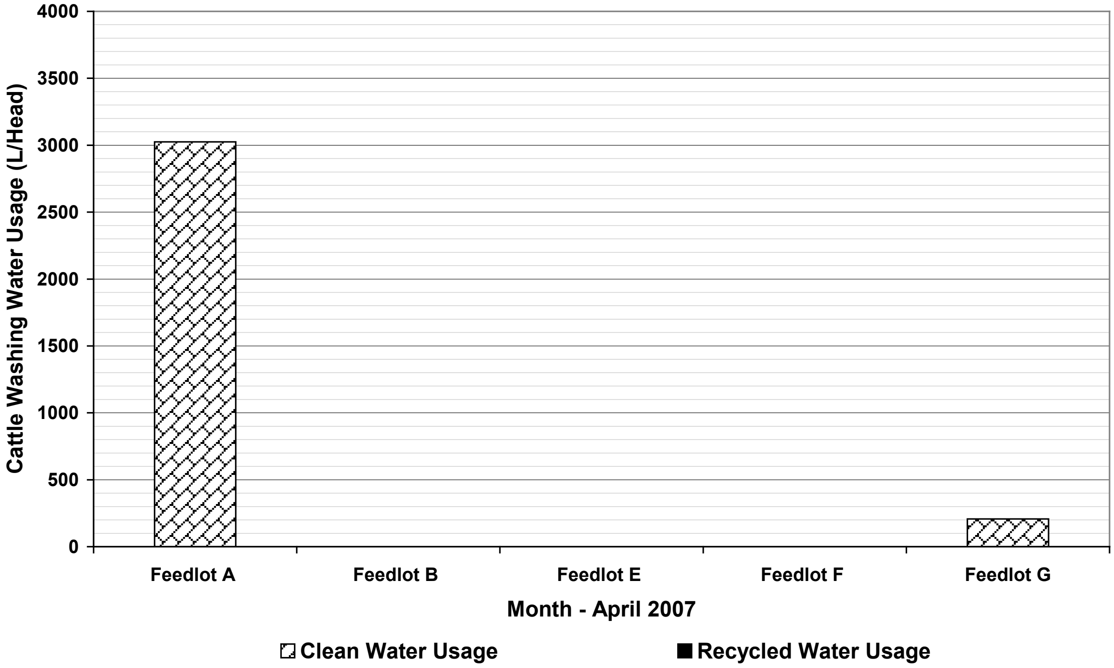

Figure 98 – Cattle washing water usage for April 2007 (L/head)

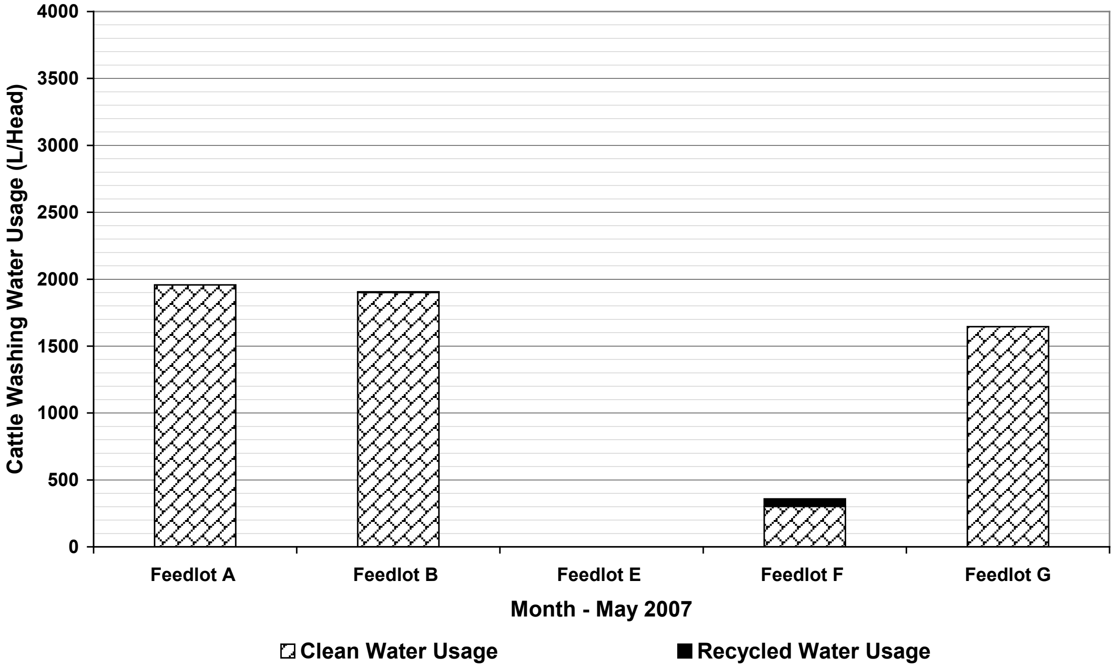

Figure 99 – Cattle washing water usage for May 2007 (L/head)

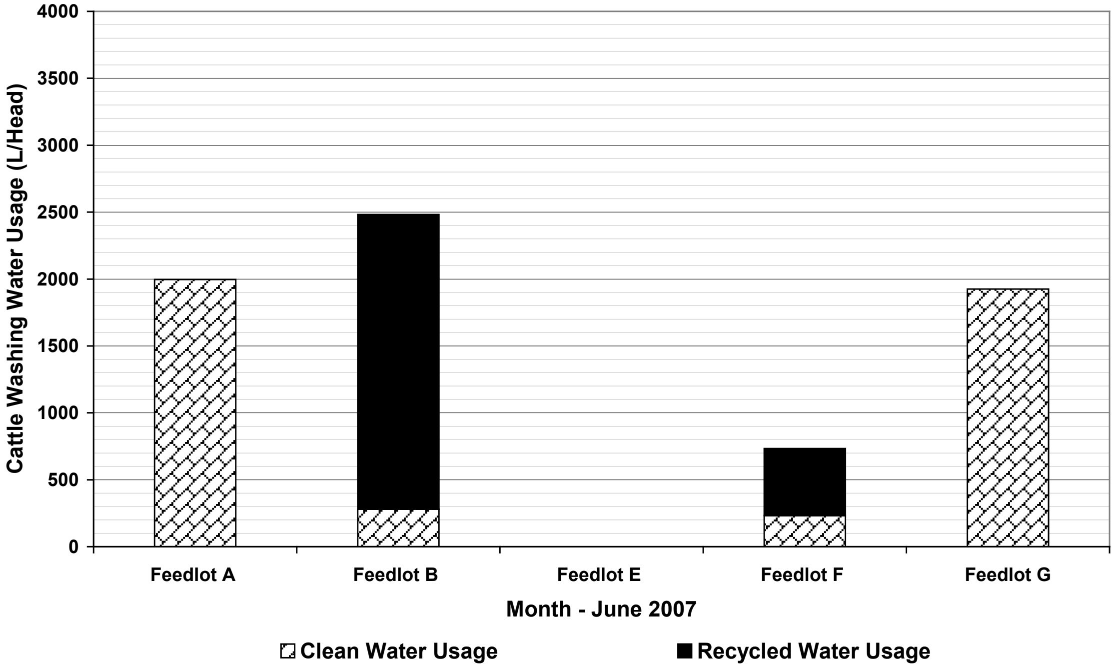

Figure 100 – Cattle washing water usage for June 2007 (L/head)

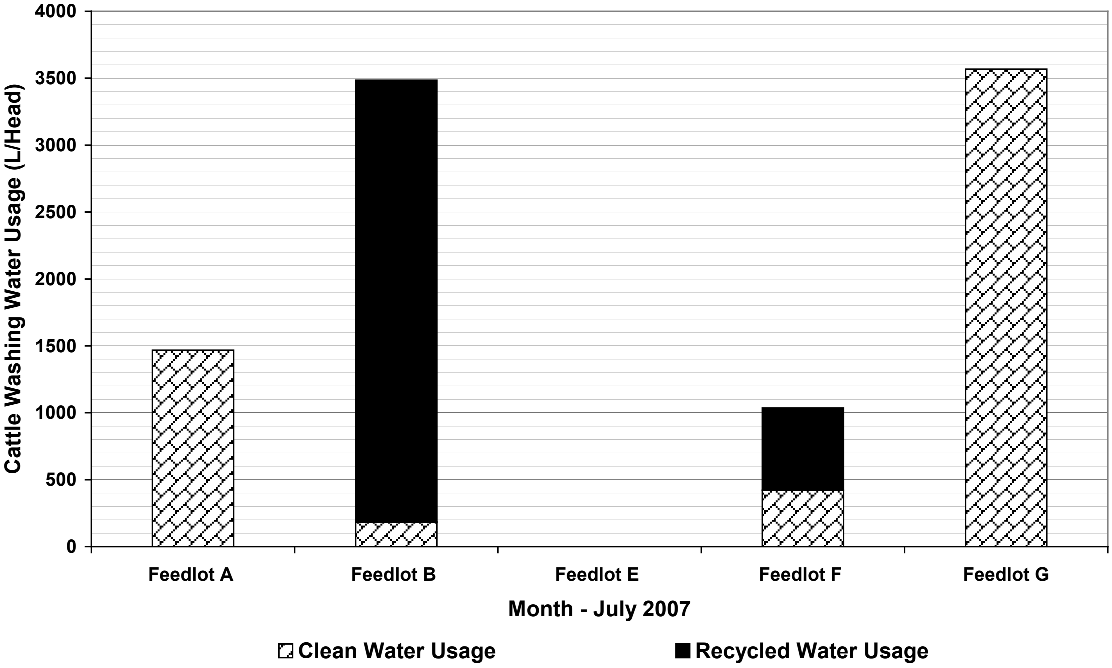

Figure 101 – Cattle washing water usage for July 2007 (L/head)

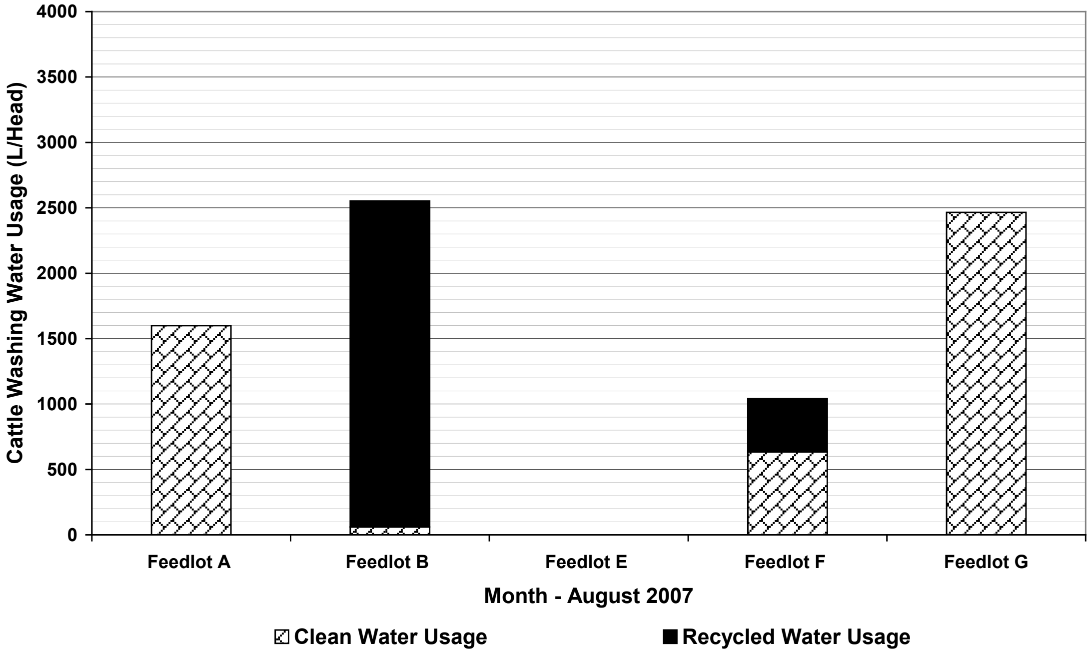

Figure 102 – Cattle washing water usage for August 2007 (L/head)

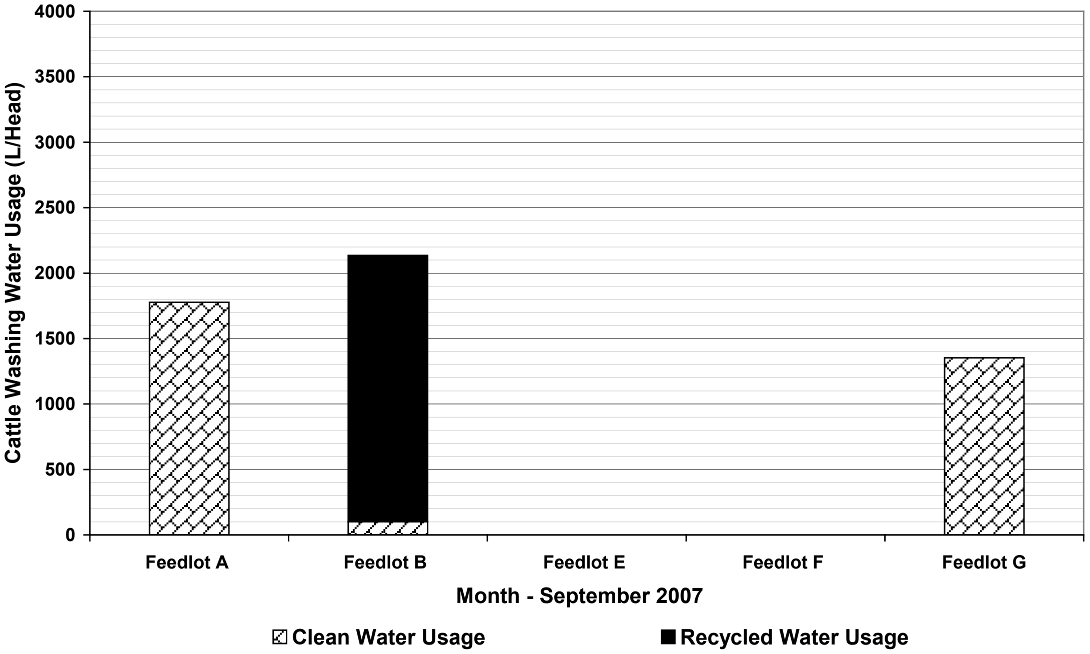

Figure 103 – Cattle washing water usage for September 2007 (L/head)

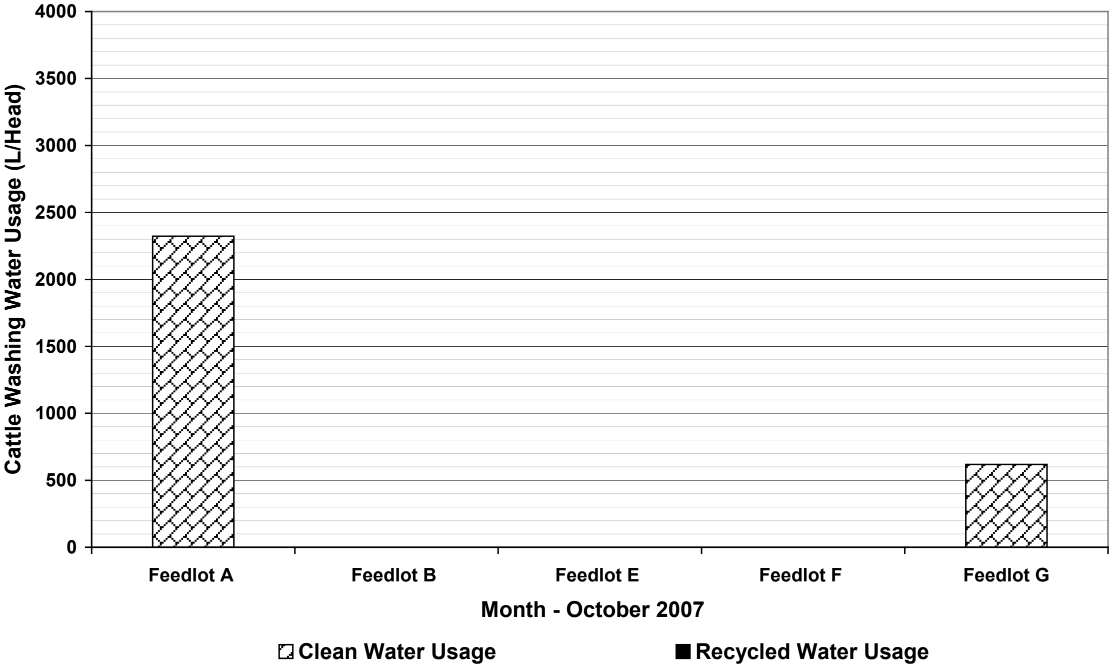

Figure 104 – Cattle washing water usage for October 2007 (L/head)

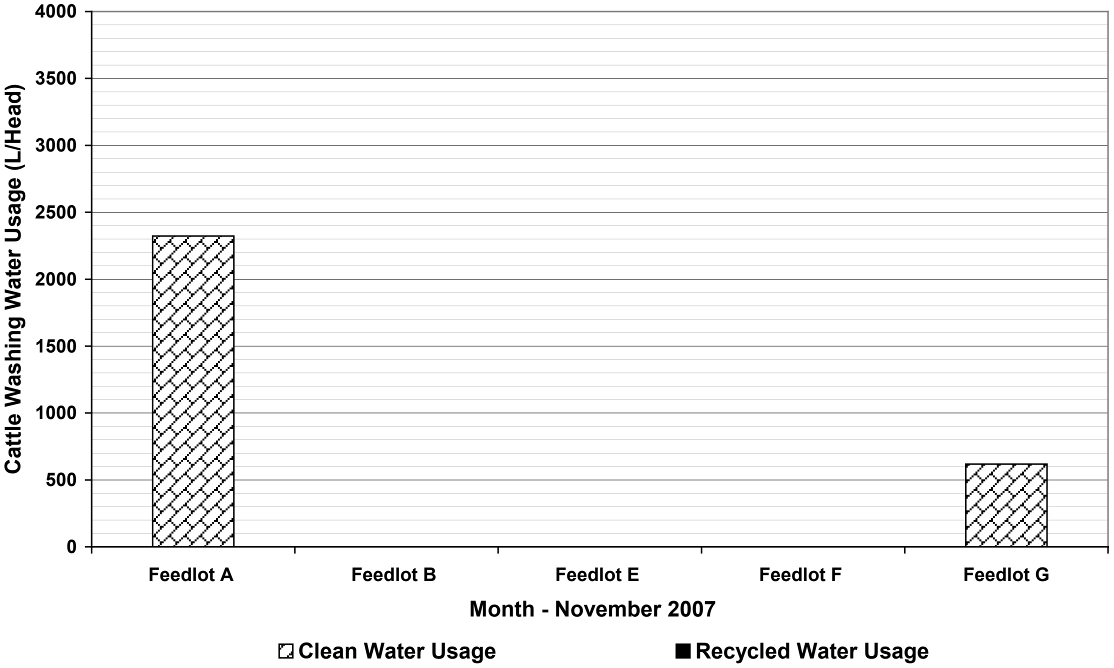

Figure 105 – Cattle washing water usage for November 2007 (L/head)

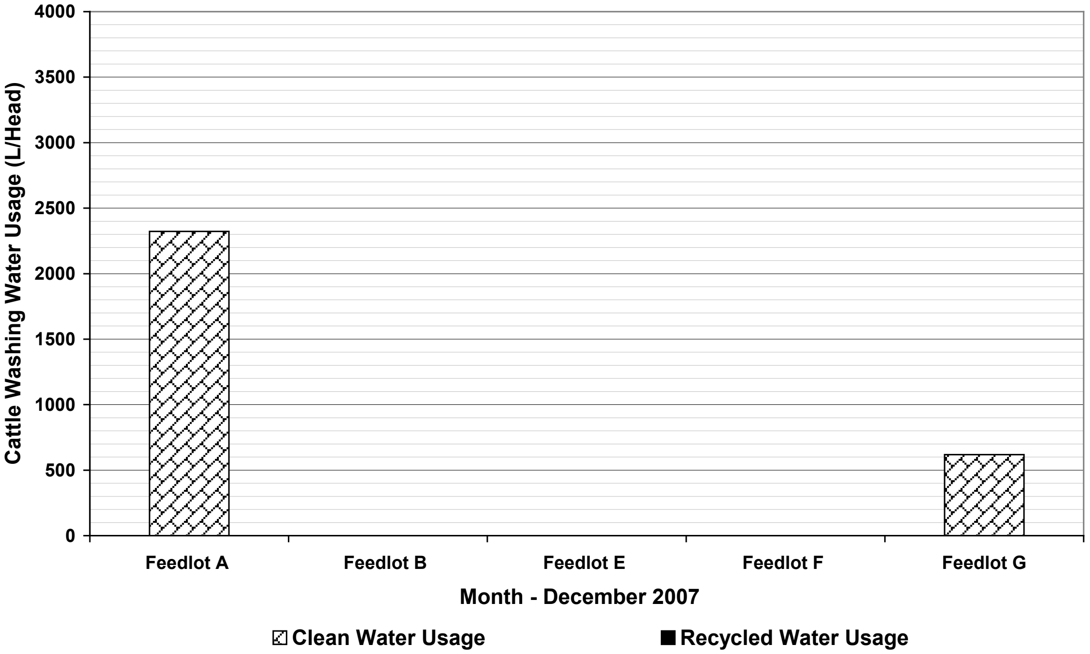

Figure 106 – Cattle washing water usage for December 2007 (L/head)

final report

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Water and energy usage for individual activities within Australian feedlots

Part B Report: Energy usage at Australian feedlots

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Abstract

Whilst total annual energy records by lot feeders are usually good, little data exists on actual usage levels in individual components viz water supply, feed management, waste management, cattle washing, administration and repairs and maintenance.

Eight feedlots were selected representing a cross-section of geographical, climatic and feeding regimes within the Australian feedlot industry. The sub-system boundary as defined here is the feedlot site itself plus the transport component of bringing cattle and feed into the feedlot and delivering cattle from the feedlot.

At seven of these feedlots, power meters were installed to allow an examination of usage by individual activities. The major energy (viz water supply, feed management, waste management, cattle washing) usage activities were monitored and recorded.

This report provides factual information on the quantity of energy used within individual activities of seven Australian feedlots for the period March 2007 to February 2008.

Executive Summary

The Australian red meat industry, as with most primary industries, is coming under increasing pressure from both the community and government to document and justify its impacts on the environment. Currently, a lack of credible supply chain data prevents the industry from being able to respond in a meaningful manner.

Meat and Livestock Australia (MLA) has undertaken a project (FLOT.328) to measure environmental costs associated with the production of one kilogram of meat from modern Australian feedlots. As part of this project factual information data on water use was obtained via a detailed on-line survey of feedlot inputs and outputs including cattle numbers, intake and sale weights, dressing percentages. Annual water usage was estimated on the basis of one kilogram of dressed hot standard carcass weight gain (kg HSCW gain). In this context, HSCW gain is the difference between total dressed carcass weights of cattle leaving the feedlot less the estimated total dressed carcass weight of cattle entering the feedlot.

Whilst, total annual clean water and energy records by lot feeders are usually good, little data exists on actual usage levels in individual components viz water supply, drinking water, feed processing, cattle washing. Hence, more information is required on the water usage of individual components before these figures can be reliably reported.

The purpose of this study is to quantify the clean water, indirect and direct energy usage from individual feedlot activities. Eight feedlots were selected such that the feedlots represent a cross section of geographical, climatic and feeding regime diversity within the Australian feedlot industry. The sub-system boundary as defined here is the feedlot site itself plus the transport component of bringing cattle and feed into the feedlot and delivering cattle from the feedlot.

Water meters and/or power meters were installed at eight feedlots to allow an examination of usage by individual activities. The major clean water-using activities include cattle drinking water, feed management, cattle washing, administration, repairs and maintenance and dilution of effluent. Similarly activities that use a significant amount of energy include water supply, feed management, waste management, administration and repairs and maintenance.

The water and power meter data collected will be supplemented with existing data collected on-site including fuel consumption (diesel, LPG) and cattle performance data. Performance data will include market types, incoming and outgoing liveweights, dressing percentages, feed data and other parameters that allow HSCW gain to be estimated. Information will be collected on a monthly basis and collated.

The data will be analysed to obtain water and energy use associated with a number of feedlot indices including a per head basis, per tonne grain processed and per kilogram of Hot Standard Weight gain (HSCW). A breakdown of resource use within the major feedlot activities and associated operations will be provided.

This report addresses energy usage by feedlots.

Results from the seven feedlots studied showed that total annual indirect energy use ranged from 1.6-8 MJ/kg HSCW gain over the period March 2007 to February 2008. Distance travelled by trucks transporting cattle and delivering feed has a large impact on the energy consumed. Combined these represent a similar usage level to direct energy consumed within the feedlot subsystem.

Incoming cattle energy usage typically ranges from 0.1 MJ/kg HSCW gain to 2.0 MJ/kg HSCW gain, when cattle are sourced close to feedlots, however can range up to 4.5 MJ/kg HSCW gain. Outgoing cattle energy usage typically ranges from 0.5 MJ/kg HSCW gain to 0.9 MJ/kg HSCW gain, however a figure of 2.8 MJ/kg HSCW gain has been measured. The average annual commodity delivery energy usage ranged from 0.8 MJ/kg HSCW gain to 5.2 MJ/kg HSCW gain, however a figure of 5.4 MJ/kg HSCW gain has been recorded.

The indirect energy usage figures illustrate the proximity of respective feedlots to cattle, abattoirs and commodities. These figures also are influenced by the differences in average daily gain between long fed cattle and domestic cattle, number and type of commodities used in rations (high grain versus high roughage). These results also clearly show the impact of the drought (grain and available cattle supply) and high grain prices on the industry in particular during the later half of 2007 and early 2008, where higher energy usage figures were recorded.

Results from the seven feedlots studied showed that total annual direct energy use ranged from a low 0.9 MJ/kg HSCW gain to 8.3 MJ/kg HSCW gain over the period March 2007 to February 2008. Expressed on a per head basis total annual energy usage ranged from 444 MJ/head to 1483MJ/head. The total energy usage is primarily dependent on the type of feed processing system in use.

A wide variation was measured in water supply energy usage. On average, water supply represents in the order of 3% of the total energy usage. Expressed on a per head basis it ranged from 0.04 MJ/head to 6.6 MJ/head, with an average in the order of 2.5 MJ/head.

Water supply energy usage between feedlots is dependent on a number of factors, including depth to groundwater and distance to supply. Within feedlots water supply energy usage is directly proportional to the water pumped per month. Additional energy is used with having to deliver water to the pens via a pumping system compared with a gravity supply system. In this case, energy consumed in delivering water to the pens can be similar to that used in supplying water to storage facilities.

Feed management is the largest single consumer of energy in the feedlot as expected. For those feedlots with steam flaking systems it contributed on average approximately 80 % of total usage, whilst those feedlots which process their grain by other means it represents around 45% of total energy usage.

Feed management energy usage has been proportioned into feed processing and feed delivery usage. Feed processing energy usage on a tonne of grain processed basis ranged from 20 to 365 MJ/t grain processed. Three different feed processing systems are represented within the seven feedlots. For feed processing systems other than steam flaking, average energy usage is typically less than 50MJ/t grain processed. For steam flaking, the total energy usage ranges from 280 to 365MJ/t grain processed. Hence, there is a large variation between feed processing systems and between feedlots with the same system.

The average feed processing electricity energy usage measured ranges from 20 to 50 MJ/t grain processed. The variation in electricity energy usage may be attributed to monthly variation in grain delivery, movement and storage and milling efficiency (tonnes per mill).

For steam flaking systems, a review of individual feedlot monthly feed processing data shows that there is an increase in energy usage during the cooler winter months. Hence, more energy is required to heat water and increased heat transfer losses. Setup and operation of feed processing systems will also influence total energy usage.

Feed delivery energy was measured and comprised electricity used by stationary mixers, diesel consumed by loaders during feed loading and by feed trucks delivering ration to pens where appropriate. The average feed delivery energy usage measured ranges from 26 to 52 MJ/t ration delivered. A number of different feed delivery systems are represented within the seven feedlots. This includes stationary mixing, bunker system, batch boxes and a number of varying combinations in mobile equipment. Mobile equipment combinations included tractor/trailed mixer units, ROTO-mix trucks (various capacities and number), loaders (number, no of ingredients and bucket capacities) and screw mixer trucks. Whilst feed delivery energy usage is dependent on the system and equipment utilised, pen layout and feedout method also influences the energy used.

Expressed on a per head on feed basis, the average annual waste management energy usage ranges from 6 to 15 MJ/head on feed/month. As expected, pen cleaning contributed the highest proportion of the total waste management energy usage. On average, pen cleaning energy usage ranged from 5 to 8.5 MJ/head on feed/month, however usage figures up to 27 MJ/head on feed were measured in one month. Manure stockpiling represents on average around 15% of the total energy usage, however can range up to 45%. The variation between feedlots can be attributed to the various manure management systems employed at each feedlot. It is driven by the frequency of cleaning, equipment used and the volume of manure removed.

Cattle washing energy usage ranged between an average 0.02 MJ/kg HSCW gain (0.3 %) and 0.1 MJ/kg HSCW gain (1 %) of total energy usage. The energy consumed in cattle washing is directly related to the volume of water used. The average cattle washing energy usage on a per head washed basis ranged from 1 to 12 MJ/head washed. The predominant energy source is electric, however an electric and diesel powered pumping system are used.

Administration and minor activities (cattle management, repairs and maintenance) contributed an average 0.01 MJ/kg HSCW gain and 0.58 MJ/kg HSCW gain (1 %) of total energy usage. Typically, administration and minor activities represented between 4 and 20% of the total energy usage on a per kg HSCW gain basis. The higher usage is associated with the warmer months, hence air conditioning of the office facilities is driving energy usage in these cases.

Cattle management energy usage includes both processing and hospital activities, and represents electricity used for lighting, cleaning and restraint facilities. The average energy usage for cattle management ranges from 0.10 MJ/head processed to 5 MJ/head processed.

Repairs and maintenance includes electricity usage in workshop facilities as well as diesel usage from mobile plant used in repair and maintenance activities. The average energy usage for cattle management ranges from 0.4 MJ/head on feed/month to 4.5 MJ/head on feed/month.

Actual energy usage levels within individual activities have been recorded in seven feedlots representative of the Australian Feedlot Industry. These included water supply, feed management, waste management, cattle washing and administration and minor activities (cattle management and repairs and maintenance).

The outcomes of this study will allow the feedlot industry to develop a better understanding of the impact and relativity that various feedlot sector operations have on overall energy consumption. This information is invaluable for future design and management considerations. This study offers individual feedlot operators the opportunity to identify options for conserving energy in the feedlot and estimated cost benefits for alternative management practices if they were implemented.

Knowledge of the total energy consumption will allow the industry to benchmark itself against other intensive or extensive livestock industries and or industrial processes.

The outcomes of this study will allow the feedlot industry to start benchmarking total water usage, hence addressing the public misconceptions associated with the water used in the production of one kilogram of grained beef. In addition, this information is invaluable for participating feedlots in understanding the drivers of drinking water consumption and targeting high water use areas for efficiency gains and for future design and management considerations.

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1 Background

The Australian red meat industry, as with most primary industries, is coming under increasing pressure from both the community and government to document and justify its impacts on the environment. Currently, a lack of credible supply chain data prevents the industry from being able to respond in a meaningful manner.

Meat and Livestock Australia (MLA) is undertaking a project (COMP.094) to address these issues and provide credible data on the industry's environmental impacts and sustainability for use by industry, including its interactions with government, community groups and the media. This project will use the standardised tool, Life Cycle Assessment (LCA), to quantify natural resource consumption and environmental interventions to water, soil and air. The goal of the LCA is to identify key environmental impacts of products. Environmental impact categories considered in LCA include but are not limited to resource energy, climate change (global warming), eutrophication, acidification, human toxicity (pesticide use) and land use.

LCA is a form of cradle-to-grave systems analysis developed for use in manufacturing and processing industries to assess the environmental impacts of products, processes and activities by quantifying their environmental effects throughout the entire life cycle. LCA can be used to compare alternative products, processes or services; compare alternative life cycles for a product or service; and identify those parts of the life cycle where the greatest improvements can be made. An international standard has now been developed to specify the general framework, principles and requirements for conducting and reporting LCA studies (Standards Australia, 1998). LCA differs from other environmental tools (e.g. risk assessment, environmental performance evaluation, environmental auditing, and environmental impact assessment) in a number of significant ways. In LCA, the environmental impact of a product or the function a product is designed to perform is assessed, the data obtained are independent of any ideology and it is much more complex than other environmental tools. As a systems analysis, it surpasses the purely local effects of a decision and indicates the overall effects (Peters et al. 2005).

The functional unit for COMP.094 was the output of 1 kg of Hot Standard Carcass Weight (HSCW) meat at the abattoir gate. "Hot" indicates the meat in question has not entered any chilling operations. This output-related functional unit was chosen, rather than an input-related one, in order to describe the human utility of the processes under consideration – the provision of nutrition for people. Although the meat could be served in different ways, this functional unit makes the different processes under consideration "functionally equivalent" from a dietary perspective.

In LCA methodology, usually all inputs and outputs from the system are based on the 'cradle-to-grave' approach. This means that inputs into the system should be flows from the environment without any transformation from humans and outputs should be discarded to the environment without subsequent human transformation (Standards Australia, 1998). Each system considers upstream processes with regard to the extraction of raw materials and the manufacturing of products being used in the system and it considers downstream processes as well as all final emissions to the environment.

Figure 1 shows the generalised system boundary for the red-meat sector as defined for the COMP.094 project. Within this boundary, there is a sub-system for the feedlot sector. The boundary chosen here (shown in red on Figure 1) is the feedlot site itself plus the transport component of bringing cattle and feed into the feedlot and delivering cattle from the feedlot.

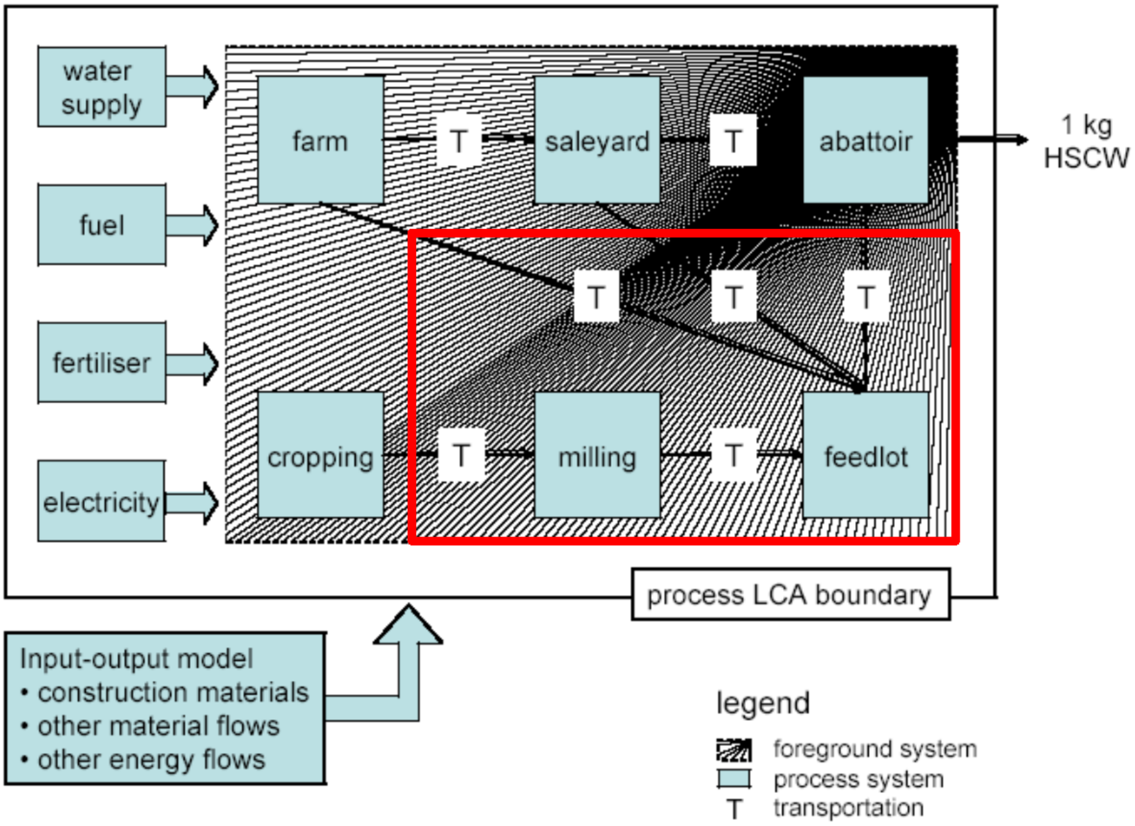


Figure 1 - Generalised system model for the red meat sector with feedlot sub-system

As part of the COMP.094 industry project, the beef cattle lot feeding sector has recently completed a related MLA project (FLOT.328) that will contribute to the whole-of-industry dataset, but more importantly addresses the public misconceptions concerning the environmental sustainability of the feedlot industry. The Terms of Reference for FLOT.328 required the researchers to address, in the context of a LCA, the feedlot-relevant natural resource management (NRM) issues water quality and water use efficiency, salinity, soil erosion, nutrient management and soil acidification, weeds, feral animals, biodiversity, vegetation management, energy efficiency and greenhouse gas emissions and solid waste. These issues were identified as issues of concern to the red meat industry.

The outcomes of FLOT.328 identified and quantified, where possible, the environmental costs (water, energy, GHG, and nutrient cycling) associated with the production of one kilogram of grained beef. It provided factual information on the volume of clean water and energy used at Australian cattle feedlots under a range of climatic, size and management conditions.

This study found that, whilst total annual clean water records by lot feeders are usually good, little data exists on actual usage levels in individual activities, viz. drinking water, feed processing and cattle washing. In addition, little is known about the variation in water use throughout the year. Similarly, total annual energy consumption records were usually limited by the lot feeders inability to separate out the electricity consumption of individual activities. Hence, more information is required on the water usage and energy usage of individual components before these figures can be reliably reported.

MLA's goal in commissioning this project is to address the lack of accurate data and quantify the contribution of individual feedlot activities on the total annual water usage and total indirect and direct energy usage. A breakdown on energy usage within a feedlot and comparison against other sites will allow energy efficiency programs to be instigated.

1.1 B.FLT.0339 project description

The purpose of this study was to quantify the clean water usage and indirect and direct energy usage from individual feedlot activities. An MLA steering committee oversaw the selection of the feedlots such that the feedlots represented a cross section of geographical, climatic and feeding regimes within the Australian feedlot industry.

The sub-system boundary, as defined for the feedlot sector in FLOT.328, has been adopted for this project. The boundary (shown in red on Figure 1) is the feedlot site itself plus the transport component of bringing cattle and feed into the feedlot and delivering cattle from the feedlot.

Water meters and/or power meters were installed at eight feedlots to allow an examination of usage by individual activities. The major clean water-using activities include cattle drinking water, feed management, cattle washing, administration, repairs and maintenance and dilution of effluent. Similarly activities that use a significant amount of energy include water supply, feed management, waste management, administration and repairs and maintenance.

The water and power meter data collected was supplemented with existing data collected on-site including fuel consumption (diesel, LPG) and cattle performance data. Performance data included market types, incoming and outgoing liveweights, dressing percentages, feed data and other parameters that allow HSCW gain to be estimated. Information was collected on a monthly basis.

The data was analysed to obtain water and energy usage associated with a number of feedlot indices including a per head basis, per tonne grain processed and per kilogram of hot standard carcase weight gain (kg HSCW gain). A breakdown of resource use within the major feedlot activities and associated operations was provided.

2 Project objectives

The primary objectives of the project were as follows:

- To capture the clean water and energy usage from individual activities and performance data from eight feedlots representing a cross section of geographical, climatic and feeding regime diversity within the Australian feedlot industry, thus allowing the clean water and energy usage to be evaluated on the basis of one kilogram of dressed hot standard carcass weight gain (kg HSCW gain).
- To communicate the results of the study to MLA in a format suitable for dissemination to industry stakeholders.

The outcomes of this project will allow the feedlot industry to develop a better understanding of the total annual clean water and energy usage and the relativity and contributions that various feedlot sector activities have on annual clean water and energy usage. This will allow the industry to reliably report actual usage levels in individual components, viz. drinking water, feed management, cattle washing etc. Data will be used for individual feedlot planning, for industry wide planning, e.g. FLOT.132 – Vision 2020 project, and to propose water use and energy efficiency options for feedlots.

This report covers the issue of indirect and direct energy usage by feedlots. Indirect energy usage within the feedlot sub-system includes transport of cattle into and exiting the feedlot and commodity delivery. Direct energy usage includes consumption within the major feedlot activities of water supply, feed management, waste management, cattle washing and other minor uses including administration and repairs and maintenance.

This report presents a background literature review of indirect and direct energy usage at feedlots, data collection and results, as well as an analysis and discussion of the data collected.

2.1 Project reporting structure

This project includes the collection and analysis of a large quantity of data from operational feedlots on the water and energy usage associated feedlot operation. All data will be standardised to a number of indices including a per head basis, per tonne grain processed and per kilogram of hot standard carcase weight gain (kg HSCW gain). To ensure all this data and information is presented in a suitable manner, two reports will be compiled.

A. Water usage at Australian feedlots. This report presents a background literature review of water usage within individual activities of feedlots, data collection and results, as well as an analysis and discussion of the data collected. It includes consumption within the major activities of cattle drinking water, feed management and cattle washing and other minor uses such as administration and repairs and maintenance.

B. Energy usage at Australian feedlots. This report presents a review of total direct and indirect energy usage at feedlots, data collection and results, as well as an analysis and discussion of the data collected. It includes consumption within the major feedlot activities of feed management, water supply, waste management, cattle washing and other minor uses including administration and repairs and maintenance. In addition, indirect energy consumption within the areas of incoming and outgoing cattle and commodity delivery are included.

3 Literature review

3.1 Energy supply

Energy is fundamental to a feedlot production system with a reliable energy supply required to operate and maintain feed supply to the cattle. Furthermore, in recent years, there has been a substantial increase in the cost of energy. Despite this, there has been little research into energy usage at feedlots. Rather, the energy requirements of feedlots have been estimated from several studies undertaken in North America in the 1970's and 1980's. In a 2006 study, Davis and Watts (2006) investigated total energy usage of Australian feedlots. They found that, whilst total energy supply data was available, it was difficult to separate usage into activities.

Feedlots use energy directly as fuel or electricity to operate machinery and equipment, to heat or cool buildings, lighting and office equipment and indirectly through incoming and outgoing cattle and commodity delivery.

At the feedyard level, energy use is classified as either direct or indirect.

Direct energy usage is primarily petroleum-based fuels to operate vehicles, trucks, tractors and other mobile machinery for feed delivery, waste management and administration. Natural gas, LPG, butane and electricity are used to power grain processing equipment, water supply and cattle processing equipment. Electricity is used for lighting, heating, and cooling in offices and staff amenities. The predominant energy sources are 3-phase electric power and diesel fuel. Single-phase power and petrol fuels are also used. Facilities with steam flaking feed processing may also use gas (LPG, natural, butane and solid fuel such as coal) as a fuel source for the boiler/s.

Indirect energy usage is off the feedlot site and includes transport of cattle to and from the feedlot and in the delivery of ration commodities.

Sweeten et al. (1986) report on several US studies that determined the amount of energy utilised at cattle feedlots in Texas. In a 1979 Texas Cattle Feeders Association (TCFA) study, Sweeten and McDonald (1979) reported that for feedlots that processed grain by steam flaking, the total annual electricity usage was 60 kWh per head of feedlot capacity. In a 1985, TCFA study, electricity usage for feedlots who processed grain by steam flaking was 77.3 kWh/yr per head on feed.

Davis and Watts (2006) found that total annual electricity usage ranged from 32.6 kWh to 52 kWh per head on feed. This study incorporated feedlots that processed their grain by steam flaking, reconstitution and tempering.

Sweeten et al. (1986) found that total energy usage was 1298 MJ per head of feedlot capacity. Davis and Watts (2006) found that total annual energy usage ranged from 450 MJ to 1300 MJ per head of feedlot capacity depending on type of grain processing method used. They found steam flaking systems accounted for the highest total energy usage when compared with reconstitution and tempering methods.

3.2 Energy usage in individual feedlot activities

3.2.1 Feed management

Feed management involves feed preparation and quality control, nutrient balancing, feed bunk management, mixing and feed delivery. The feed preparation component incorporates grain unloading, movement, storage and processing and processing of roughage. The feed delivery component incorporates feed mixing and delivery to livestock.

Feed preparation

Cattle fed in feedlots require a scientifically-formulated grain-based ration to meet production and economic performance demands and target specifications. Metabolisable energy and crude protein are the major components that need to be met in a formulated ration, followed by minerals and vitamins. The various commodities used in the formulated ration will depend on the nutrient requirements needed to meet the desired level of cattle performance, the nutrient content of the feed, the availability of the feed, and current price of the commodity (Forster, 2006).

Grain-based finishing rations typically contain over 80% cereal grains on a dry matter basis (Watts & Tucker, 1994). Hence, infrastructure associated with grain processing is a predominant component of the feed preparation facility.

It is more economical for smaller feedlots to obtain processed grain off site, either as a single commodity or in the form of a pre-mix, due to the reduced quantity required. For larger feedlots, it is more essential to have a processing system on site due to the large quantities of grain required each day. Both steam flaking and reconstitution systems require the most costly infrastructure, followed by tempering.

The feed preparation facility consists of a composite of simple components and processes. The major components may include storage structures, handling equipment, grain processing and feed mixing operations. Whilst many of the components are interactive, component design, selection, maintenance and operation can influence the overall energy efficiency of the feed preparation facility. Electricity is the predominant energy source. It is utilised in the operation of electric motors in the mechanical grain handling and processing activities. Gas, diesel and solid (coal) fuel are used in boilers for heat/steam generation and mobile equipment respectively. Photograph 1 illustrates a typical grain storage system.

Feed processing methods are designed to improve the starch availability of grains, which in turn improves digestion and feed efficiency (Sweeten, 1990). Various processing methods are used to produce a physical or chemical change in the grain.

‘Wet’ processing systems are more energy dependent than ‘dry’ processing methods due to the additional processing required. However, a number of components such as grain movement and roller milling are still required irrespective of the processing method.

Photograph 1 - Typical grain storage system

Some of the processing methods used in Australian feedlots include:

- Dry-rolling. Dry rolling the grain involves passing the grain between two rotating corrugated rollers that crack or crush the kernels. This disrupts the integrity of the seed coat and reduces the particle size.
- Steam flaking. This involves steaming grain under atmospheric conditions for 15 to 30 minutes at 95 to 110°C, before rolling the grain to produce a thin, digestible flake. The flaking process gelatinises the starch (hydration or rupturing of complex starch molecules), resulting in moisture content of 18 to 22% (Davis & Watts, 2006). Hence, this process requires energy for grain movement, to generate steam for processing and rolling.
- Reconstitution. Reconstitution increases the moisture content of the grain from approximately 12% to 28-30% by storing the grain in an airtight vertical silo for 21 days (minimum of 14 days), before passing the grain through a roller to disrupt the integrity of the outer seed coat. The ensilage process improves the digestibility of the grain by altering the nature of the endosperm. However, results may become variable if the process is not carefully monitored and controlled (Holcomb & Klett, 1994). The energy consumed in this process is predominantly utilised for grain movement and rolling.

Individual feed processing equipment may include boilers for heat/steam generation and/or hammermills and roller mills for grinding or rolling. These processes are described in detail in other works (Holcomb & Klett, 1994; Sweeten, 1990). Photograph 2 illustrates a typical steam flaking boiler and steam chest.

Flaking mills are among the largest consumers of energy in the feed processing facility (Roth, 2007). Roth (2007) also states that they are also among the least efficiently operated in many circumstances.

In studies in North America, feed processing has been identified as the largest single consumer of energy. Sweeten and McDonald (1979) found that steam flaking required in the order of 1010 cubic feet (28.6 kL) of natural gas and 60 kWh of electricity per head of feedlot capacity. This equates to approximately 1065 MJ of natural gas energy and 221 MJ of electricity consumption per head per year. Sweeten et al. (1986) undertook a similar survey of Texas feedyards in 1985 and, for steam flaking, found similar natural gas energy consumption and slightly higher electricity consumption of 274 MJ per head per day.

Lipper et al. (1976) found that feed processing accounted for 56.7% of the total energy use in Kansas feedlots. However, the USDA estimated the energy use for feed processing and distribution accounted for 39.9% of the total energy (Sweeten, 1990). This work also found lower consumption of natural gas and electricity and hence probably does not reflect steam flaking, dry rolling or dry heating of grain. It would appear to be more reflective of self-mixing trucks using whole grain rations (Sweeten, 1990). Steam flaking is the most energy intensive grain processing alternative (Schake et al. 1981).

Photograph 2 - Typical steam flaking system - Boiler (Left) and Steam Chest (Right)

Feed delivery systems

Feed delivery systems are generally planned during the design phase of a new feedlot. The optimal layout and design of the feedlot is often site and size specific, which will ultimately affect which feed delivery system will be used and the energy efficiency of the system.

The distance needed in the delivery of rations to livestock, often twice a day, makes fuel, labour and equipment costs a high priority in the design phase (Drouillard, 2004). The components of the feed delivery system, once installed, are not frequently changed due to the high capital costs involved with infrastructure. However, changes may be considered during major renovation of an existing feedlot, such as increasing the feedlot capacity (Reed, 2001).

Photograph 3 - Pen layout will affect the efficiency of the feed delivery system

The feed delivery system will be determined by the type of feed-out system installed. Self-feeder bins are commonly used in small or opportunity feedlots, whereas open feed bunks are used in the large or commercial feedlots. In this study, all participating feedlots had the open feed bunk system.

Open feed bunks (Photograph 4) cater for all types of rations, partially rations processed on-site that are fed out once or twice a day. Open feed bunks are located along the fence line on the outside of the pen. The components of various types of feed delivery systems are discussed below.

Photograph 4 - Open feed bunk commonly used in large feedlots

Feed mixability and delivery

Ration consistency is the most crucial factor that directly or indirectly relates to the proper nutrition and high performance of cattle. Variation in feed can significantly affect the final nutrient composition ingested by the animal (Turney, 2005). By optimising the mixability of the feed, the cattle are given the best opportunity to obtain exactly what the nutritionist has formulated. The various ration ingredients need to be mixed thoroughly. Aspects that may affect mixability include mixing action, mixing time, sequence of ingredient addition, accuracy of addition and the type of feed delivery. The high range in particle size, ranging from coarse grains and roughage, to liquids and fine chemical particles, increases the challenge of a uniform ration (Turney, 2005).

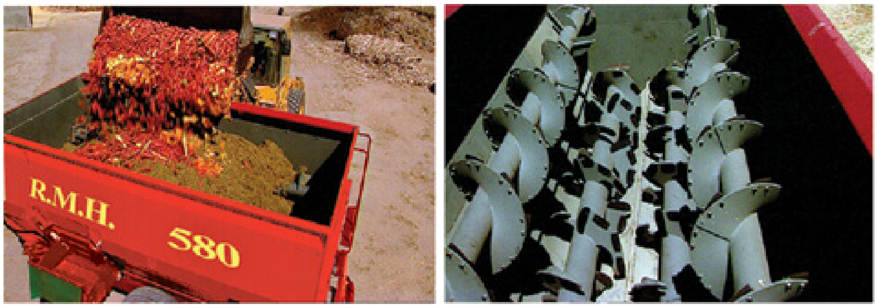
The type of mixer will vary according to the size of the feedlot, the ration, and method of feed delivery. Mixers can be categorised as either stationary or mobile with either horizontal or vertical mixing actions. As the name suggests, stationary mixers are permanently stationed with the ingredients weighed and mixed in the mixer feeder and the fed out using alternative equipment. The vertical feed mixer (Photograph 5) is often less efficient than the horizontal feed mixer (Photograph 6) due to its reduced size, restricting the level of liquid addition and requiring a longer mixing time (Reed, 2001). The disadvantage of all stationary feed mixers is the need for alternative equipment to deliver the feed. Hence, there are relatively few stationary mixers within the Australian feedlot industry.

Photograph 5 - RMH stationary vertical mixer suited for smaller feedlots (RMH, 2003).

Photograph 6 - RMH stationary horizontal mixer suited for smaller feedlots (RMH, 2003).

An alternative to the stationary feed mixer is the mobile feed mixer. Mobile feed mixers can either be trailed (behind a tractor) or permanently mounted on a truck. Mobile mixers allow the feed to be mixed on-the-go whilst the feed is being delivered, therefore, avoiding the need for double handling. Photograph 7 shows a typical trailed vertical feed mixer. Photograph 8 shows a horizontal feed mixer trailer. These are commonly used in small to medium sized feedlots.

Photograph 7 - RMH vertical feed mixer trailer (RMH, 2003).



Photograph 8 - RMH horizontal feed mixer suited to small and medium feedlots (RMH, 2003).

Medium to larger feedlots are more suited to using a truck mounted with a mixer feeder. This increases feed mixing and delivery efficiency due to the speed at which the feed can be delivered and, most importantly, the time it takes for the ration to be mixed. The mounted mixer feeder caters for all types of commodities within the ration from grains to liquids. Typically, the mixer feeder is mounted on load-cells to record the loading of each commodity. Depending on the size of the feedlot, more than one truck can be utilised. This allows a truck to be delivering the feed while the other truck is being loaded. There are two common types of truck mounted mixer feeders including the screw mixer and paddle type 'Roto-mix'.

The screw mixer has two top augers rotating in opposite directions and two non-continuous bottom augers for effective mixing of a large volume of ration (RMH, 2003). Photograph 9 shows an

International truck mounted with a 480 RMH David Evans Group screw mixer feeder. Typically, liquids are placed in the mixer following a grain commodity to prevent balling.

Photograph 9 - Truck mounted with a RMH David Evans Group screw feed mixer.

The paddle type ‘Roto-mix’ mixer feeder is quickly becoming the predominant configuration in use in larger feedlots due to claims of increased mixing efficiency, consistency of the ration and reduction in fines. There has been limited work undertaken to assess the energy efficiency of the screw and paddle type systems. The ‘Roto-mix’ mixer feeder consists of a horizontal rotor that lifts the feed upwards to the upper and lower side augers, which then move the feed from end-to-end for a thorough mix (Photograph 10). The tumbling action mixes the lighter roughage and high moisture ingredients without grinding or high pressure feed movement, resulting in a fluffier, more palatable ration (ROTO-MIX, 2006). The rotor and augers may be stopped or running while the truck is mobile. However, they must be going during feed delivery as it aids in the flow of the feed to the bunk.

Photograph 10 - Diagrammatic representation of the Paddle Type ROTO-mix (ROTO-MIX, 2006).

Photograph 11 displays a truck mounted 920 -18 'Roto-mix' mixer feeder.

Photograph 11 - Truck mounted 920 -18 'Roto-mix' mixer feeder

Bunker System

The most commonly used method of feed mixing and loading in Australia is the bunker system. This system consists of a storage shed where each feed commodity is stored in separate bunkers. Commodities are handled via a front-end loader, which transfers the commodities from the bunker into a truck-mounted mixer feeder (feed truck) (Photograph 12). Each commodity has a pre-determined weight, monitored by load cells mounted on the trucks. Liquid supplements are typically loaded via an overhead piping system, controlled by the operator using a remote control. The load is then mixed and delivered to the appropriate pens. This system is suited to large commercial feedlots of 20,000 head or less and has the advantage of having low investment and maintenance costs. The disadvantage of this system is a reduced control of weighing each commodity (operator factor), inconsistent mixing times due to the variation in speed of loading each commodity, and it creates difficulties for future expansion of feedlot capacity (Holcomb and Klett, 1994). The biggest inefficiency with this system is the time spent running a loader between feed commodities; the time spent waiting for a feed truck, or more commonly, the feed truck/s waiting on the loader.

There have been few previous studies undertaken on the energy consumption of feed delivery systems. Madden (2006) looked at the advantages and disadvantages of two types of feeding systems in terms of efficiency at a Queensland feedlot. These included the bunker management feed delivery system and a dual configuration batch-box feed delivery system. Madden (2006) compared data from before and after the installation of the batch-box system, looking at the litres used per tonne, tonnes delivered per truck and loader hour, and tonnes delivered per labour hour. Williams (2007) investigated the efficiency of the bunker management feed delivery system at a Queensland feedlot whilst Reeves (2007) undertook a similar assessment of a NSW feedlot.

Photograph 12 - Screw mixer feeder loaded with commodities by a front-end loader

Madden (2006) found that the diesel consumed by two trucks in feed delivery for the bunker management feed delivery system is in the order of 1 L per tonne of ration delivered. This equates to an energy usage of 38.6 MJ per tonne of ration. Hence, a feedlot feeding 10,000 head with 13.5 kg/head/day will consume approximately 5211 MJ during feed delivery.

Williams (2007) found that approximately 24% of the feed delivery truck activity time is spent loading each feed truck, 35% travelling, 21% unloading, 8% waiting for the next load and 12% stationary mixing. Williams (2007) recorded a diesel consumption of 2.7 L per tonne of ration delivered for the three trucks used in feed delivery and 0.2 L per tonne loaded for the loader. Hence, feed delivery fuel usage will depend on the make, model and age of truck, capacity of truck, efficiency of loading and the feedlot layout. Reeves (2007) found that approximately 26% of the feed delivery truck activity time is spent loading dry ingredients, 40% travelling, 17% unloading, 3% waiting for the next load and 14% loading liquids. Reeves (2007) recorded a diesel consumption of 1 L per tonne of ration delivered for the two trucks used in feed delivery and 0.4 L per tonne loaded for the loader.

Batch-Box System

A relatively new method of feed delivery in Australia is the batch-box system, with only three currently installed in the country. This system is similar to the bunker system but it incorporates an additional component, a stationary side-dump batch-box. The side-dump batch-box is hydraulically raised and lowered, powered by an electric motor and controlled via remote control (Photograph 13). The commodities for a batch of feed are loaded from the bunkers into the batch-box via a front-end loader while the feed truck/s are delivering their current load. Once the feed truck/s return, the accumulated feed is dumped into the feed truck in 30 seconds (minimum), reducing the time spent waiting for each individual commodity to be loaded into the feed truck, or the loader waiting for a feed truck to load. A dual configuration batch-box system is commonly used so that while one is tipping, the loader driver can be filling the other batch-box (Batch Box, 2006). The boxes are mounted on a static load cell platform, which potentially improves the loading accuracy due to the stationary nature of the platform, compared with a mobile feed truck (Madden, 2006). Madden (2006) claims the major advantage of the batch-box system is a reduction in loading variability, a faster turnover of trucks, and efficient use of equipment, furthering opportunity to increase feedlot capacity. At 2006 values, the capital outlay for a dual configuration batch-box system is significantly less than for a new Roto-Mix truck and the projected life span is significantly longer (D. Bailey pers. Comm.). In addition, the maintenance requirements of the batch-box system are significantly less than the costs of maintaining mobile equipment such as a truck.

Photograph 13 - The Batch box System incorporates a side dump box

Madden (2006) found that the diesel consumed by two trucks in feed delivery with a batch-box feed delivery system is in the order of 0.9 L per tonne of ration delivered, a reduction of 10% when compared with the bunker management system.

Liquid Commodity Loading

The loading site of the liquid commodities will vary according to the existing infrastructure and feedlot layout. The liquid commodities are typically loaded via an overhead piping system. This system can be located separately or at the same site as the dry commodities as shown in Photograph 14 (left) or batched in a liquid batcher, which is batched and loaded at a separate loading site to the dry commodities (Photograph 14).

Therefore, the energy usage during feed delivery will depend on a number of factors. These include the management system (bunker, batch-box), equipment utilised (type of truck, number of trucks, capacity of trucks, loader capacity), feed out process (number per day) and feedlot layout.

Photograph 14 - The liquid commodities may be individually Loaded (left) or Batched (right)

3.2.2 Water supply

The energy usage for supplying water to the feedlot and for reticulation is a direct function of the system design (gravity, pumped), pumping requirements (source of water, pumping head, distance), efficiency of the pumping system and power source (diesel, electric). Water for feedlots can be obtained from a variety of sources including shallow and artesian bores, rivers, creeks, irrigation channels, water harvesting of overland flow into on-farm dams and reticulated pipelines.

There are two types of system designs, gravity feed and reticulated systems. Typically, water from the supply source is stored in a buffer storage for contingency supply reasons. These buffer storages are either above-ground concrete tanks or earthen turkey's nest dams. In most cases, they are located such that they can give gravity-feed water to the feedlot pens (Watts et al. 1994). The pumping requirements are dependent on the volume of water pumped, source of water, distance from feedlot and whether further reticulation pumping is required to deliver water from the buffer storage to the pens.

The pumping efficiency will be dependent on the type of pump chosen for the system and pump wear. If the pumping system is poorly maintained, the energy usage and pumping costs can be increased.

Photograph 15 - Water supply pump (Left) and Reticulation pump station (Right)

3.2.3 Cattle washing

The energy usage for cattle washing is a direct function of the volume of water used. This will depend on the system design (clean water, recycled), pumping requirements (volume, pressure), efficiency of the pumping system, power source (diesel, electric) and importantly the cleanliness requirements of the cattle and this varies between feedlots.

Typically, cattle wash facilities utilise a two-stage washing process. Firstly, cattle are soaked for a period with high-volume low-pressure clean or recycled water. Cattle are then automatically or manually cleaned with high-pressure clean water.

The pumping efficiency will be dependent on the type of pump chosen for the system and pump wear. Pumping recycled effluent leads to high pump wear rates and relatively short pump life. If the pumping system is poorly maintained, the energy usage and pumping costs can be increased.

Research on cattle washing has concentrated on the effectiveness of various techniques and cleanliness achieved. No published data on the energy consumed during cattle washing is available.

Photograph 16 - Typical cattle washing process – Soaking (Left) and Pressure cleaning (Right)

3.2.4 Waste management

Maintenance of pen conditions that promote drainage, reduce moisture absorption, minimise odour and reduce pen maintenance expense is one of the most important factors in optimising the performance of cattle in feedlots and minimising environmental issues. In addition, health issues and dags can be reduced with regularly cleaned pens. This can be achieved by careful attention to manure collection or pen cleaning (Lott et al. 1994). To maximise cost efficiency, it is important to know about the problems that can be caused by manure build-up, the physical nature of manure, good pen and lane design, manure harvesting, manure storage, manure disposal and solid waste disposal.

The lack of pen cleaning or manure removal can cause a number of problems from poor cattle performance to pollution problems. Pens which have deep manure can have a detrimental effect on daily weight gains and feed conversion efficiency. Bond et al. (1970) found that deep mud could reduce daily gains by 25 to 37% and feed conversion efficiency by 20 to 33% (Lott et al. 1994). While deep manure can cause problems, so can wet conditions.

Wet conditions can affect animal welfare, as there may be an increase in health problems and cattle comfort levels decline. Matsushima (1990) found that wet muddy conditions increase the incidence of foot problems such as footrot. These wet conditions can also pose an occupational health and safety issue for pen riders. Deep wet manure can also increase odour. Watts et al. (1993) found that wet manure generates 50-100 times more odour than dry manure. Obviously deep manure takes longer to dry therefore the odour tends to be more prolonged when compared to a thin layer of manure in a pen (Lott et al. 1994).

Dry manure also causes problems with the resulting dust causing respiratory problems in the cattle and cannot be compacted into mounds. Therefore, to control the dust it is important to retain some level of moisture in the pens (Lott et al. 1994). While manure build up can cause problems, its physical nature will also have an impact on collection efficiency.

Manure forms a distinct profile in the pens. Typically, a hard crust develops on the surface. Under this, there is a moist plastic layer with a lower bulk density than the layer above and below. The bottom layer is a mixture of pen foundation material (i.e. soil, gravel etc) and manure, which is known as the interface layer and should be very dense and impermeable. This interface layer should prevent leaching from the manure profile into the soil. A break in this layer may allow infiltration to occur causing pollution of the ground water (Lott et al. 1994). In addition, this soft floor will reduce foot soreness in the cattle. It is recommended that 25-50 mm of manure is left on the pen floor. Therefore, care needs to be taken to ensure this interface layer is not damaged when pen cleaning is being completed (Lott et al. 1994).

In recent years, some lot feeders have chosen to remove all manure, including the interface layer, from pens. There can be several reasons for this management choice. Complete manure removal minimises odour issues. In feedlots located in a winter-dominant rainfall zone, complete manure removal prior to winter allows for better pen conditions during winter. If this practice is followed, the underlying pen surface needs to be thoroughly compacted and levelled.

The moisture content of the manure also plays an important role when cleaning pens. The correct moisture content is important because if the manure is too wet, it becomes too difficult to handle and cleaning is very slow. The same can be said when the pens are dry and the surface becomes extremely hard and difficult to remove, which may require a shallow ripping process to break up the hard layer adding further cost to the manure collection process.

Therefore, the ideal time to clean the pens is when the manure is moist but not wet, which can easily be cut or scraped from the bottom of the pens but this will depend on a combination of environmental and operational factors (Lott et al. 1994). The frequency of pen cleaning will depend on manure accumulation and once again the operational and environmental management of the feedlot. Manure accumulation rates will depend on the animal size and stocking density (Watts 1991).

The design of the feedlot and, in particular, the pens will influence the ease and method of manure removal. Factors that will affect this include the foundation material and pen surface, pen size and shape, stocking density, fence construction, location and design of feed and water troughs, location and design of shade structures, access into the pens, manure distribution system and manure removal machinery (Lott et al. 1994).

The pen size and shape will determine the type of machinery can be used to clean the pens. For ease of manure removal, the minimum pen size should be 25 metres across and at least 30 metres deep. Pens this size will still limit certain machinery from being used. Both the width of the fence panels and height of bottom cable are important in pen cleaning because the manure accumulates under fence lines and therefore machinery needs access to be able to clean the manure. Therefore, panel width needs to be at least 3 metres and 400 mm is required between the bottom rail or wire and the pen surface (Lott et al. 1994).

High traffic areas around the feed and water troughs are subject to greater wear and tear than other parts of the pen. It is recommended that there is a concrete apron around the water trough and along the feed bunk being at least 3 metres wide. Narrow aprons can cause problems for machinery when cleaning the pens.

The last issue in the design features of pens is the access. Manure collection and transport machinery must be able to freely enter, manoeuvre within and depart from each pen. The configuration of fence lines and gates at the bottom of the pens affects stock and machinery access into pens (Lott et al. 1994). Pen design features are obviously done at the building stage and little can be done once completed, not like the manure distribution system which is where the real cost savings can be made.

Butchbaker et al. (1971) reported that solid manure handling costs for a 20,000 head South-western USA feedlot were approximately 12% of the total feedlot operating expense. Similarly, Park (1972) found that manure collection and handling costs accounted for 11.7%of the total operating costs of a 22,000 head feedlot in Oklahoma. The management of manure involves four key processes including harvesting and removal from pens, storage and spreading. These processes can be completed in a number of different ways and different combinations. Each distribution system has benefits and disadvantages.

All manure distribution systems start with the pen cleaning operation. The collected manure can either be directly spread or stored in a stockpile prior to spreading. The storage can either be a temporary stockpile such as an in pen mound, removal to a common stockpile at the feedlot or removal to a stockpile at the site where it is to be spread (Lott et al. 1994).

Butchbaker et al. (1971) found that investment and operation cost of solid manure handling systems varied with feedlot size, manure handling distance and equipment usage. The costs involved in collecting the manure reduced as equipment usage increased 25 to 100 days per year (Sweeten & Reddell 1979).

A range of equipment is used within feedlots such as elevating scraper, grader, box scraper, wheel loader, dozer and bobcat for the pen cleaning activity. Trucks of all shapes and sizes are used to cart the manure from the pens.

Not all types of the equipment are suitable for every feedlot. The main criteria for equipment selection are the size of the pens, pen access and laneway access. Climate can also determine the type of machinery that can be used. For example, the mild summers and cold wet winters in southern Australia means that the machinery needs to be able to operate in wet boggy conditions.

Elevating scrapers can only be used in a feedlot with large pens being a minimum of 50 x 50 metres. The scraper should be fitted with a cutting edge rather than rippers and they are unable to clean in certain areas of the pen such as corners, under and along fences as well as water and feed troughs. A wheel loader or bobcat would be needed in conjunction with the elevating scraper to clean the areas that are inaccessible to the elevating scraper.

Graders are an option but are rarely used in Australia. Once again, a larger pen size is required, but provide good control over the depth of cut and provide a smooth finish.

The most commonly used equipment in Australia for medium to large feedlots is a combination of box scraper and tractor, and bobcat or front-end loader for manure removal. The box scraper and tractor scrape the manure from the pen and mound it into the middle of the pen. The box scraper and tractor combination is compact, manoeuvrable, has good depth control and gives a smooth finish to the pen surface. This system can be done by a single operation and is normally faster rate of cleaning. The bobcat is typically used to clean under fences and aprons. A front-end loader is used to remove manure from the pens. In some facilities, a loader is used to clean the aprons and under fences (Lott et al. 1994).

Front-end loaders or wheel loaders are required for some components of the manure collection and removal operation in all but the very small feedlots. Front-end loaders are able to collect and remove manure in the same operation and at a faster rate than a box-scraper tractor combination. However, using the loader can result in damage to the interface layer because of the lack of control over the bucket height (Lott et al. 1994).

While bulldozers can be used, they are not recommended because the damage the tracks cause to the surface of the pens. A bulldozer can cut and push the manure into mounds. However, the lack of depth control and skid-steering will impact the interface layer (Lott et al. 1994).

Pen size and shape, pad moisture and depth as well as machinery type and operation have a large influence on operating efficiency. Collection rates of manure are influenced by environmental conditions and management factors. The level of moisture and the current state of biological decomposition will affect the amount of manure removed.

In-pen mounds are commonly used for the temporary storage of manure because the mounds give a number of benefits or flexibility in the harvesting operation. These include the *in-situ* decomposition of manure in the mound and thus a reduction in the mass to be removed from the pen. The removal of the manure can take place at more convenient times and the manure collection can occur when required rather than when transport and removal machinery are available (Lott et al. 1994). In-pen mounding is used in a number of feedlots to reduce harvesting rates by up to 38 percent (Lott et al. 1994). While this practise enables timely pen scraping and improved removal efficiency, it has little impact on the cost of gathering the manure (Lott et al. 1994).

There is very little published work on the efficiency of various feedlot manure collection systems. Sweeten and Reddell (1979) undertook time and motion studies to evaluate machine productivity, energy consumption and cost of feedlot manure collection at four Texas cattle feedlots.

Photograph 17 – PTO-driven compost windrow turner

Photograph 18 – Screening machinery at manure stockpile

Photograph 19 – Manure spreading machinery

Sweeten and Reddell (1979) suggests that the efficient collection of feedlot manure can mean savings for cattle feedlot operators and profit for manure contractors who sell manure for fertiliser, therefore manure handling to be profitable, time, energy and equipment costs must be controlled.

The specific objective of the study by Sweeten and Reddell (1979) was to compare alternate manure collection systems based on machine productivity, energy consumption and cost. They also evaluated the productivity, cost and operator performance for loading manure trucks and determined the time required to haul and spread manure. The study looked at the use of an elevating scraper, wheel loader, wheel loader with the surface prepared with a roto-tiller and a wheel loader with the surface prepared with a chisel-plough.

Sweeten and Reddell (1979) found that the wheel loader / chisel-plough combination had the highest collection rate of 160 tonnes per hour at 100 percent operator efficiency. This was followed by the elevating scraper, wheel loader, and the wheel loader / roto-tiller combination. The most energy efficient collection system was the elevating scraper.

Table 1 - Time-motion study of feedlot manure collection systems

Feedlots	Primary collection machine	Feedlot surface preparation	Finishing steps required	No. pens studied	Manure collection rate at 100 percent efficiency, t/h	Energy requirements at 100 percent efficiency, kWh/t	Collection cost, $/t
A	Elevating scraper	None	Wheel loader to clean pen corners	4	114	0.88	0.21
B	Wheel loader	Rototilled	None	1	106	0.99	0.19
C	Wheel loader	None	None	1	107	1.28	0.23
C & D	Wheel loader	Chisel-plowed 3 times	None	4	160	0.96	0.20

(Source: Sweeten & Reddell 1979).

Reeves (2007) evaluated the efficiency of the manure collection system at a NSW and QLD feedlot in a time and motion study. Reeves (2007) calculated energy requirements per tonne of manure collected. A number of equipment combinations were used within each manure collection system. Reeves (2007) found that diesel fuel usage ranged from 0.35 to 0.60 L per tonne of manure. Therefore, the energy usage during manure collection will depend on a number of factors. These include the management system (mounding in pens, direct to stockpile), equipment utilised (excavator, scraper, loader, trucks, equipment number and equipment capacity) and cleaning frequency.

In addition to removal of manure from pens, there is additional energy usage in manure handling. This can include windrow composting of manure (Photograph 17), screening of stockpiled manure (Photograph 18) and then spreading of manure in the fields (Photograph 19).

3.2.5 Administration

Energy plays a vital role in the administration and operation of feedlots. Administration energy usage has been defined as that used in office facilities, staff amenities and for operation of staff vehicles around the facility. Office facilities use energy for many purposes including heating and cooling, lighting, hot water, office equipment (computers, faxes, photocopiers, etc.) and weighbridge.

Staff amenities use energy in lighting, refrigeration, cooking, hot water, heating and cooling and sundry uses. Transport of staff around the feedlot is an important component of administration energy usage.

Lipper et al. (1976) reported that administration consumed approximately 5.6% of the total energy requirement of Kansas feedlots. Increased heating costs in winter may be a plausible explanation for the high percentage use.

3.2.6 Repairs and maintenance

Energy is also consumed in repairs and maintenance activities around the feedyard. The majority of feedlots have a workshop facility, which does minor repairs to vehicles, mechanical equipment and infrastructure. The size and capability of the workshop is dependent on the location of the feedlot from a major retail centre. Repairs and maintenance has been defined as that used in workshop facilities and mobile plant used for road maintenance etc.

Photograph 20 - Water truck for road maintenance and dust suppression

3.3 Indirect energy usage

The energy or fuel consumed for transport of incoming and outgoing cattle can be significant and depends upon the types of vehicles used, fuel type/s, fuel efficiency, distance travelled and loading capacity. Most feedlots are located within a couple of hundred kilometres of abattoirs. However, incoming cattle can be sourced from sites thousands of kilometres away, especially for vertically integrated corporate feedlots.

Fuel efficiency in transport vehicles is measured by fuel usage over a set distance, traditionally litres of fuel per 100 kilometres travelled. Vehicle fuel consumption is a function of the efficiency of vehicle weight, vehicle motor technology, fuel technology and other factors. An ongoing interest in reducing transportation energy use has resulted in a continuing focus on fuel efficiency. Vehicle weight reductions and advances in technology have led to improvements in truck fuel efficiency.

3.3.1 Livestock transport

Heavy vehicles over 10 tonnes gross vehicle mass (GVM) are predominantly used to transport livestock. These vehicles use turbocharged, four stroke compression ignition engines commonly referred to as 'diesel engines'. Photograph 21 illustrates a typical semi trailer livestock transport with two decks.

Photograph 21 - Typical semi trailer (2 decks) livestock transport

3.3.2 Commodity delivery to the feedlot

The energy, or fuel, consumed for transport delivery of feed commodities depends upon the vehicle type, fuel used, fuel efficiency, loading efficiency and distance travelled. Diesel powered vehicles are mainly used for the transport of commodities.

Vehicle loading efficiency can vary greatly between commodity types, with straws and roughages being volume limited and grains and molasses being mass limited. Photograph 22 illustrates a semi trailer unloading grain.

Photograph 22 - Semi trailer unloading grain

3.3.3 Manure removal from the site

Removal of manure off-farm is also an indirect energy consumer. This process may be undertaken by the feedlot operator or by independent contractors. The energy efficiency of manure transport depends upon the truck type and fuel efficiency, the distance travelled and the volume and dry matter content of the manure. Stockpiling of manure pre-transport, either in the pen or in a designated stockpile area, reduces its moisture content and thus the volume of manure for transportation. However, no data was collected in this project on this component.

4 Materials and Methods

4.1 Overview – experimental work

The objective of the project was to collect good-quality data on energy usage and relate this to production parameters in feedlots so that the information could be used across Australia. To that end, it was necessary to ensure that the feedlots involved were representative and that reliable data could be obtained. The steps in the project were:

1. Select a range of feedlots across Australia that were representative of climatic zones, feeding regimes, management styles and cattle markets.
2. Review the design and management of these feedlots to select those where reliable data could be collected at a reasonable cost.
3. Select the preferred feedlots and complete negotiations at each site.
4. Design an instrumentation system for each feedlot.
5. Design a data collection system for each feedlot.
6. Undertake regular (monthly or fortnightly) data collection.
7. Undertake short-term detailed data collection for specific aspects of water usage.
8. Analyse and review the data.

4.2 Selected feedlots

Following a lengthy process, eight feedlots were selected to provide a representative sample. Table 2 summarises the key characteristics of the selected feedlots. To maintain confidentiality, none of the feedlots are identified by name and will be referred to as Feedlots A to H.

The selected feedlots provide a range of climatic conditions from a northern feedlot in a hot, humid summer-dominant rainfall to southern feedlots in cooler, winter-dominant rainfall zones.

Figure 2 and Figure 3 shows the mean monthly temperatures and monthly rainfall probabilities for Feedlot A respectively. Feedlot A is considered to have a strongly summer-dominant rainfall with a reasonable probability of high rainfall in some months. It has warm to hot summers and mild winters. In summer, the maximum monthly temperatures range from 33 to 35°C. During winter, average maximum monthly temperatures range from 22 to 26°C with monthly minimum temperature around 8 to 9°C.

Figure 4 and Figure 5 shows the mean monthly temperatures and monthly rainfall probabilities for Feedlot H respectively. Feedlot H is considered to have a winter-dominant rainfall and much lower than Feedlot A. It has mild to warm summers and cool to cold winters. In summer, the maximum monthly temperatures range from 27 to 30°C. During winter, average maximum monthly temperatures range from 13 to 15°C with monthly minimum temperature around 4 to 6°C.

Grain processing methods vary from simple tempering to reconstitution and steam flaking. Some feedlots wash cattle (mainly in winter) while other feedlots do not undertake any cattle washing.

Feedlot D was not included in the water studies and Feedlot C was not included in the energy studies.

Table 2 – Characteristics of selected feedlots

Feedlot Name		A	B	C	D	E	F	G	H
Climate									
Mean Annual Rainfall	mm	577	582	403	641	679	831	640	716
Rainfall Pattern		Summer dominant	Winter dominant	Winter dominant	Summer dominant	Summer dominant	Uniform	Summer dominant	Summer dominant
Mean Annual Class A Pan Evaporation	mm	2372	1825	1788	1934	1934	1423	1934	1715
Mean Max Temp – January	°C	34.1	31.2	29.6	31.6	31.6	25.9	31.6	29.7
Mean Min Temp – June	°C	8.9	2.7	4.3	5.7	5.7	2.0	5.7	4.6
Feedlot Capacity and Design									
Licensed Capacity	head	>15000	>15000	>15000	>15000	>15000	>15000	>5000	>1000
Cattle Washing	% of turnoff	0	30	40	0	10*	40	0	65
Feed Processing									
Grain Processing Method		Steam Flaked	Steam Flaked	Steam Flaked	Reconstitution	Reconstitution	Steam Flaked	Steam Flaked	Tempering
Main Energy Source		LPG	Natural Gas	LPG	Electricity	Electricity	Butane	LPG	Electricity

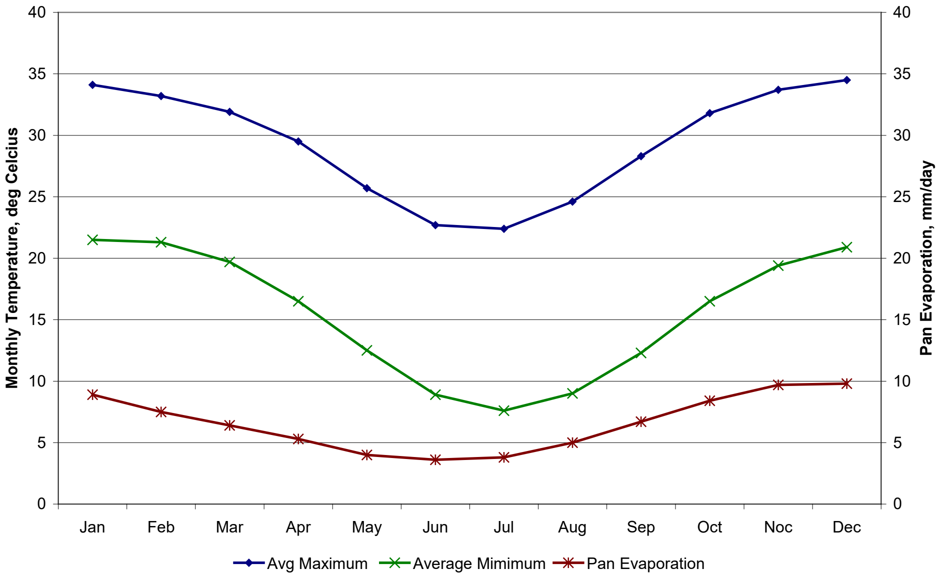
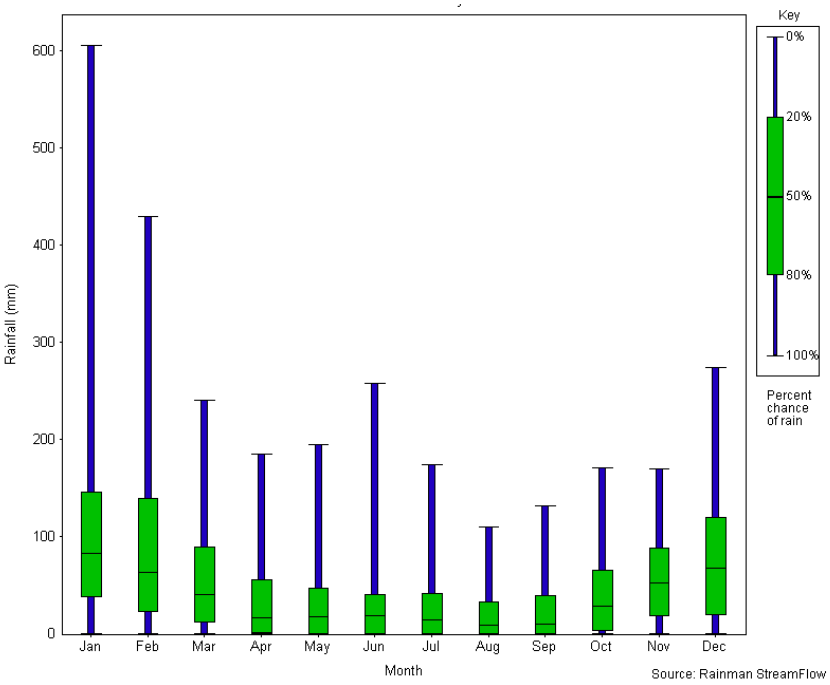


Figure 2 - Average monthly temperatures and pan evaporation for Feedlot A



Source: Rainman StreamFlow

Figure 3 - Monthly rainfall probabilities for Feedlot A

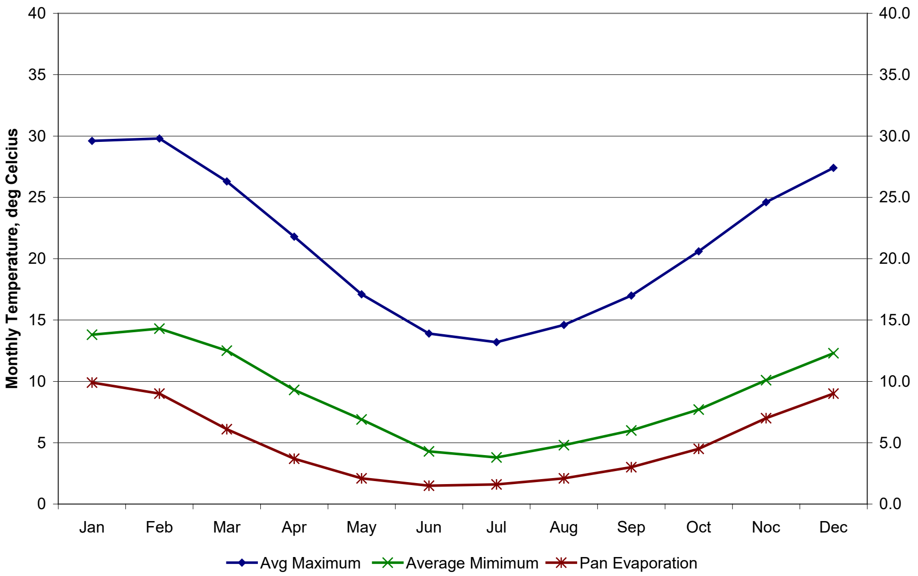
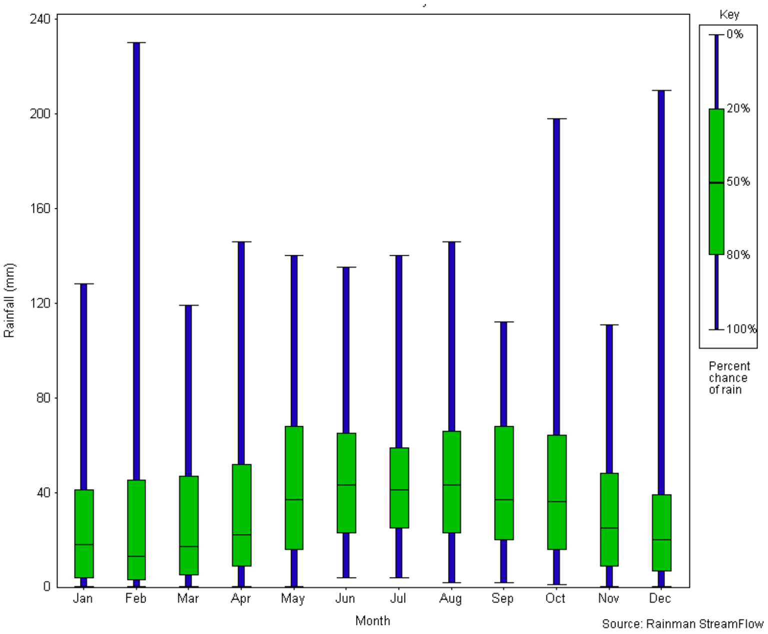


Figure 4 - Average monthly temperatures and pan evaporation for Feedlot H



Source: Rainman StreamFlow

Figure 5 - Monthly rainfall probabilities for Feedlot H

4.3 Energy supply network

As part of the selection process, the energy supply network at each feedlot was inspected and a flow chart prepared. Figure 6, Figure 7, Figure 8, Figure 9, Figure 10, Figure 11 and Figure 12 show the energy supply networks for Feedlots A, B, D, E, F, G and H respectively. Feedlot C did not participate in the energy usage studies.

The project needed to be able to measure total energy usage at each feedlot (Focus Area 1 on each energy supply network), the direct energy usage in the main feedlot activities and indirect energy usage. The main areas of interest were:

1. Focus Area 2 - Water Supply
2. Focus Area 3 - Feed management - Processing & Delivery
3. Focus Area 4 - Waste management - Pen cleaning, manure stockpiling, effluent irrigation
4. Focus Area 5 - Cattle Washing
5. Focus Area 6 - Administration

Energy sources include electricity, diesel, petrol and gas (e.g. LPG, butane etc). Usage of diesel, petrol and gas are typically available from existing fuel bowser and gas meters. In most cases, electricity is provided by overhead supply to a main switchboard then distributed internally throughout the feedlot. Therefore, total feedlot electricity usage can be easily recorded from onsite power authority metering. However, electricity usage by individual activities or components within activities cannot be easily determined without installation of power metering on the individual supply.

During the feedlot inspection, existing metering was located. This included reviewing electricity, fuel and gas metering. In all cases fuel and gas metering was adequate. The required positioning of any additional power meters for electricity usage was determined.

A gap analysis was undertaken to determine the quantity and type of power measurement instrumentation required to allow direct or indirect measurement of the major activities. This was undertaken in collaboration with the Condamine Electric Company (CEC), a company that specialises in industrial power installations.

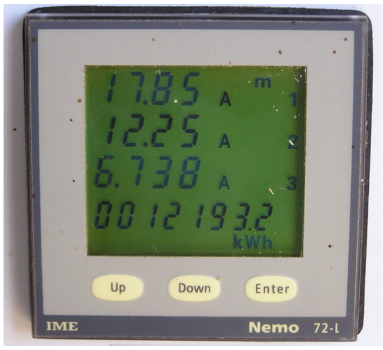
4.4 Energy supply network instrumentation

A local company, Condamine Electric Company (CEC), in consultation with FSA Consulting, selected a number of power meters to suit the type of installation. The selection parameters included the size (amperage) of the sub-main, cable size, current transformer (CT) size, type and quantity, mounting requirements (surface, panel, enclosure) and ease of installation. Power meters and associated switchgear were selected that best suited the individual installation and that were widely in use.

CEC undertook a site visit to each feedlot and installed the power meters. This ensured a coordinated, standardised and timely installation of the instrumentation. Two types of power meters were selected. These included the IME NEMO 72-L and the IME CONTO 43. The following sections provide a brief overview of the specifications and capabilities of each type of power meter and associated switchgear.

4.4.1 IME NEMO 72-L power meter

The IME NEMO 72-L (Photograph 23) is a programmable network monitor that can monitor single-phase (50-290v) or three-phase (80-500v) networks. The unit is provided in a self-extinguishable polycarbonate enclosure 72 mm (wide) x 72 mm (breadth) x 75 mm (depth) and is flush mounted on the switchboard panel. All of the main quantities of a three-phase network are measured including voltage (phase and linked), current (phase and neutral), power (phase and three-phase active), power factor, frequency and working hours and minutes. These measurement quantities are displayed on different key activated pages on the backlit LCD. The unit has a reading accuracy for voltage (v), current (a), power (kWh) of ± 0.5%, power factor ± 2% and frequency of ± 0.2 Hz. The unit is connected to the respective supply with dedicated CT. The unit also has a programmable pulse output and RS485 communication for control and logging capabilities.



Photograph 23 - IME NEMO 72-L power meter

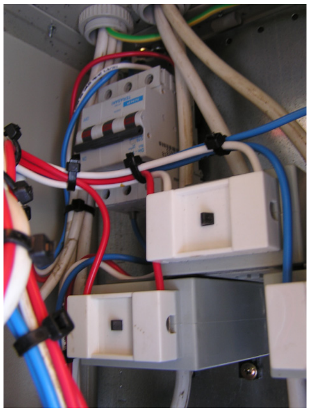
4.4.2 IME CONTO D4-S power meter

The IME CONTO D4-S (Photograph 24) is a programmable three-phase (190-440v) network monitor. The unit is provided in a sealable self-extinguishing polycarbonate housing and terminal block 72 mm (wide) x 89 mm (breadth) x 60 mm (depth) and is typically mounted on a 35 mm DIN rail inside the switchboard panel. Partial and total power, power demand and power maximum demand of a three-phase network are measured. These measurement quantities are displayed on different push-button activated pages on the backlit LCD. The unit has a reading accuracy for power (kWh) of ± 1%. The unit is connected to the respective supply with dedicated CT. The unit also has a programmable pulse output and RS485 communication for control and logging capabilities.

Photograph 24 - IME CONTO D4-S power meter

4.4.3 Associated equipment – current transformer (CT)

To facilitate the safe measurement of large currents, a current transformer (CT) was also installed on each phase circuit of the power meter. The circuit is largely unaffected by the insertion of the CT. A CT is a type of instrument transformer designed to provide a current in its secondary winding proportional to the alternating current flowing in its primary. The CT safely isolated the measurement circuitry from the high voltages typically present each circuit being measured. The secondary winding for all CT used in this work was 5 amperes. For example, a 100/5 CT provides an output current of 5 amperes when the primary was passing 100 amperes.



Photograph 25 - Typical installed current transformers

4.4.4 Feedlot A instrumentation

At Feedlot A, there is an overhead electricity supply to the water pumping system, feedmill, office, induction/stables and hospital complexes. Each overhead supply has associated power authority metering. At this facility, the power supply for the workshop and vehicle washing activities is sourced from the feedmill supply. Therefore, only one new power sub-meter was required to allow the usage of the workshop and vehicle washing activities to be measured. This meter was located to sub-meter the power usage for the workshop and vehicle washing activities. The selected meter was a CONTO D4-S (See Photograph 26) and was installed within a dedicated enclosure, surface mounted on the workshop meter board. The meter was installed with 100/5 CT and three circuit break fuses mounted in the enclosure.

Photograph 26 - Installed power meter E6 at Feedlot A

There was no requirement to install flow meters to the diesel/petrol bowsers as existing meters were installed. Similarly, an existing gas meter recorded the usage of LP gas.

4.4.5 Feedlot B Instrumentation

At Feedlot B, there is an overhead electricity supply to two of the three water supply bores and to the facility's main switchboard. From the main switchboard, electricity is distributed to a number of activities via a series of aerial sub-mains. Therefore, a number of new power sub-meters were required to monitor usage levels in the required focus areas. New power meters were installed on the grain movement, tub grinder, roller mills, cattle wash bay, office/workshop and water supply bore sub-mains.

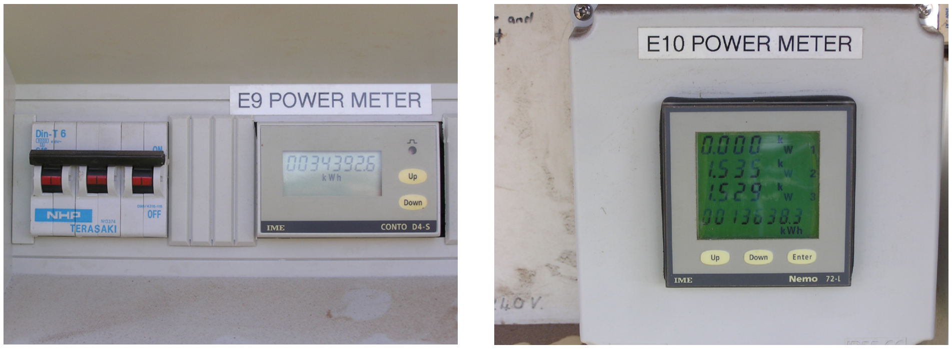
The selected meters (see Photograph 27 and Photograph 29) for the grain movement (E2), tub grinder (E3), roller mills (E4) and liquid supplements (E10) metering was a NEMO 72-L. These were mounted on the front panel of the main switchboard. Each meter was installed with appropriately sized CT of 300/5 for the tub grinder and 200/5 for the grain movement and the roller mills. Each meter had three associated circuit break fuses mounted in the switchboard.

The selected meters (see Photograph 28) for the water supply bore (E5, E9), cattle wash (E7) and office/workshop (E8) was a CONTO D4-S. Each meter was installed within a dedicated enclosure, surface mounted on the respective complex meter board. Each meter was installed with appropriately sized CT of 100/5 for the water supply bore, and 80/5 for the office/workshop and 50/5 for the cattle wash bay. Each meter had three associated circuit break fuses mounted in the enclosure.

There was no requirement to install flow meters to the diesel/petrol bowsers as existing meters were installed.

Photograph 27 - Installed power meters E2, E3 and E4 at Feedlot B

Photograph 28 - Installed power meters E5, E7 and E8 at Feedlot B



Photograph 29 - Installed power meters E9 and E10 at Feedlot B

4.4.6 Feedlot D instrumentation

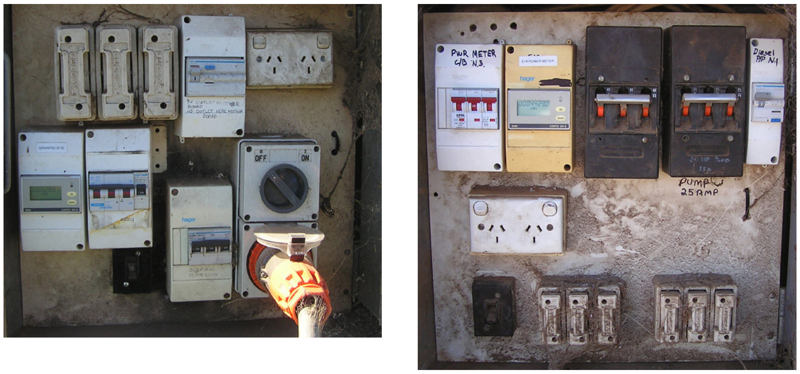
At Feedlot D, there is an overhead electricity supply to the three of the four bore water supply pumps and to the facility's main switchboard. From the main switchboard, electricity is distributed to a number of activities via a series of aerial sub-mains. Therefore, a number of new power sub-meters were required to monitor usage levels in the required focus areas. New power meters were installed on the office, roller mills, tub grinder, grain movement, stationary mixer/batch boxes, workshop, bore water supply pump, grain pad and water reticulation pumps.

The selected meter for the office (E6), grain movement (E6), tub grinder (E9), roller mills (E8), stationary mixer/batch boxes (E10 & E15) and workshop (E16) metering was a NEMO 72-L (see Photograph 30). These were mounted on the front panel of the main switchboard or sub-main switchboards. Each meter was installed with appropriately sized CT of 300/5 for the tub grinder, 200/5 for grain movement, roller mills and stationary mixer, 150/5 for the workshop and 50/5 for the office. Each meter had three associated circuit break fuses mounted in the switchboard.

The selected meter for the water supply bore (E13), reticulation pumps (E11 and E12) and grain pad (E14) was a CONTO D4-S. Each meter was installed within a dedicated enclosure, surface mounted on the respective complex meter board (See Photograph 31 and Photograph 32). Each meter was installed with appropriately sized CT of 50/5 and each meter had three associated circuit break fuses mounted in the enclosure.

Photograph 30 - Installed power meters E6, E7, E8 (Left) and E9, E10, E15, E16 (Right) at Feedlot D

Photograph 31 - Installed power meters E11 and E12 at Feedlot D



Photograph 32 - Installed power meters E13 and E14 at Feedlot D

4.4.7 Feedlot E instrumentation

At Feedlot E, there is an overhead electricity supply to the water supply and irrigation bores and to the facility's main switchboard. From the main switchboard, electricity is distributed to a number of activities via a series of sub-mains. Therefore, a number of new power sub-meters were required to monitor usage levels in the required focus areas. New power meters were installed on the Grain movement and Induction/Hospital and water supply bore sub-mains. The office/workshop usage was obtained by deduction.

Photograph 33 shows the four power meters installed at Feedlot E. The selected meters for grain storage and movement (E5 and E6) and Induction/Hospital (E7) metering was a CONTO D4-S. These were mounted on the front panel of the main switchboard. The meters were installed with an appropriately sized 80/5 CT and three associated circuit break fuses per meter mounted in the switchboard.

The selected meter for the water supply bore (E4) was a CONTO D4-S. Meter E4 was installed within a dedicated enclosure, an appropriately sized CT of 50/5 and three associated circuit break fuses mounted in the enclosure.

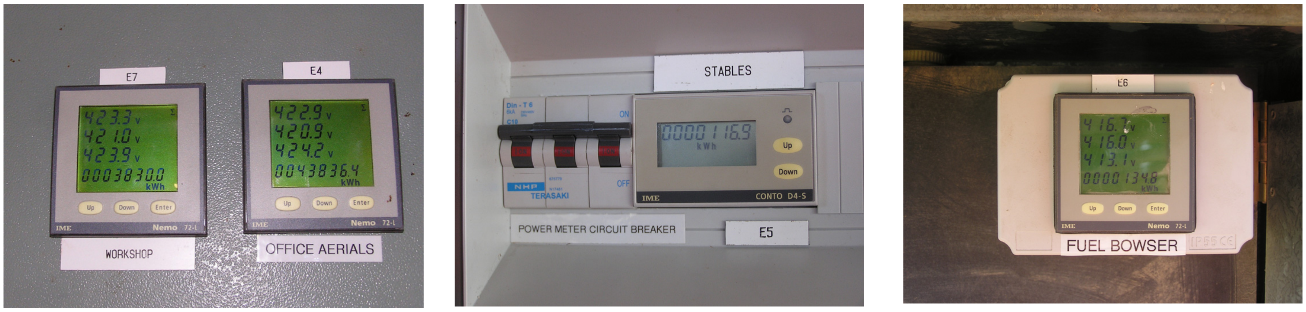
Photograph 33 - Installed power meters E4, E5, E6 and E7 at Feedlot E

4.4.8 Feedlot F instrumentation

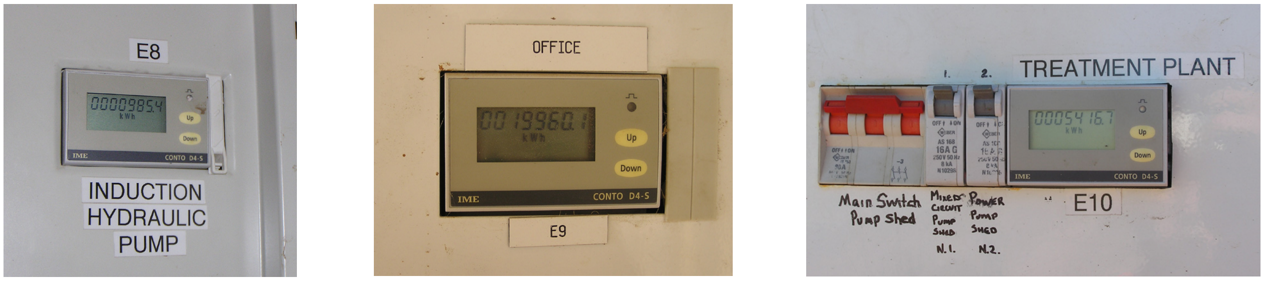
At Feedlot F, there is an overhead electricity supply to the water supply pump, induction and cattle wash complex and to the facility's main switchboard. From the main switchboard, electricity is distributed to a number of activities via a series of aerial sub-mains. Therefore, a number of new power sub-meters were required to monitor usage levels in the required focus areas. New power meters were installed on the workshop, office, induction, stables, water treatment plant and diesel bowser. The grain movement and feed processing usage was obtained by deduction.

The selected meter for the workshop (E7), diesel bowser (E6) and office aerials (E4) was a NEMO 72-L (see Photograph 34). These were mounted on the front panel of the main switchboard. Each meter was installed with appropriately sized CT of 150/5 for the office aerials and 100/5 for the workshop and diesel bowser. Each meter had three associated circuit break fuses mounted in the switchboard.

The selected meter for the office (E9), stables (E5), induction (E8) and treatment plant (E10) was a CONTO D4-S (see Photograph 35). Each meter was installed within a dedicated enclosure, surface mounted on the respective complex meter board. Each meter was installed with appropriately sized CT of 150/5 for the office, 80/5 for the stables and 50/5 treatment plant and for induction. Each meter had three associated circuit break fuses mounted in the enclosure.



Photograph 34 - Installed power meters E4, E5, E6 and E7 at Feedlot F



Photograph 35 - Installed power meters E8, E9 and E10 at Feedlot F

4.4.9 Feedlot G instrumentation

At Feedlot G, there is an overhead electricity supply to the water supply bore, Induction, Hospital and to the facility’s main switchboard. From the main switchboard, electricity is distributed to a number of activities via a series of aerial sub-mains. Therefore, a number of new power sub-meters were required to monitor usage levels in the required focus areas. New power meters were installed on the water supply/reticulation pumping system, cattle wash bay, workshop and old mill/office sub-mains. The selected meter for the old mill/office (E7), cattle wash bay (E9) and workshop (E10) was a NEMO 72-L. These were mounted on the front panel of the main switchboard (see Photograph 36). Each meter was installed with appropriately sized CT of 100/5 for the old mill/office and 100/5 for the cattle wash and workshop. Each meter had three associated circuit break fuses mounted in the switchboard. The selected meter for the water supply/reticulation pumping system (E8) was a CONTO D4-S. The meter was installed within a dedicated enclosure, surface mounted on the complex meter board (see Photograph 36). The meter was installed with an appropriately sized CT of 80/5 and three associated circuit break fuses mounted in the enclosure.

Photograph 36 - Installed power meters E7, E8, E9 and E10 at Feedlot G

4.4.10 Feedlot H instrumentation

At Feedlot H, there is an overhead electricity supply to the bore water supply pumps, hospital/stables and to a main switchboard at the feedmill. From the main switchboard, electricity is distributed to a number of activities via a series of aerial sub-mains. Therefore, a number of new power sub-meters were required to monitor usage levels in the required focus areas. New power meters were installed on the feedmill, tub grinder, office, cattle wash, induction/hospital, workshop and water reticulation pump.

The selected meter for the feedmill (E4), tub grinder (E5), office and weighbridge (E8), cattle wash (E7) and induction/hospital (E6) was a NEMO 72-L. These were mounted on the front panel of the main switchboard or at the respective complexes meter board (see Photograph 37 and Photograph 38). Each meter was installed with appropriately sized CT of 400/5 for the feedmill, 300/5 for the tub grinder, 200/5 for the cattle wash pumps and office, 150/5 for the workshop and 100/5 for induction/hospital. Each meter had three associated circuit break fuses mounted in the switchboard.

The selected meter for the water reticulation pump (E10) was a CONTO D4-S. This meter was installed within a dedicated enclosure, surface mounted on the pump meter board See Photograph 38). The meter was installed with an appropriately sized CT of 80/5 and had three associated circuit break fuses mounted in the enclosure.

Photograph 37 - Installed power meters E4, E5 and E8 at Feedlot H

Photograph 38 - Installed power meters E6, E7 and E10 at Feedlot H

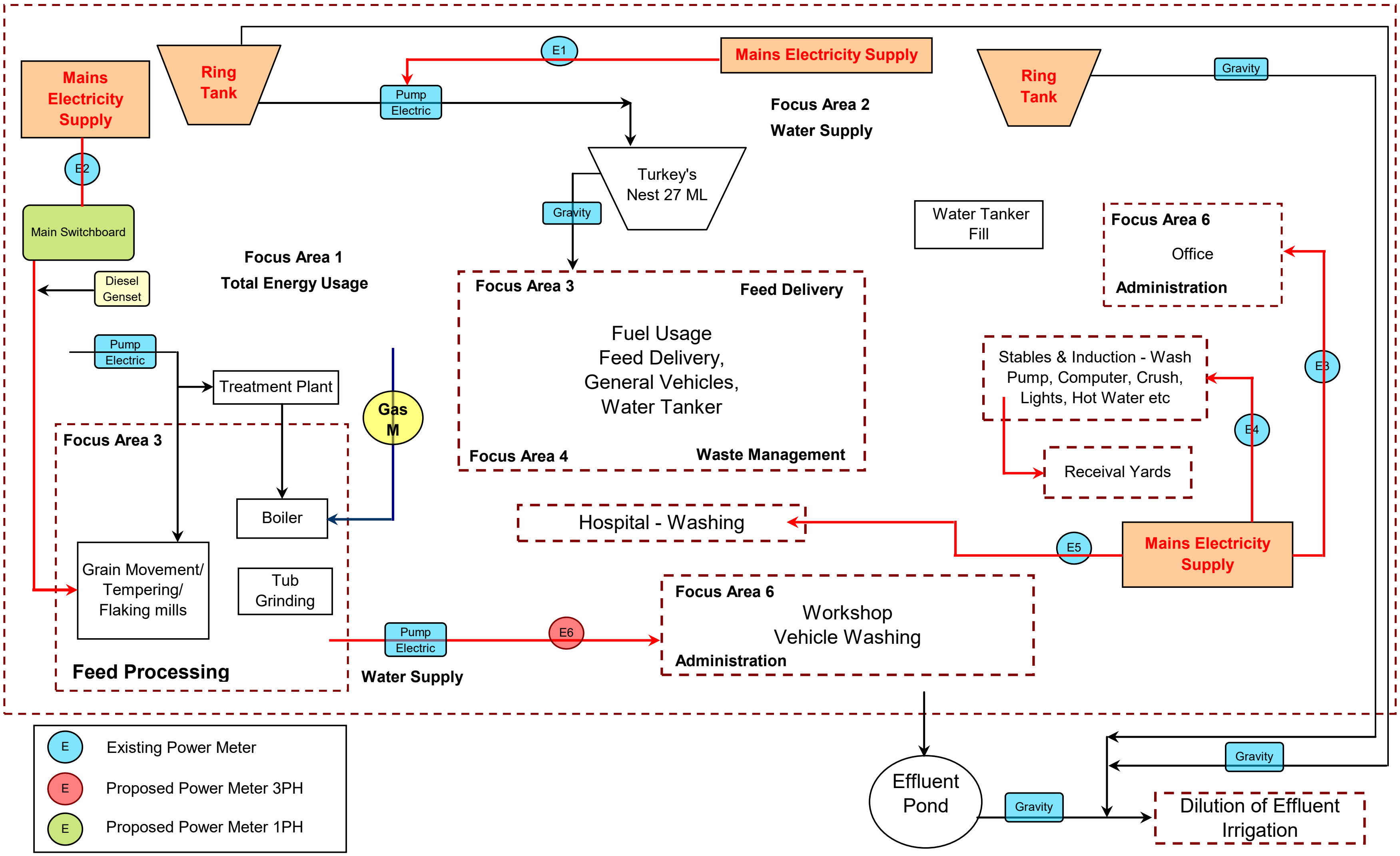


Figure 6 - Energy supply network – Feedlot A

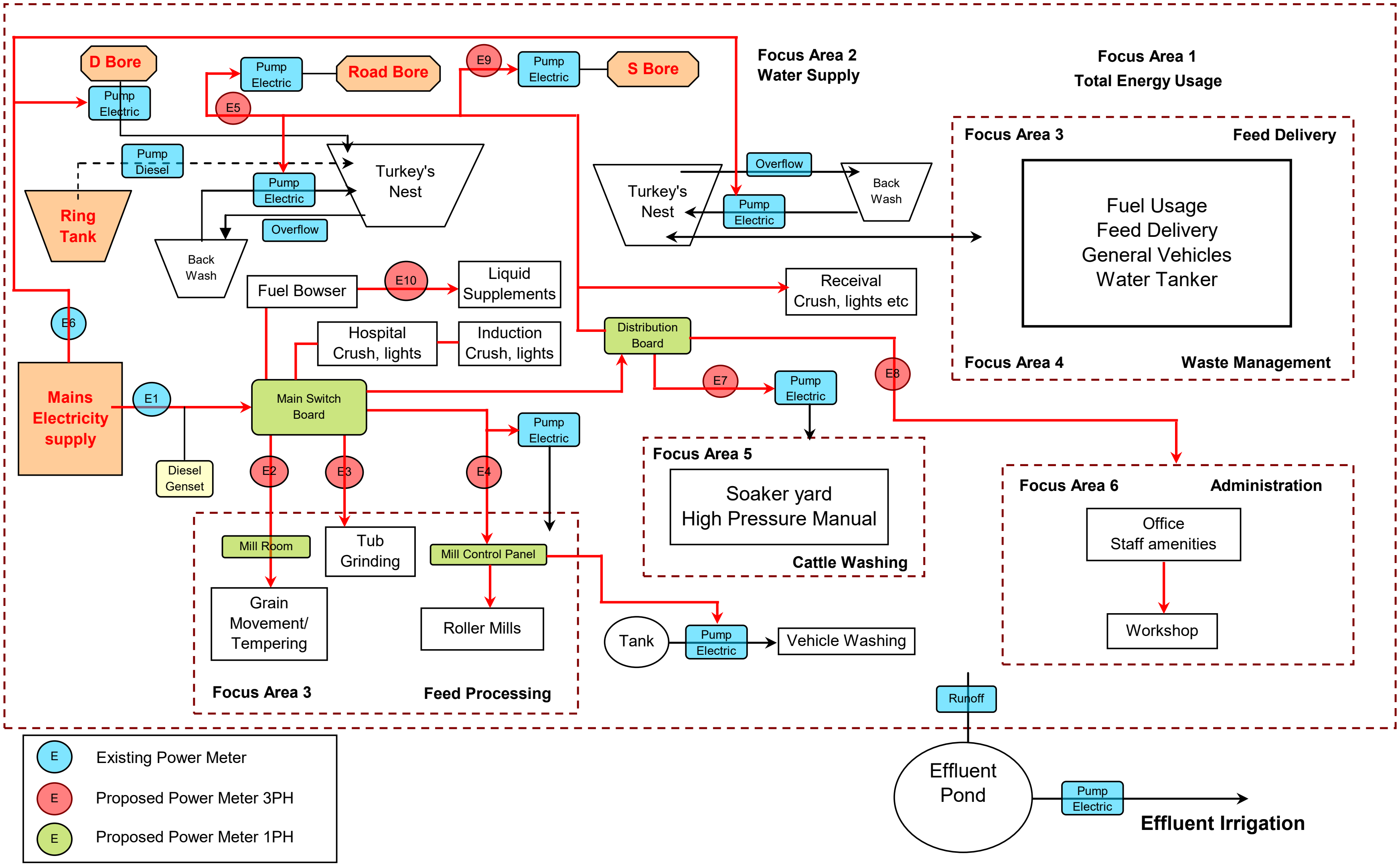


Figure 7 - Energy supply network – Feedlot B

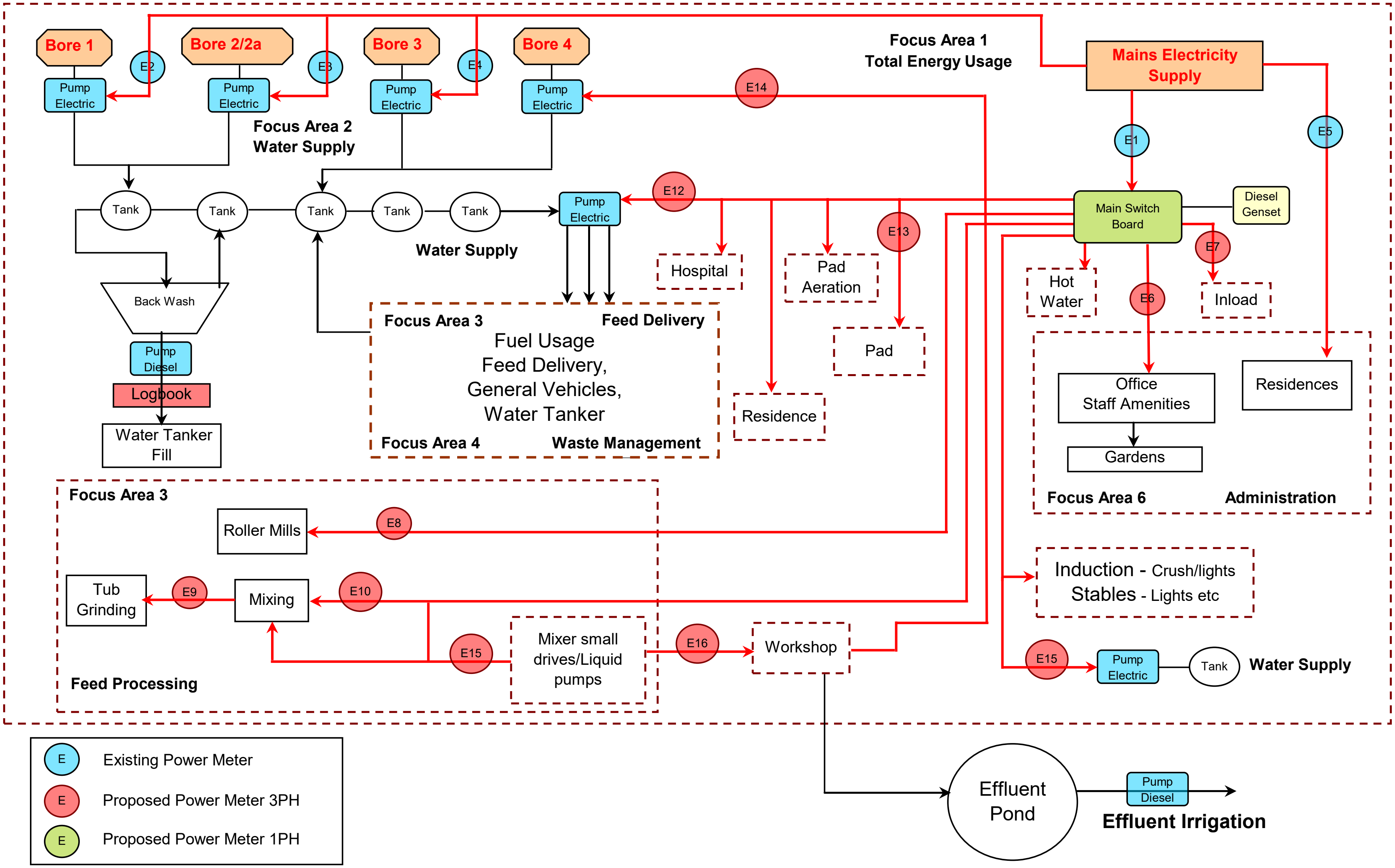


Figure 8 - Energy supply network – Feedlot D

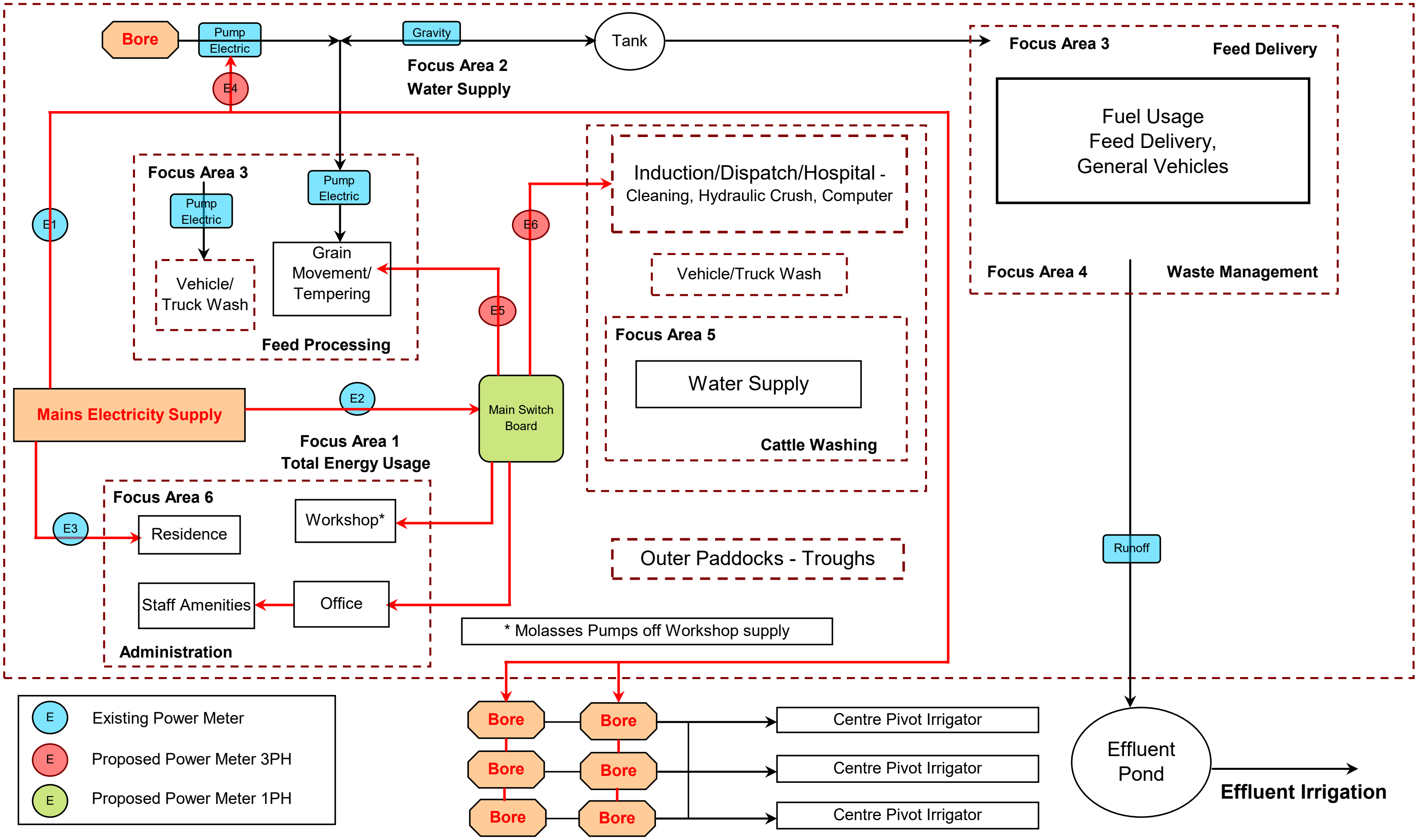


Figure 9 - Energy supply network – Feedlot E

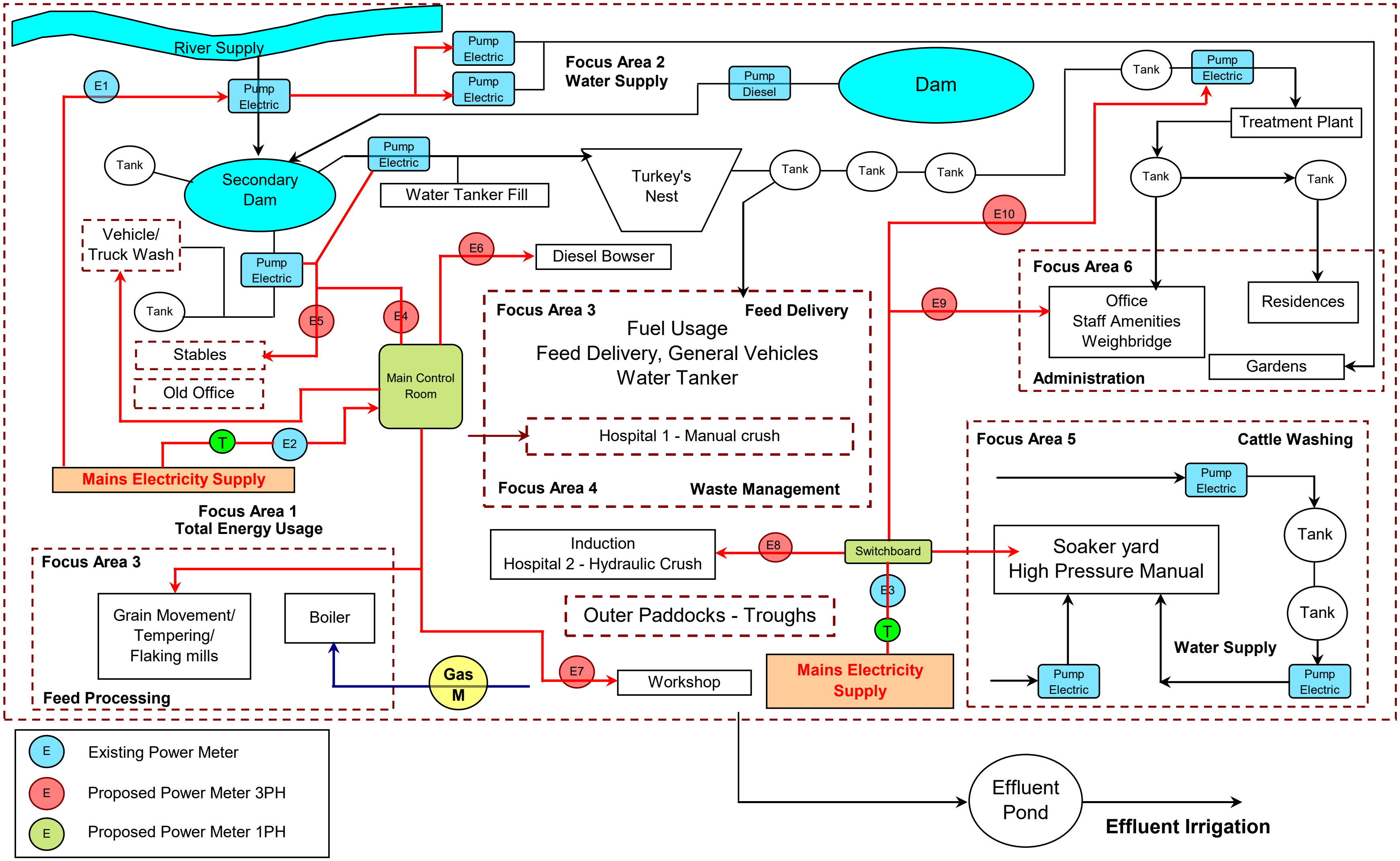


Figure 10 - Energy supply network – Feedlot F

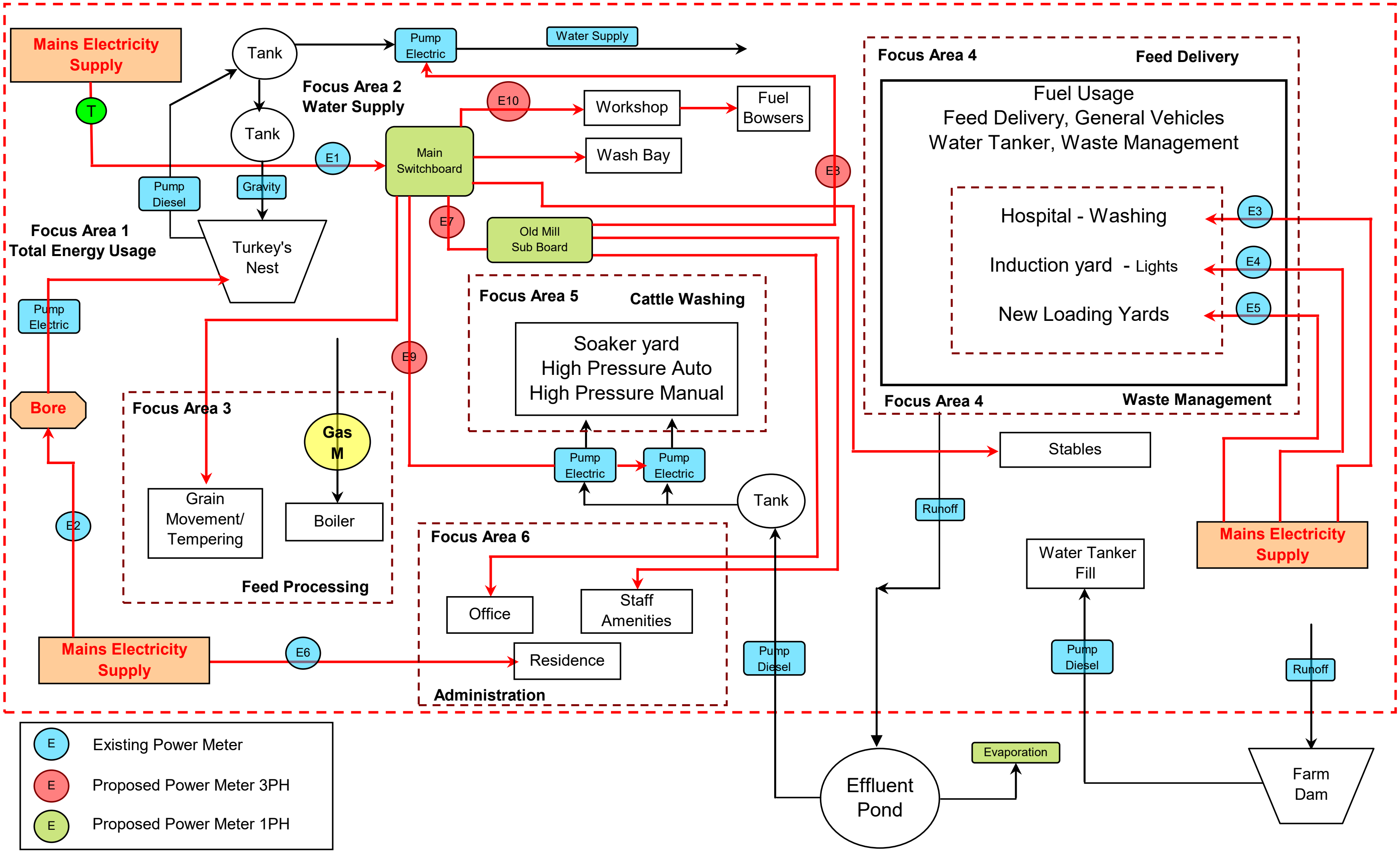


Figure 11 - Energy supply network – Feedlot G

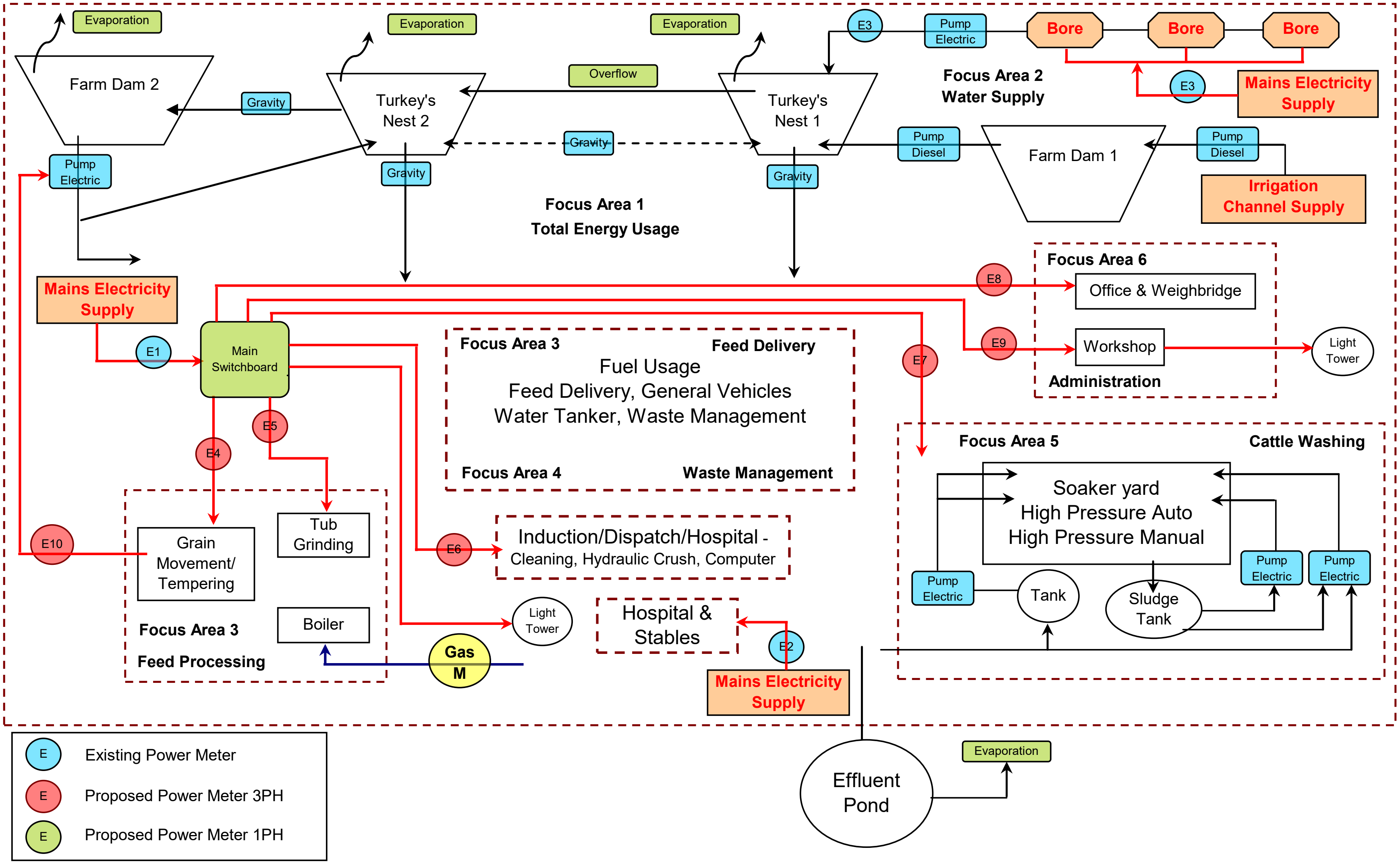


Figure 12 - Energy supply network – Feedlot H

4.5 Monthly direct and indirect energy usage recording

Each feedlot was given a recording sheet that detailed all energy metering onsite. This included power authority electricity metering, new power metering, gas metering and fuel metering.

No onsite metering had any digital recording capability. Hence, each meter had to be read manually at the end of each period. The nominal period was monthly. However, if the last day of the month fell on a weekend, the meters were read either prior too or soon after the last day of the month. Therefore, the nominal period varied from a minimum of 27 to a maximum of 33 days.

The power authority meters and newly installed power meters had a number allocated. The feedlot manager or a nominated staff member read the power authority and new power meters and recorded the reading on the recording sheet. The power authority metering allowed each phase power usage, high or off-peak supply usage or the total usage to be recorded. The new power meters provided only a total power usage. The reading along with the respective units in kilowatt hours (kWh) were recorded on the recording sheet.

At the same time, the gas reading in litres was recorded on the sheet. Fuel consumption was broken up into diesel and petrol usage. This information was obtained from fuel logbooks and grouped by the respective categories and recorded. The recording sheet was then faxed or emailed to FSA Consulting at the end of each month.

Indirect energy usage was estimated from cattle and commodity transport distances, and typical truck types. Information on transport distances and typical truck types was obtained directly from the respective feedlots in-house feedlot management software (e.g. FY3000). This information was recorded on the recording sheet and then faxed or emailed to FSA Consulting at the end of each month.

4.6 Monthly herd performance and feed consumption recording

Due to the potentially sensitive nature of the information produced by this research, the reported information is presented in such a way that individual feedlots cannot be identified. Therefore, energy use is presented as a function of a number of feedlot indices to protect the anonymity of the feedlot. The feedlot indices corresponded to the activity measured and included usage on a per head basis, per tonne grain processed and per kilogram of hot standard carcase weight gain (kg HSCW gain). In this context, HSCW gain is the difference between total dressed carcase weight of cattle leaving the feedlot less the estimated total dressed carcase weight of cattle entering the feedlot.

To enable the respective indices to be estimated, herd performance and feed consumption data was provided. Herd performance data was provided on a market type basis and included liveweight of incoming and shipped cattle, days on feed, average daily gain, dressing percentage, number of cattle entering the feedlot along with number shipped. Commodity usage for the period was provided, broken into categories of major grains, protein sources, roughages/silages, liquids and supplements.

The herd performance and feed consumption data was obtained directly from the respective feedlots in-house feedlot management software (e.g. Bunk Management System, Possum Gully, Feedlot

3000). These systems are dedicated cattle feeding software systems to assist operations in better managing assets, inventories, commodities and maintenance of financial records.

4.7 Data collection period

Monthly data was collected over a 12-month period from March 2007 to February 2008. This period allowed for the annual variation in total energy usage to be quantified along with the variation in individual feedlot activities.

4.8 Data analysis

Monthly power meter readings, fuel and gas usage figures were imported into a large Excel spreadsheet and cross-checked with previous month’s readings. Where anomalous data were detected, the participating feedlot was contacted and the data were examined in more detail. Anomalous data may have included a reduction in meter reading from previous or unexplained extraordinarily large increases in power, fuel or gas usage.

Herd performance and feed consumption data were imported into the same spreadsheet. Similarly, data quality checks were undertaken. For example, the mean number of cattle on hand were compared with licensed capacity to ensure market types were not counted twice or missed. Where anomalous data was detected, the participating feedlot was contacted and the data were examined in more detail. The HSCW gain was calculated from the data for estimated liveweight in lot at the start of the month, total liveweight in, total liveweight out and estimated liveweight in lot at the end of the month. In some cases, feedlots were able to directly supply kilograms of beef produced for the month calculated from the identical method.

The spreadsheet then calculated the energy usage of the major feedlot activities as a function of their respective indices including on a per head basis, per tonne grain processed and per kilogram of hot standard carcase weight gain (kg HSCW gain).

5 Results and Discussion

Total indirect and direct energy usage and activity energy usage are presented in the following sections. It is important to note that the feedlot numbering system in the methodology section does not align with the number system in the results and discussion sections. That is, Feedlot B in Section 5.1 is not Feedlot B in Section 4.2. This has been deliberate to maintain anonymity for the participating feedlots.

Table 4 gives the conversion factors used to convert fuel usage to energy (MJ).

Table 3 – Energy conversion factors for common fuels

Energy Form	**Units of Measure**	**Energy Conversion Factor MJ**
Diesel	Litres	38.6
Petrol	Litres	34.2
LPG	Litres	25.7
Natural	m^3	38.5
Butane	Litres	28.1
Butane	m^3	122.0
Electricity	kWh	3.6

5.1 Total indirect energy usage

The energy (fuel consumed) for transport of incoming and outgoing livestock was calculated from cattle numbers, intake and exit liveweight, truck transport type (fuel usage & loading capacity) and estimated mean distance travelled to and from the feedlot. These data were supplied directly by the participating feedlots. Truck fuel usage and loading capacity was calculated from best available data. The raw consumption data for the respective fuel type was then converted into an equivalent energy consumption and then standardised per kg HSCW gain.

Truck transport fuel usage was determined from gathering transport industry data on average fuel use per 100 km for different truck types. Table 4 shows the average fuel use per 100 km for different truck types commonly used for livestock transport. Fuel consumption is a function of the efficiency of vehicle weight, fuel technology, topography, road conditions as well as other factors. The fuel usage presented here is only an average based typical highway performance for fully loaded vehicles.

Table 4 – Fuel usage for livestock and commodity transport vehicles

	Table Top	Semi Trailer	Semi Trailer	B Double	Road Train
	1 Deck	1 Deck	2 Deck	3 Decks	4 Decks
Fuel (L) / 100 km	23.8	34.55	42.6	56.8	68.4

Loading capacity depends upon truck type and size of the livestock. Loading rates were taken from Davies, Blackwood and Richards (2002).

Table 5 shows average livestock loading rates for different truck types commonly used for livestock transport.

From Table 5, and the number of incoming and outgoing cattle, it was possible to calculate the number of incoming and outgoing vehicles. When multiplied by the estimated travel distance, the total kilometres of livestock transport was calculated. From Table 4, it was possible to estimate fuel use.

Table 5 – Livestock loading rates (head per vehicle) for livestock transport truck types

Animal LWT	Table Top	Semi Trailer	Semi Trailer	B double	Road Train
kg	1 deck	1 deck	2 decks	3 decks	4 decks
250	22	38	75	114	150
300	20	34	67	102	134
350	18	30	60	91	120
400	16	28	55	83	110
450	15	25	51	77	102
500	14	24	47	71	94
550	13	22	43	65	86
600	12	20	39	59	78
650	11	18	35	54	70
700	10	16	32	49	64
750	9	14	28	44	56
800	8	12	24	39	48

Similarly, the energy (fuel consumed) for transport of off-farm feed commodities to the feedlot was calculated from the mass of each commodity delivered, type of truck delivering commodity (fuel usage & loading capacity) and estimated mean delivery distance. These data were provided by the participating feedlot. Truck fuel usage and loading capacity was calculated from best available data. The energy used to transport commodities produced on-farm to the feedlot were not included in these figures.

Table 4 shows the average fuel use per 100 km for different truck types commonly used for commodity transport.

Loading capacity depends upon truck type and the density of the commodity delivered. The loading capacity was determined from gathering transport industry data on average commodity loading rates for different truck types. Table 6 shows average loading capacity for different truck types commonly used for commodity transport.

Table 6 – Loading rates for commodity delivery vehicles

Commodity	Body Truck, 10t	Truck and Dog	Semi Trailer	B Double	Road Train
	tonnes	tonnes	tonnes	tonnes	tonnes
Roughages/Straws	6	12	12	18	24
Fully prepared ration	12	24	24	36	48
Liquids	12	24	24	36	48
Major Grains	12	24	24	36	48
Molasses	12	24	24	36	48
Protein Sources	12	24.5	25.5	37	50
Silage	12	25	25	36	50

Figure 13 to Figure 19 inclusive present the monthly results for the period March 2007 to February 2008 of the energy use for livestock transport and commodity delivery for the seven feedlots. The usage for the respective activities was standardised per kg HSCW gain for the respective month. These figures clearly show the impact of travel distance on energy consumption for livestock transport and commodity delivery.

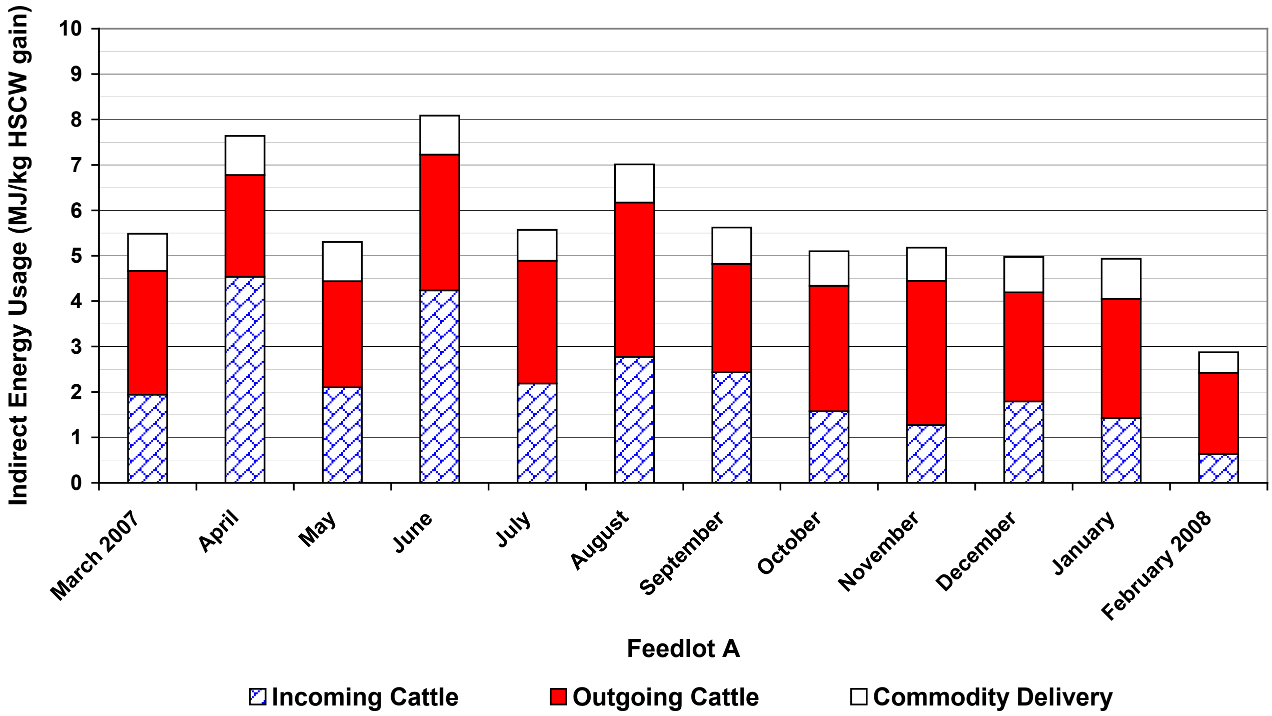


Figure 13 – Monthly total indirect energy usage at Feedlot A (MJ/kg HSCW gain)

Figure 13 shows the total indirect energy usage for Feedlot A during the period March 2007 to March 2008. For Feedlot A, the total indirect energy usage ranges from 2.9 MJ/kg HSCW gain in February 2008 to 8 MJ/kg HSCW gain in June 2007. The primary driver of total energy usage is incoming cattle with a fourfold variation in energy usage. Outgoing cattle and commodity delivery are similar between months.

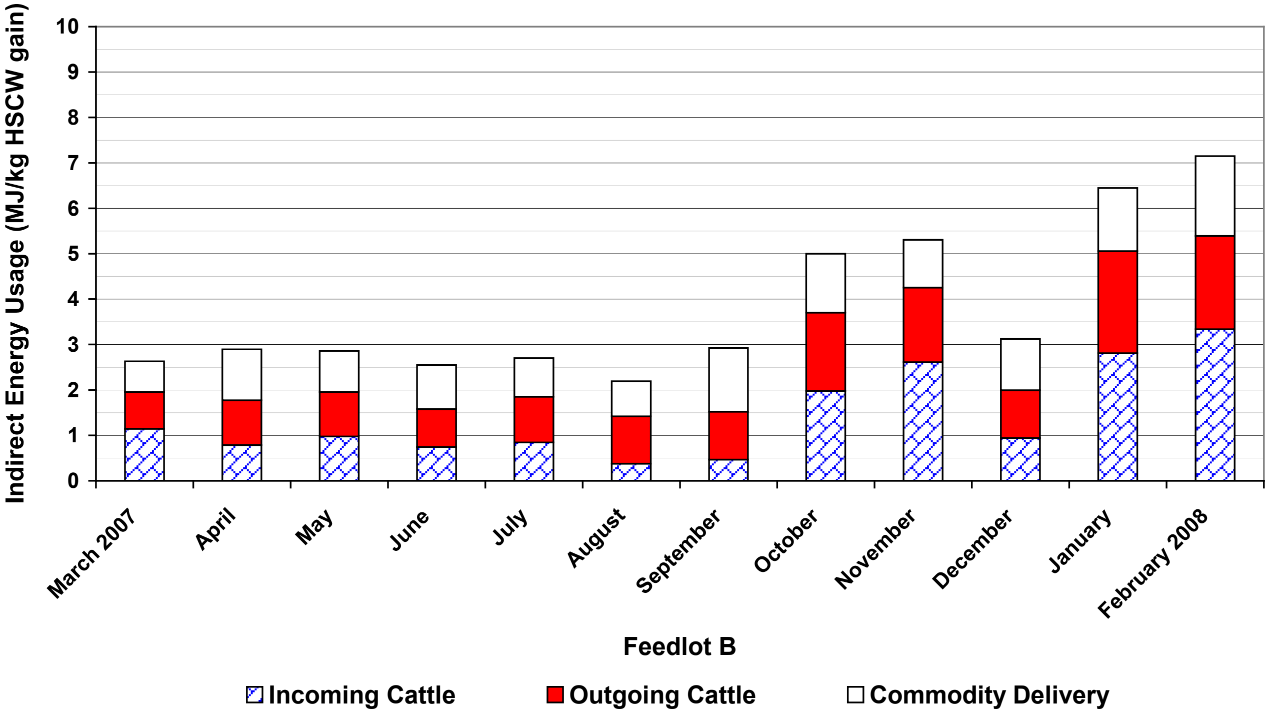


Figure 14 – Monthly total indirect energy usage at Feedlot B (MJ/kg HSCW gain)

Figure 14 shows the total indirect energy usage for Feedlot B during the period March 2007 to March 2008. For Feedlot B, the total indirect energy usage ranges from 2.1 MJ/kg HSCW gain in August 2007 to 7.2 MJ/kg HSCW gain in February 2008. Energy consumed in transport of cattle to slaughter ranges from 0.81 MJ/kg HSCW gain to 2.2 MJ/kg HSCW gain. Between March and September 2007, the total energy usage was relatively similar and less than 3 MJ/kg HSCW gain. From October 2007 to February 2008, energy usage has risen steadily across all activities to a peak of 7.2 MJ/kg HSCW gain.

Figure 15 shows the total indirect energy usage for Feedlot C during the period March 2007 to March 2008. For Feedlot C, the total indirect energy usage ranges from 1.6 MJ/kg HSCW gain to 3.5 MJ/kg HSCW gain. Feedlot C and Feedlot G have the lowest average total indirect energy usage across all feedlots. The largest component of total energy usage is commodity delivery, representing on average 53% of total energy usage. Outgoing cattle is similar between months, with a low figure recorded in September and October 2007.

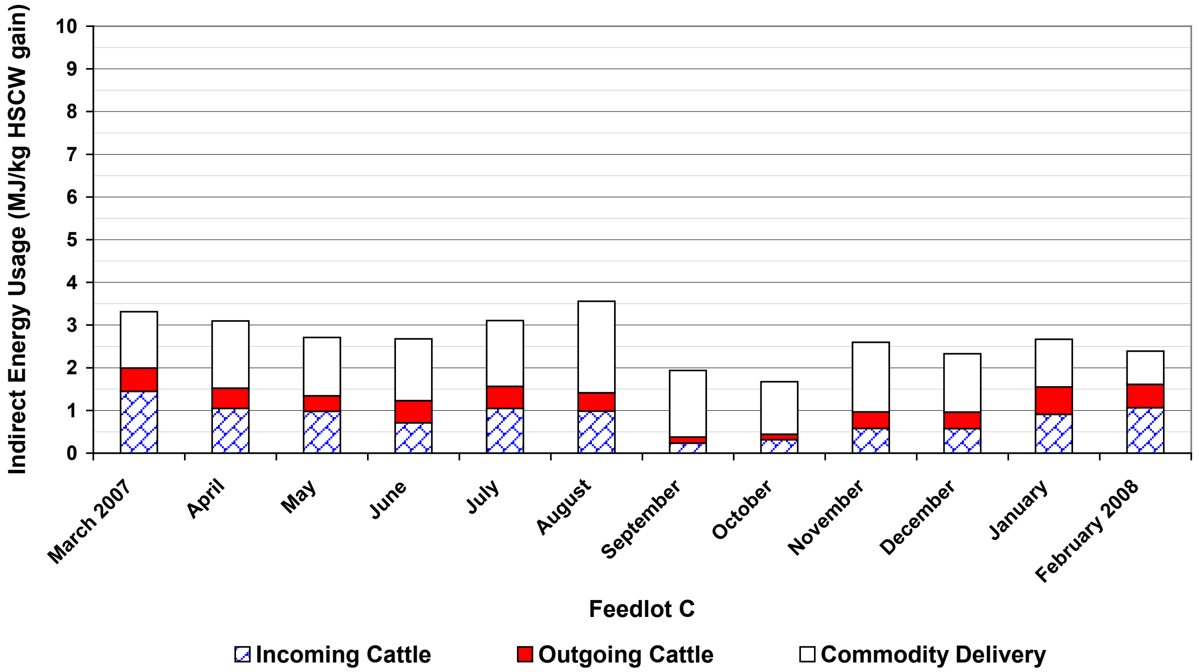


Figure 15 – Monthly total indirect energy usage at Feedlot C (MJ/kg HSCW gain)

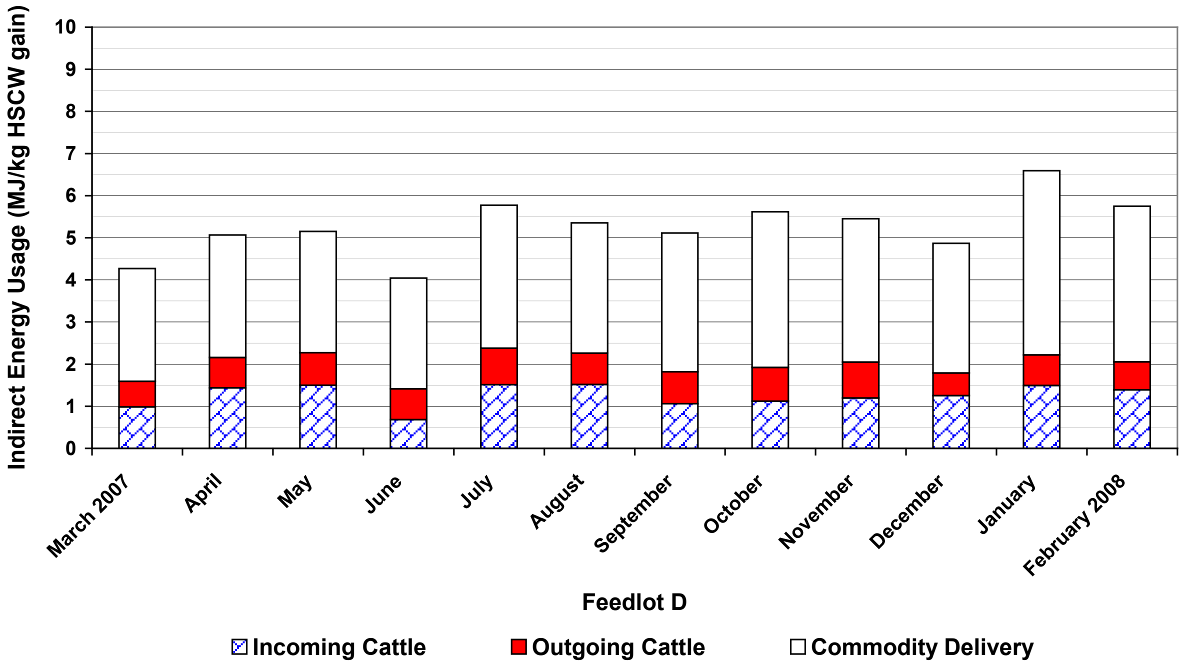


Figure 16 – Monthly total indirect energy usage at Feedlot D (MJ/kg HSCW gain)

Figure 16 shows the total indirect energy usage for Feedlot D during the period March 2007 to March 2008. For Feedlot D, the total indirect energy usage ranges from 4.0 MJ/kg HSCW gain in June 2007 to 6.6 MJ/kg HSCW gain in January 2008. The largest component of total energy usage is commodity delivery, representing on average 62% of total energy usage. Incoming and outgoing cattle are similar between months. Commodity delivery energy usage ranges from 2.6 MJ/kg HSCW gain to 4.4 MJ/kg HSCW gain. Outgoing cattle energy usage ranges from 0.5 MJ/kg HSCW gain to 0.9 MJ/kg HSCW gain.

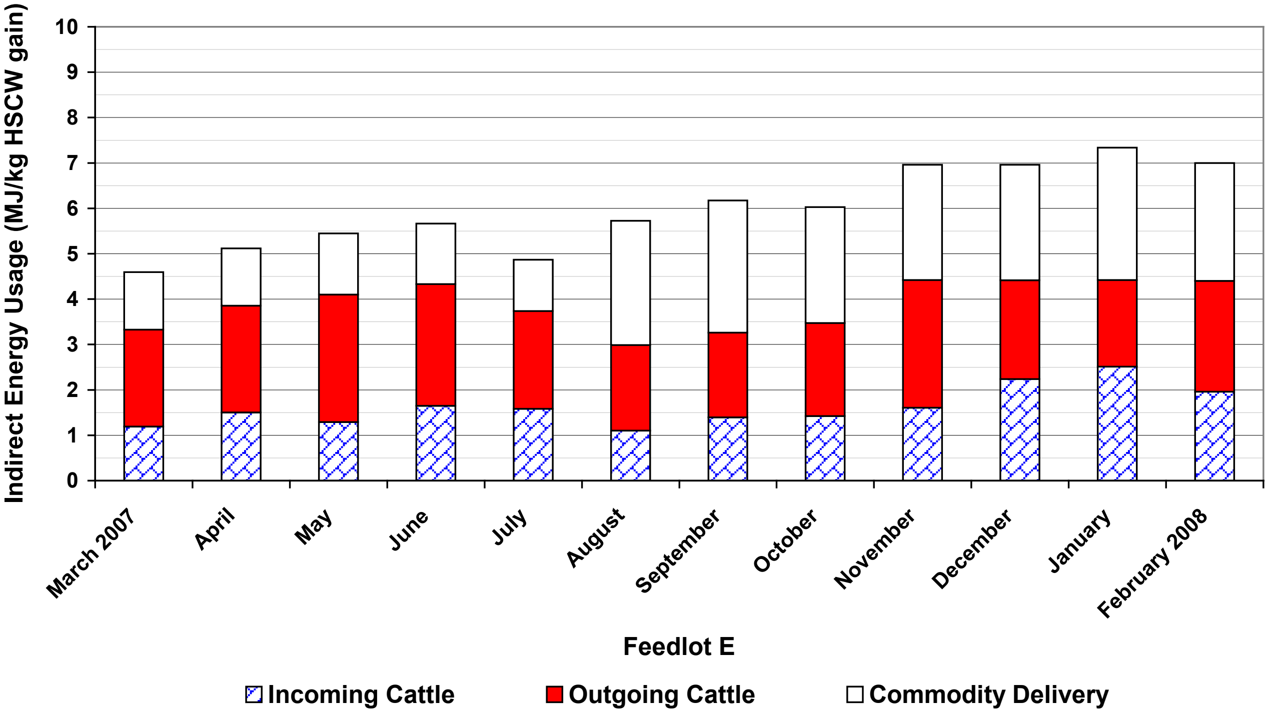


Figure 17 – Monthly total indirect energy usage at Feedlot E (MJ/kg HSCW gain)

Figure 17 shows the total indirect energy usage for Feedlot E during the period March 2007 to March 2008. For Feedlot E, the total indirect energy usage ranges from 4.6 MJ/kg HSCW gain in July 2007 to 7.4 MJ/kg HSCW gain in January 2008. For this feedlot, incoming cattle represents the lowest energy usage in the order of 27%, whilst outgoing cattle (38%) and commodity delivery (35%) contributed the remaining energy usage. Commodity delivery energy usage ranges from 1.1 MJ/kg HSCW gain to 2.9 MJ/kg HSCW gain. Outgoing cattle energy usage ranges from 1.9 MJ/kg HSCW gain to 2.8 MJ/kg HSCW gain.

Figure 18 shows the total indirect energy usage for Feedlot F during the period March 2007 to March 2008. For Feedlot F, the total indirect energy usage ranges from 3.5 MJ/kg HSCW gain in September 2007 to 7.9 MJ/kg HSCW gain in November 2007. For this feedlot, transport of cattle to slaughter represents the lowest energy usage in the order of 13%, whilst incoming cattle (27%) and commodity delivery (60%) contributed the remaining energy usage. Commodity delivery energy usage ranges from 2.2 MJ/kg HSCW gain to 5.2 MJ/kg HSCW gain. Outgoing cattle energy usage ranges from 0.5 MJ/kg HSCW gain to 0.9 MJ/kg HSCW gain, whilst incoming cattle energy usage ranges from 0.3 MJ/kg HSCW gain to 4.3 MJ/kg HSCW gain.

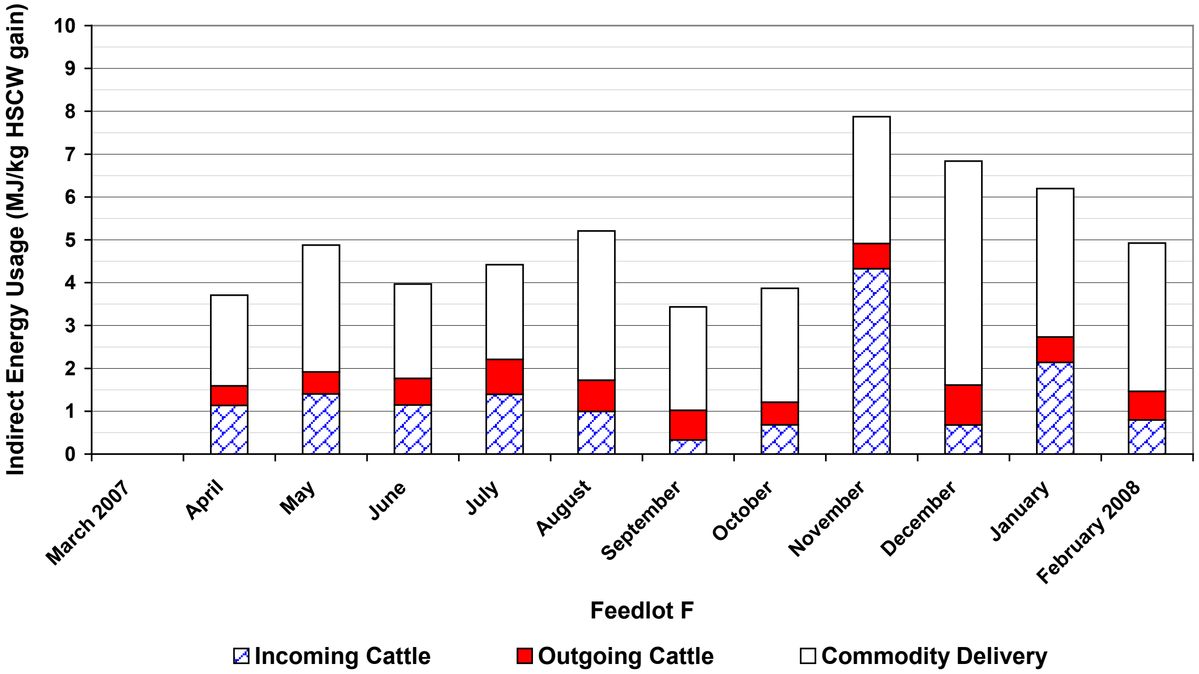


Figure 18 – Monthly total indirect energy usage at Feedlot F (MJ/kg HSCW gain)

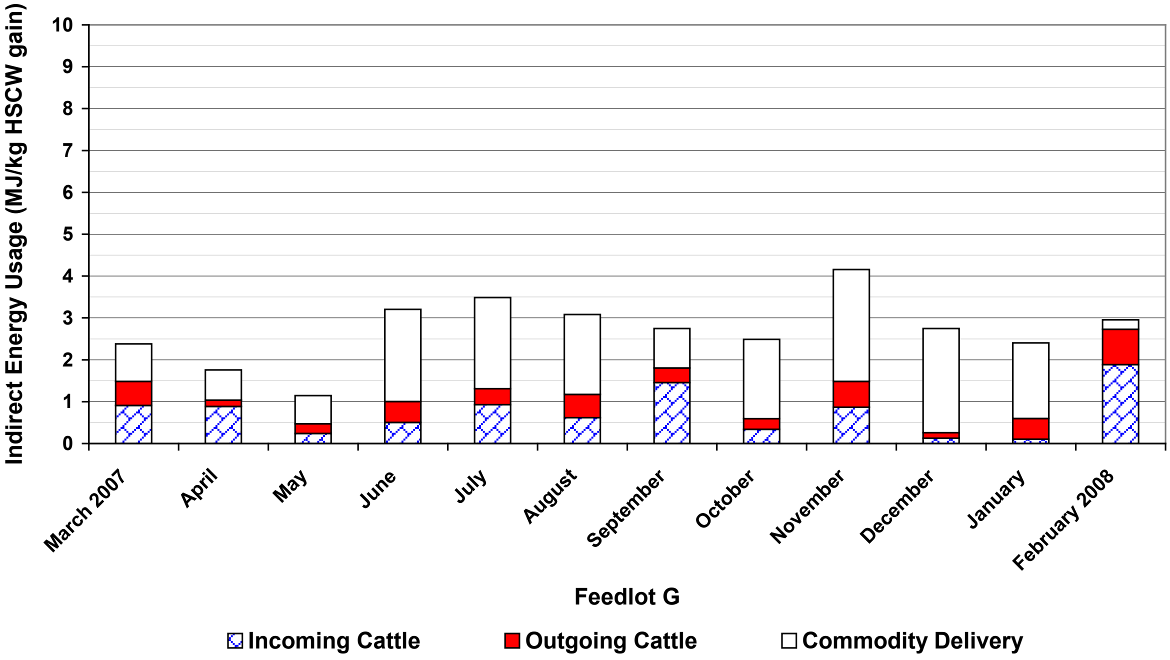


Figure 19 – Monthly total indirect energy usage at Feedlot G (MJ/kg HSCW gain)

Figure 19 shows the total indirect energy usage for Feedlot G during the period March 2007 to March 2008. For Feedlot G, the total indirect energy usage ranges from 1.1 MJ/kg HSCW gain in May 2007 to 4.2 MJ/kg HSCW gain in November 2007. Feedlot G and Feedlot C have the lowest average total indirect energy usage across all feedlots. For this feedlot, transport of cattle to slaughter represents the lowest energy usage in the order of 15%, whilst incoming cattle (27%) and commodity delivery (58%) contributed the remaining energy usage. Commodity delivery energy usage ranges from 0.7 MJ/kg HSCW gain to 2.6 MJ/kg HSCW gain. Outgoing cattle energy usage ranges from 0.15 MJ/kg HSCW gain to 0.84 MJ/kg HSCW gain, whilst incoming cattle energy usage ranges from 0.24 MJ/kg HSCW gain to 1.9 MJ/kg HSCW gain.

The indirect energy usage figures illustrate the proximity of respective feedlots to cattle, abattoirs and commodities. These figures also are influenced by the differences in average daily gain between long fed cattle and domestic cattle, number and type of commodities used in rations (high grain versus high roughage). These results also clearly show the effect of the drought (grain and available cattle supply) and high grain prices on the industry in particular during the latter half of 2007 and early 2008, where higher energy usage figures were recorded. Feedlot G is a smaller feedlot and therefore is able to source cattle and feed locally. This is reflected in lower indirect energy costs.

5.2 Total direct energy usage

Figure 20 to Figure 32 inclusive present the monthly total direct energy use for the seven feedlots from March 2007 to February 2008. Total energy usage is the combination of water supply, feed management (processing and delivery), cattle washing (where this practice is undertaken), administration and minor activities uses such as repairs and maintenance and cattle management. The usage for the respective activities was standardised per kg HSCW gain and per head on feed for the respective month.

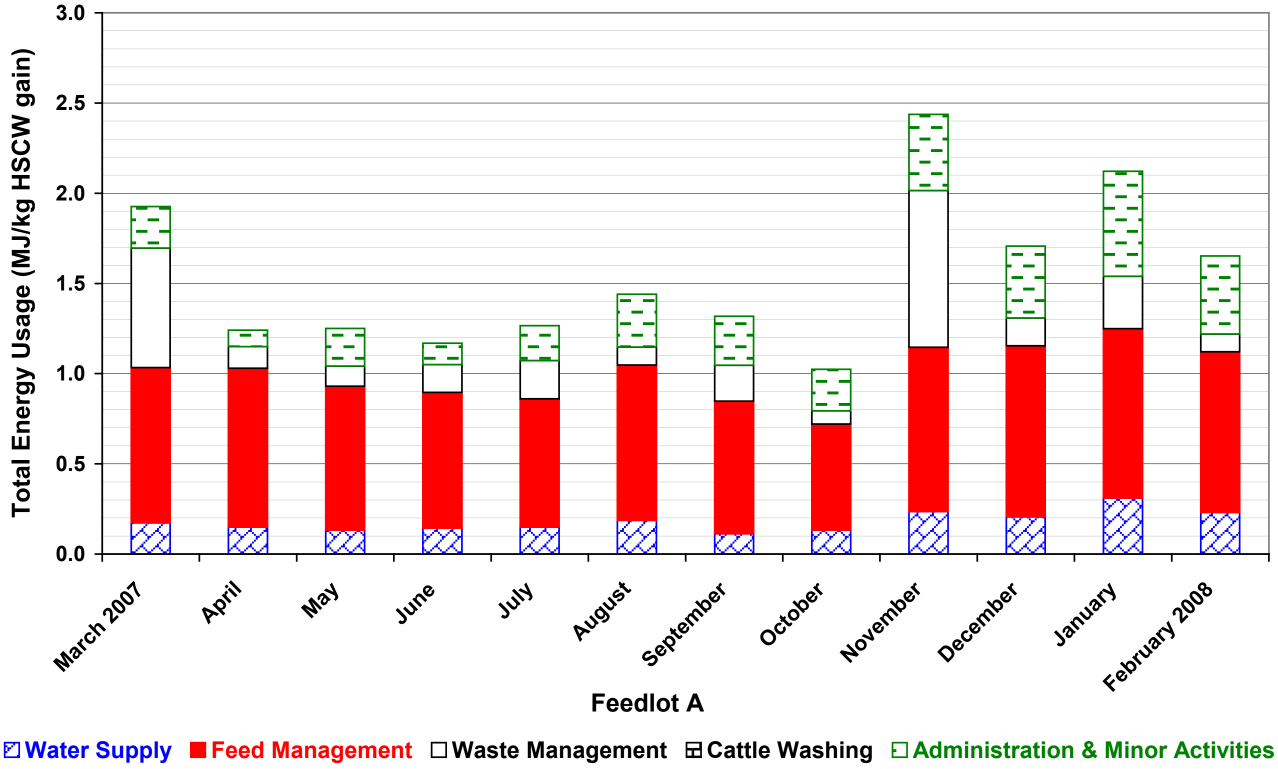


Figure 20 – Monthly total energy usage at Feedlot A (MJ/kg HSCW gain)

Figure 20 shows the total monthly energy usage at Feedlot A for the period March 2007 to February 2008. At Feedlot A, the total monthly energy use ranges from 1.0 to 2.4MJ/kg HSCW gain. The lowest energy usage was measured in spring (October) and the highest in the following month, November. In months where pen cleaning only is undertaken, feed management is the single largest consumer of energy in the feedlot as expected and contributed 0.6 to 0.95 MJ/kg HSCW gain or in the order of 50 % of total usage. In March and November waste management energy usage contributed 0.66 MJ/kg HSCW gain (38 %) and 0.87 MJ/kg HSCW gain (39 %) of total energy usage respectively. Typically, waste management contributes 18 % of total energy usage. Water supply contributed an average of 0.18 L/kg HSCW gain or around 12 % of total usage. No cattle were washed during the study period at this feedlot. Administration and minor activities (20 %) contribute the remaining usage. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

Figure 21 shows the total monthly energy usage at Feedlot A on a MJ/head on feed basis for the period March 2007 to February 2008.

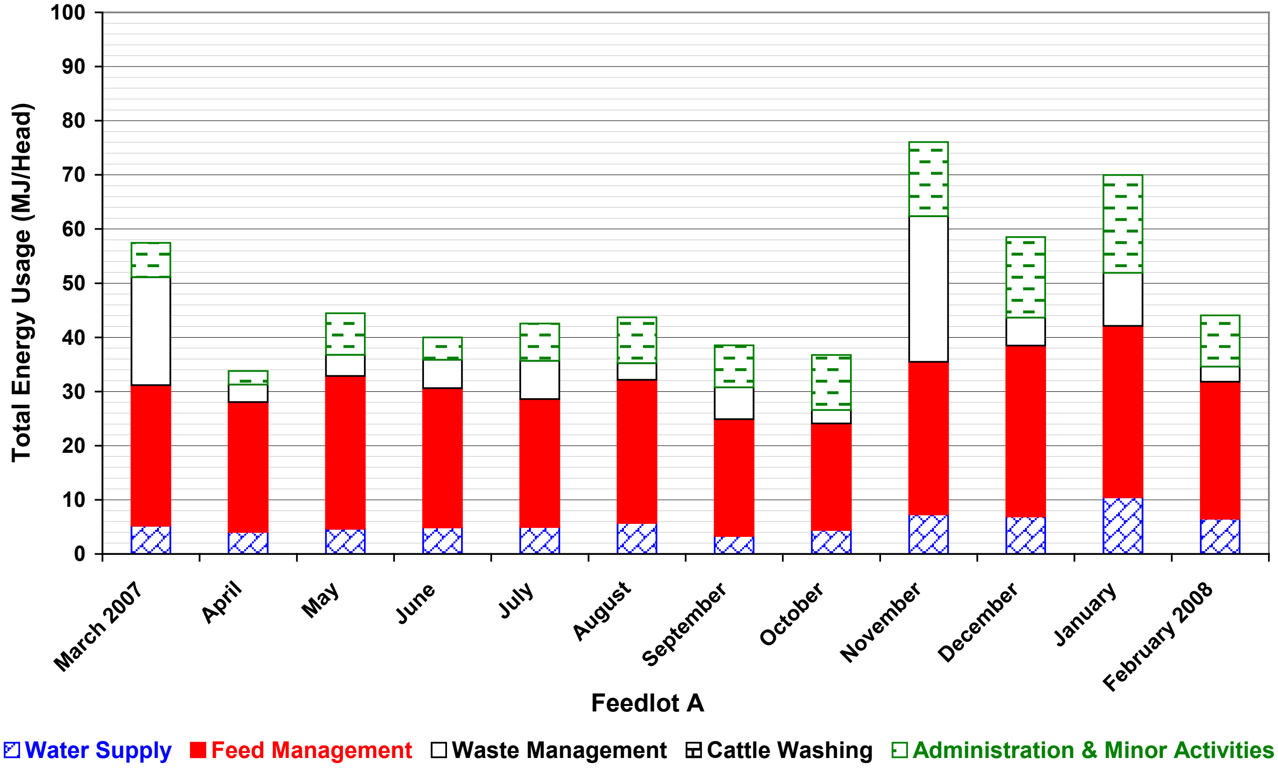


Figure 21 – Monthly total energy usage at Feedlot A (MJ/head on feed/month)

At Feedlot A, the total monthly energy use ranges from 32 to 76 MJ/head on feed/month. The total energy usage for the year is 585 MJ/head on feed. This compares with the lower end of the range of 450 – 1300 MJ/head on feed/yr found by Davis and Watts (2006). In months where pen cleaning only is undertaken, feed management is the single largest consumer of energy in the feedlot. The effect of lower head on feed from November is evident with higher energy consumption per head when compared to previous months. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

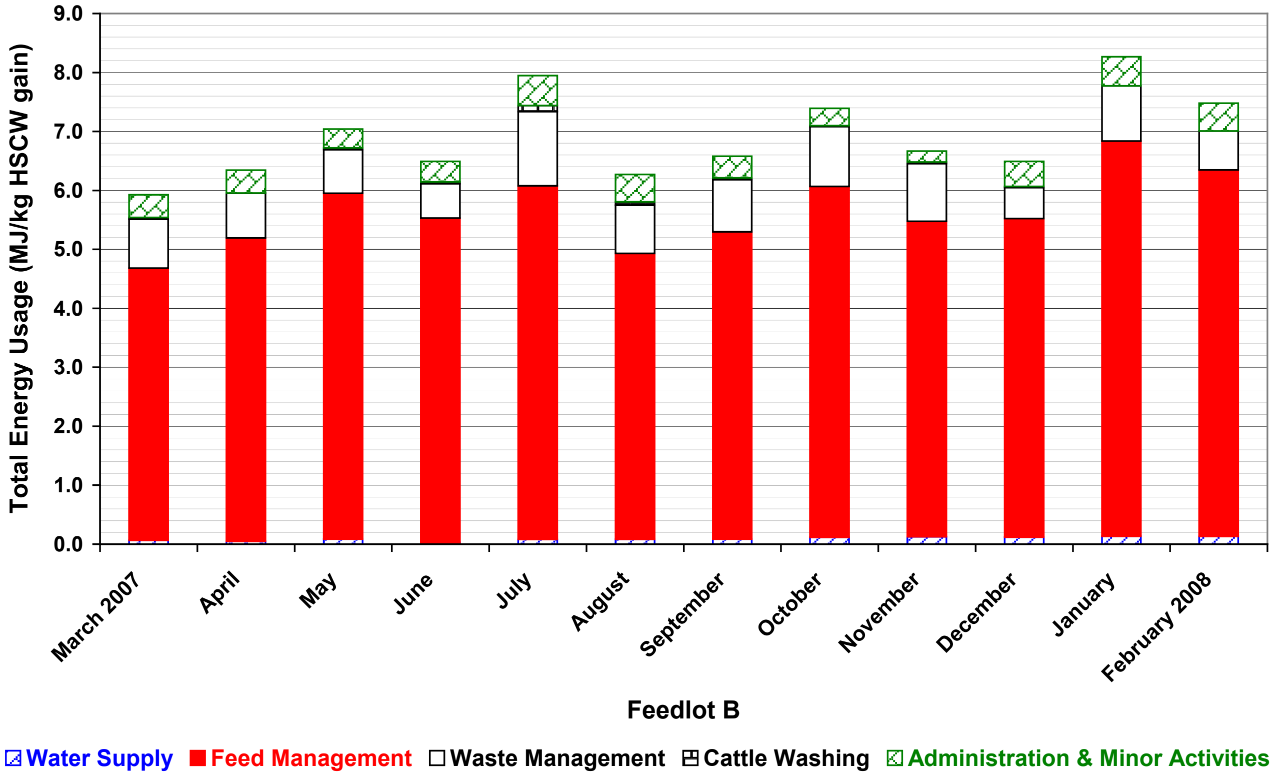


Figure 22 – Monthly total energy usage at Feedlot B (MJ/kg HSCW gain)

Figure 22 shows the total monthly energy usage at Feedlot B for the period March 2007 to February 2008. At Feedlot B, the total monthly energy use ranges from 6.0 to 8.3 MJ/kg HSCW gain. The lowest energy usage was measured in March and the highest in January 2008. Feed management is the single largest consumer of energy in the feedlot as expected and contributed 4.85 to 6.7 MJ/kg HSCW gain or in the order of 80 % of total usage. Waste management energy usage contributed between 0.59 MJ/kg HSCW gain (9 %) and 1.26 MJ/kg HSCW gain (16 %) of total energy usage. On average, waste management is 12% of the total energy usage. Water supply contributed an average of 0.09 L/kg HSCW gain or around 2 % of total usage. Cattle washing contributed between 0.02 MJ/kg HSCW gain (0.3 %) and 0.1 MJ/kg HSCW gain (1 %) of total energy usage. The energy consumed in cattle washing is directly related to the volume of water used. Administration and minor activities (5 %) contribute the remaining usage. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

Figure 23 shows the total monthly energy usage at Feedlot B on a MJ/head on feed basis for the period March 2007 to February 2008.

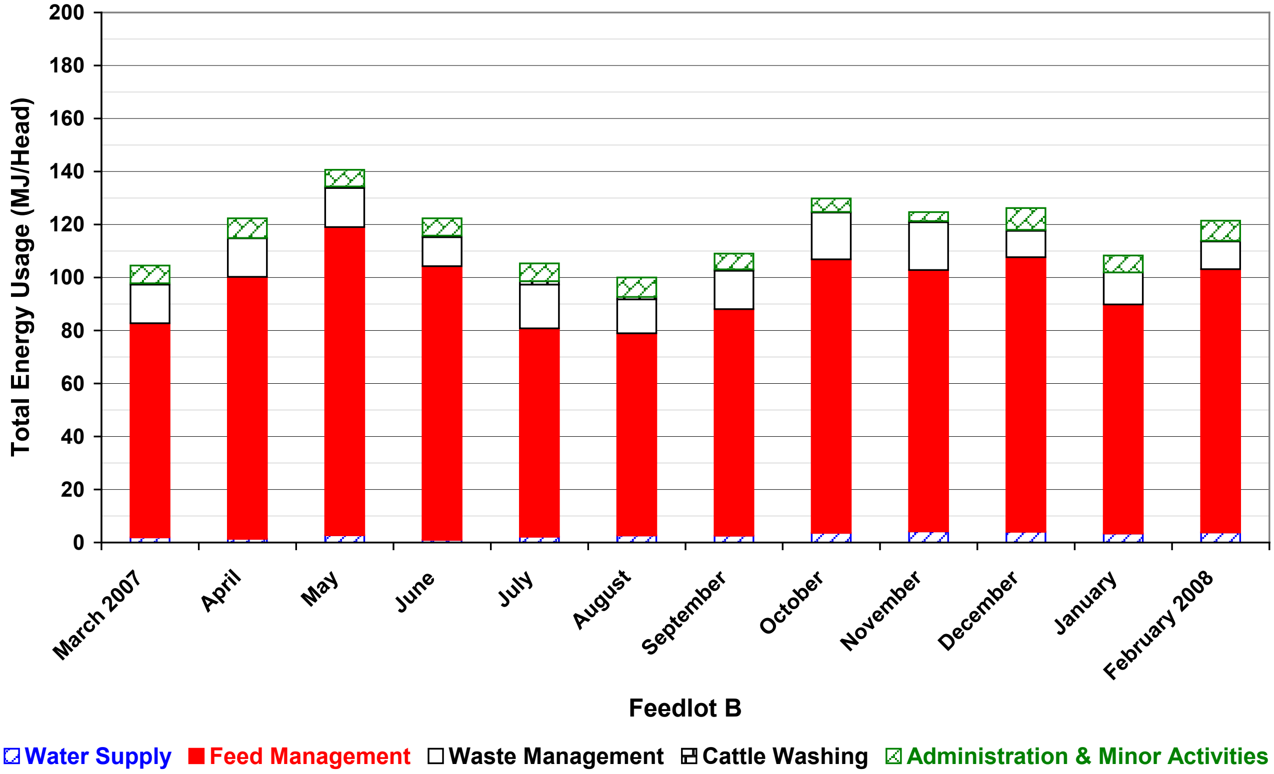


Figure 23 – Monthly total energy usage at Feedlot B (MJ/head on feed/month)

At Feedlot B, the total monthly energy use ranges from 100 to 141 MJ/head on feed/month. The total energy usage for the year is 1415 MJ/head on feed. This is a higher figure than the 1300 MJ/head on feed maximum recorded by Davis and Watts (2006). Feed management is the single largest consumer of energy in the feedlot. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

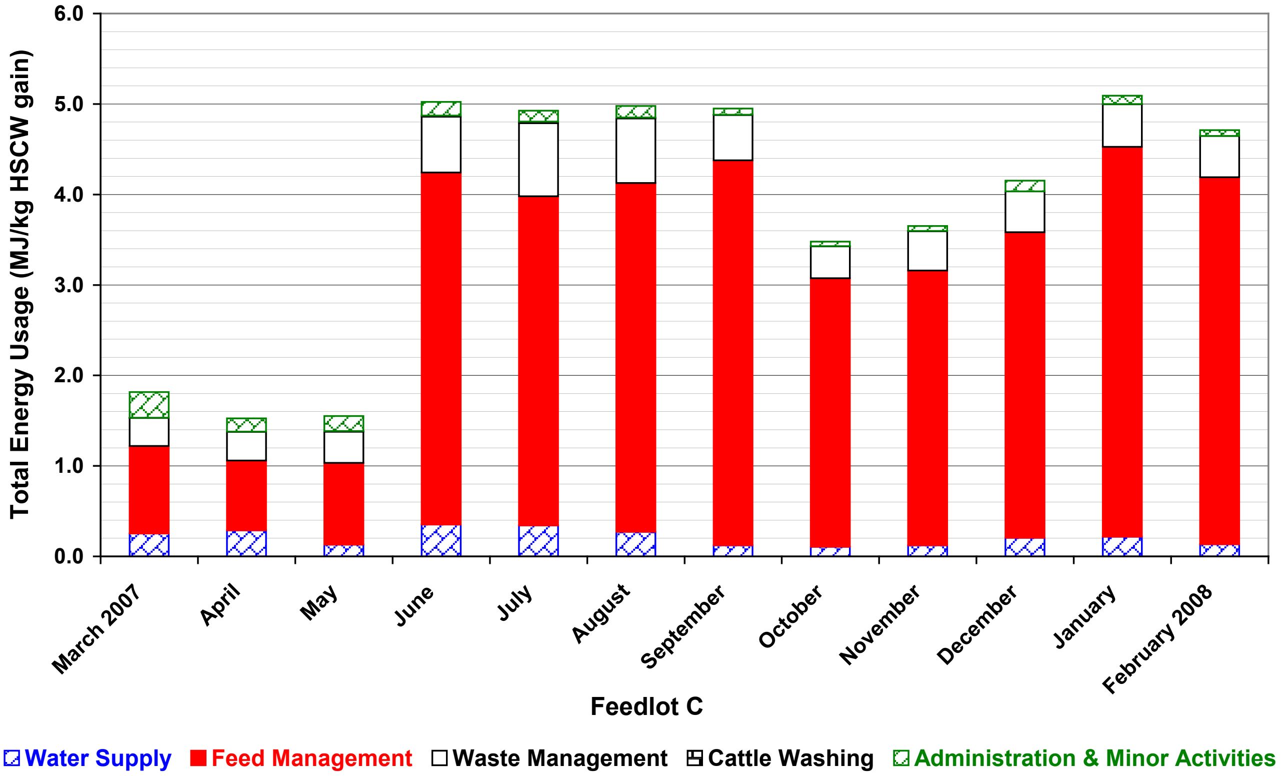


Figure 24 – Monthly total energy usage at Feedlot C (MJ/kg HSCW gain)

Figure 24 shows the total monthly energy usage at Feedlot C for the period March 2007 to February 2008. At Feedlot C, for months March to May the total monthly energy use ranged from 1.5 to 1.9 MJ/kg HSCW gain whilst for June to February, the total monthly energy use ranged from 3.4 to 5.1MJ/kg HSCW gain. Commissioning of a steam flaking feed processing system in June 2007, accounts for the increased total energy usage. Feed management is the largest single consumer of energy in the feedlot. For the period, March to May feed management contributed 0.8 to 1 MJ/kg HSCW gain or in the order of 42 % of total usage. For the period, June to July feed management contributed 2.9 to 4.3 MJ/kg HSCW gain or in the order of 80 % of total usage. Waste management energy usage contributed an average 0.32 MJ/kg HSCW gain (23 %) for March to May, whilst from June to February it averaged 0.53 MJ/kg HSCW gain or 12 % of total energy usage.

Water supply contributed an average of 0.21 MJ/kg HSCW gain or around 5 % of total usage with steam flaking and 16% with tempering only. Cattle washing contributed an average of 0.02 MJ/kg HSCW gain (<1 %) of total energy usage. The energy consumed in cattle washing is directly related to the volume of water used. Administration and minor activities (15 %) contribute the remaining usage during March to May and 2% for the period June to February. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

Figure 24 shows the total monthly energy usage at Feedlot B on a MJ/head on feed basis for the period March 2007 to February 2008.

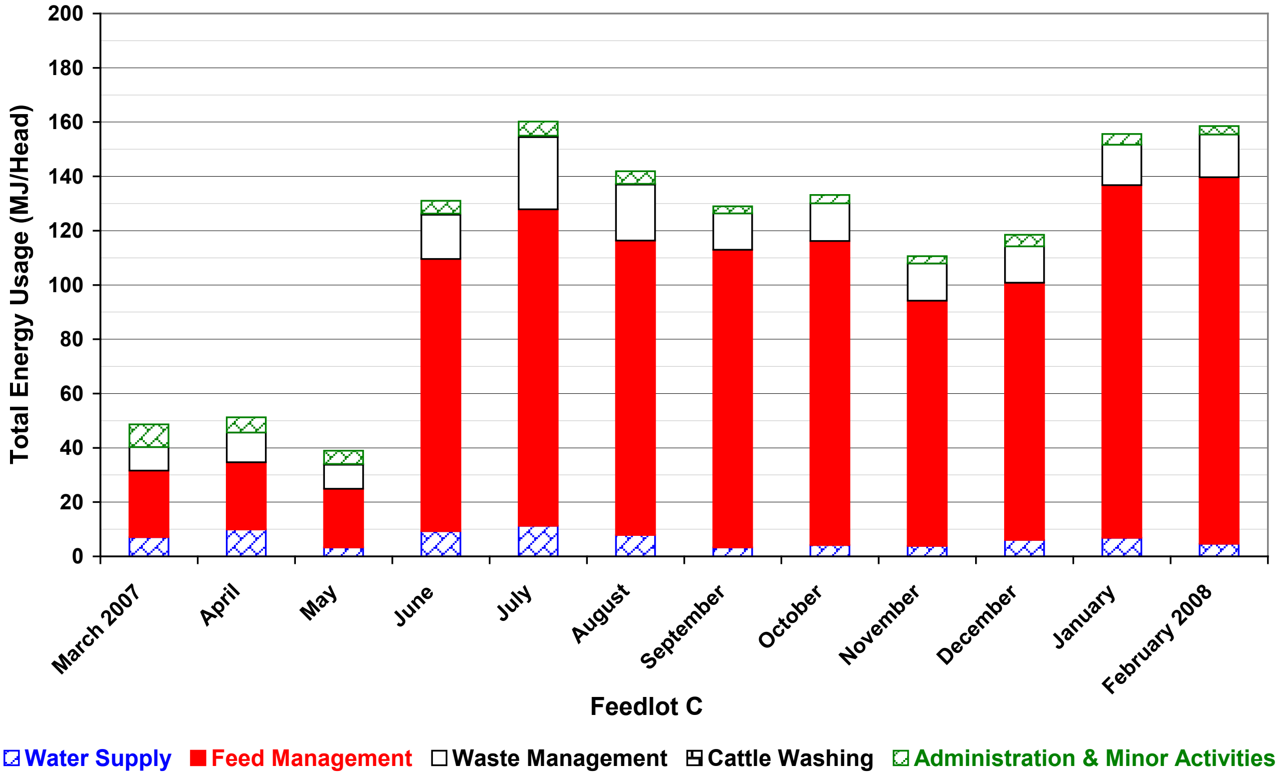


Figure 25 – Monthly total energy usage at Feedlot C (MJ/head on feed/month)

At Feedlot C, the total monthly energy use ranged from 40 to 51 MJ/head on feed/month when grain was tempered only. This increased to a minimum of 110 to a maximum of 160 MJ/head on feed when the steam flaking unit was in use. The total energy usage for the year is 1377 MJ/head on feed. Feed management is the single largest consumer of energy in the feedlot. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

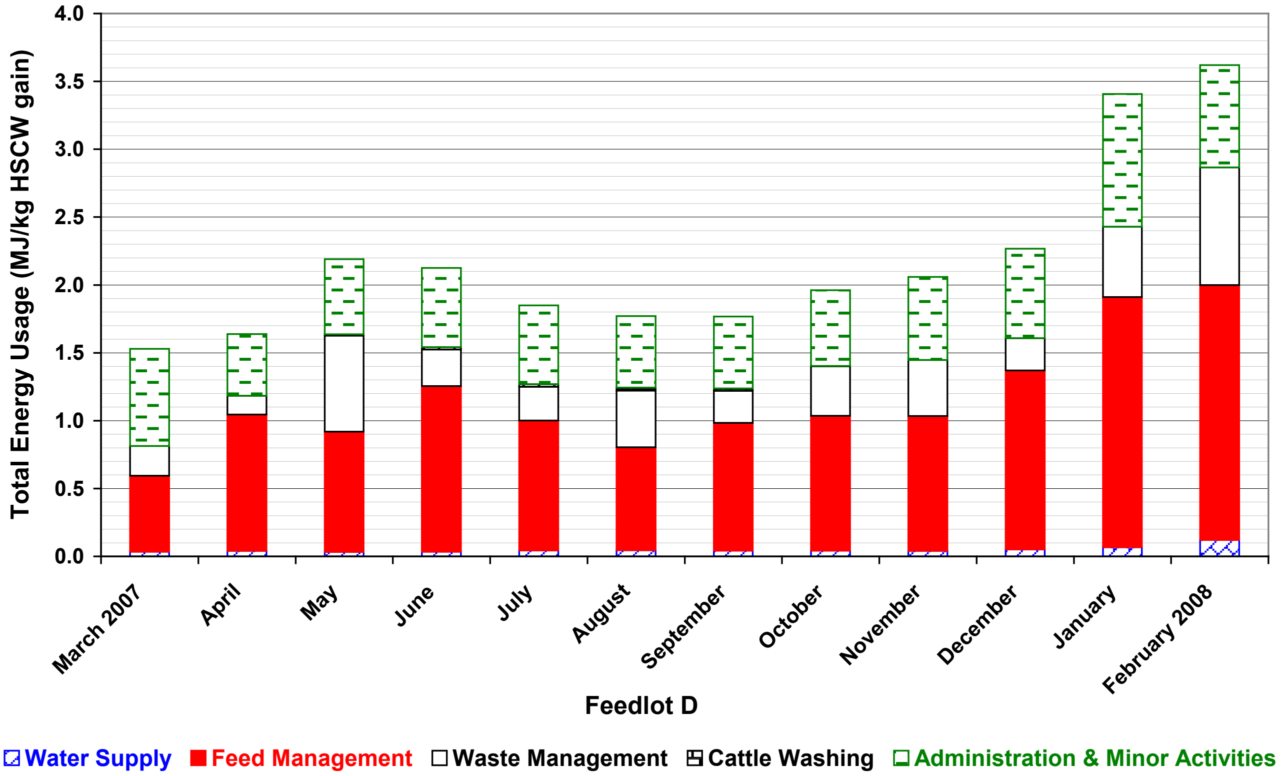


Figure 26 – Monthly total energy usage at Feedlot D (MJ/kg HSCW gain)

Figure 26 shows the total monthly energy usage at Feedlot D for the period March 2007 to February 2008. At Feedlot D, the total monthly energy use ranges from 1.5 to 2.6 MJ/kg HSCW gain. The lowest energy usage was measured in March and the highest in January 2008. Feed management is the single largest consumer of energy in the feedlot as expected and contributed 0.56 to 1.88 MJ/kg HSCW gain or in the order of 60 % of total usage. Waste management energy usage contributed between 0.14 MJ/kg HSCW gain (13 %) and 0.87 MJ/kg HSCW gain (31 %) of total energy usage. On average, waste management is 25% of the total energy usage. Water supply contributed an average of 0.05 MJ/kg HSCW gain or around 3 % of total usage. Cattle washing contributed an average of 0.02 MJ/kg HSCW gain (1.5 %) of total energy usage. The energy consumed in cattle washing is directly related to the volume of water used. Administration and minor activities contribute in the order of 10% of the total energy usage. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

Figure 27 shows the total monthly energy usage at Feedlot D on a MJ/head on feed/month basis for the period March 2007 to February 2008.

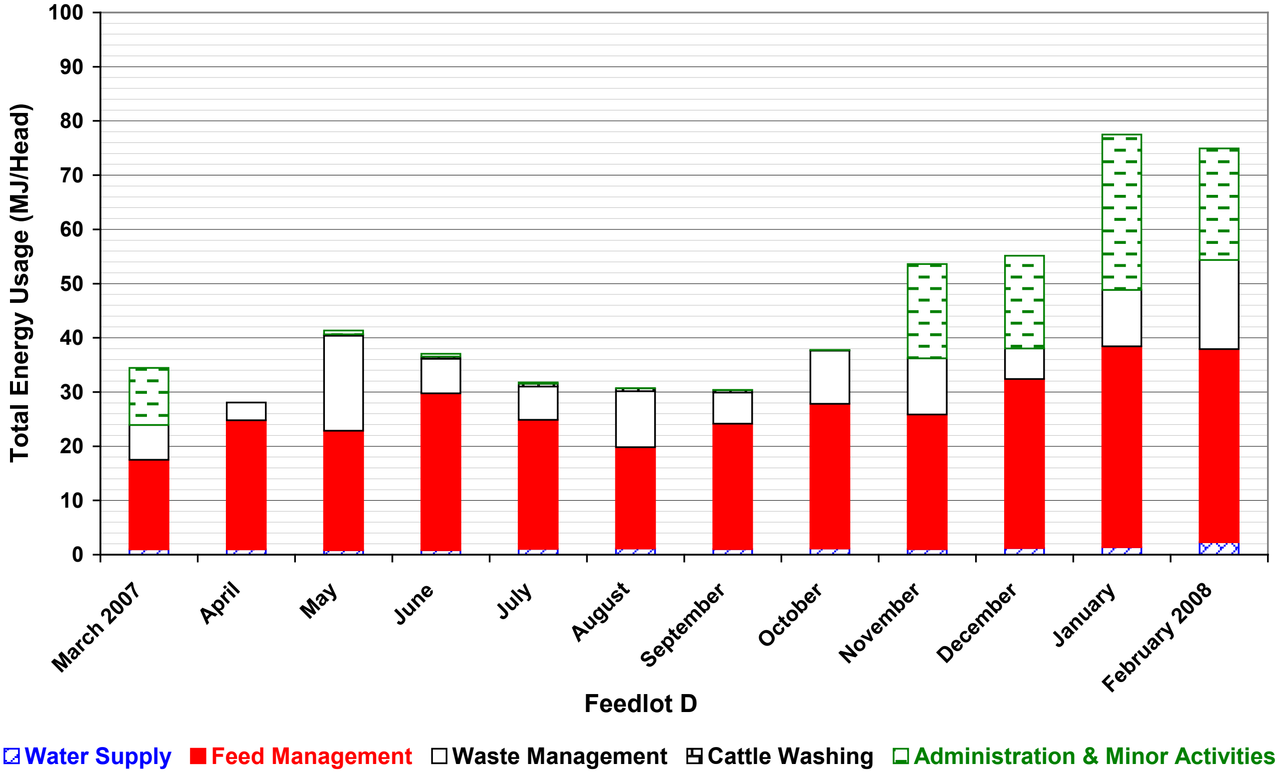


Figure 27 – Monthly total energy usage at Feedlot D (MJ/head on feed/month)

At Feedlot D, the total monthly energy use ranges from 28 to 78 MJ/head on feed/month. The total energy usage for the year is 532 MJ/head on feed. Feed management is the single largest consumer of energy in the feedlot followed by administration and minor activities (note this includes repairs and maintenance and residence). Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

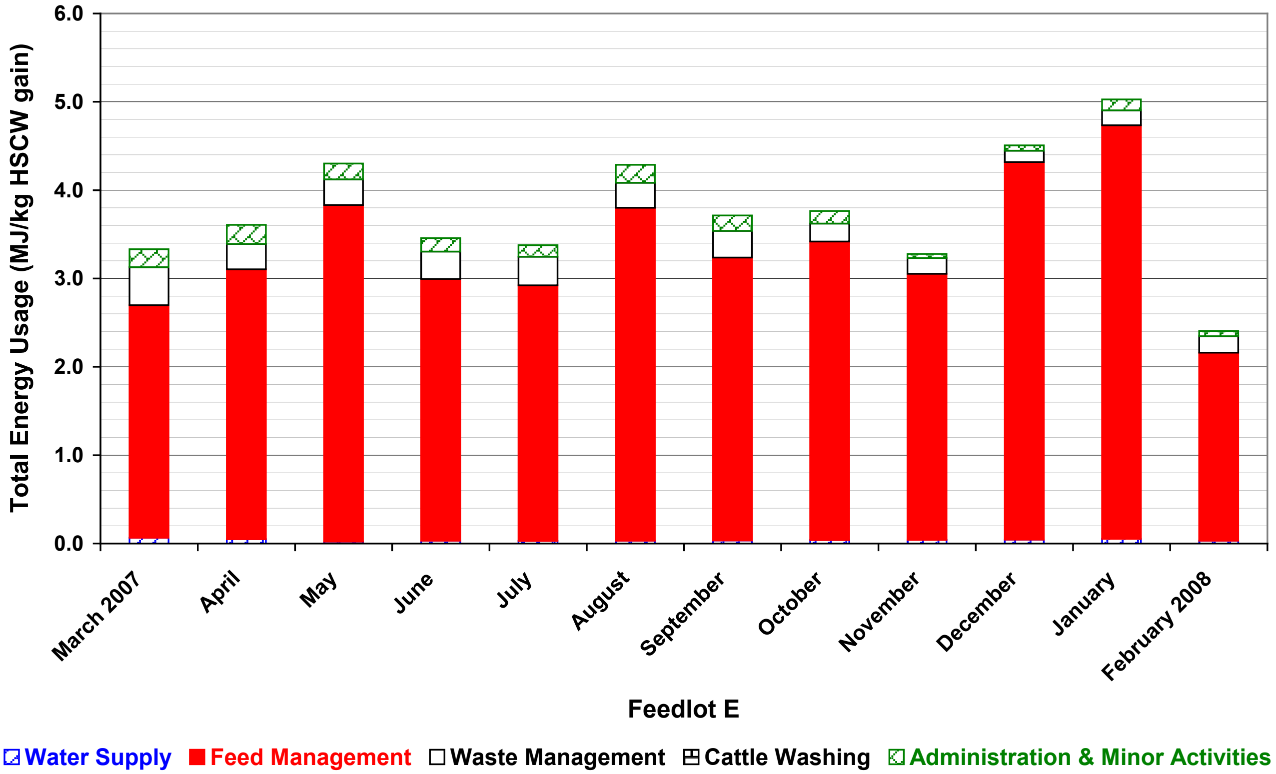


Figure 28 – Monthly total energy usage at Feedlot E (MJ/kg HSCW gain)

Figure 28 shows the total monthly energy usage at Feedlot E for the period March 2007 to February 2008. At Feedlot E, the total monthly energy use ranges from 2.4 (February 2008) to 5.0 MJ/kg HSCW gain (January 2008). Feed management is the largest single consumer of energy in the feedlot as expected and contributed 2.1 to 4.7 MJ/kg HSCW gain or in the order of 88 % of total usage. Waste management energy usage contributed between 0.13 MJ/kg HSCW gain (3 %) and 0.43 MJ/kg HSCW gain (13 %) of total energy usage, however on average represents 7% of the total energy usage. Water supply contributed an average of 0.04 MJ/kg HSCW gain or around 1 % of total usage. This feedlot does not wash cattle Administration and minor activities contribute in the order of 4% of the total energy usage. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

Figure 36 shows the total monthly energy usage at Feedlot E on a MJ/head on feed/month basis for the period March 2007 to February 2008.

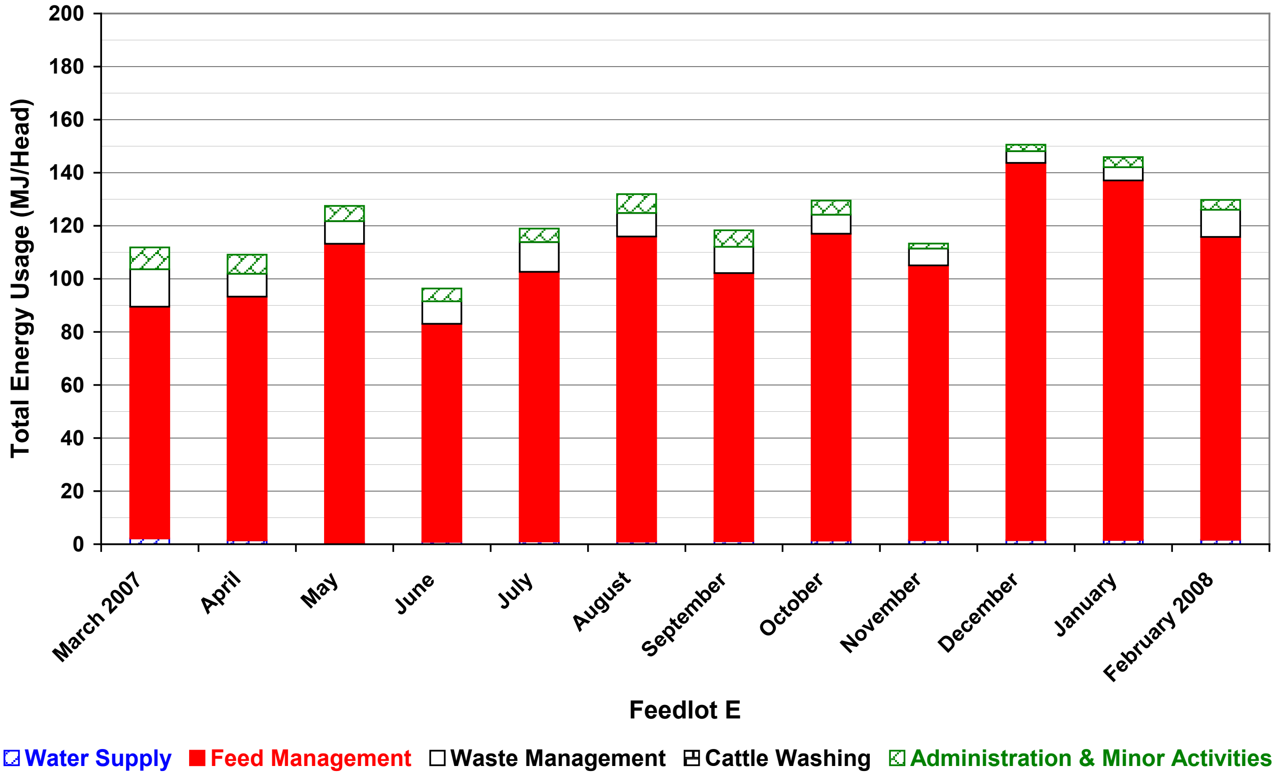


Figure 29 – Monthly total energy usage at Feedlot E (MJ/head on feed/month)

At Feedlot E, the total monthly energy use ranges from 95 to 151 MJ/head on feed/month. The total energy usage for the year is 1483 MJ/head on feed, slightly higher than the maximum figure of 1300 MJ/head on feed recorded by Davis and Watts (2006). Feed management is the single largest consumer of energy in the feedlot. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

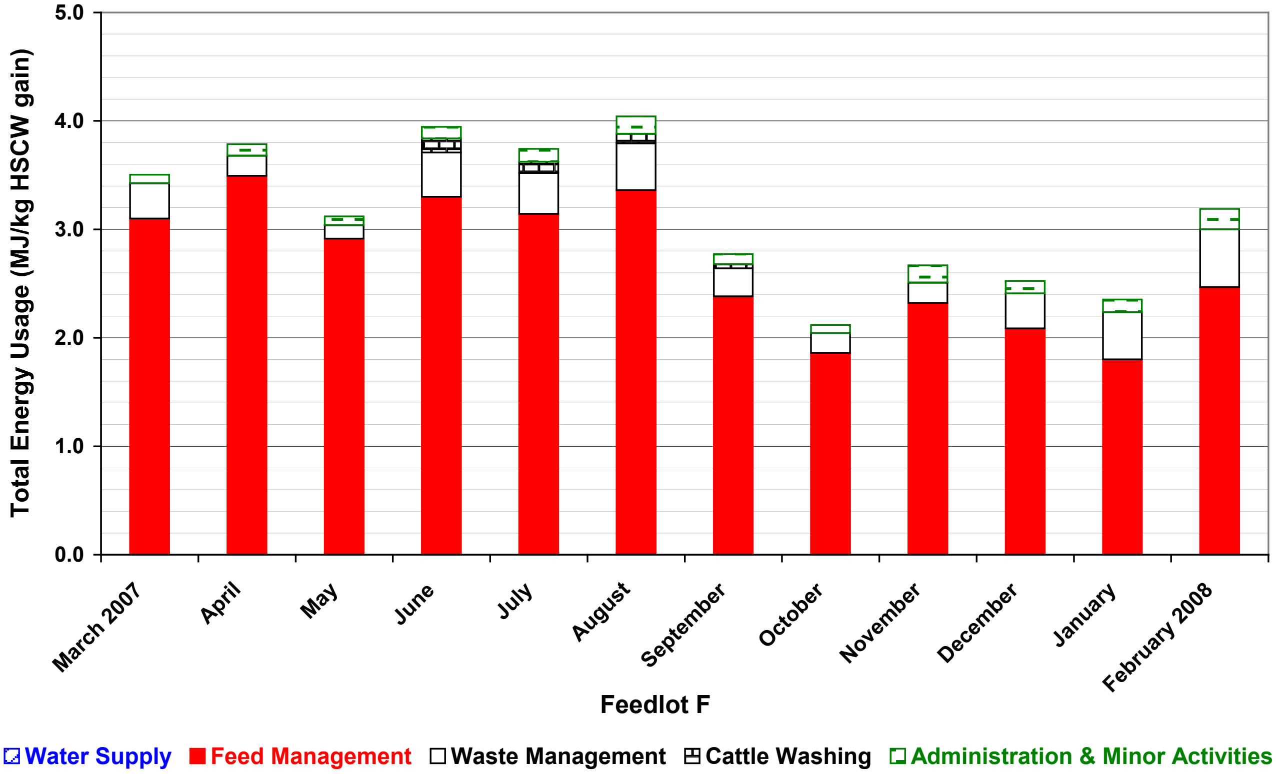


Figure 30 – Monthly total energy usage at Feedlot F (MJ/kg HSCW gain)

Figure 30 shows the total monthly energy usage at Feedlot F for the period March 2007 to February 2008. At Feedlot F, the total monthly energy use ranges from 2.1 (October 2007) to 4.1 MJ/kg HSCW gain (August 2007). Feed management is the largest single consumer of energy in the feedlot as expected and contributed between 1.8 to 3.5 MJ/kg HSCW gain or on average approximately 85 % of total usage. Waste management energy usage contributed between 0.12 MJ/kg HSCW gain (4 %) and 0.54 MJ/kg HSCW gain (17 %) of total energy usage, however on average represents 10% of the total energy usage. Water supply contributed an average of 0.006 MJ/kg HSCW gain or less than 0.2 % of total usage. This feedlot does not wash cattle. Administration and minor activities contribute in the order of 4% of the total energy usage. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

Figure 31 shows the total monthly energy usage at Feedlot F on a MJ/head on feed/month basis for the period March 2007 to February 2008.

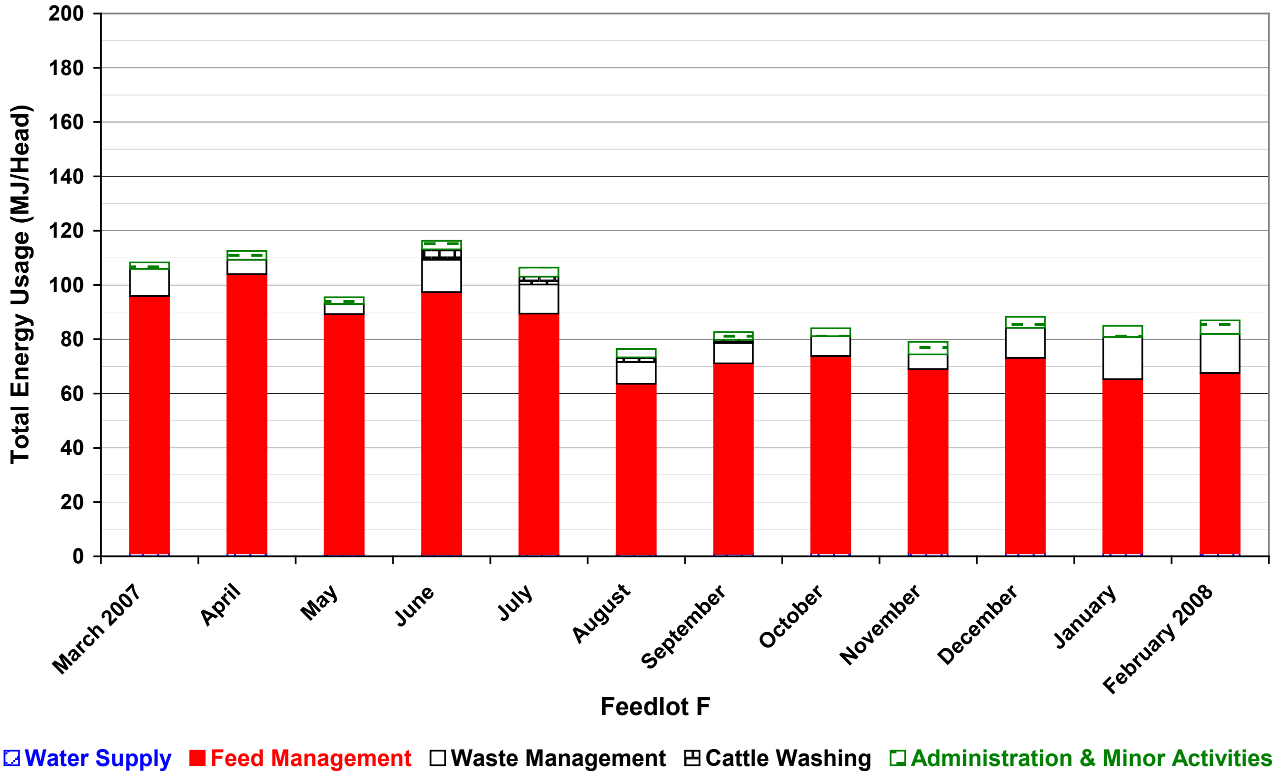


Figure 31 – Monthly total energy usage at Feedlot F (MJ/head on feed/month)

At Feedlot F, the total monthly energy use ranges from 75 to 115 MJ/head on feed/month. The total energy usage for the year is 1121 MJ/head, a figure slightly lower than that recorded by Sweeten et al. (1986) and Davis and Watts (2006). Feed management is the single largest consumer of energy in the feedlot. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

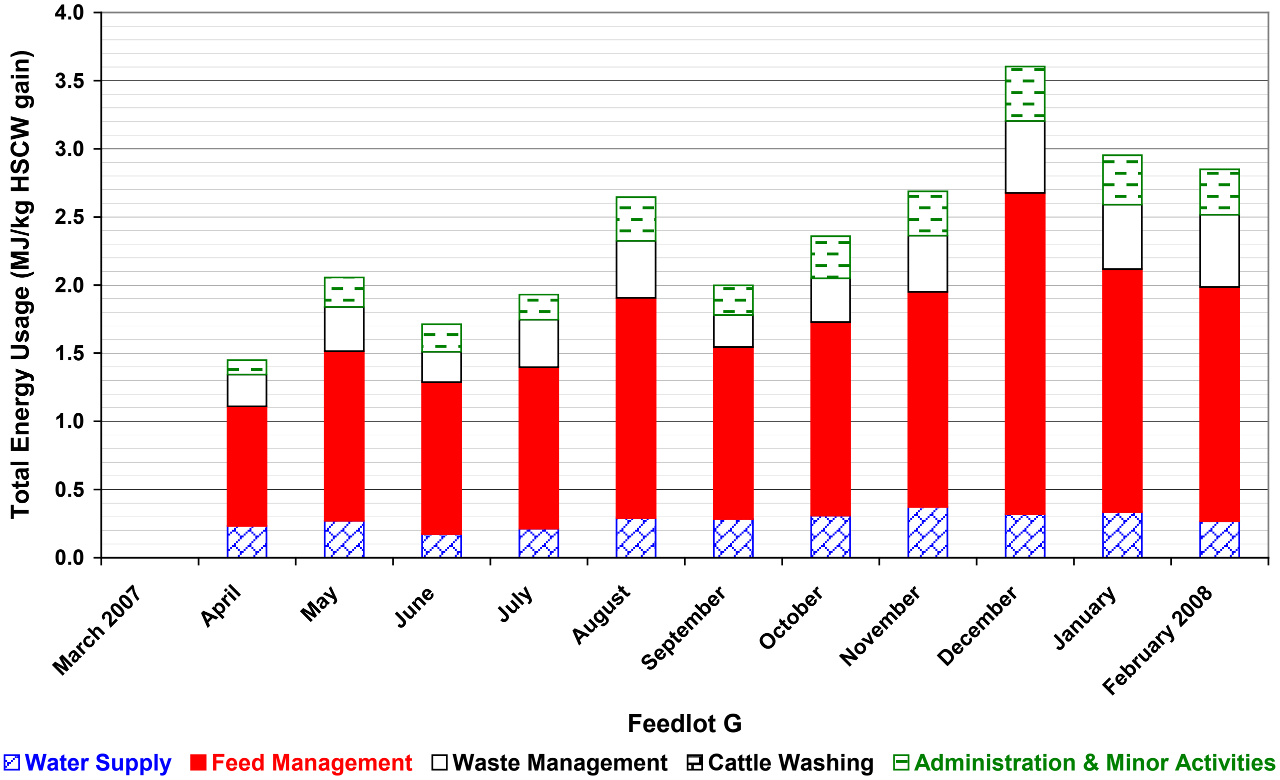


Figure 32 – Monthly total energy usage at Feedlot G (MJ/kg HSCW gain)

Figure 32 shows the total monthly energy usage at Feedlot G for the period March 2007 to February 2008. At Feedlot G, the total monthly energy use ranges from 1.4 (April 2007) to 3.6 MJ/kg HSCW gain (December 2007). Water supply contributed an average of 0.28 MJ/kg HSCW gain or approximately 13 % of total usage. Feed management is the largest single consumer of energy in the feedlot as expected and contributed between 0.88 to 2.4 MJ/kg HSCW gain or on average approximately 55 % of total usage. Waste management energy usage contributed between 0.22 MJ/kg HSCW gain (15 %) and 0.53 MJ/kg HSCW gain (21 %) of total energy usage, however on average represents 18% of the total energy usage. Administration and minor activities contribute in the order of 13% of the total energy usage. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

Figure 33 shows the total monthly energy usage at Feedlot G on a MJ/head on feed/month basis for the period March 2007 to February 2008.

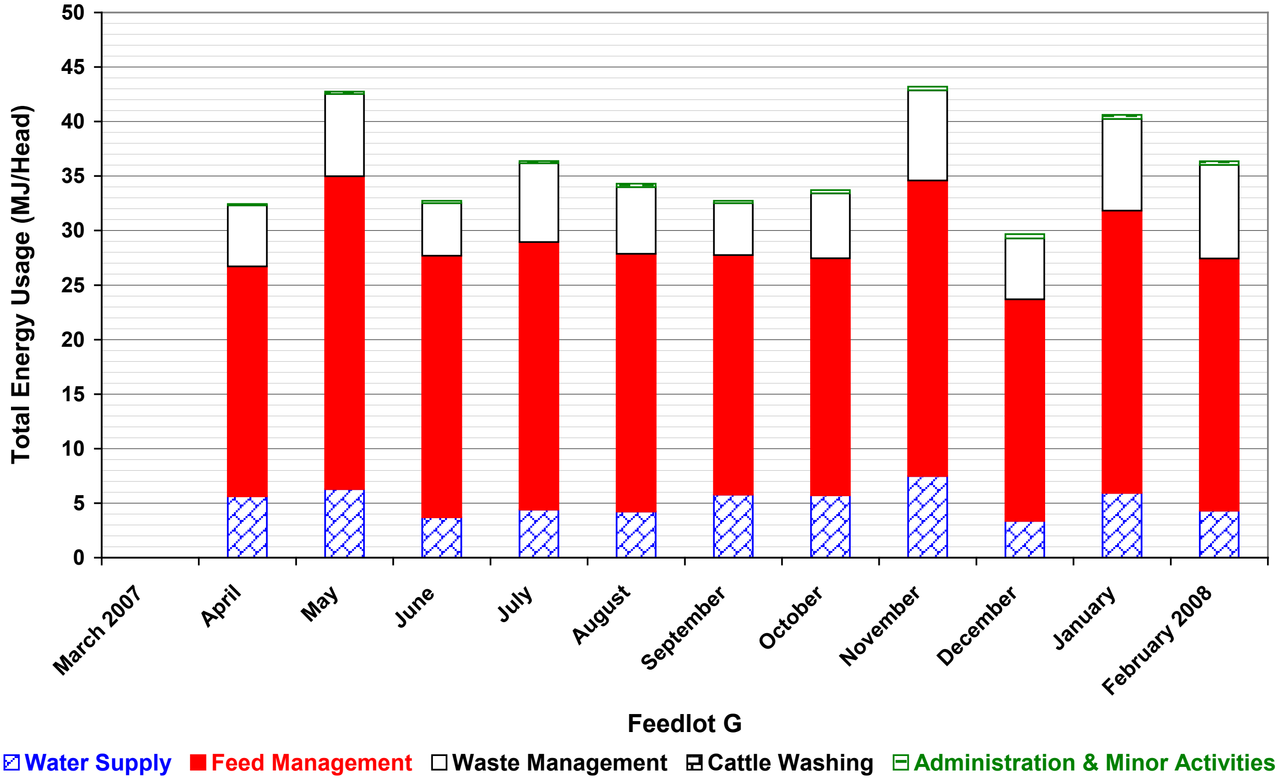


Figure 33 – Monthly total energy usage at Feedlot G (MJ/head on feed/month)

At Feedlot G, the total monthly energy use ranges from 30 to 43 MJ/head on feed/month. The total energy usage for the year is 444 MJ/head. Feed management is the single largest consumer of energy in the feedlot. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

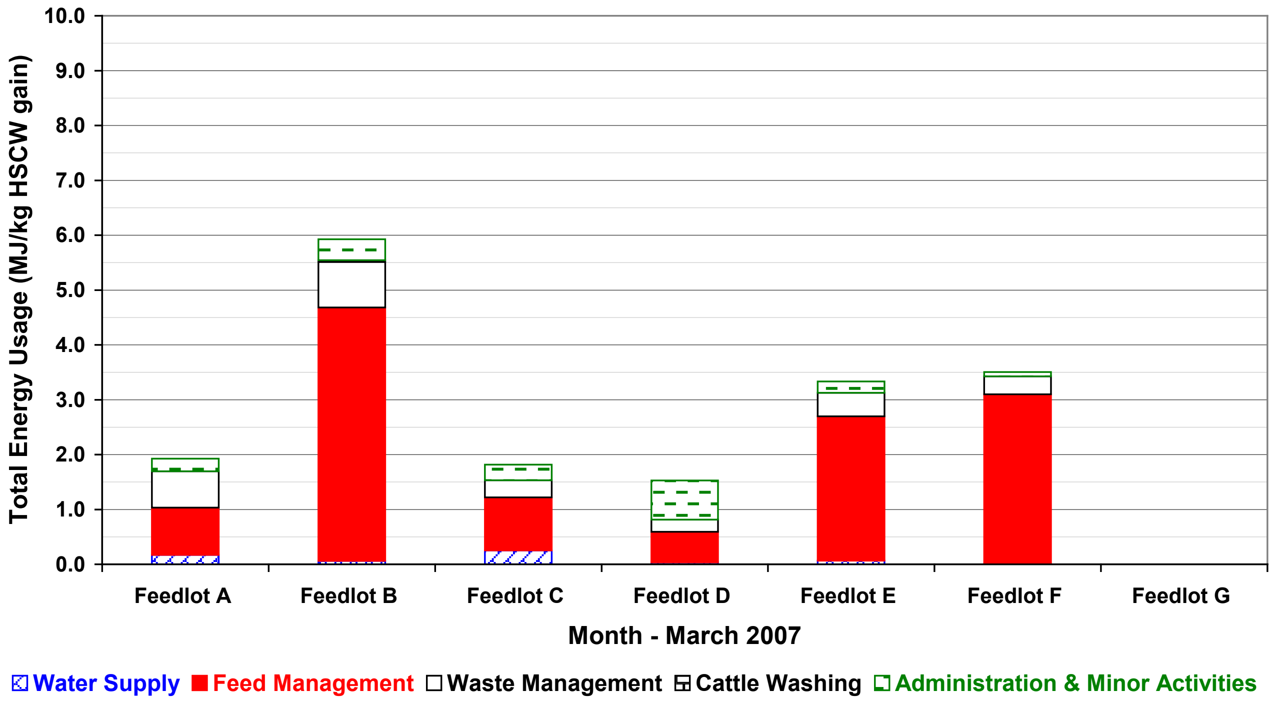


Figure 34 – Total energy usage for March 2007 (MJ/kg HSCW gain)

Figure 34 shows the total energy usage across all feedlots for March 2007. Total monthly energy use ranges from 1.0 to 5.9 MJ/kg HSCW gain and is primarily determined by the type of feed processing system in operation. The lowest energy usage was measured at Feedlot D (tempering only) and the highest at Feedlot B (steam flaking). Total energy usage was not recorded at Feedlot G during March 2007. Water supply energy consumption is dependent on the type of supply and reticulation system. Feedlots may access water from deep bores (Feedlot A) or source water from greater distances (Feedlot C) than feedlots on reticulated supply and /or gravity fed reticulation systems. Water supply energy usage ranged from 0.004 to 0.25 MJ/kg HSCW gain across all feedlots. Feed processing energy usage ranged from 0.56 (Feedlot D) to 4.6 (Feedlot B) MJ/kg HSCW gain. Waste management energy usage ranged from 0.22 to 0.83 MJ/kg HSCW gain. Administration and minor activities energy usage was found to range from 0.08 to 0.39 MJ/kg HSCW gain. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

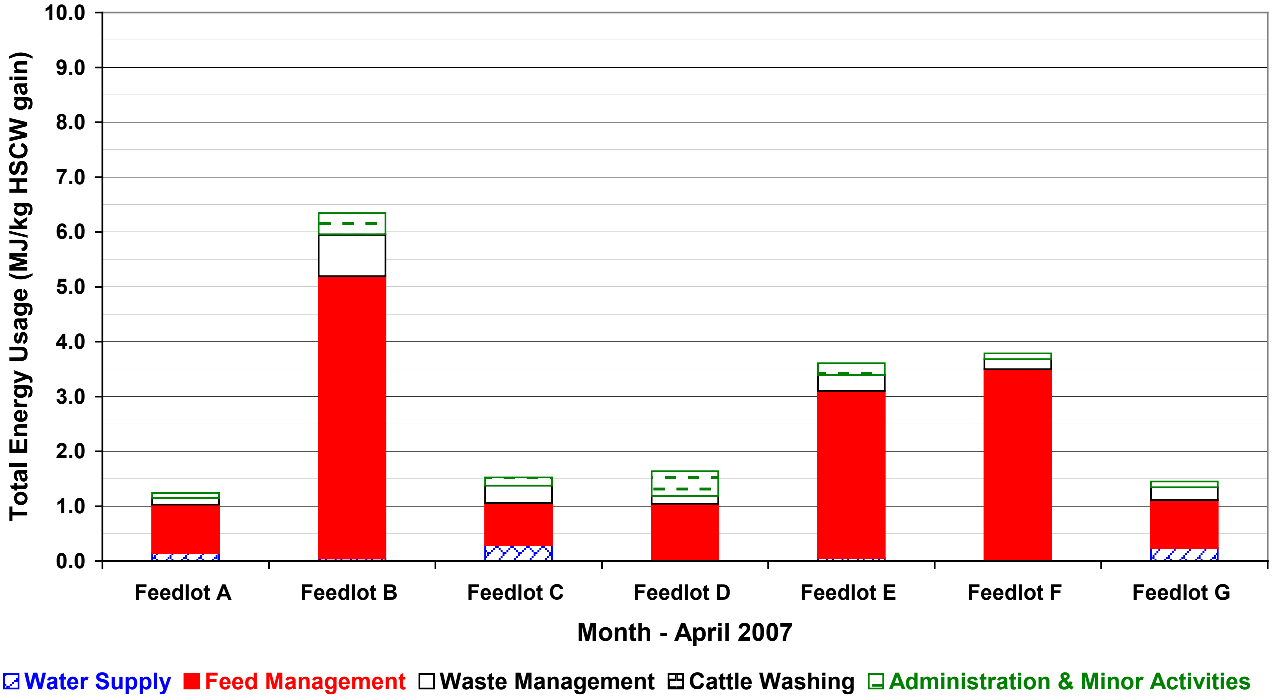


Figure 35 – Total energy usage for April 2007 (MJ/kg HSCW gain)

Figure 35 shows the total energy usage across all feedlots for April 2007. Total monthly energy use ranges from 1.25 to 6.4 MJ/kg HSCW gain, similar levels to March. The lowest energy usage was measured at feedlots A, C, D and G (reconstitution and tempering) with higher energy usage at feedlots B, E and F (steam flaking). Water supply energy consumption is dependent on the type of supply and reticulation system. Water supply energy usage ranged from 0.005 MJ/kg HSCW gain at Feedlot F to 0.29 MJ/kg HSCW gain at Feedlot C. Feed processing energy usage ranged from 0.77 (Feedlots A and G) to 5.15 (Feedlot B) MJ/kg HSCW gain. Waste management energy usage ranged from 0.12 to 0.76 MJ/kg HSCW gain. Administration and minor activities energy usage were found to range from 0.01 to 0.39 MJ/kg HSCW gain, similar levels when compared to March. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

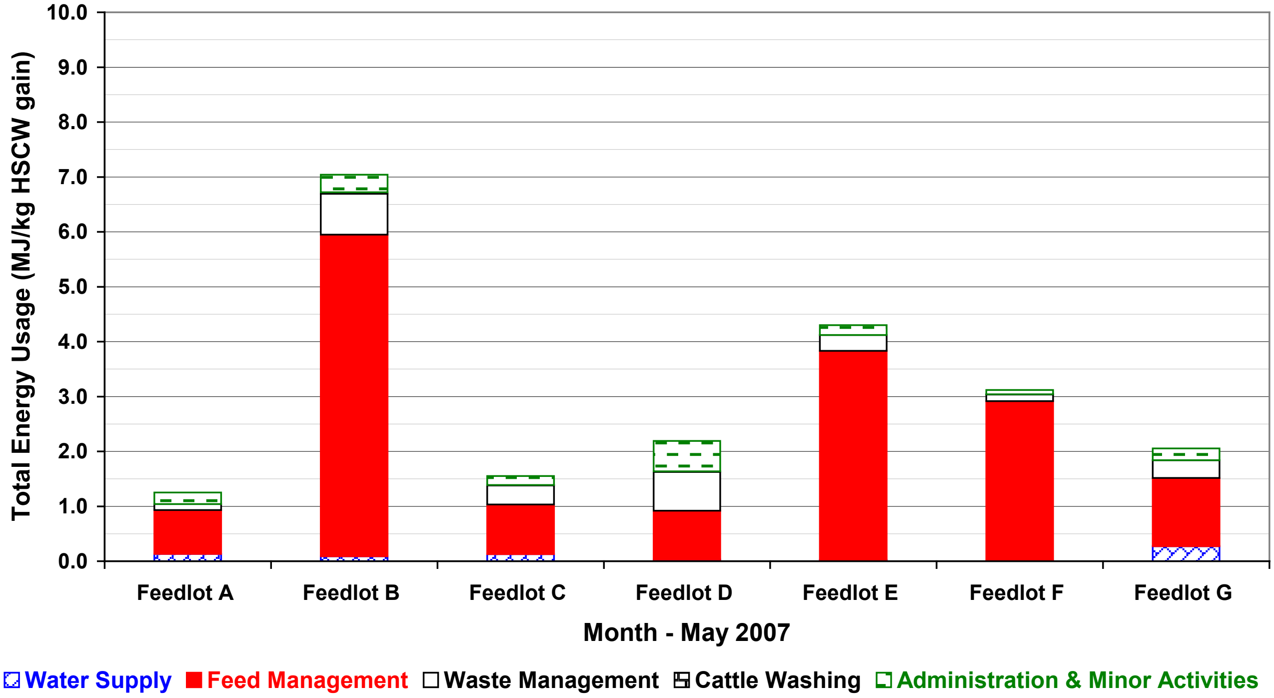


Figure 36 – Total energy usage for May 2007 (MJ/kg HSCW gain)

Figure 36 shows the total energy usage across all feedlots for May 2007. Total monthly energy use ranged from 1.25 to 7.0 MJ/kg HSCW gain. Feedlots B, D, E and G have slightly higher total energy usage then previously measured. The lowest energy usage was measured at feedlots A, C, D and G (reconstitution and tempering) with higher energy usage at feedlots B, E and F (steam flaking). For May 2007, water supply energy usage ranged from 0.004 MJ/kg HSCW gain at Feedlot F to 0.27 MJ/kg HSCW gain at Feedlot G. Feed processing energy usage ranged from 0.80 (Feedlot A) to 5.8 (Feedlot B) MJ/kg HSCW gain. Waste management energy usage ranged from 0.11 to 0.74 MJ/kg HSCW gain, a similar range to April. Energy usage within administration and minor activities was found to range from 0.08 to 0.32 MJ/kg HSCW gain. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

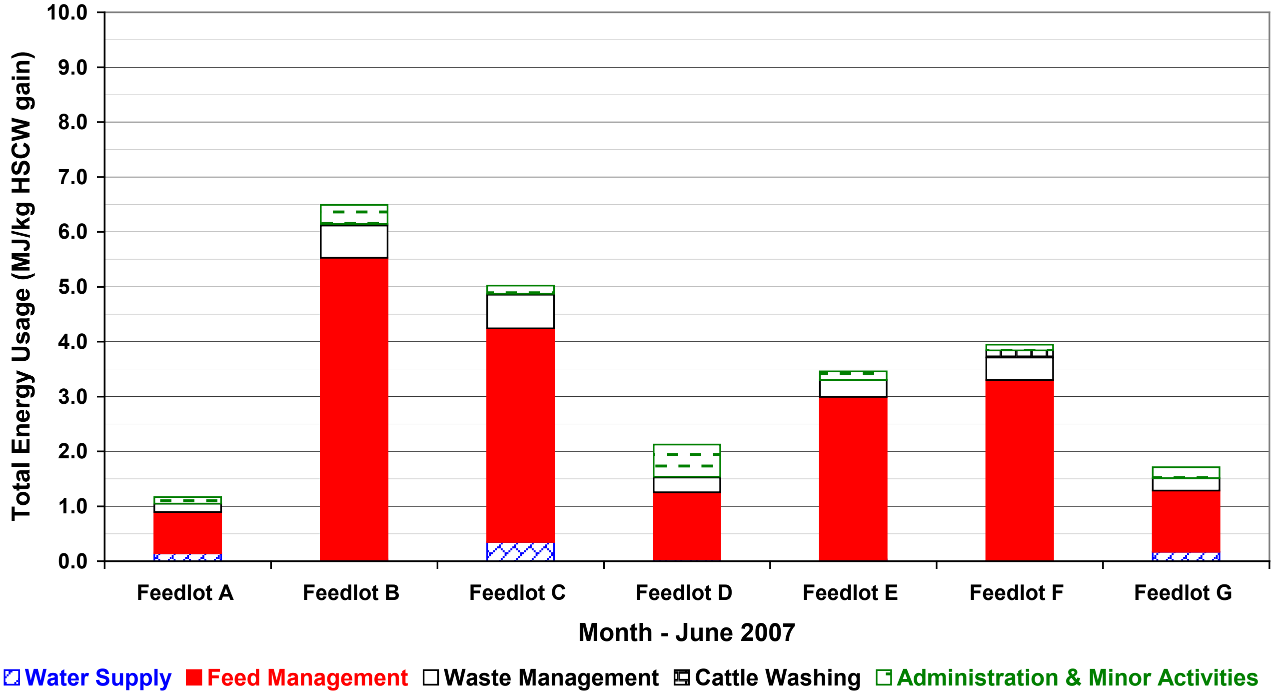


Figure 37 – Total energy usage for June 2007 (MJ/kg HSCW gain)

Figure 37 shows the total energy usage across all feedlots for June 2007. Total monthly energy use ranged from 1.15 to 6.5 MJ/kg HSCW gain. The impact of an energy dominant feed processing system on total energy usage can be seen with Feedlot C. In June a steam flaking system was commissioned and hence energy usage has increased considerably from 1.3 to 4.7 MJ/kg HSCW gain. Water supply energy usage ranged from 0.007 MJ/kg HSCW gain at Feedlot F to 0.35 MJ/kg HSCW gain at Feedlot C. Feed processing energy usage ranged from 0.75 (Feedlot A) to 5.8 (Feedlot B) MJ/kg HSCW gain. Waste management energy usage ranged from 0.11 to 0.74 MJ/kg HSCW gain, a similar range to April. Administration and minor activities energy usage was found to range from 0.10 to 0.35 MJ/kg HSCW gain. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

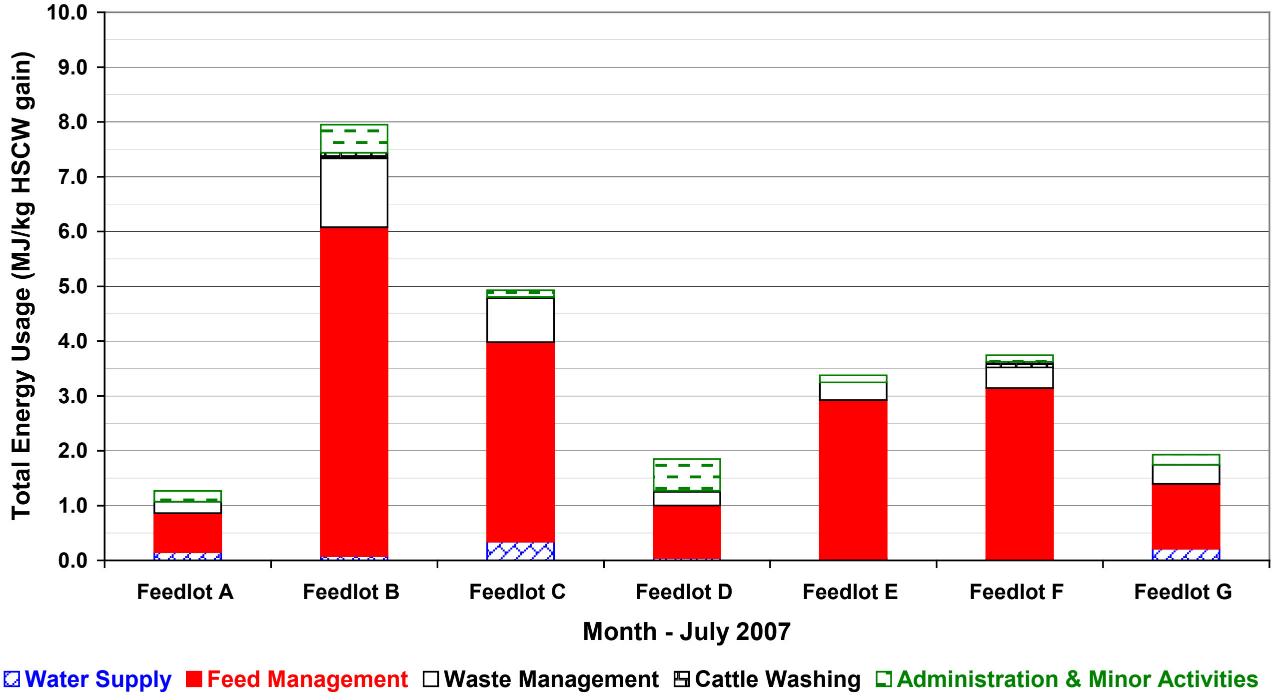


Figure 38 – Total energy usage for July 2007 (MJ/kg HSCW gain)

Figure 38 shows the total energy usage across all feedlots for July 2007. Total monthly energy use ranged from 1.25 to 8.0 MJ/kg HSCW gain. Feedlot B has a higher total energy usage than previously measured, whilst Feedlot D has a slightly lower total energy usage than previously measured. The lowest energy usage was measured at Feedlots A, D and G (reconstitution and tempering) with higher energy usage at feedlots B, C, E and F (steam flaking). For July 2007, water supply energy usage ranged from 0.01 MJ/kg HSCW gain at Feedlot F to 0.34 MJ/kg HSCW gain at Feedlot C. Feed management energy usage ranged from 0.71 (Feedlot A) to 6.0 (Feedlot B) MJ/kg HSCW gain. Waste management energy usage ranged from 0.21 to 1.26 MJ/kg HSCW gain, a higher range than previously measured. Cattle washing energy usage ranges from 0.02 MJ/kg HSCW gain at Feedlots C and D to 0.1 MJ/kg HSCW gain at Feedlot B. Energy usage within administration and minor activities was found to range from 0.12 to 0.51 MJ/kg HSCW gain. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

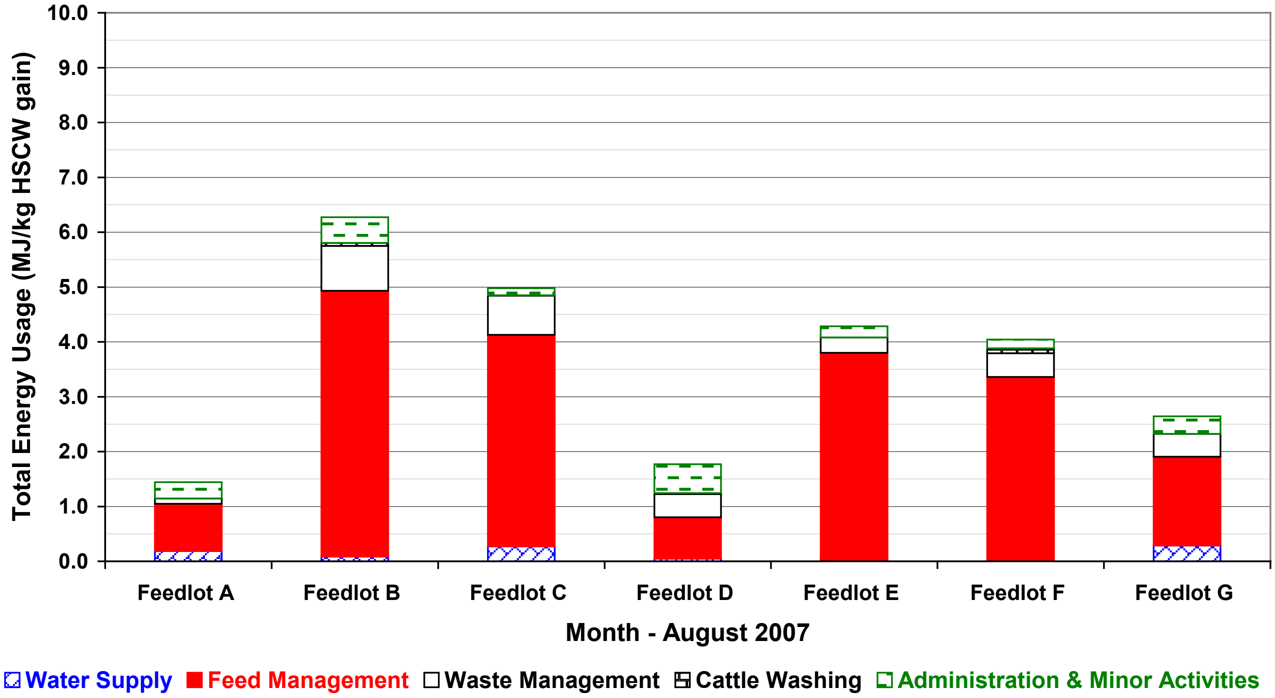


Figure 39 – Total energy usage for August 2007 (MJ/kg HSCW gain)

Figure 39 shows the total energy usage across all feedlots for August 2007. Total monthly energy use ranged from 1.5 to 6.3 MJ/kg HSCW gain. Feedlot B has significantly reduced its total energy usage from 8 to 6.25 MJ /kg HSCW gain, whilst feedlots E and G have slightly increased its total energy usage when compared to July. The lowest energy usage was measured at Feedlots A, D and G (reconstitution and tempering) with higher energy usage at feedlots B, C, E and F (steam flaking). There is still a large range in feed management energy usage between feedlots with steam flaking. In these feedlots, feed management energy usage ranges from 3.4 MJ/kg HSCW gain at Feedlot F to 4.9 MJ/kg HSCW gain at Feedlot B. Water supply energy usage is similar to previous months and ranged from 0.01 MJ/kg HSCW gain at Feedlot F to 0.29 MJ/kg HSCW gain at Feedlot G. Waste management energy usage has the most variability between months and feedlots as this activity is dependent on climatic conditions and management strategies. For August, it ranged from 0.10 to 0.82 MJ/kg HSCW gain. Cattle washing energy usage ranges from 0.01 MJ/kg HSCW gain at Feedlots C and D to 0.09 MJ/kg HSCW gain at Feedlot F. Energy usage within administration and minor activities was found to range from 0.09 to 0.47 MJ/kg HSCW gain. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

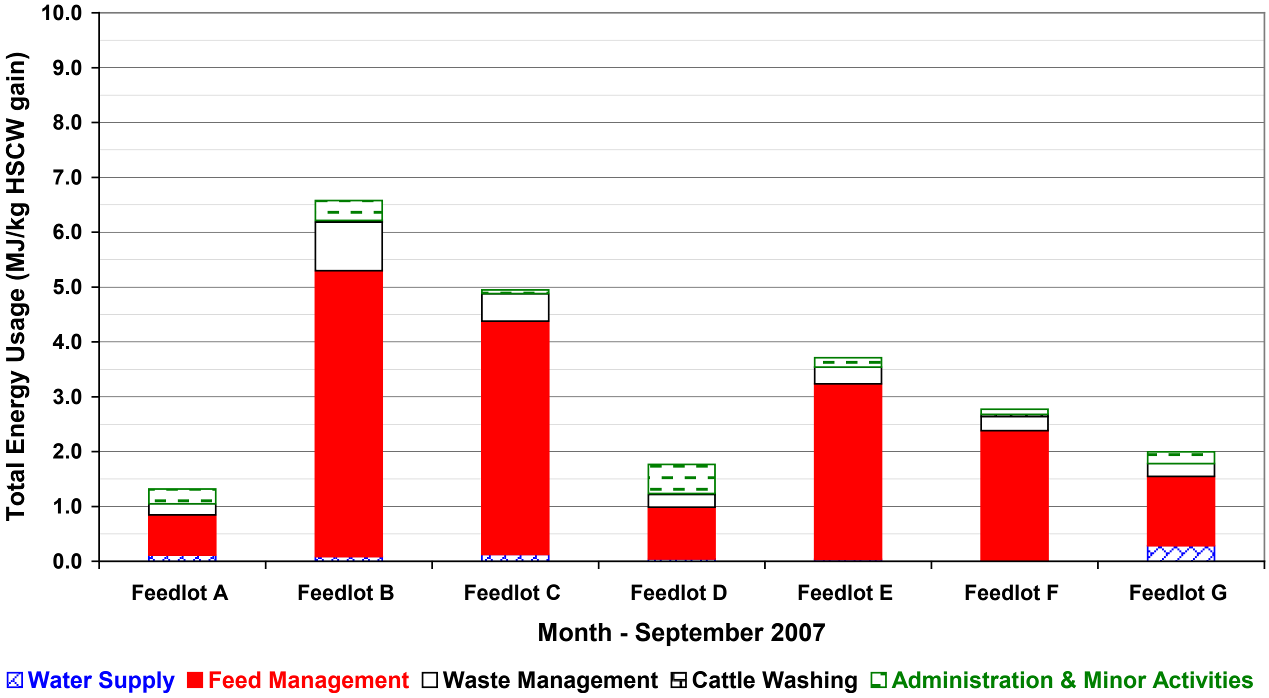


Figure 40 – Total energy usage for September 2007 (MJ/kg HSCW gain)

Figure 40 shows the total energy usage across all feedlots for September 2007. Total monthly energy use ranged from 1.3 to 6.6 MJ/kg HSCW gain, a similar range to August. Water supply energy usage is similar to previous months in all feedlots with the exception of Feedlot G which has decreased from 0.28 MJ/kg HSCW gain to 0.12 MJ/kg HSCW gain. Feed management energy usage ranged from 0.73 (Feedlot A) to 5.2 (Feedlot B) MJ/kg HSCW gain. Waste management energy usage ranged from 0.2 to 0.88 MJ/kg HSCW gain a similar range to previous months. Cattle washing energy usage ranges from 0.001 MJ/kg HSCW gain at Feedlot C to 0.40 MJ/kg HSCW gain at Feedlot F. Similar energy usage levels to previous months was measured within administration and minor activities and was found to range from 0.07 to 0.36 MJ/kg HSCW gain. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

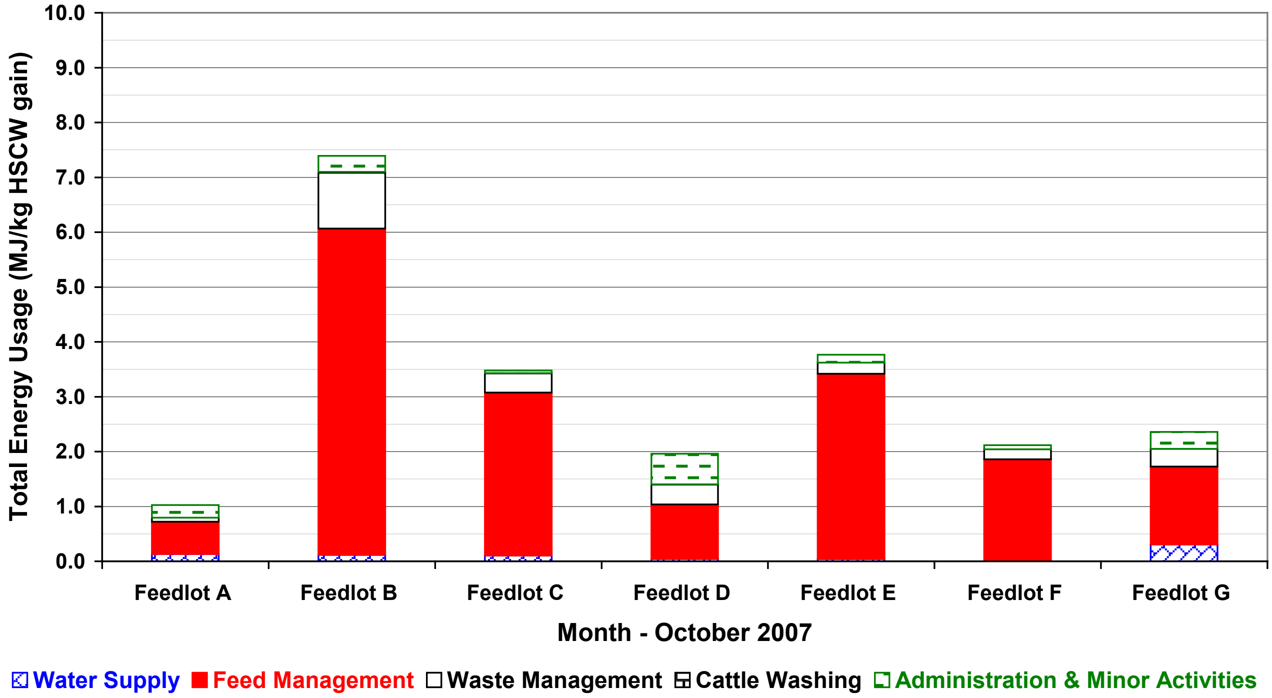


Figure 41 – Total energy usage for October 2007 (MJ/kg HSCW gain)

The total energy usage across all feedlots for October 2007 is shown in Figure 41. Total monthly energy use ranged from 1 to 7.4 MJ/kg HSCW gain. Feedlots A, C and F have slightly reduced their total energy usage when compared with previous months, whilst feedlots B, D, E and G have increased their total usage when compared with September levels. Water supply energy usage is similar to previous months in all feedlots and ranges from 0.003 MJ/kg HSCW gain to 0.31 MJ/kg HSCW gain. Feed management energy usage ranged from 0.59 (Feedlot A) to 5.95 (Feedlot B) MJ/kg HSCW gain. Waste management energy usage ranged from 0.07 to 1.02 MJ/kg HSCW gain at Feedlot B. Cattle washing energy usage ranges from 0.001 MJ/kg HSCW gain at Feedlot C to 0.017 MJ/kg HSCW gain at Feedlot B. Similar energy usage levels to previous months was measured within administration and minor activities and was found to range from 0.05 to 0.31 MJ/kg HSCW gain. Feedlot B continues to record the highest total energy usage per kg HSCW gain across all the feedlots, this in part is due to this feedlot having long fed cattle with low average daily gain. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

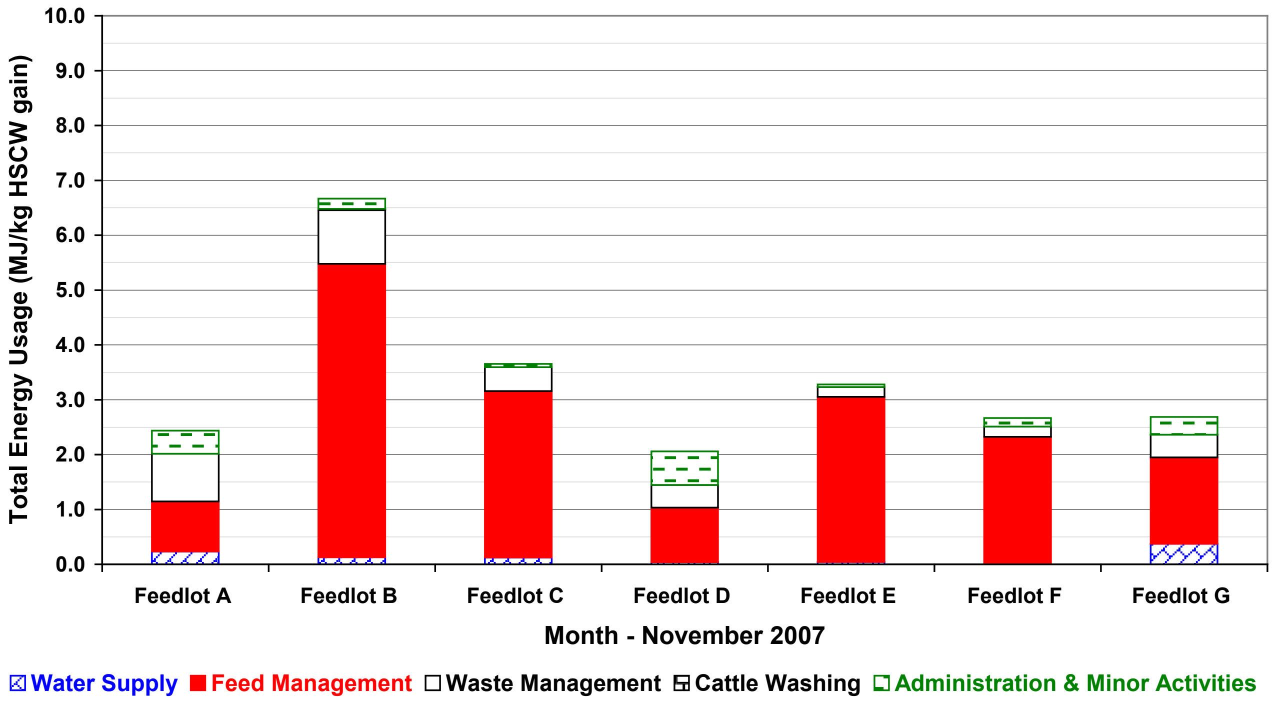


Figure 42 – Total energy usage for November 2007 (MJ/kg HSCW gain)

The total energy usage across all feedlots for November 2007 is shown in Figure 42. Total monthly energy use ranged from 2.5 to 6.7 MJ/kg HSCW gain. Feedlot A has doubled its energy usage from October, driven by a marked increase in waste management, a resultant of the high level of pen cleaning undertaken during November. Feedlots F and G have slightly increased their total energy usage when compared with previous months, whilst feedlots C and D are similar. Feedlot B and E has reduced their total usage when compared with October levels, due to a reduction in feed management and administration and minor activities usage. Water supply energy usage is similar to previous months and ranges from 0.004 MJ/kg HSCW gain to 0.37 MJ/kg HSCW gain. Feed management energy usage ranged from 0.9 (Feedlot A) to 5.4 (Feedlot B) MJ/kg HSCW gain. Waste management energy usage ranged from 0.18 MJ/kg HSCW gain at Feedlot F to 0.98 MJ/kg HSCW gain at Feedlot B. Cattle washing had ceased for the season at all feedlots except Feedlot B. where a energy usage of 0.02 MJ/kg HSCW gain was measured. Similar energy usage levels to previous months was measured within administration and minor activities and was found to range from 0.05 to 0.38 MJ/kg HSCW gain. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

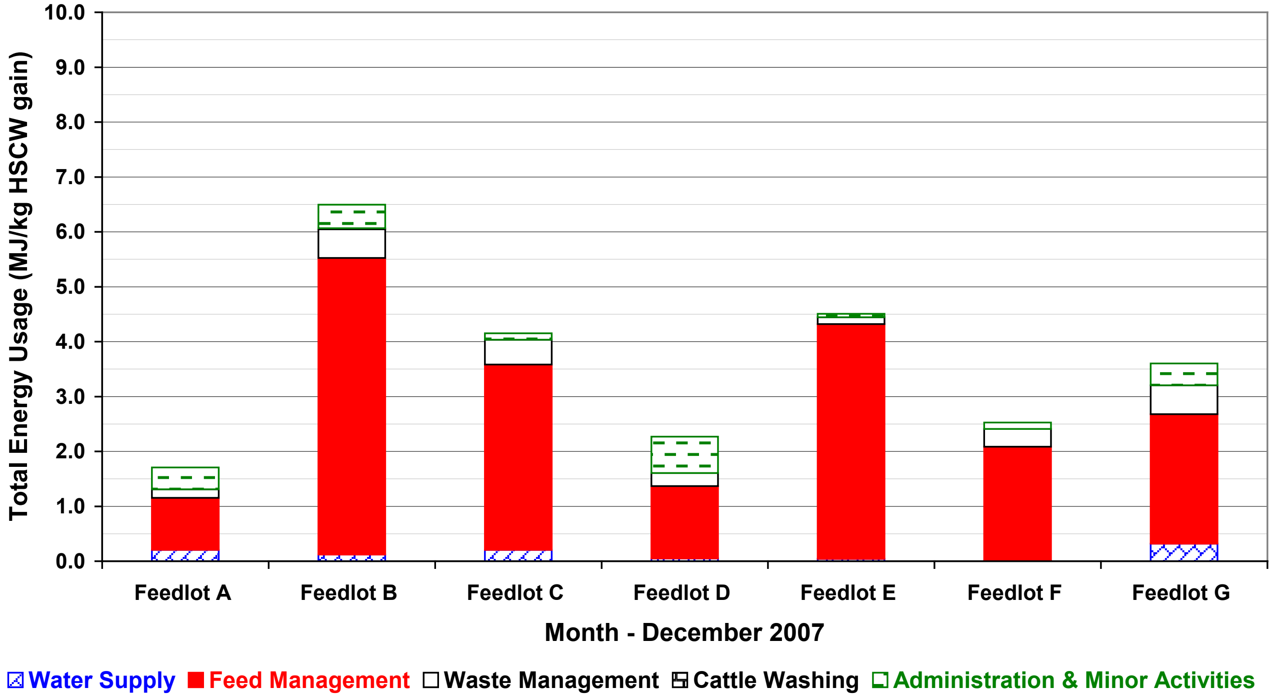


Figure 43 – Total energy usage for December 2007 (MJ/kg HSCW gain)

The total energy usage across all feedlots for December 2007 is shown in Figure 43. Total monthly energy use ranged from 1.7 MJ/kg HSCW gain at Feedlot A to 6.5 MJ/kg HSCW gain at Feedlot B. The impact of lower cattle numbers on feed and hence lower HSCW gain may be contributing to the increases in total energy usage when compared with previous months at feedlots E and G. Feedlot A has reduced their total usage when compared with November levels, due to a reduction in waste management energy usage. Water supply energy usage is similar to previous months and ranges from 0.004 MJ/kg HSCW gain to 0.32 MJ/kg HSCW gain. Feed management energy usage ranged from 0.95 (Feedlot A) to 5.4 (Feedlot B) MJ/kg HSCW gain. Waste management energy usage ranged from 0.13 MJ/kg HSCW gain at Feedlot E to 0.53 MJ/kg HSCW gain at Feedlot G. In December cattle were washed only at all Feedlot B, where an energy usage of 0.02 MJ/kg HSCW gain was measured. Similar energy usage levels to previous months was measured within administration and minor activities and was found to range from 0.06 to 0.43 MJ/kg HSCW gain. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

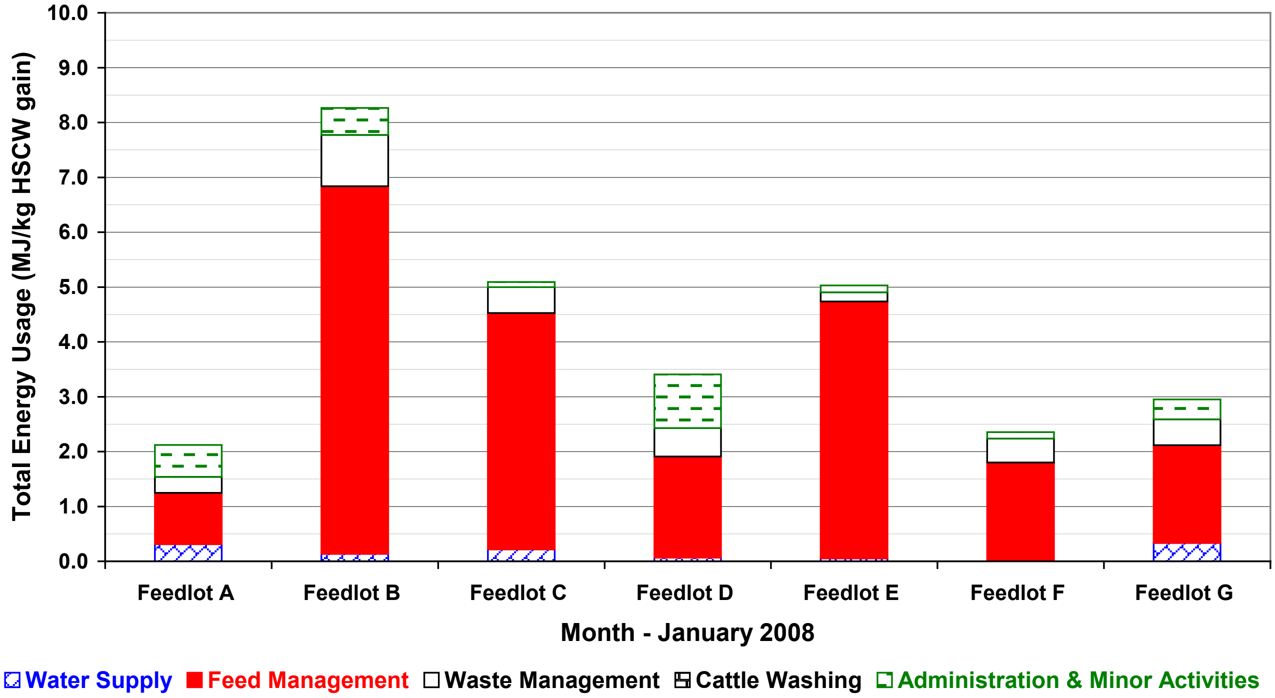


Figure 44 – Total energy usage for January 2008 (MJ/kg HSCW gain)

Figure 44 shows the total energy usage across all feedlots for January 2008. Total monthly energy use ranged from 2.1 MJ/kg HSCW gain at Feedlot A to 8.25 MJ/kg HSCW gain at Feedlot B. Feedlot B has increased their total usage from 6.5 to 8.25 MJ/kg HSCW gain when compared with December levels. Water supply energy usage is similar to previous months and ranges from 0.004 MJ/kg HSCW gain to 0.33 MJ/kg HSCW gain. Feed management energy usage ranged from 0.94 (Feedlot A) to 6.7 (Feedlot B) MJ/kg HSCW gain. Waste management energy usage ranged from 0.17 MJ/kg HSCW gain at Feedlot E to 0.94 MJ/kg HSCW gain at Feedlot B. All feedlots had ceased cattle washing by January 2008. Similar energy usage levels to previous months was measured within administration and minor activities and was found to range from 0.09 to 0.57 MJ/kg HSCW gain. For Feedlots A, D and E, hotter temperatures in January has led to an increase in administration (cooling) energy usage. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

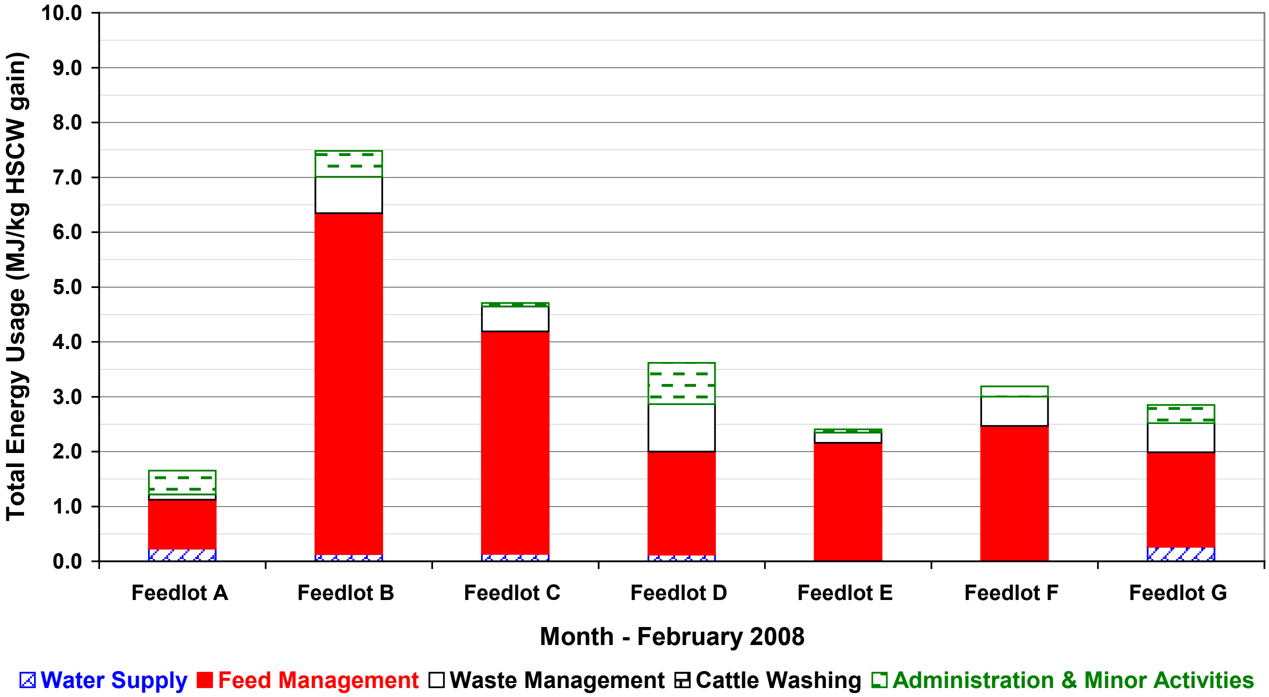


Figure 45 – Total energy usage for February 2008 (MJ/kg HSCW gain)

Figure 45 shows the total energy usage across all feedlots for February 2008. Total monthly energy use ranged from 1.6 MJ/kg HSCW gain at Feedlot A to 7.5 MJ/kg HSCW gain at Feedlot B. Feedlot E has almost halved their total energy usage for February when compared to January levels. This is due to a large increase in HSCW gain for this month.

Water supply energy usage is similar to previous months and ranges from 0.004 MJ/kg HSCW gain to 0.27 MJ/kg HSCW gain. Feed management energy usage ranged from 0.89 (Feedlot A) to 6.2 (Feedlot B) MJ/kg HSCW gain. Waste management energy usage ranged from 0.1 MJ/kg HSCW gain at Feedlot A to 0.87 MJ/kg HSCW gain at Feedlot D. There was no cattle washing in February 2008. Administration and minor activities energy usage levels had reduced slightly in February when compared to January readings and were found to range from 0.06 to 0.47 MJ/kg HSCW gain. For Feedlots A, D and E, cooler temperatures in February led to an decrease in administration (cooling) energy usage. Further discussion on activity energy usage is presented in Sections 5.3 to 5.7.

The monthly variation and variation between feedlots when standardised on a per kg of HSCW can be attributed to a number of factors. These include the design and layout of the water supply system, feed processing and feed delivery system, cattle market types (short fed v long fed) and management operations. Energy usage is less dependent on climatic variation when compared with water usage. Further discussion on individual activity energy usage is presented in the following sections.

5.3 Water supply energy usage

Figure 46 illustrates the average water supply energy consumption on a MJ/head on feed/month basis for the seven feedlots. Water supply energy usage has been divided into supply (delivery from source) and reticulation around the feedlot (secondary pumping). The water supply systems ranged from combinations of delivery and gravity fed, delivery and reticulation, delivery, reticulation and gravity fed systems.

The minimum and maximum energy usage per head for any one month is presented. Note that feedlot numbering in this section does not match the numbering in previous sections to maintain anonymity for the participating feedlots. Whilst a summary is provided in this section, complete individual feedlot monthly water supply energy usage figures on a per head basis are presented in Appendix A.

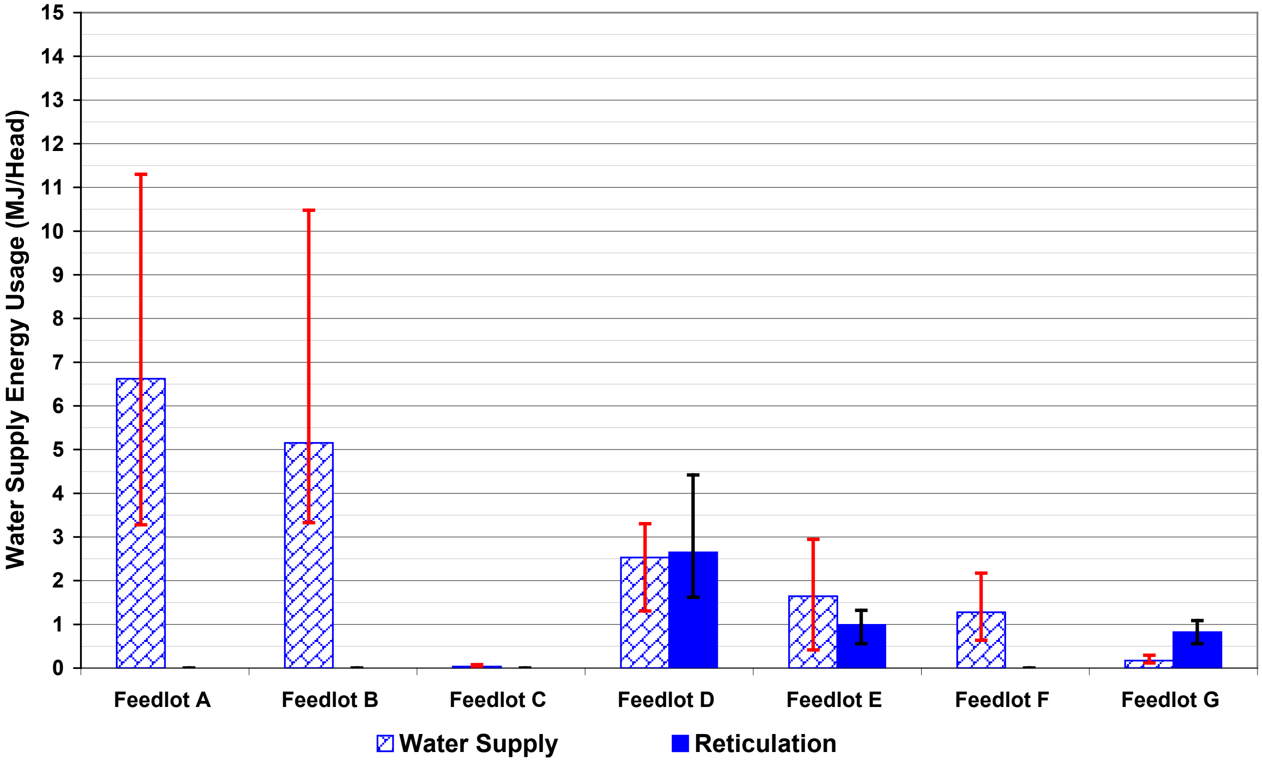


Figure 46 – Water supply energy usage (MJ/head on feed/month)

The average total water supply energy usage across all feedlots for March 2007 to February 2008 ranged from 0.04 MJ/head on feed/month at Feedlot C to 6.6 MJ/head on feed/month at Feedlot A, with an average in the order of 2.5 MJ/head on feed/month. The data presented is based on total kWh used in water supply and or reticulation. In most cases, total kWh is made up of a combination of off-peak and peak electricity tariffs. Therefore, only an approximate cost of supply can be gained from this figure, if desired.

Water supply energy usage between feedlots is dependent on a number of factors, including depth to groundwater and distance to supply. Within feedlots, water supply energy usage is directly proportional to the water pumped per month. Feedlot A had the highest average water supply energy consumption due to sourcing its water from bores located some distance to the feedlot and pumping against high head. Feedlots A, B, C and F have gravity fed water reticulation systems. Feedlot D demonstrates the additional energy usage with having to deliver water to the pens via a pumping system compared with a gravity supply system. In this case, energy consumed in delivering water to the pens is greater than supplying water to buffer storage facilities. Future consideration should be given to gravity supply if possible. For example, an energy usage of 2.5 MJ/head on feed/month for a feedlot with 10,000 head on feed will utilise 300000 MJ/year or approximately 83,000 kWh in direct electricity usage. At 0.15c/kWh, this equates to about $12,500/year.

An indication of the monthly variability in water supply energy usage can be gained through comparison of the maximum, minimum and average consumption levels. Figure 46 shows that the majority of feedlots, with the exception of feedlots C and G, have a degree of variability in energy usage. Feedlot C has a consistent usage with only one or two months of high usage. Conversely, Feedlot G has a less variability. The variability in energy usage can be explained by the variation in monthly total water usage.

5.4 Feed management energy usage

Feed management energy usage has been proportioned into feed processing and feed delivery usage. The energy used within each respective activity is presented in the following sections.

5.4.1 Feed processing energy usage

Figure 47 illustrates the average feed management processing energy usage on a tonne of grain processed basis for the seven feedlots. In this section, as feed processing energy used is expressed on a per tonne of grain basis, it only includes the electricity and gas used in grain storage, movement and preparation. It does not include the energy used in tub grinding. Energy used in tub grinding is included in Appendix C, Section C.1.

The minimum and maximum feed processing water usage on a tonne of grain processed basis for any one month is also presented. The feedlot numbering in this section does not match the numbering in previous sections to maintain anonymity for the participating feedlots. Whilst a summary is provided in this section, complete individual feedlot monthly feed processing energy usage on a MJ used per tonne of ration (including tub grinding) and grain processed basis are presented in Appendix C, Section C.1.

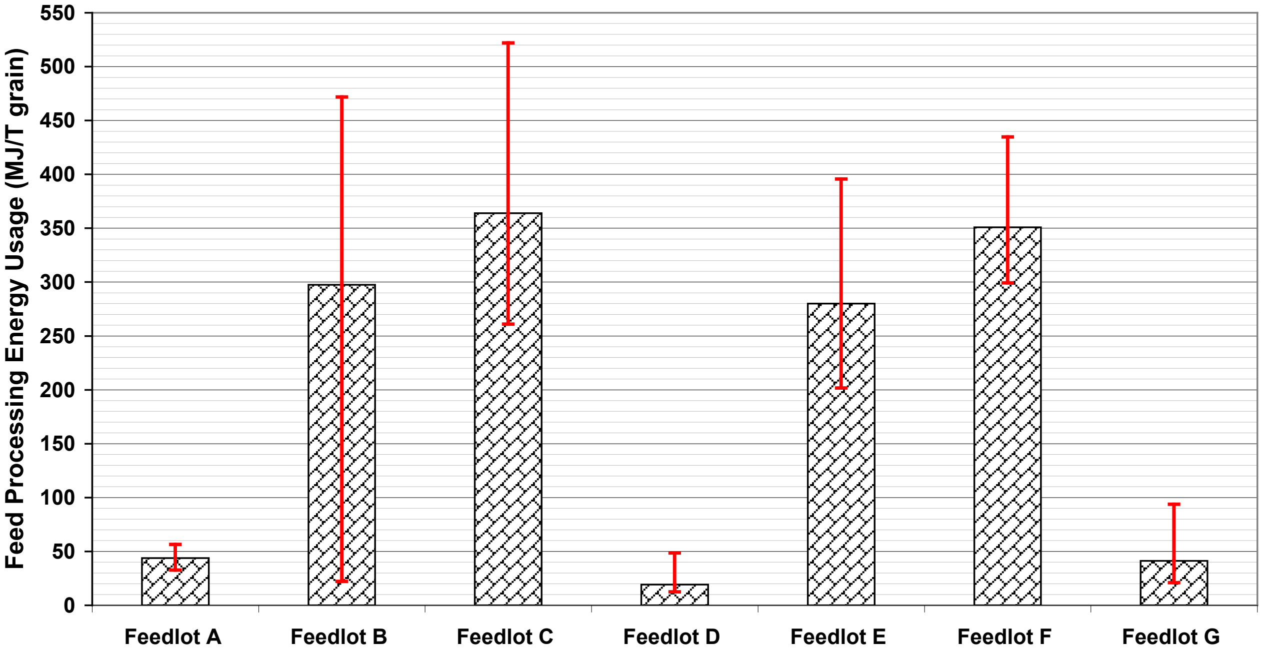


Figure 47 – Total feed processing energy usage (MJ/t grain)

Feed processing energy usage is the largest single consumer of energy in feedlots. The average feed processing energy usage measured ranges from 20 to 365 MJ/t grain processed. Three different feed processing systems are represented within the seven feedlots. Feedlots B, C, E and F steam flake grain whilst Feedlots A, D and F either temper only or temper and reconstitute grain. For feed processing systems other than steam flaking, average energy usage is typically less than 50 MJ/t grain processed. For steam flaking, the total energy usage ranges from 280 to 365 MJ/t grain processed. Hence, there is a large variation between feed processing systems and between feedlots with the same system.

An indication of the monthly variability in feed processing energy usage can be gained through comparison of the maximum, minimum and average consumption levels. Figure 47 shows that, at the majority of feedlots with the exception of feedlots A, D and G, there is a large variability in energy usage. In some cases, e.g. Feedlot E, there is a 100% difference between minimum and maximum monthly usage. The variation in Feedlot B can be explained by a change in feed processing system during the study period from tempering to steam flaking. In addition, the lower average energy usage in Feedlot B, when compared with Feedlots C, E and F, may be attributed to the newer technology being more efficient. Feedlot D has a consistent usage with only one or two months of high usage. Conversely, Feedlot A has a less variability. For steam flaking systems, a review of individual feedlot monthly feed processing data from Appendix C.1, there is an increase in energy usage during the cooler winter months. Hence, more energy is required to heat water and increased heat transfer losses. Setup and operation of feed processing systems will also influence total energy usage.

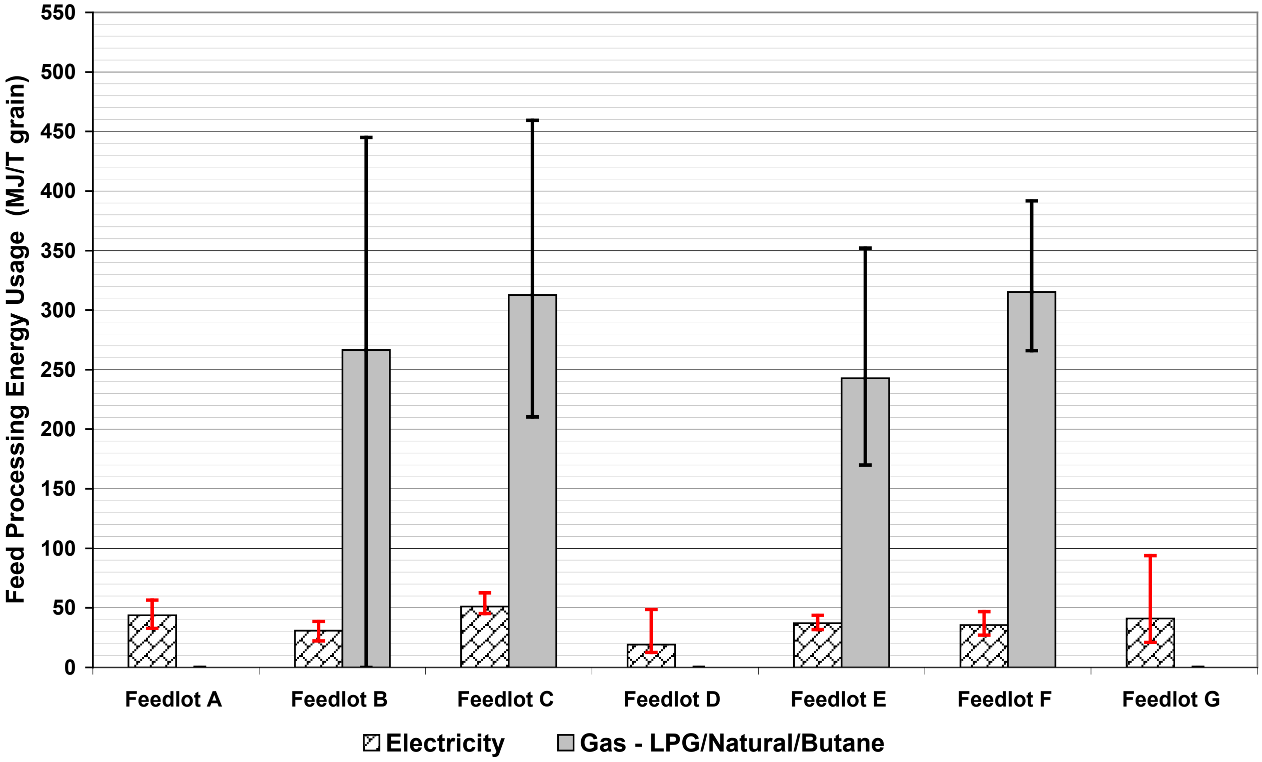


Figure 48 – Feed processing component energy usage (MJ/t grain)

At all feedlots, the feed processing energy usage was able to be divided into that consumed in electricity usage (grain delivery, movement and milling) and gas usage for boiler fuel in steam flaking systems. Note that the feedlot numbering in Figure 48 is consistent with the numbering in Figure 47. Figure 48 illustrates the average feed processing component energy usage on a tonne of grain-processed basis for the seven feedlots.

The average feed processing electricity energy usage measured ranges from 20 to 50 MJ/t grain processed. Feedlots B and D have an average electricity energy usage of 20 MJ/t grain. In one month, Feedlot D used 50 MJ/t grain. The remaining feedlots have electricity energy usage between 40 and 50 MJ/t grain processed. The variation in electricity energy usage may be attributed to monthly variation in grain delivery, movement and storage and milling efficiency (tonnes per mill). Note that in the majority of feedlots, the electricity used in grain delivery and storage could not be partitioned from total feed mill electricity usage.

For steam flaking systems, the average gas energy usage measured ranges from 240 to 315 MJ/t grain processed. There were three types of gases used within the four feedlots with steam flaking systems. These included LPG, butane and natural gas. All of these gas sources have different calorific values (heating content) and pricing structures. Some of the variation in gas usage can be attributed to heating efficiency during winter months.

5.4.2 Feed delivery energy usage

Figure 49 illustrates the average feed delivery energy usage on a tonne of ration delivered for the seven feedlots. In this section, feed delivery energy use comprises electricity used by stationary mixers, diesel consumed by loaders during feed loading and by feed trucks delivering ration to pens where appropriate.

The minimum and maximum feed processing water usage on a tonne of ration delivered basis for any one month is presented. The feedlot numbering in this section is consistent with the numbering is Section 5.4.1. Whilst a summary is provided in this section, complete individual feedlot monthly feed delivery energy usage on a MJ used per tonne of ration delivered basis are presented in Appendix C, Section C.2.

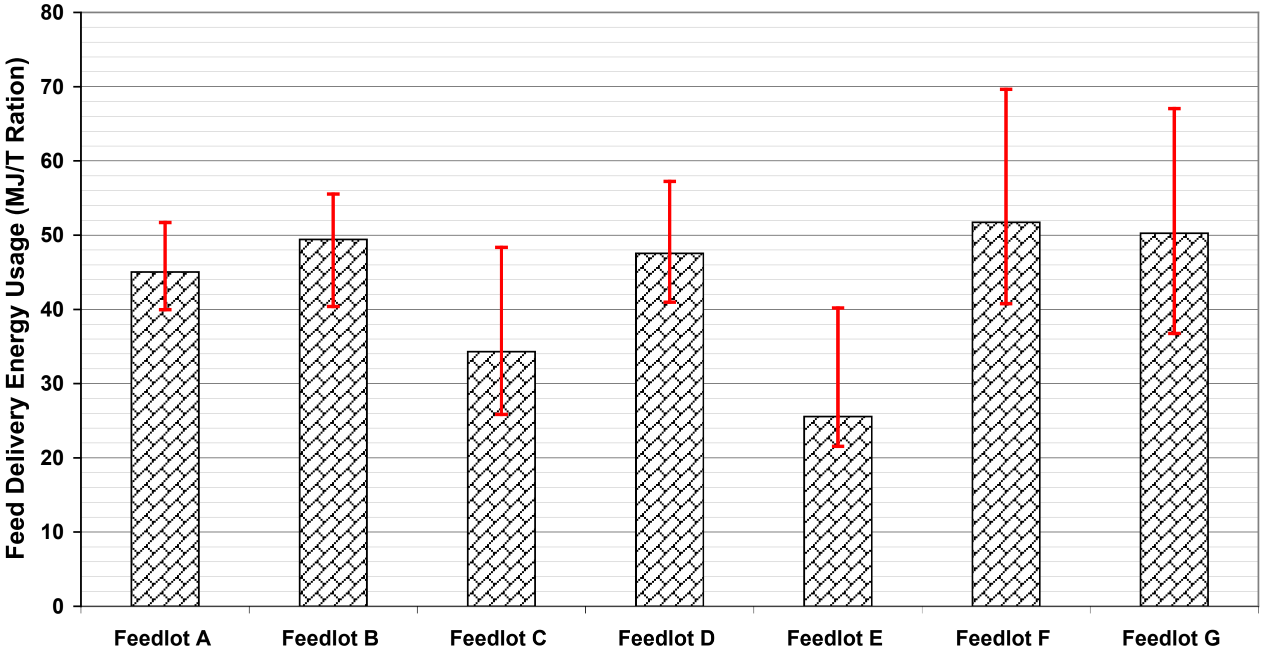


Figure 49 – Total feed delivery energy usage (MJ/t ration)

The average feed delivery energy usage measured ranges from 26 to 52 MJ/t ration delivered. A number of different feed delivery systems are represented within the seven feedlots. This includes stationary mixing, bunker system, batch-boxes and a number of varying combinations in mobile equipment. Mobile equipment combinations included tractor/trailed mixer units, ROTO-mix trucks (various capacities and number), loaders (number, no of ingredients and bucket capacities) and screw mixer trucks.

Feedlots A, B, F and G have an average feed delivery energy usage measured range from 45 to 52 MJ/t ration delivered. Feedlot C (34 MJ/t ration) and Feedlot E (26 MJ/t ration) have considerably less energy usage when compared with the remaining feedlots. Feedlot E uses, on average, half of the energy of the highest average feed delivery energy usage (Feedlot F). Whilst feed delivery energy usage is dependent on the system and equipment utilised, pen layout and feed-out method also influences the energy used. At Feedlot E, feed delivery is undertaken with two primary ROTO-Mix trucks with a combined horsepower of 535 hp (26 hp per tonne capacity) and cattle are fed twice per day. The hp per tonne capacity for Feedlot C is similar to Feedlot E. Feedlot E delivers finisher rations to consecutive rows and pens thus minimising travel distance. This approach may be a plausible explanation for the lower energy usage measured.

An indication of the monthly variability in feed processing energy usage can be gained through comparison of the maximum, minimum and average consumption levels. Figure 49 shows that, at the majority of feedlots with the exception of Feedlot E, there is a large variability in energy usage. In some cases, such as Feedlots C and D, there is close to a 100% difference between minimum and maximum monthly usage.

The results from the feed delivery energy usage figures show that there appears to be little energy efficiency gained from economies of scale with larger feedlots.

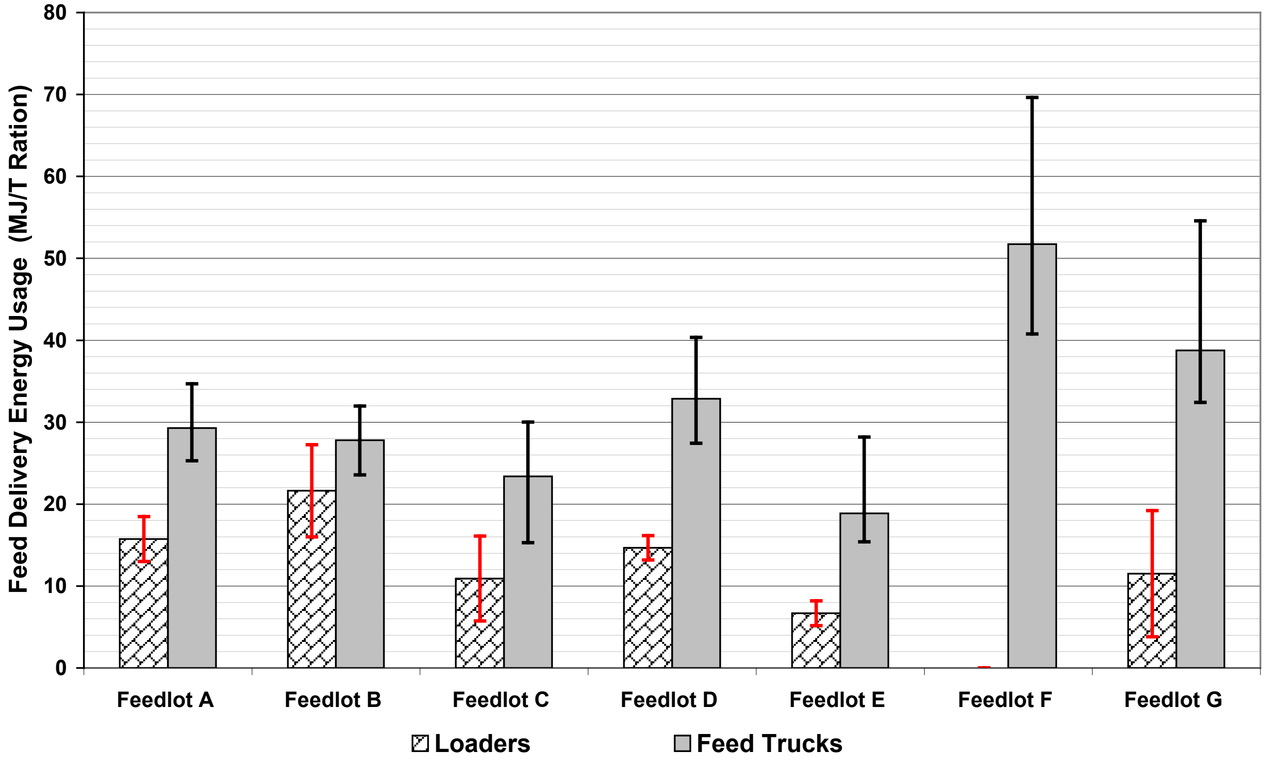


Figure 50 – Feed delivery component energy usage (MJ/t ration)

At all feedlots, with the exception of Feedlot F, the total feed delivery energy usage was able to be divided into that consumed during loading of commodities and that used by the mobile equipment during delivery. The feedlot numbering in Figure 50 is consistent with the numbering in Figure 49. Figure 50 illustrates the average feed delivery component energy usage on a tonne of ration delivered for the seven feedlots.

The average energy usage by loaders ranges from 7 to 22 MJ/t ration delivered. The energy used by loaders is dependent on a number of factors including the size of loader, bucket capacity, number of ingredients loaded and the other feed related activities that the loader/s may need to undertake. Other feed related activities may include transporting hay/straw from storage areas to tub grinders, silage from silage pits, high moisture grain from storage areas etc.

The average energy usage by feed delivery equipment ranges from 19 to 39 MJ/t ration delivered. The energy used by feed delivery equipment is dependent on a number of factors including the number, volumetric capacity, engine capacity, commodity loading positions and pen layout.

A number of different feed delivery systems are represented within the seven feedlots. This includes stationary mixing, bunker system, batch-boxes and a number of varying combinations in mobile equipment. Mobile equipment combinations included tractor/trailed mixer units, ROTO-mix trucks (various capacities and number), loaders (number, no of ingredients and bucket capacities) and screw mixer trucks.

Whilst it is appreciated that mobile equipment is selected based on a number of criteria, it would appear that one of the major drivers of feed delivery energy usage is feed-out strategy. For example, an energy saving of 5 MJ t/ration for a feedlot delivering 100,000t of ration per year, will reduce energy usage by 500000 MJ/year or approximately 12 kL in diesel usage. At 1.50c/L, (including rebate) this equates to about $18,000/year.

5.5 Waste management energy usage

Figure 51 illustrates the average waste management energy usage on a head on feed basis for the seven feedlots. Whilst standardising energy usage on a tonne of manure basis may be more appropriate, this information was not collected from each feedlot. Note that in this section, waste management energy use comprises diesel consumed by mobile plant in pen cleaning, manure stockpiling and manure spreading. Where these activities are undertaken by contractors, their fuel has been included.

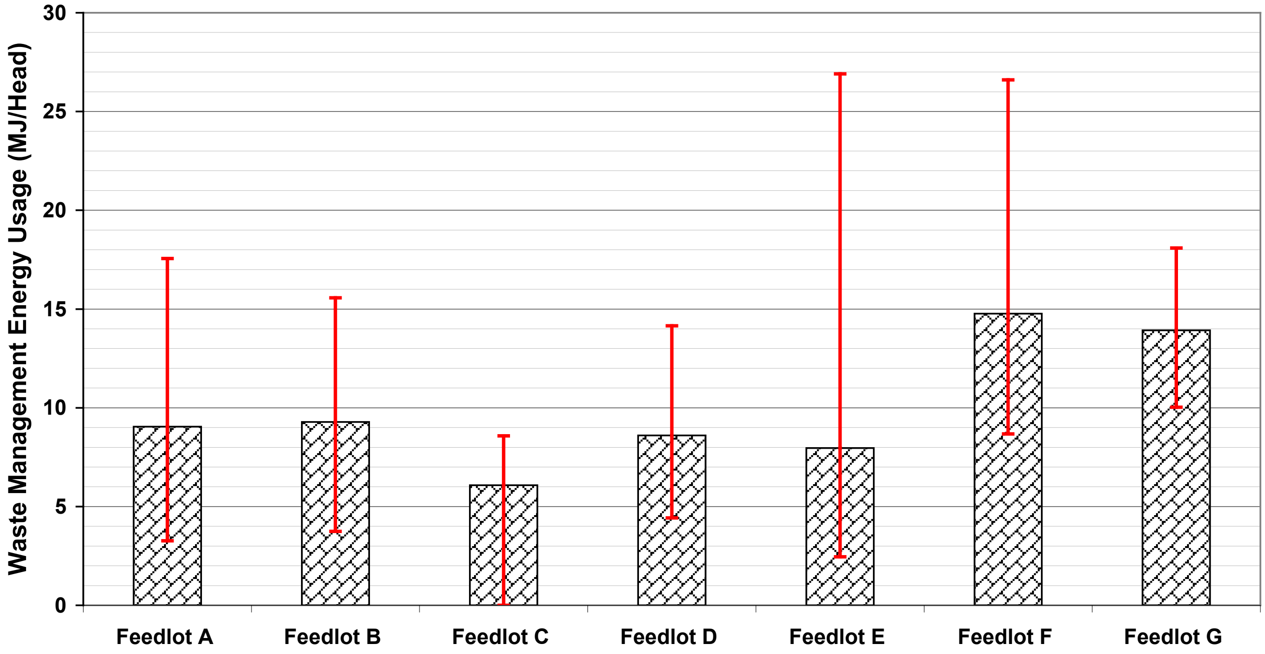


Figure 51 – Total waste management energy usage (MJ/head on feed/month)

The average waste management energy usage ranges from 6 to 15 MJ/head on feed/month. The variation between feedlots can be attributed to the various manure management systems employed at each feedlot. It is driven by the frequency of cleaning, equipment used and the volume of manure removed.

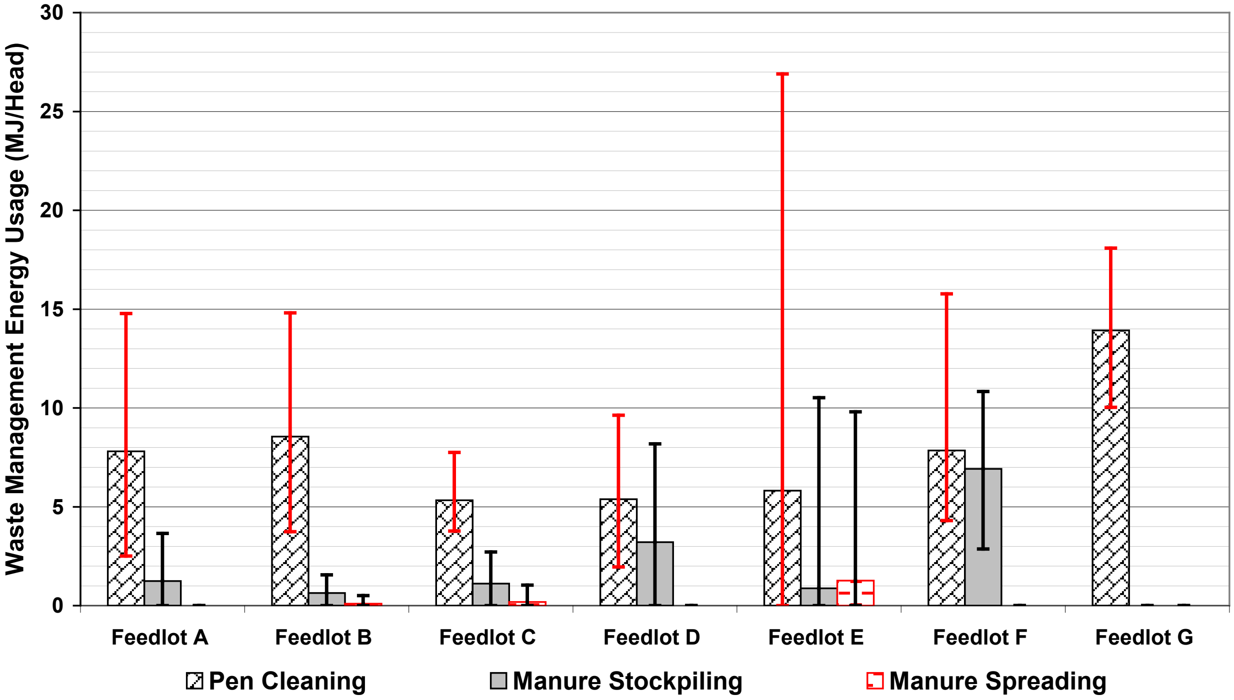


Figure 52 – Waste management energy usage (MJ/head on feed/month)

Figure 52 illustrates the average waste management component energy usage on a MJ/head on feed/month basis for the seven feedlots. Energy use for pen cleaning, manure stockpiling and manure spreading was able to be determined for all feedlots, with the exception of Feedlot G. At Feedlot G, pen cleaning energy usage also includes energy used to transporting manure to the stockpile. Where these activities are undertaken by contractors, their fuel has been included.

As expected, pen cleaning contributed the highest proportion of the total waste management energy usage. On average, pen cleaning energy usage ranged from 5 to 8.5 MJ/head on feed/month. However, usage figures up to 27 MJ/head on feed/month were measured in one month at Feedlot E. Manure stockpiling represents on average around 15% of the total energy usage. At Feedlots D and F, stockpiling is 38 and 45% respectively. Feedlots B, C and E reported manure spreading during the study period. For Feedlot E, manure spreading energy usage was slightly higher than manure stockpiling energy usage. The variation between feedlots can be attributed to the various manure management systems employed at each feedlot. It is driven by the frequency of cleaning, equipment used and the volume of manure removed.

5.6 Cattle washing energy usage

Figure 47 illustrates the average energy usage during cattle washing on a MJ per head washed basis for the seven feedlots. Feedlot C and Feedlot D do not wash cattle and that Feedlot E did not wash any cattle during the study period. The minimum and maximum water usage per head washed for any one month is presented. The feedlot numbering in this section does not match the numbering in previous sections to maintain anonymity for the participating feedlots. Whilst a summary is provided in this section, complete individual feedlot monthly cattle washing energy usage on a per head basis are presented in Appendix E.

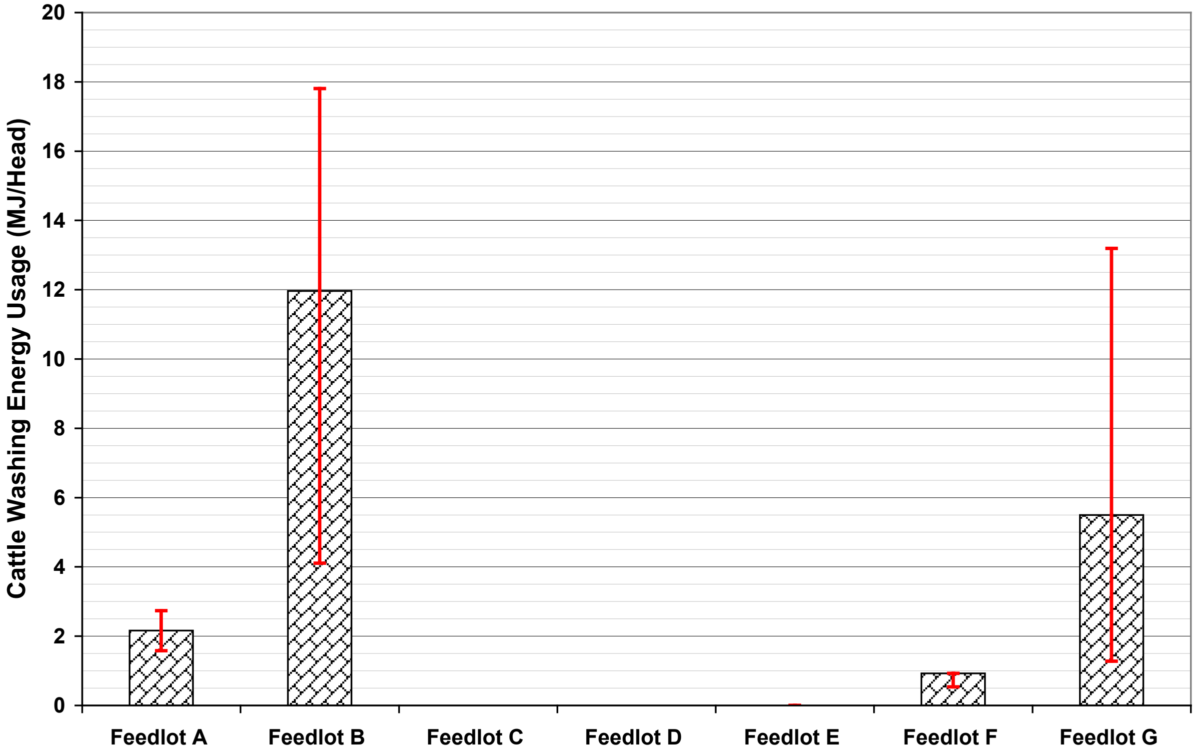


Figure 53 – Cattle washing energy usage (MJ/head washed)

The average cattle washing energy usage measured ranges from 1 to 12 MJ/head washed. The predominant energy source is electric but an electric and diesel powered pumping system is used at Feedlot B. The energy usage is directly proportional to the volume of water pumped and the energy source. For example, Feedlot G uses more water on average per head than Feedlot B, however energy usage is twice that used when compared with Feedlot B. This is due to one litre of diesel having a higher energy conversion than one kWh. The variability between feedlots A, F and G is directly related to respective water used in each feedlot.

5.7 Administration and minor activities energy usage

Figure 54 illustrates the average administration energy usage on a MJ per full time staff equivalent for the seven feedlots. In this context, administration energy usage is that only used by electricity in office facilities and weighbridge. The minimum and maximum administration usage per full time staff equivalent for any one month is presented. The feedlot numbering in this section does not match the numbering in previous sections to maintain anonymity for the participating feedlots. Whilst a summary is provided in this section, complete individual feedlot monthly administration energy usage on a MJ per kg HSCW gain basis are presented in Appendix E, Section E.1.

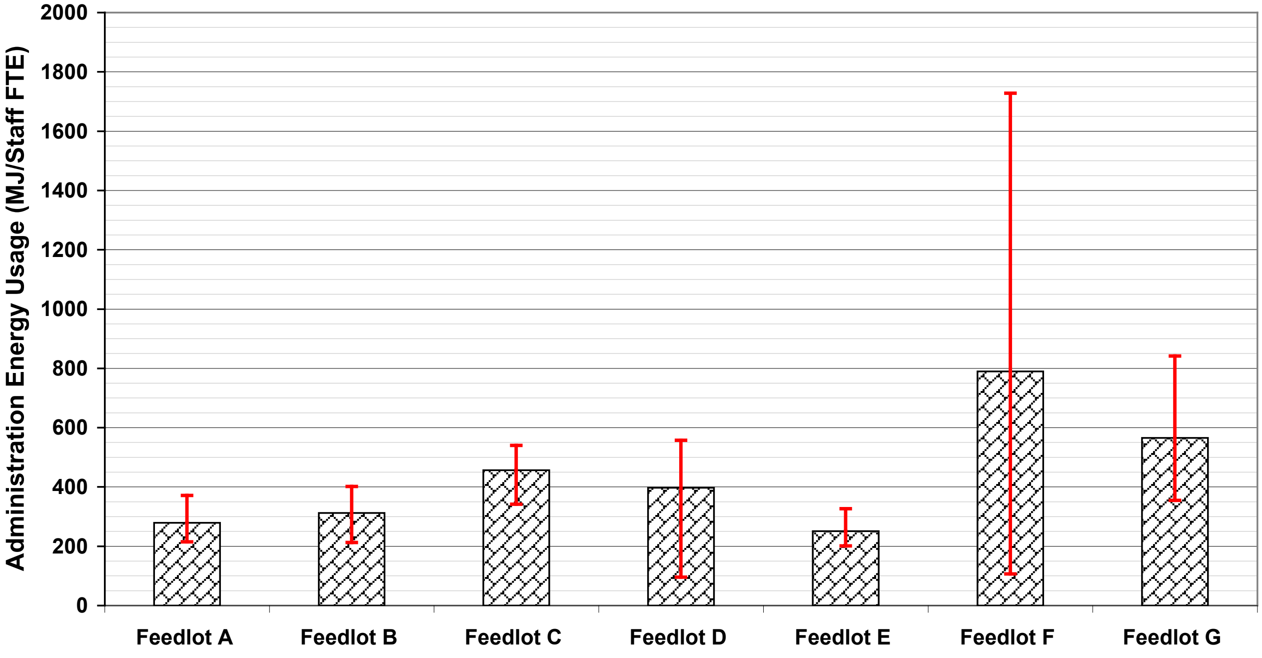


Figure 54 – Administration energy usage (MJ/staff FTE)

The average administration energy usage ranges from 240 MJ/staff FTE at Feedlots E to 530 MJ/ Staff FTE at Feedlot A where administration electricity usage was metered separately. For Feedlot F, electricity usage for administration purposes includes a residence, office and workshop. There is a high variation in usage at feedlots D and G with Feedlot D having ranged from 100 to 550 MJ/Staff FTE. The higher usage is associated with the warmer months suggesting that air conditioning of the office facilities is driving energy usage.

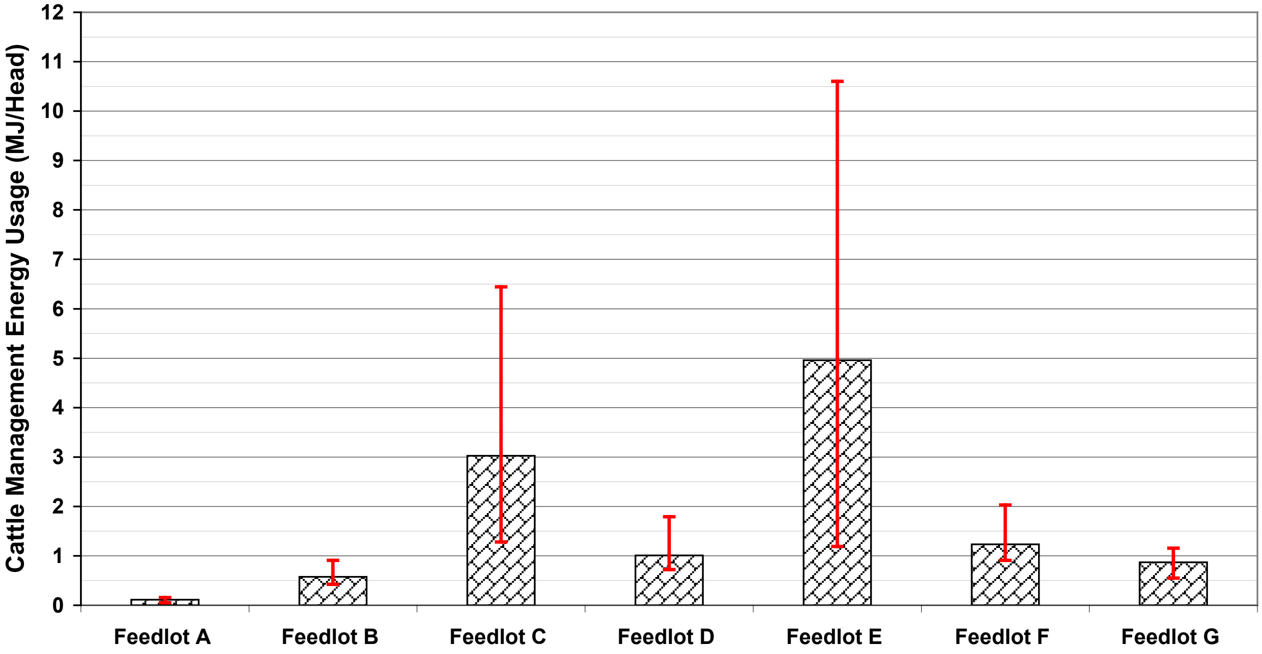


Figure 55 – Cattle management energy usage (MJ/head processed)

Figure 55 illustrates the average cattle management energy usage on a MJ per head processed basis for the seven feedlots. In this context, cattle management energy usage includes induction/hospital and is expressed per total head processed (inducted and shipped), not head on feed. Energy usage is predominantly electricity used for lighting, cleaning and restraint facilities. Note that the energy usage for Feedlot C and E was determined by residual and includes other minor uses such as fuel bowser, staff amenities and stables. The minimum and maximum cattle management usage per head basis for any one month is presented. Whilst a summary is provided in this section, complete individual feedlot monthly cattle management usage on a MJ per kg HSCW gain basis are presented in Appendix E, Section E.2.

The average energy usage for cattle management ranges from 0.10 MJ/head processed at Feedlot A to 5 MJ/head processed at Feedlot E.

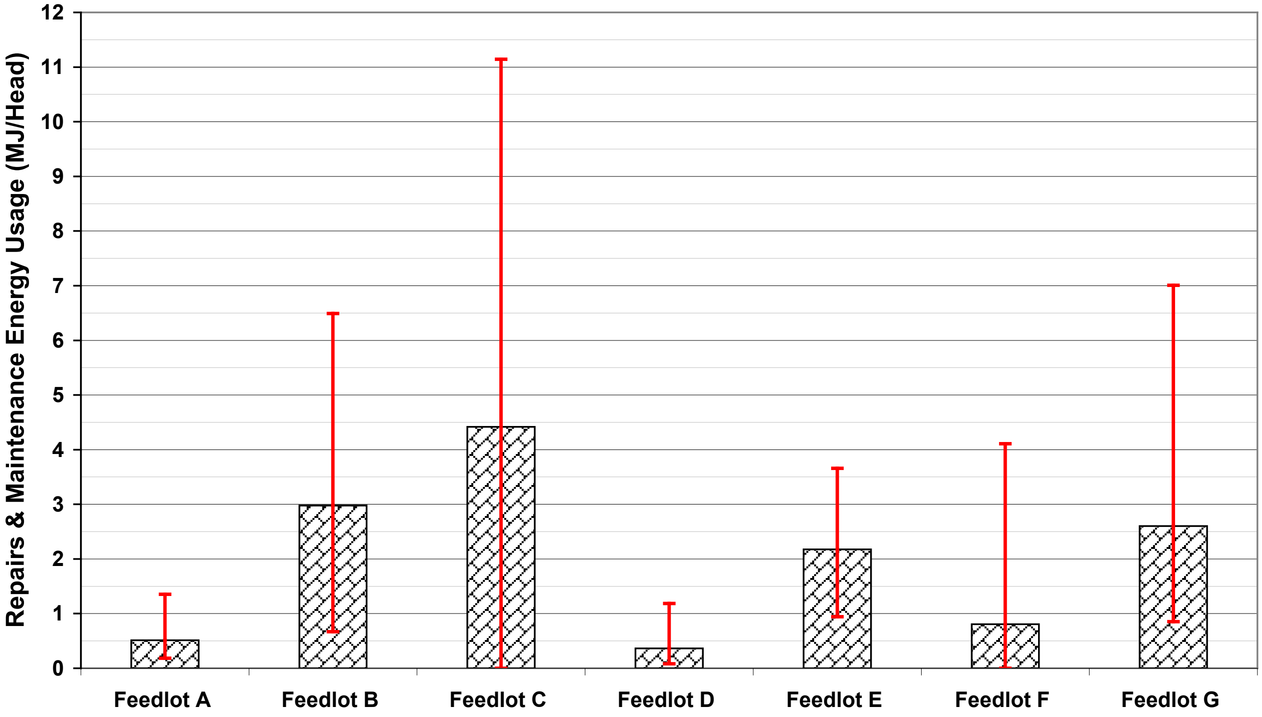


Figure 56 – Repairs and maintenance energy usage (MJ/head on feed/month)

Figure 56 illustrates the average repairs and maintenance energy usage on a MJ/head on feed/month basis for the seven feedlots. In this context, repairs and maintenance includes electricity usage in workshop facilities as well as diesel usage from mobile plant used in repair and maintenance activities. It is expressed as MJ/head on feed/month. The minimum and maximum repairs and maintenance usage per head basis for any one month is presented. Whilst a summary is provided in this section, complete individual feedlot monthly cattle management usage on a MJ per kg HSCW gain basis are presented in Appendix E, Section E.2.

The average energy usage for cattle management ranges from 0.4 MJ/head on feed/month at Feedlot D to 4.5 MJ/head on feed/month at Feedlot C. The large variation in repairs and maintenance energy usage and is due to the variation in mobile plant fuel usage between months.

6 Opportunities for energy use efficiency improvements

6.1 Improvements to total energy usage

The feedlot Industry is acutely aware of the direct costs of energy consumption and the effect of this cost on the economic sustainability of individual feedlots within the industry. Therefore, energy use efficiency within feedlots is a high priority. Furthermore, any reduction in energy usage is a reduction in greenhouse gas emissions, which will be increasingly important in the future.

This study had identified the energy usage of major activities and the variation in energy usage between feedlots. This variation is due to a number of factors including differing equipment, plant, feedlot layout and management.

Most energy efficiency projects deal with only some elements of an energy-consuming system, not the whole system. Hence, that is one reason why they fail to capture the full savings potential. For example, consider an electric motor driving a pump that circulates water around a facility. This system might include the following elements:

- electric motor (sizing and efficiency rating)
- motor controls (switching, speed or torque control)
- motor drive system (belts, gearboxes etc)
- pump
- pipe work
- demand for the water (or in many cases the heat or cooling it carries)

The efficiencies of these elements interact in complex ways. However, consider a simplistic situation where the overall efficiency of the motor is improved by 10% (by a combination of appropriate sizing and selection of a high efficiency model). Then overall energy efficiency is improved by 10%. However, if every element in the chain is improved in efficiency by 10%, then the overall level of energy use is:

0.9 x 0.9 x 0.9 x 0.9 x 0.9 x 0.9 = 0.53. That is 47% savings are achieved.

In most situations, such a system’s perspective is rarely applied, because responsibilities for different elements of the system are allocated to different groups and the individual savings captured are small. Indeed, individual agents may not be aware of the potential for savings in other parts of the chain – or may prefer them not to happen. Further, if a system’s approach is applied, it is possible to re-allocate capital costs from one area to another. For example, savings from downsizing motors and other components and using shorter pipes may offset the cost of installing larger diameter pipes (for reduced flow resistance) and improved controls.

Two areas have been identified in which energy or cost efficiency improvements could be targeted. These are feed processing and feed delivery.

Feed processing is an added cost to the feedstuff due to the cost of energy expended, equipment maintenance, person hours, etc. Processing is economically feasible only when the increased cost of the feedstuff is more than offset by the reduced kilograms of the feedstuff required to yield a kilogram of animal liveweight gain. Energy required for processing contributes much of the added cost.

Grain processing accounts for the majority of energy consumed during feed processing. Results from this work have shown that the energy consumed in grain preparation can account for up to 70% of the total feedlot energy consumption. Similarly, a large variation in grain-preparation energy usage has been measured across feedlots.

The most common energy source and a common element in all grain processing systems is electricity consumption. In most cases, electricity is provided by an overhead supply to a main switchboard then distributed internally throughout the feedlot. Electricity is used for a number of activities within grain processing including grain movement (in-loading, tempering, storage) and processing (rolling, hammer milling).

Processing grain at night to utilise ‘off-peak’ electricity tariffs in an attempt to reduce energy costs may be a realisable opportunity. However, there are obvious social and workplace health and safety issues to be considered. This approach to feed processing could provide significant cost and energy savings and is transferable to any feedlot within the industry.

A number of different feed delivery systems are represented within the seven feedlots. This includes stationary mixing, bunker system, batch boxes and a number of varying combinations in mobile equipment. Mobile equipment combinations included tractor/trailed mixer units, ROTO-mix trucks (various capacities and number), loaders (number, no of ingredients and bucket capacities) and screw mixer trucks.

Feed delivery energy usage is dependent on the system and equipment utilised, pen layout and feed-out method also influences the energy used. Whilst pen layout is fixed in existing facilities, mobile equipment (during replacement) and feed-out strategy could be targeted for energy efficiency improvements.

7 Conclusions and Recommendations

7.1 Conclusions

Energy is fundamental to a feedlot production system. Despite this, little work has been undertaken to evaluate energy consumption by feedlots. Energy use by feedlots was collected through several studies in North America in the 1970's and 1980's. To date, only a limited study on feedlot energy usage has been undertaken in Australia.

Energy consumption was classified into two categories, indirect and direct sources. Indirect sources arise mainly from the transport of cattle in and out of the feedlot and commodity delivery. Energy is used directly in the operation of the feedlot for the production of beef – feed processing, feed delivery, water supply, administration etc.

Little information exists on the energy usage of individual components of the feedlot system, viz. water supply, feed processing, feed delivery, cattle washing, waste management, administration, repairs and maintenance and cattle management. Factual information on indirect and direct energy usage was collected on individual feedlot sector operations from seven feedlots in Australia. These feedlots were representative of climatic zones, feed management systems, management styles and cattle markets.

Results from the seven feedlots studied showed that total annual indirect energy use ranged from 1.6-8 MJ/kg HSCW gain over the period March 2007 to February 2008. Distance travelled by trucks transporting cattle and delivering feed has a large impact on the energy consumed. Combined these represent a similar usage level to direct energy consumed within the feedlot subsystem.

Incoming cattle energy usage typically ranges from 0.1 MJ/kg HSCW gain to 2.0 MJ/kg HSCW gain, when cattle are sourced close to feedlots, however can range up to 4.5 MJ/kg HSCW gain. Outgoing cattle energy usage typically ranges from 0.5 MJ/kg HSCW gain to 0.9 MJ/kg HSCW gain, however a figure of 2.8 MJ/kg HSCW gain has been measured. The average annual commodity delivery energy usage ranged from 0.8 MJ/kg HSCW gain to 5.2 MJ/kg HSCW gain, however a figure of 5.4 MJ/kg HSCW gain has been recorded.

The indirect energy usage figures illustrate the proximity of respective feedlots to cattle, abattoirs and commodities. These figures also are influenced by the differences in average daily gain between long fed cattle and domestic cattle, number and type of commodities used in rations (high grain versus high roughage). These results also clearly show the impact of the drought (grain and available cattle supply) and high grain prices on the industry in particular during the latter half of 2007 and early 2008, where higher energy usage figures were recorded.

Results from the seven feedlots studied showed that total annual direct energy use ranged from a low 0.9 MJ/kg HSCW gain to 8.3 MJ/kg HSCW gain over the period March 2007 to February 2008. Expressed on a per head basis, total annual energy usage ranged from 444 MJ/head to 1483MJ/head. The total energy usage is primarily dependent on the type of feed processing system in use.

A wide variation was measured in water supply energy usage. On average, water supply represents in the order of 3% of the total energy usage. Expressed on a per head basis it ranged from

0.04 MJ/head on feed/month to 6.6 MJ/head on feed/month, with an average in the order of 2.5 MJ/head on feed/month.

Water supply energy usage between feedlots is dependent on a number of factors, including depth to groundwater and distance to supply. Within feedlots, water supply energy usage is directly proportional to the water pumped per month. Feedlot A had the highest average water supply energy consumption due to sourcing its water from bores located some distance to the feedlot and pumping against high head. Feedlots A, B, C and F have gravity fed water reticulation systems. Feedlot D, demonstrates the additional energy usage with having to deliver water to the pens via a pumping system compared with a gravity supply system. In this case, energy consumed in delivering water to the pens is greater than supplying water to storage facilities.

Feed management is the largest single consumer of energy in the feedlot as expected. For those feedlots with steam flaking systems it contributed on average approximately 80 % of total usage, whilst those feedlots which process their grain by other means it represents around 45% of total energy usage.

Feed management energy usage has been proportioned into feed processing and feed delivery usage. Feed processing energy usage on a tonne of grain processed basis ranged from 20 to 365 MJ/t grain processed. Three different feed processing systems are represented within the seven feedlots. For feed processing systems other than steam flaking, average energy usage is typically less than 50 MJ/t grain processed. For steam flaking, the total energy usage ranges from 280 to 365 MJ/t grain processed. Hence, there is a large variation between feed processing systems and between feedlots with the same system.

The average feed processing electricity energy usage measured ranges from 20 to 50 MJ/t grain processed. The variation in electricity energy usage may be attributed to monthly variation in grain delivery, movement and storage and milling efficiency (tonnes per mill).

For steam flaking systems, a review of individual feedlot monthly feed processing data shows that there is an increase in energy usage during the cooler winter months. Hence, more energy is required to heat water and increased heat transfer losses. Setup and operation of feed processing systems will also influence total energy usage.

For steam flaking systems the average gas energy usage measured ranges from 240 to 315 MJ/t grain processed. There were three types of gases used within the four feedlots with steam flaking systems. These included LPG, butane and natural gas. All of these gas sources have different calorific values (heating content) and pricing structures. Some of the variation in gas usage can be attributed to heating efficiency during winter months.

Feed delivery energy was measured and comprised electricity used by stationary mixers, diesel consumed by loaders during feed loading and by feed trucks delivering ration to pens where appropriate. The average feed delivery energy usage measured ranges from 26 to 52 MJ/t ration delivered. A number of different feed delivery systems are represented within the seven feedlots. This includes stationary mixing, bunker system, batch boxes and a number of varying combinations in mobile equipment. Mobile equipment combinations included tractor/trailed mixer units, ROTO-mix trucks (various capacities and number), loaders (number, no of ingredients and bucket capacities) and screw mixer trucks.

The feedlot with the highest average feed delivery usage was double that of the lowest. Whilst feed delivery energy usage is dependent on the system and equipment utilised, pen layout and feed-out method also influences the energy used.

The total feed delivery energy usage was able to be divided into that consumed during loading of commodities and that used by the mobile equipment during delivery. The average energy usage by loaders ranges from 7 to 22 MJ/t ration delivered. The energy used by loaders is dependent on a number of factors including the size of loader, bucket capacity, number of ingredients loaded and the other feed related activities that the loader/s may need to undertake. Other feed related activities may include transporting hay/straw from storage areas to tub grinders, silage from silage pits, high moisture grain from storage areas etc.

A number of different feed delivery systems are represented within the seven feedlots. This includes stationary mixing, bunker system, batch boxes and a number of varying combinations in mobile equipment. Mobile equipment combinations included tractor/trailed mixer units, ROTO-mix trucks (various capacities and number), loaders (number, no of ingredients and bucket capacities) and screw mixer trucks.

A wide variation was measured in water supply energy usage. The average water supply energy usage ranged between 0.006 MJ/kg HSCW gain (0.2%) to 0.28 MJ/kg HSCW gain (13%). On average, water supply represents in the order of 3% of the total energy usage. Expressed on a per head per day basis it ranged from 0.02 MJ/head on feed/day at Feedlot G to 0.22 MJ/head on feed/day at Feedlot A, with an average in the order of 0.1 MJ/head on feed/day.

Typically, waste management contributes 18 % of total energy usage. Water supply contributed an average of 0.18 L/kg HSCW gain or around 12 % of total usage. Waste management energy usage contributed between 0.12 MJ/kg HSCW gain and 1.26 MJ/kg HSCW gain of total energy usage. Typically, it represents on average in the order of 15% of the total annual energy usage, however is quite variable between months.

Expressed on a per head on feed basis, the average annual waste management energy usage ranges from 6 to 15 MJ/head. As expected, pen cleaning contributed the highest proportion of the total waste management energy usage. On average, pen cleaning energy usage ranged from 5 to 8.5 MJ/head, however usage figures up to 27 MJ/head were measured in one month. Manure stockpiling represents on average around 15% of the total energy usage, however can range up to 45%. The variation between feedlots can be attributed to the various manure management systems employed at each feedlot. It is driven by the frequency of cleaning, equipment used and the volume of manure removed.

Cattle washing energy usage ranged between an average 0.02 MJ/kg HSCW gain (0.3 %) and 0.1 MJ/kg HSCW gain (1 %) of total energy usage. The energy consumed in cattle washing is directly related to the volume of water used. The average cattle washing energy usage on a per head washed basis ranged from 1 to 12 MJ/head washed. The predominant energy source is electric, however an electric and diesel powered pumping system are used. The variability between feedlots is directly related to respective water used for washing cattle at each feedlot.

Administration and minor activities (cattle management, repairs and maintenance) contributed an average 0.01 MJ/kg HSCW gain and 0.58 MJ/kg HSCW gain (1 %) of total energy usage. Typically, administration and minor activities represented between 4 and 20% of the total energy usage on a per kg HSCW gain basis.

The average administration energy usage ranges from 240 MJ/kg Staff FTE to 530 MJ/kg Staff FTE. The higher usage is associated with the warmer months, hence air conditioning of the office facilities is driving energy usage in these cases.

Cattle management energy usage includes both processing and hospital activities and is expressed on per total head processed (inducted and shipped) not head on feed. Energy usage is predominantly electricity used for lighting, cleaning and restraint facilities. The average energy usage for cattle management ranges from 0.10 MJ/head processed to 5 MJ/head processed.

Repairs and maintenance includes electricity usage in workshop facilities as well as diesel usage from mobile plant used in repair and maintenance activities. It is expressed as head on feed. The average energy usage for cattle management ranges from 0.4 MJ/head on feed/month to 4.5 MJ/head on feed/month. The large variation in repairs and maintenance energy usage and is due to the variation in mobile plant fuel usage between months.

Actual energy usage levels within individual activities have been recorded in seven feedlots representative of the Australian Feedlot Industry. These included water supply, feed management, waste management, cattle washing and administration and minor activities (cattle management and repairs and maintenance).

The outcomes of this study will allow the feedlot industry to develop a better understanding of the impact and relativity that various feedlot sector operations have on overall energy consumption. This information is invaluable for future design and management considerations. This study offers individual feedlot operators the opportunity to identify options for conserving energy in the feedlot and estimated cost benefits for alternative management practices if they were implemented.

Knowledge of the total energy consumption will allow the industry to benchmark itself against other intensive or extensive livestock industries and or industrial processes.

The outcomes of this study will allow the feedlot industry to start benchmarking total water usage, hence addressing the public misconceptions associated with the water used in the production of one kilogram of grained beef. In addition, this information is invaluable for participating feedlots in understanding the drivers of drinking water consumption and targeting high water use areas for efficiency gains and for future design and management considerations.

7.2 Recommendations

The data collected to date have indicated a large variation in energy usage between participating feedlots. This variation can be attributed to a number of factors including water supply and reticulation, feedlot design and layout, type of feed processing and delivery systems, mobile plant involved in waste management and management and operation of these activities.

Energy usage is less dependent on climatic variation when compared with water usage. However, climatic factors will directly affect waste management (pen cleaning) and indirectly on other areas such as water supply (water requirements) and cattle washing (dagginess of cattle) energy usage.

Results have also shown that energy usage in steam flaking systems increases during periods of cooler weather.

Benchmarking of this information has raised awareness of energy usage within the participating feedlots. This project has also provided industry with a set of industry statistics on energy usage over a 12-month period. A number of feedlots have installed or upgraded plant and mobile equipment during the previous study period. Hence, continuing the data collection will allow any efficiency gains resulting from changes to activities that may have been implemented. This is important both at an industry and feedyard level.

To consolidate and build on the work already undertaken it is recommended that the data collection and collation of water and energy usage within all of the existing participating feedlots continue for a further 12 months. The rationale for this option is that all of the equipment is installed and recording well, hence is a cost-effective activity. This option would require the development, implementation and use of a simplified electronic reporting system to ensure ease and consistency in reporting.

Firstly, this will allow the industry to establish a more robust baseline for energy usage. Secondly, this will allow individual feedlots to benchmark their operation and identify areas to target for improved energy or cost efficiency. Thirdly, the impact on changes to management practices to demonstrate energy efficiency gains from changes to activities will be documented.

In addition, it is important that this information is extended to industry and industry research community. Therefore, it is recommended that a series of information sheets and case studies to assist lot feeders in understanding, planning and organising, implementing and monitoring a water and energy efficiency program based on the outcomes of this work be prepared.

This would include an ‘Understanding’, ‘Benchmarking’ and ‘Case study’ series of information sheets. The ‘understanding’ series would outline the protocols on how to develop a system to measure, collate, analyse and report energy use data, assess their water consumption for benchmarking purposes and identify energy impacts and opportunities. Examples of information sheets within this series include, but not limited to – ‘Commitment - Establishing the drivers for resource management’, ‘Understanding your system – Mapping energy distribution networks’, ‘Designing a energy usage monitoring system’, ‘Measuring energy usage’, ‘Reading power meters’, ‘Defining functional units’ etc.

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Appendix A – Cattle transport and commodity delivery energy usage

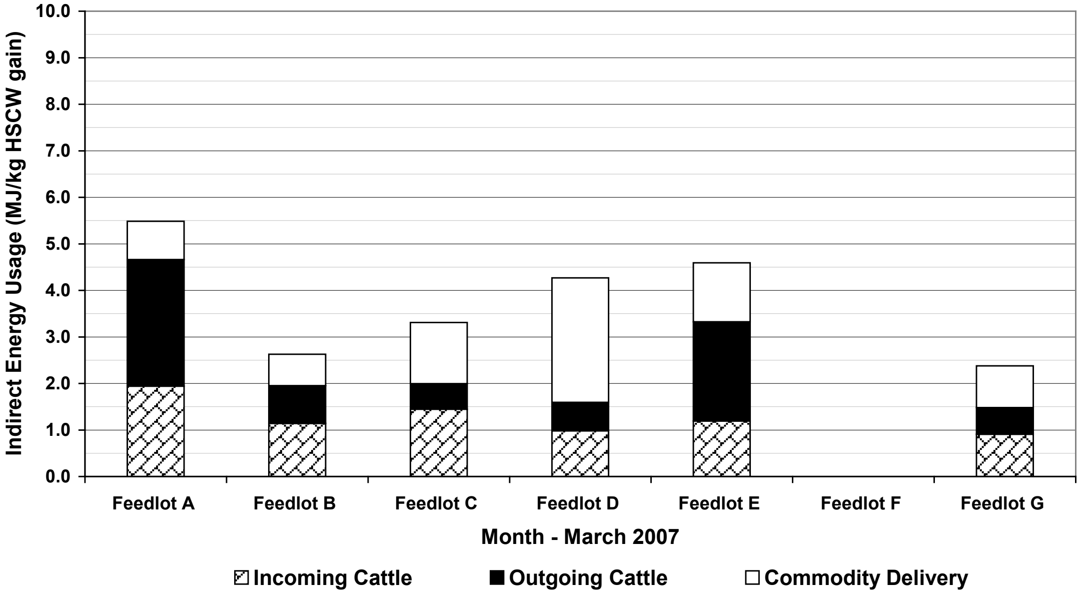

Figure 57 – Indirect energy usage for March 2007 (MJ/kg HSCW gain)

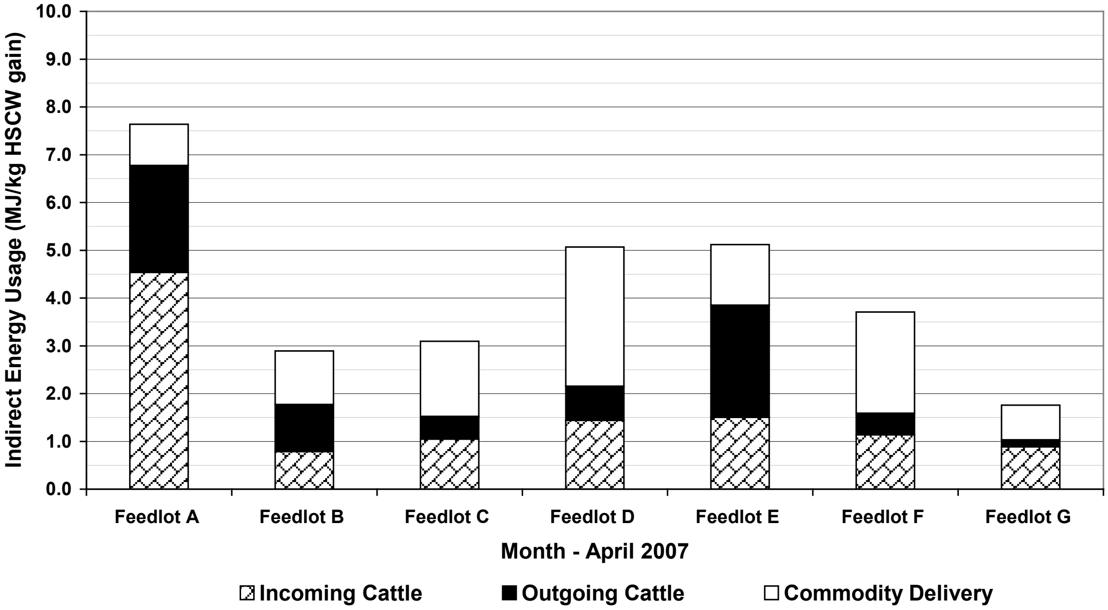

Figure 58 – Indirect energy usage for April 2007 (MJ/kg HSCW gain)

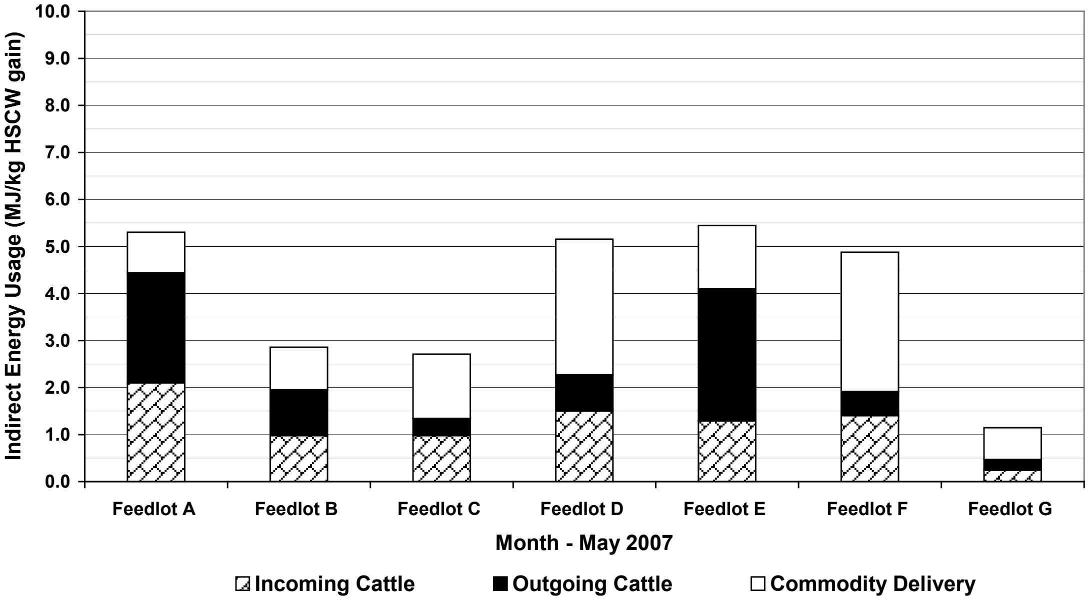

Figure 59 – Indirect energy usage for May 2007 (MJ/kg HSCW gain)

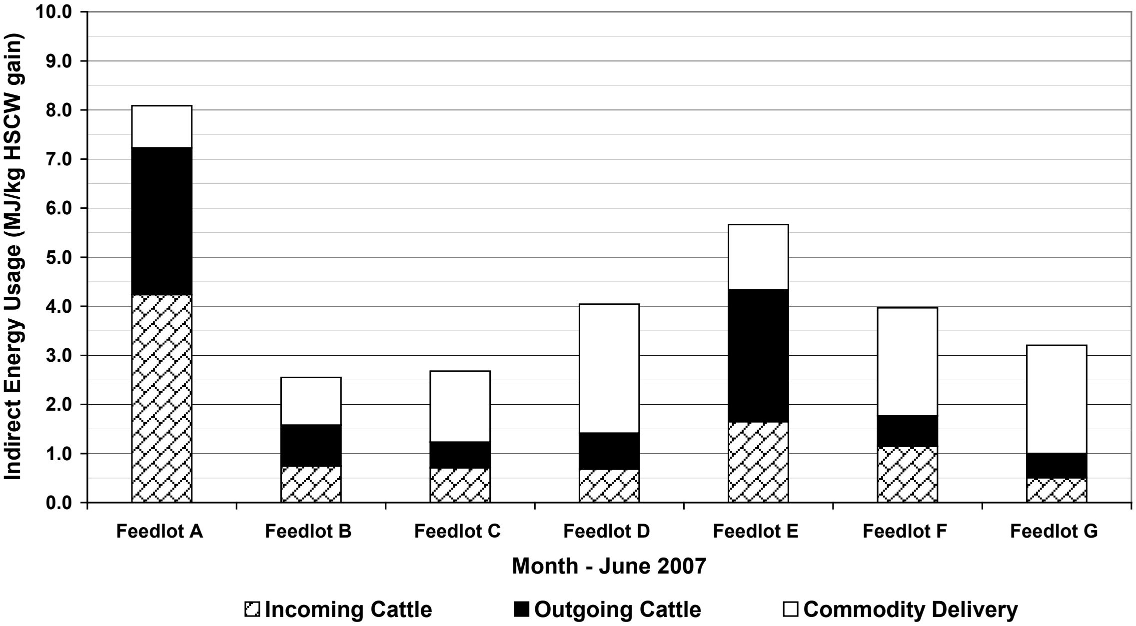

Figure 60 – Indirect energy usage for June 2007 (MJ/kg HSCW gain)

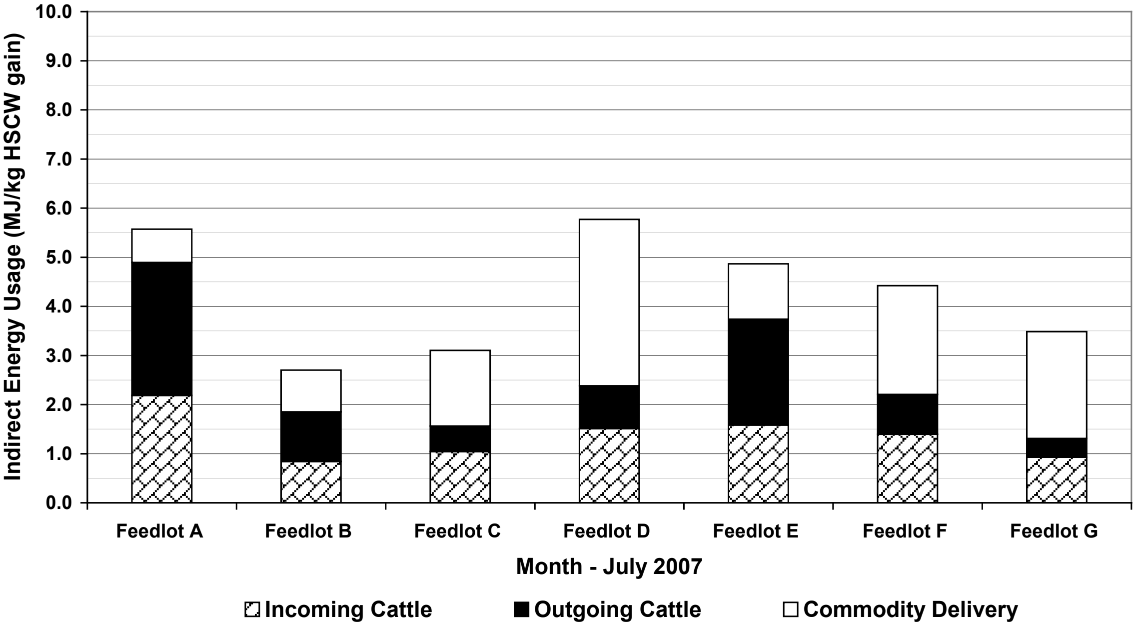

Figure 61 – Indirect energy usage for July 2007 (MJ/kg HSCW gain)

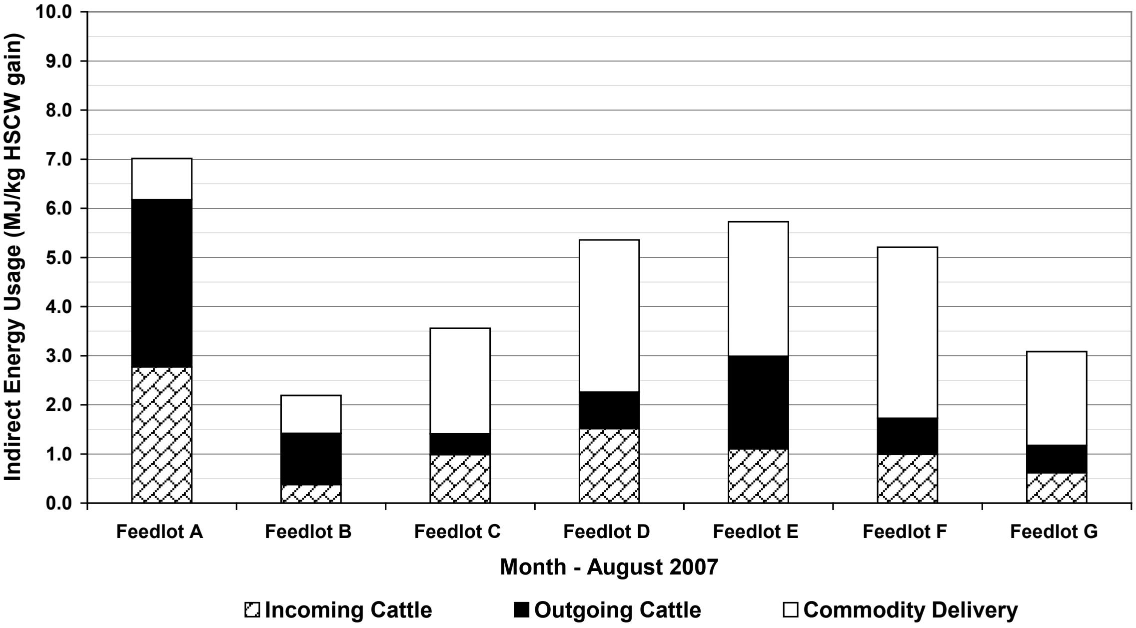

Figure 62 – Indirect energy usage for August 2007 (MJ/kg HSCW gain)

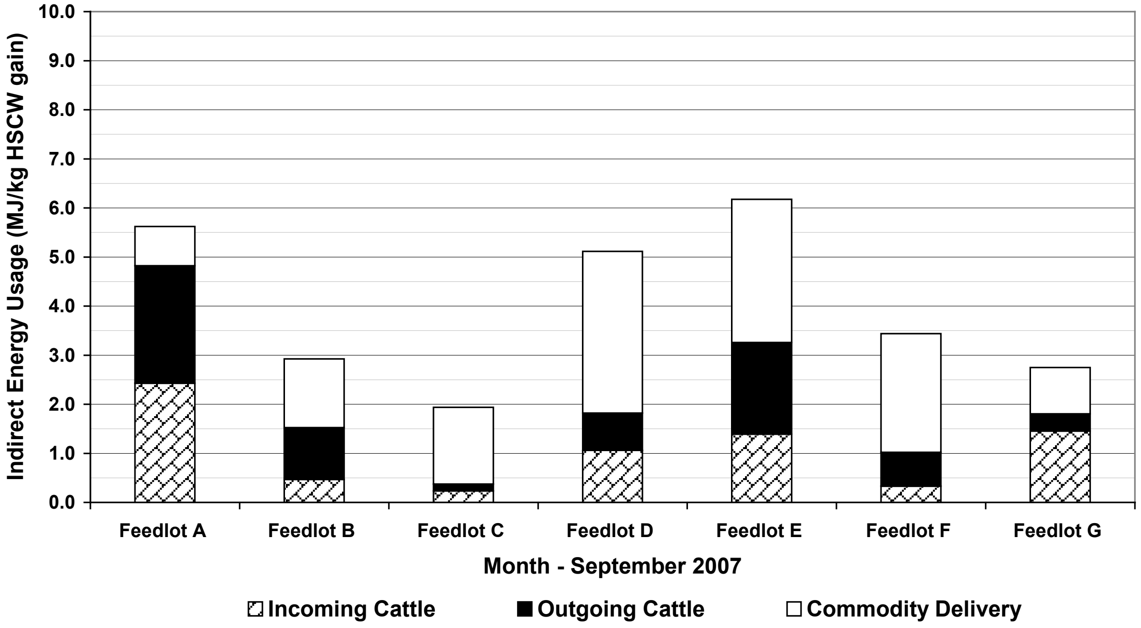

Figure 63 – Indirect energy usage for September 2007 (MJ/kg HSCW gain)

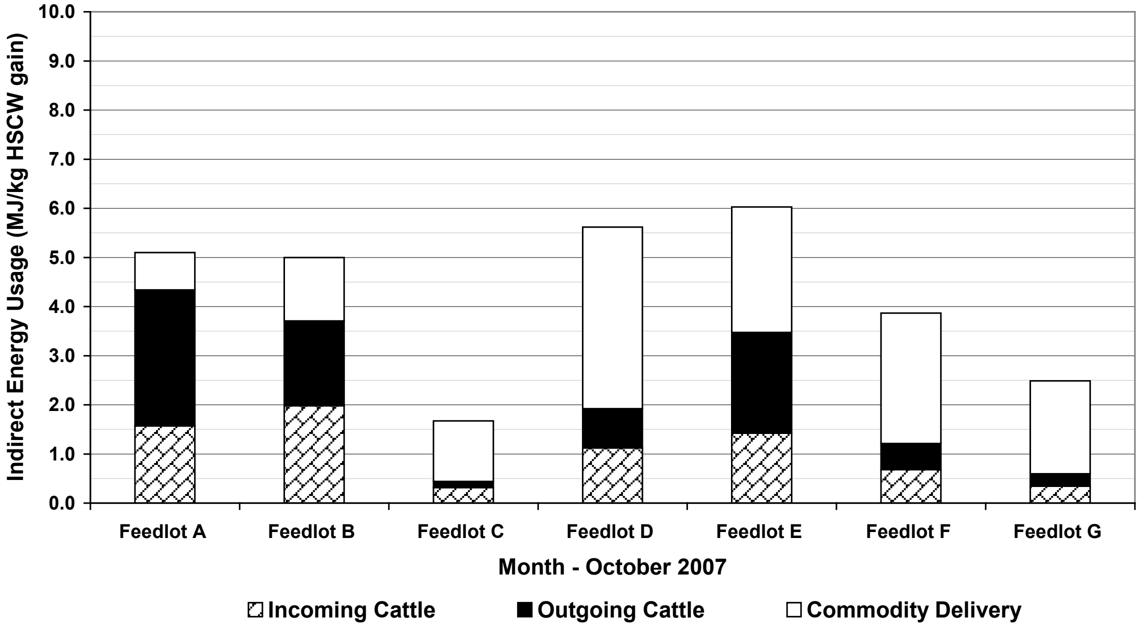

Figure 64 – Indirect energy usage for October 2007 (MJ/kg HSCW gain)

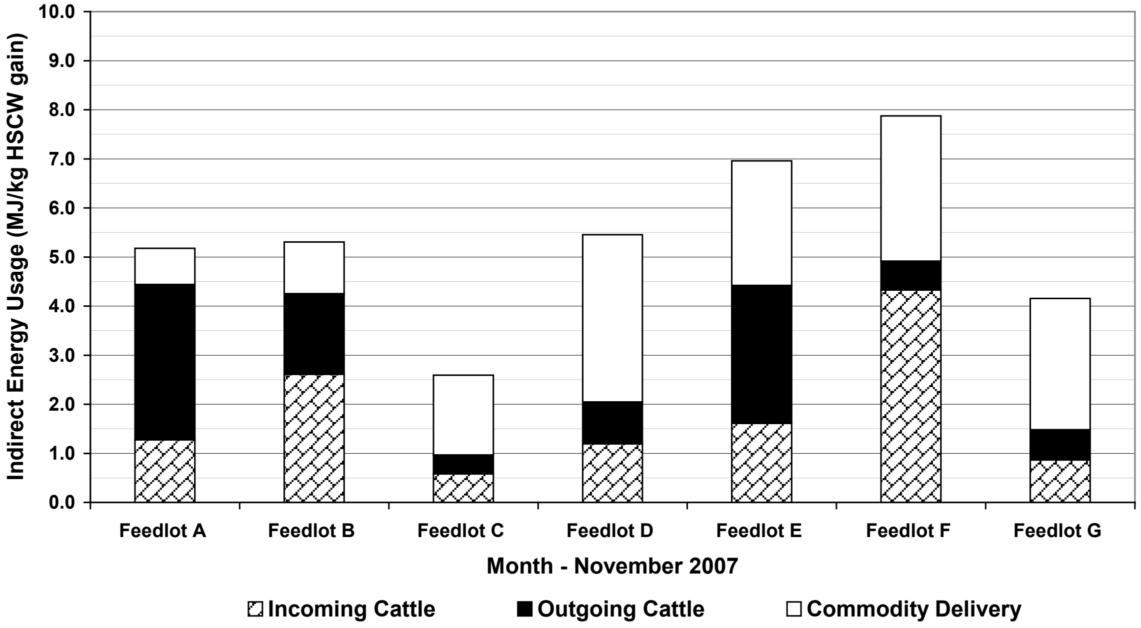

Figure 65 – Indirect energy usage for November 2007 (MJ/kg HSCW gain)

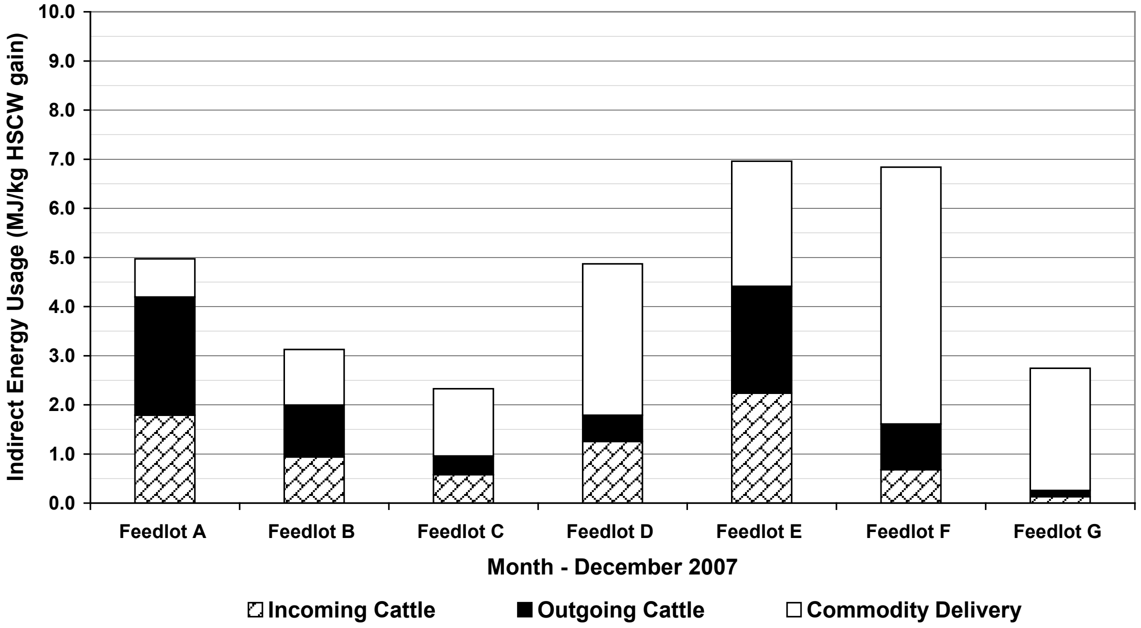

Figure 66 – Indirect energy usage for December 2007 (MJ/kg HSCW gain)

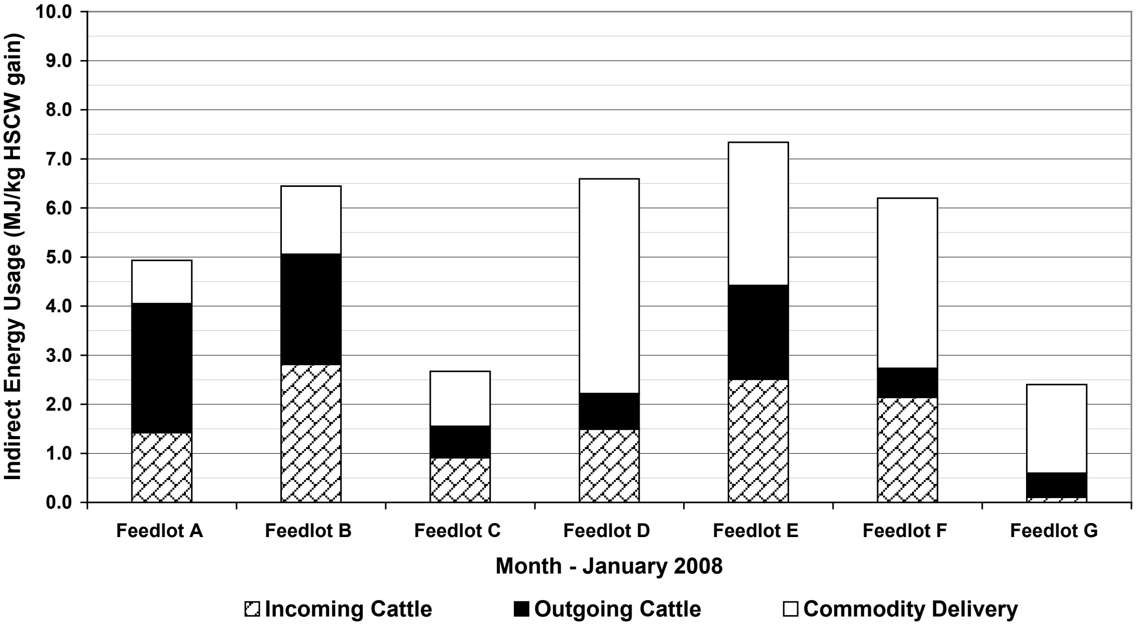

Figure 67 – Indirect energy usage for January 2008 (MJ/kg HSCW gain)

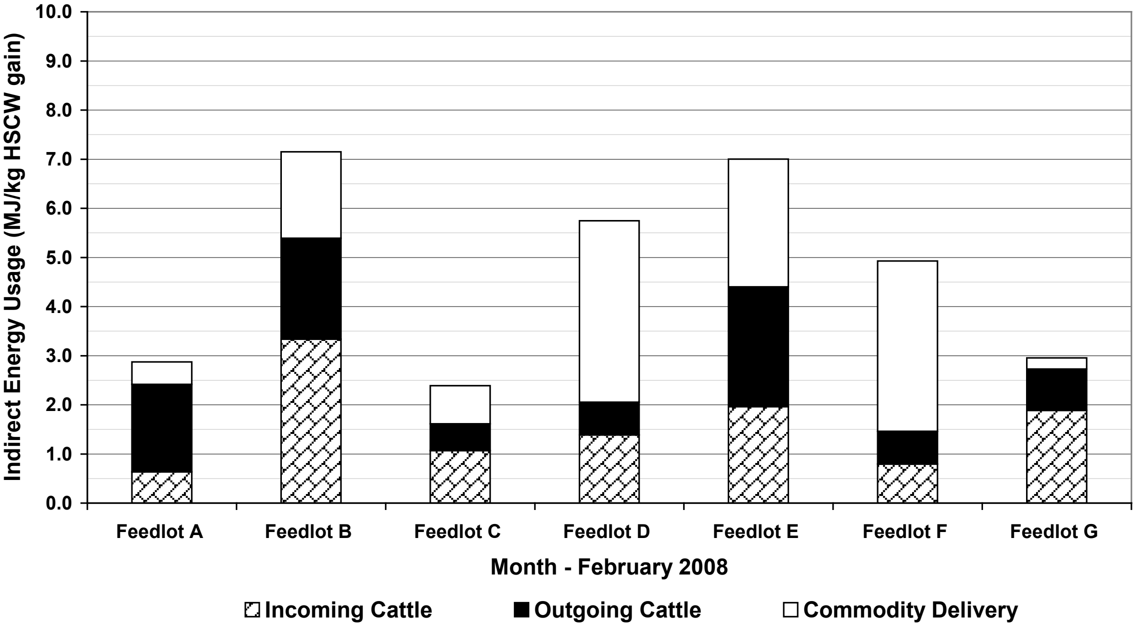

Figure 68 – Indirect energy usage for February 2008 (MJ/kg HSCW gain)

Appendix B – Water supply energy usage

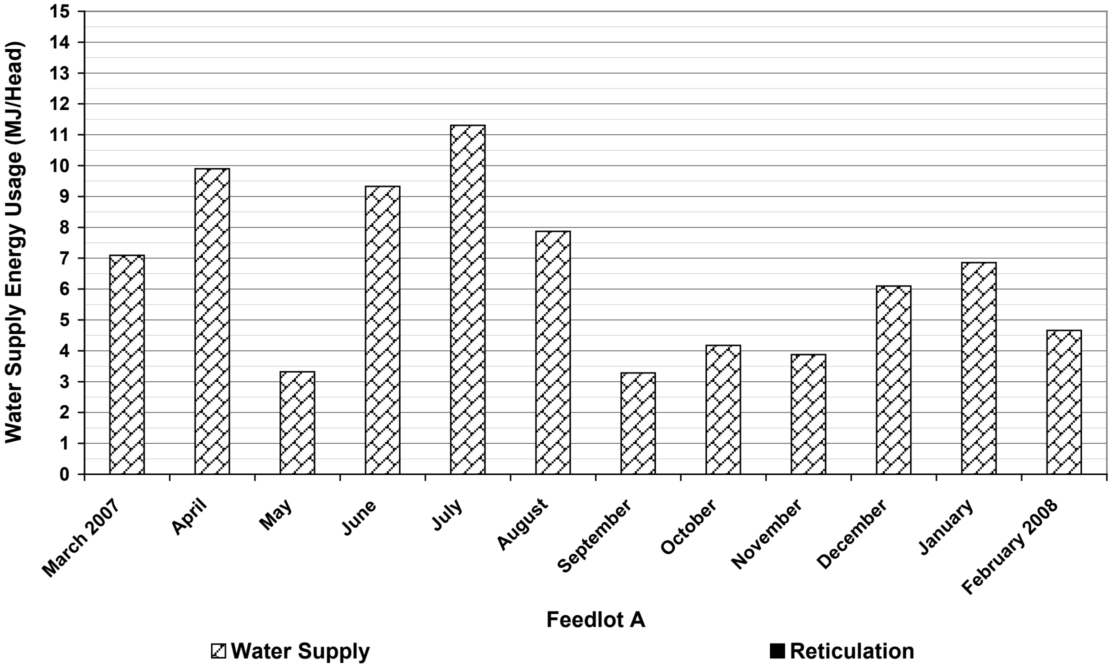

Figure 69 – Water supply energy usage for Feedlot A (MJ/head-on-feed/month)

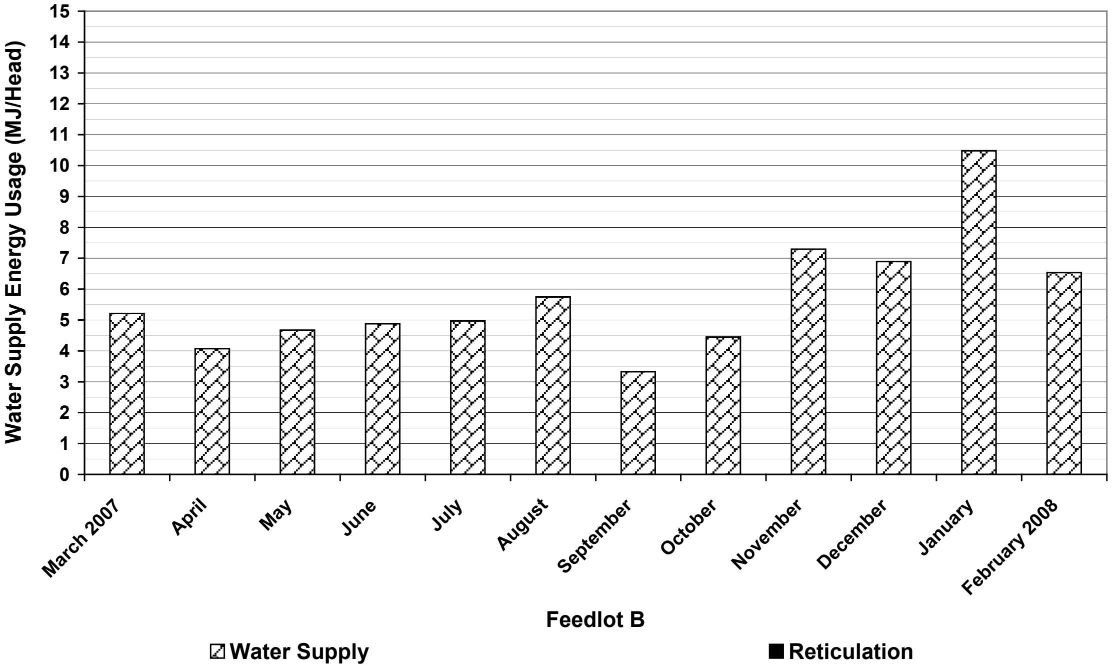

Figure 70 – Water supply energy usage for Feedlot B (MJ/head-on-feed/month)

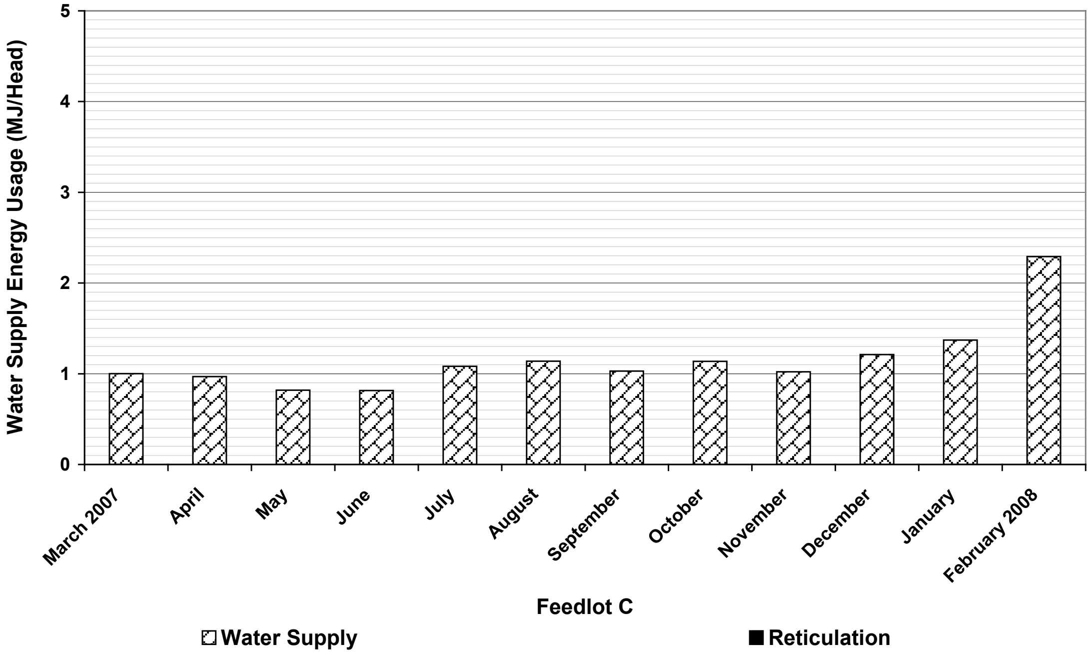

Figure 71 – Water supply energy usage for Feedlot C (MJ/head-on-feed/month)

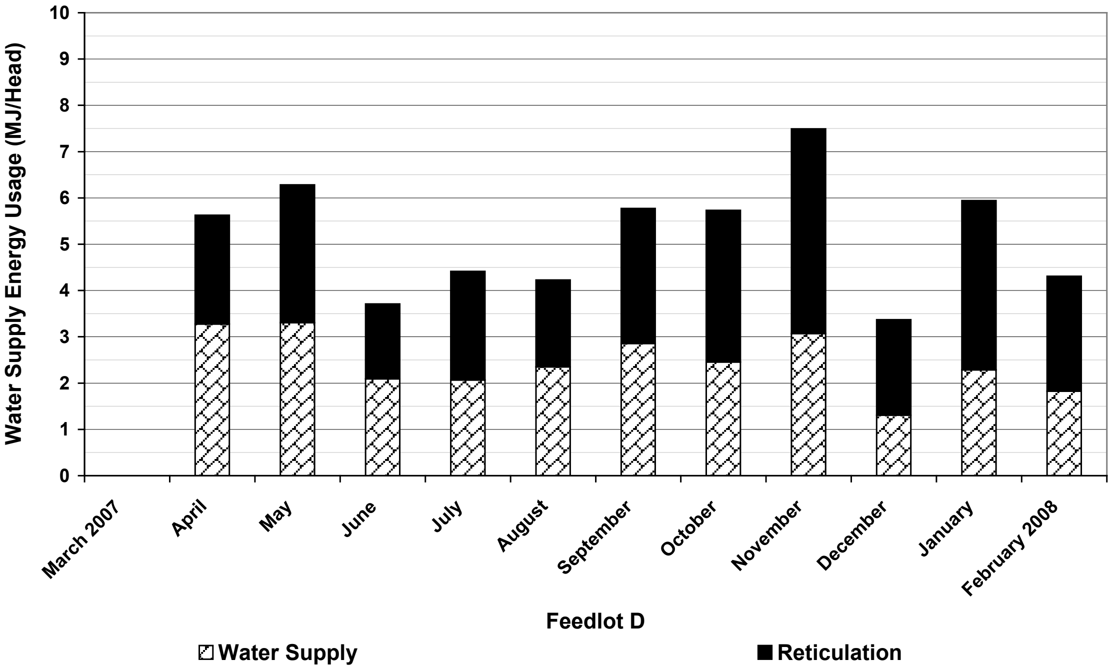

Figure 72 – Water supply energy usage for Feedlot D (MJ/head-on-feed/month)

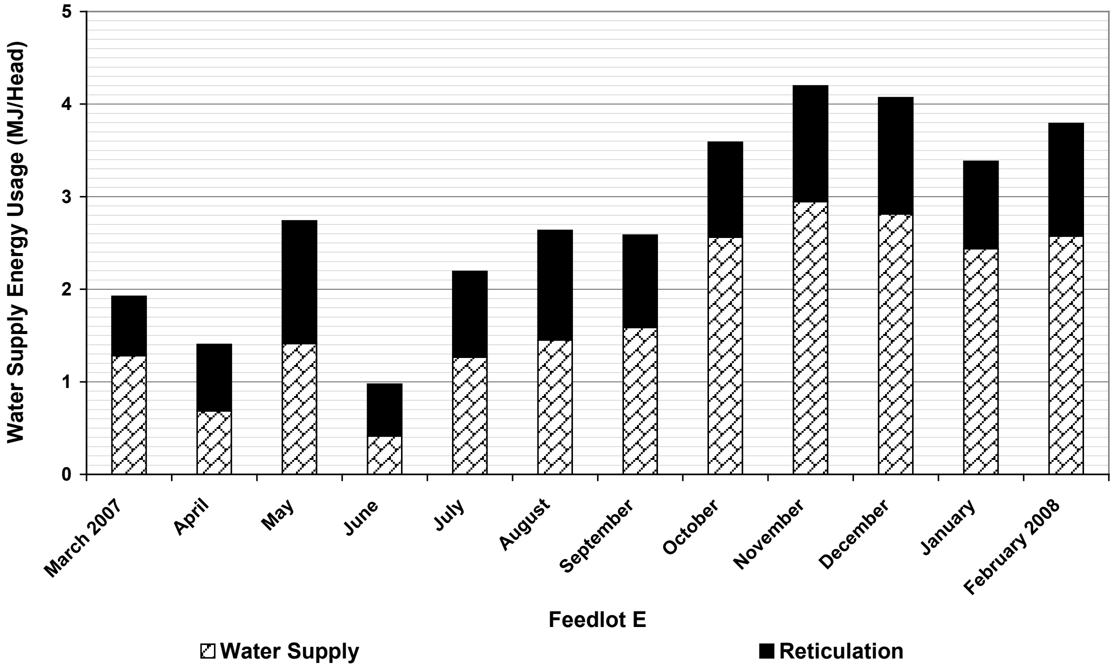

Figure 73 – Water supply energy usage for Feedlot E (MJ/head-on-feed/month)

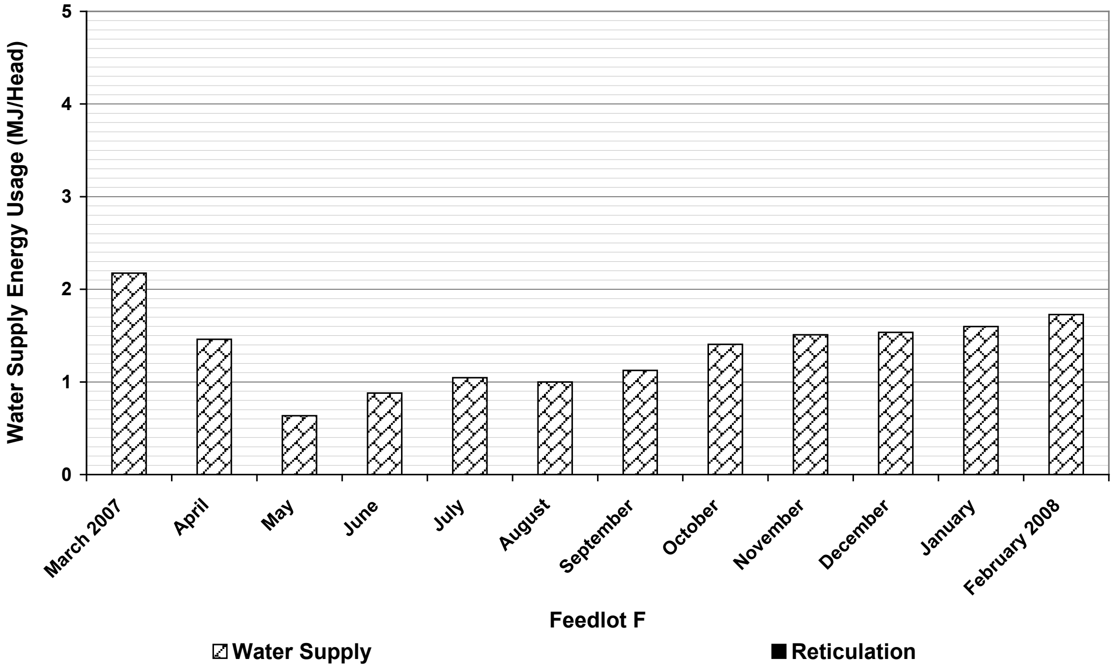

Figure 74 – Water supply energy usage for Feedlot F (MJ/head-on-feed/month)

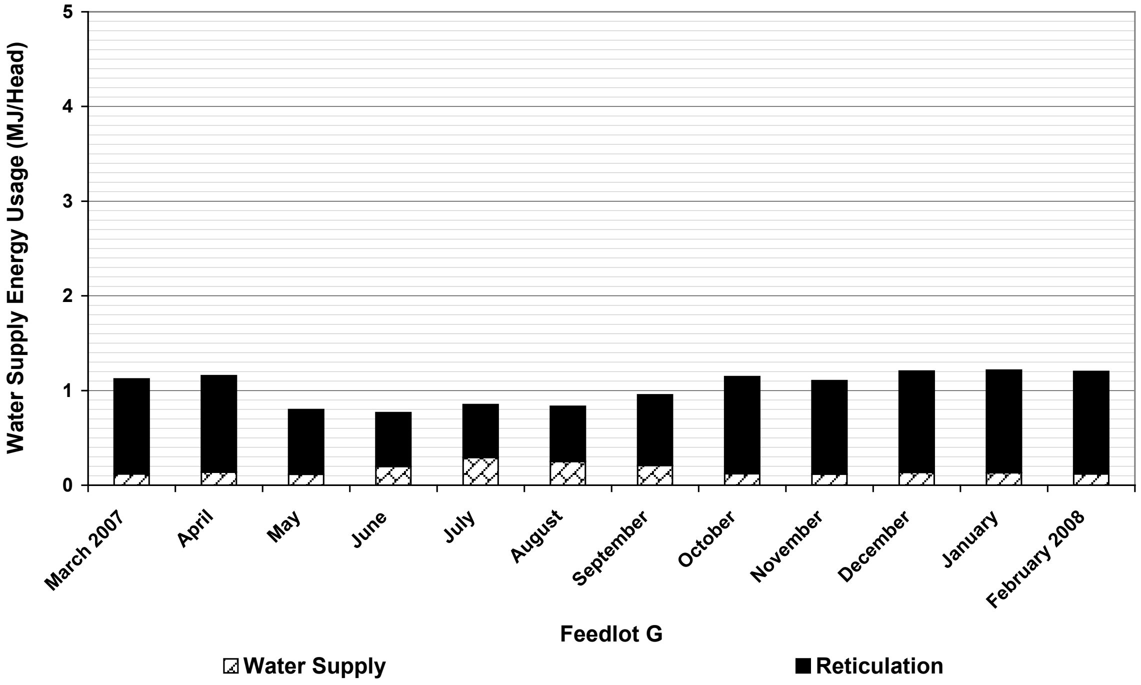

Figure 75 – Water supply energy usage for Feedlot G (MJ/head-on-feed/month)

Appendix C – Feed management energy usage

Appendix C.1 – Feed processing energy usage

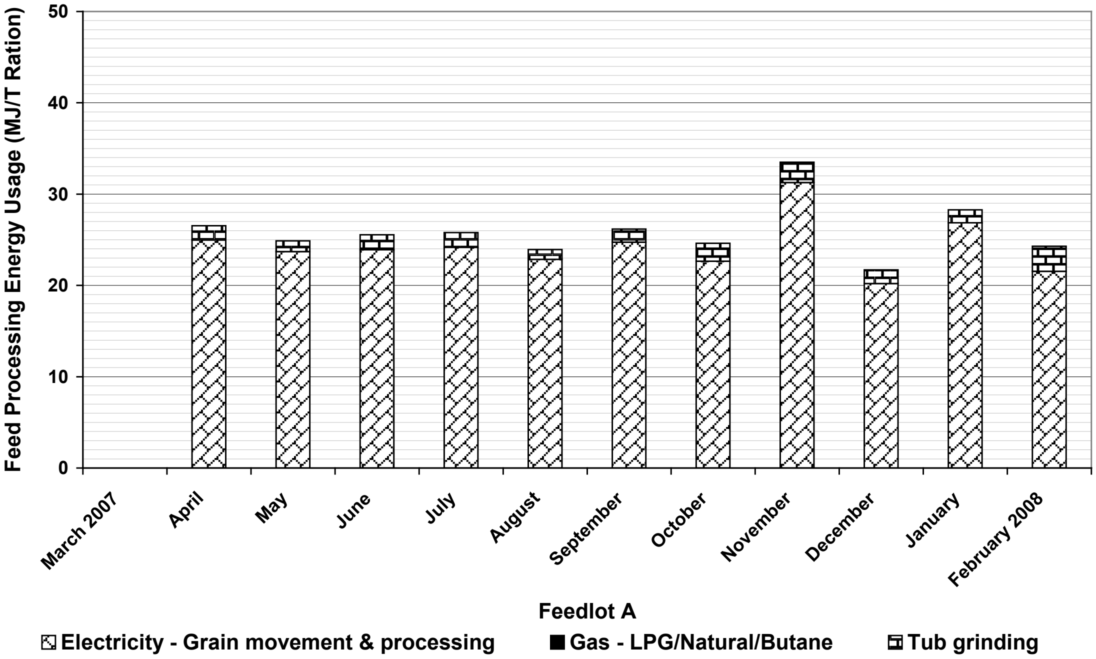

Figure 76 – Feed processing energy consumption for Feedlot A (MJ/t ration)

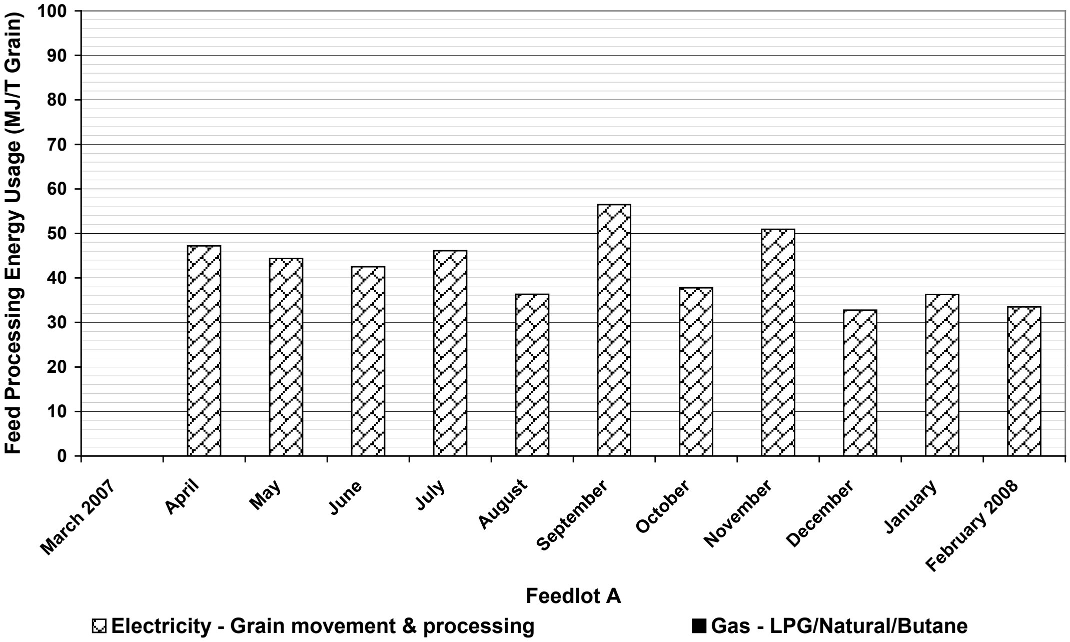

Figure 77 – Feed processing energy consumption for Feedlot A (MJ/t grain)

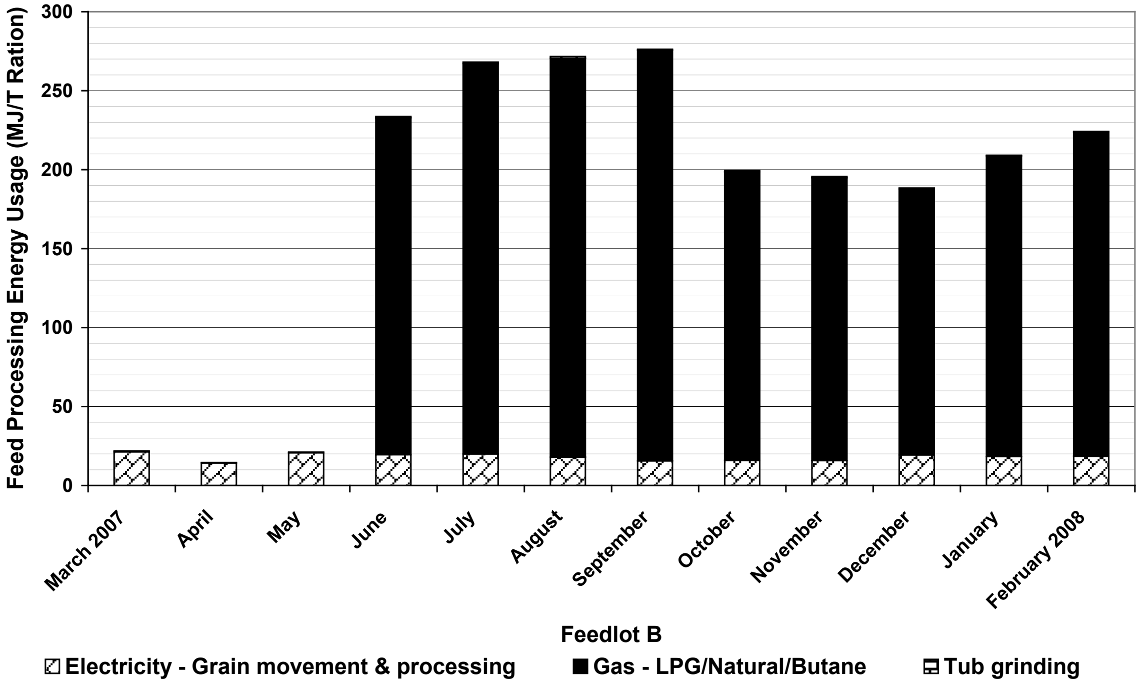

Figure 78 – Feed processing energy consumption for Feedlot B (MJ/t ration)

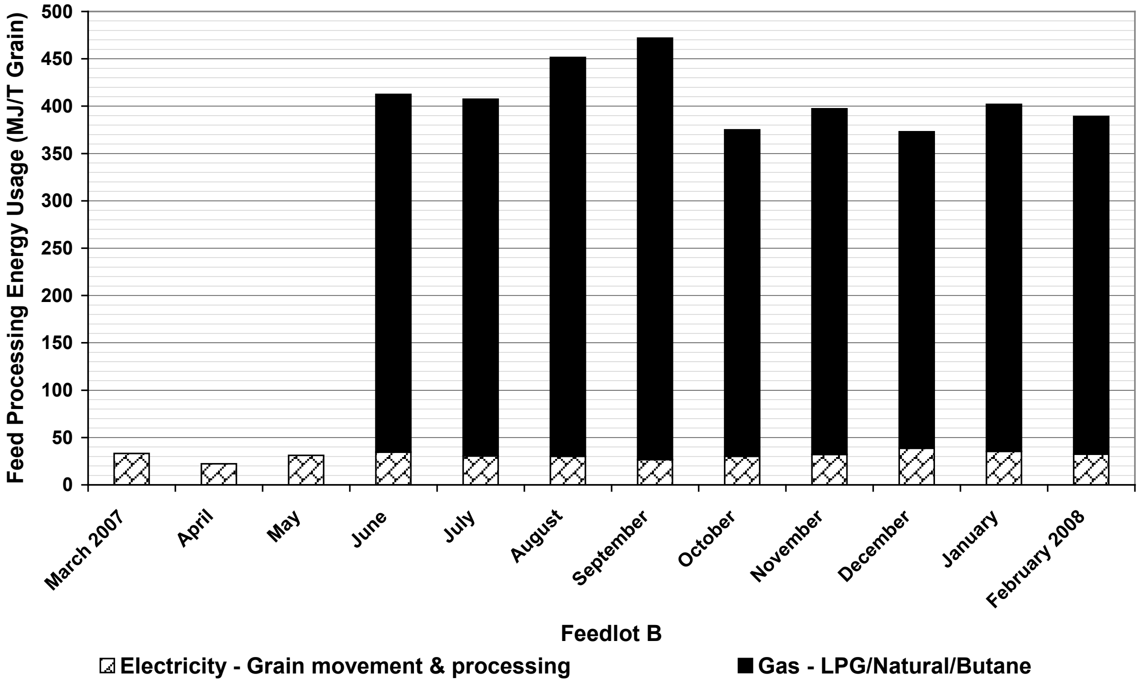

Figure 79 – Feed processing energy consumption for Feedlot B (MJ/t grain)

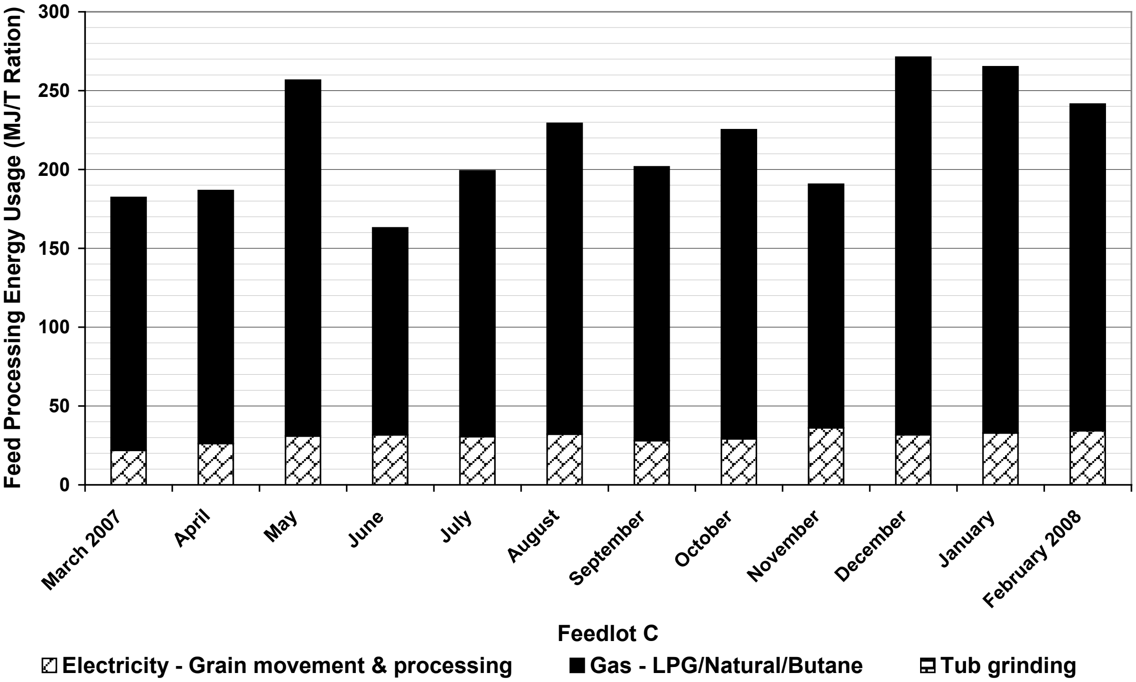

Figure 80 – Feed processing energy consumption for Feedlot C (MJ/t ration)

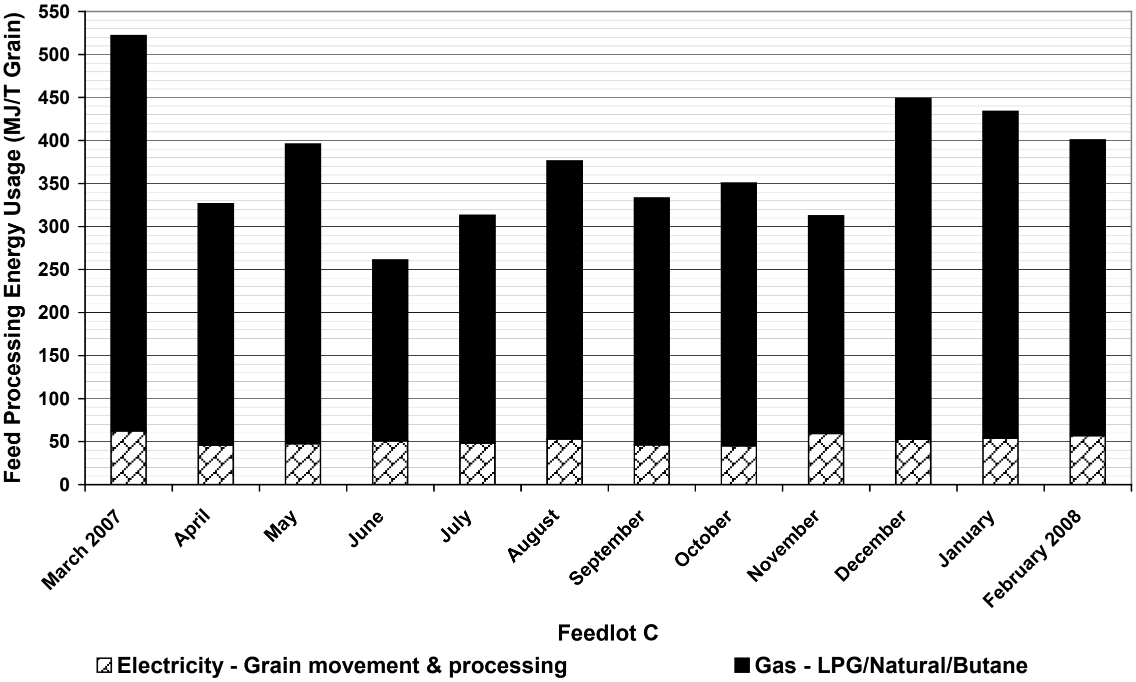

Figure 81 – Feed processing energy consumption for Feedlot C (MJ/t grain)

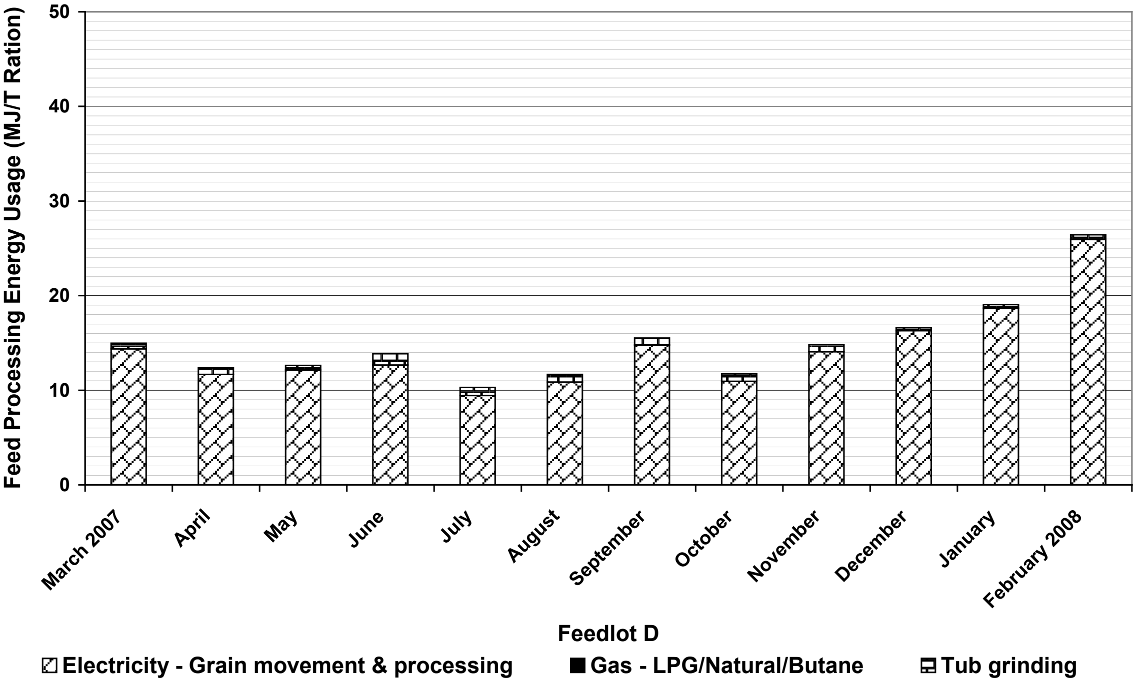

Figure 82 – Feed processing energy consumption for Feedlot D (MJ/t ration)

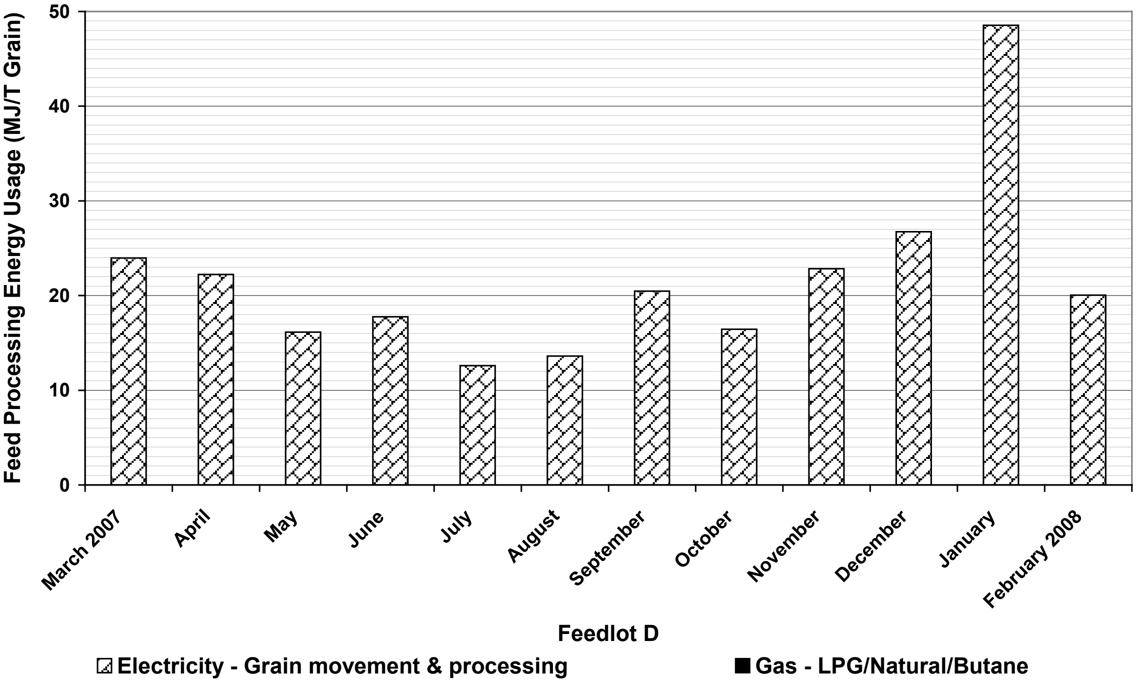

Figure 83 – Feed processing energy consumption for Feedlot D (MJ/t grain)

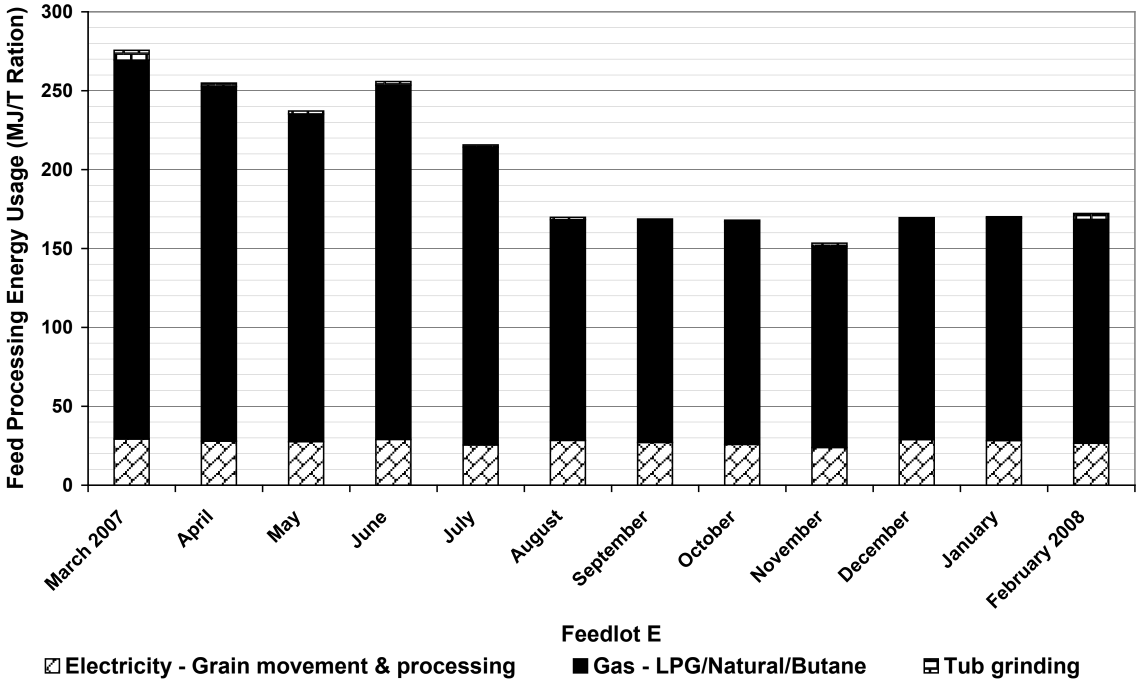

Figure 84 – Feed processing energy consumption for Feedlot E (MJ/t ration)

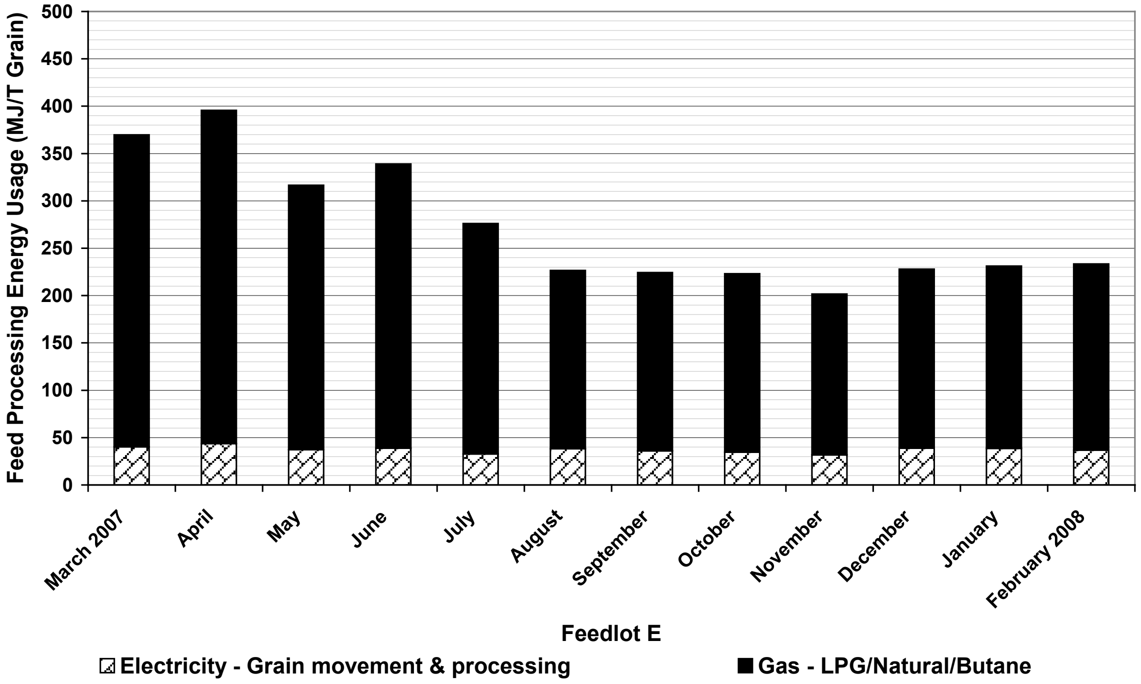

Figure 85 – Feed processing energy consumption for Feedlot E (MJ/t grain)

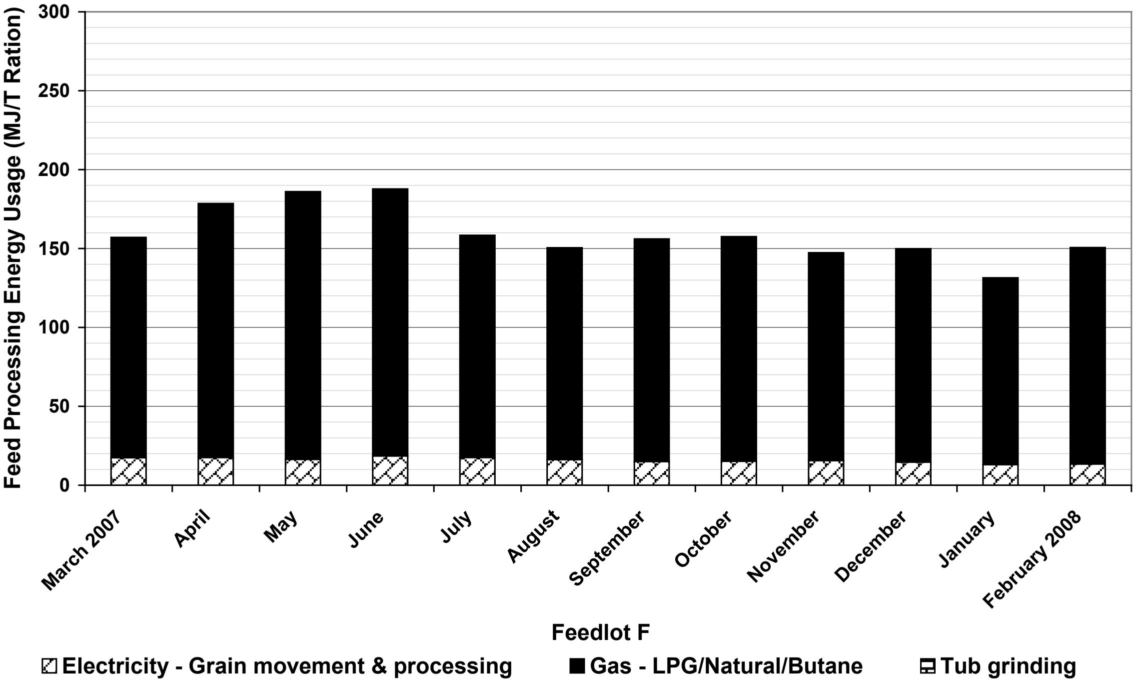

Figure 86 – Feed processing energy consumption for Feedlot F (MJ/t ration)

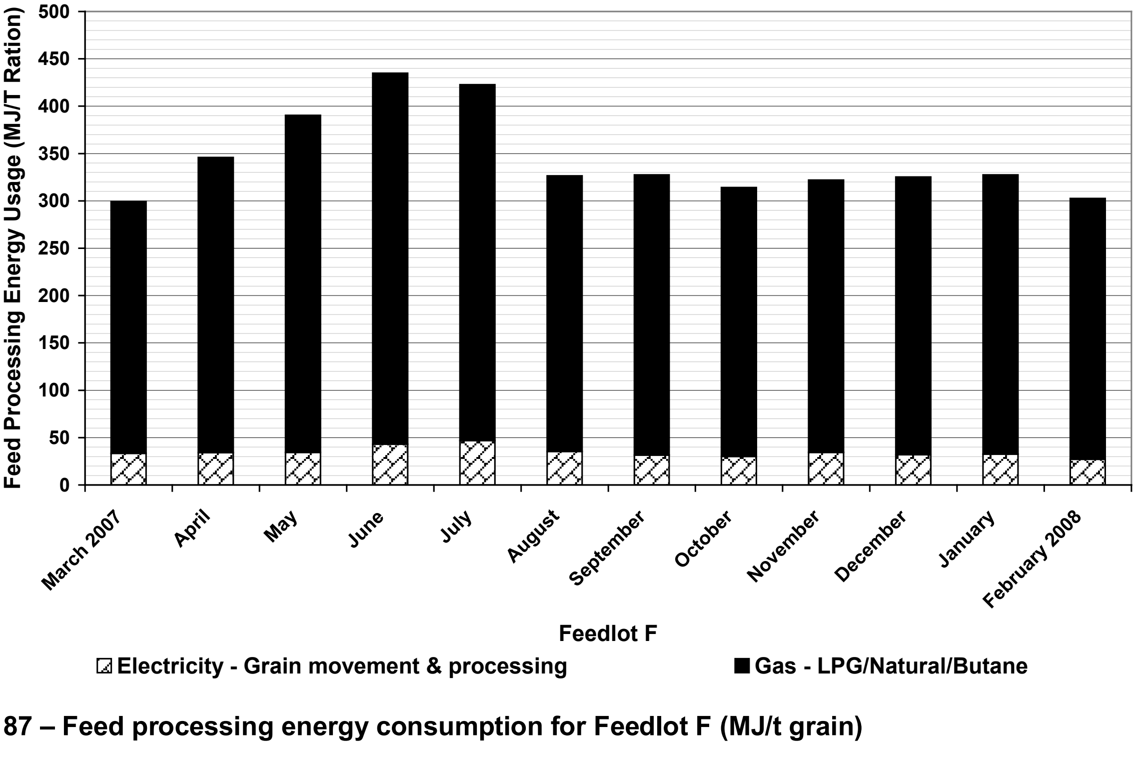

Figure 87 – Feed processing energy consumption for Feedlot F (MJ/t grain)

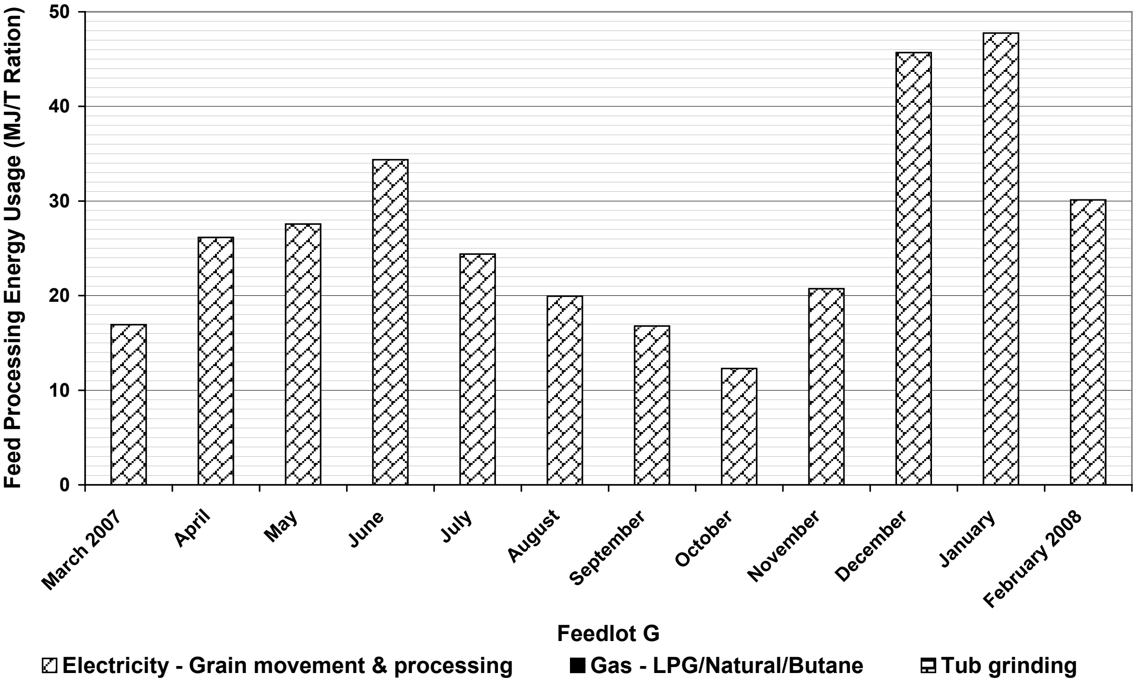

Figure 88 – Feed processing energy consumption for Feedlot G (MJ/t ration)

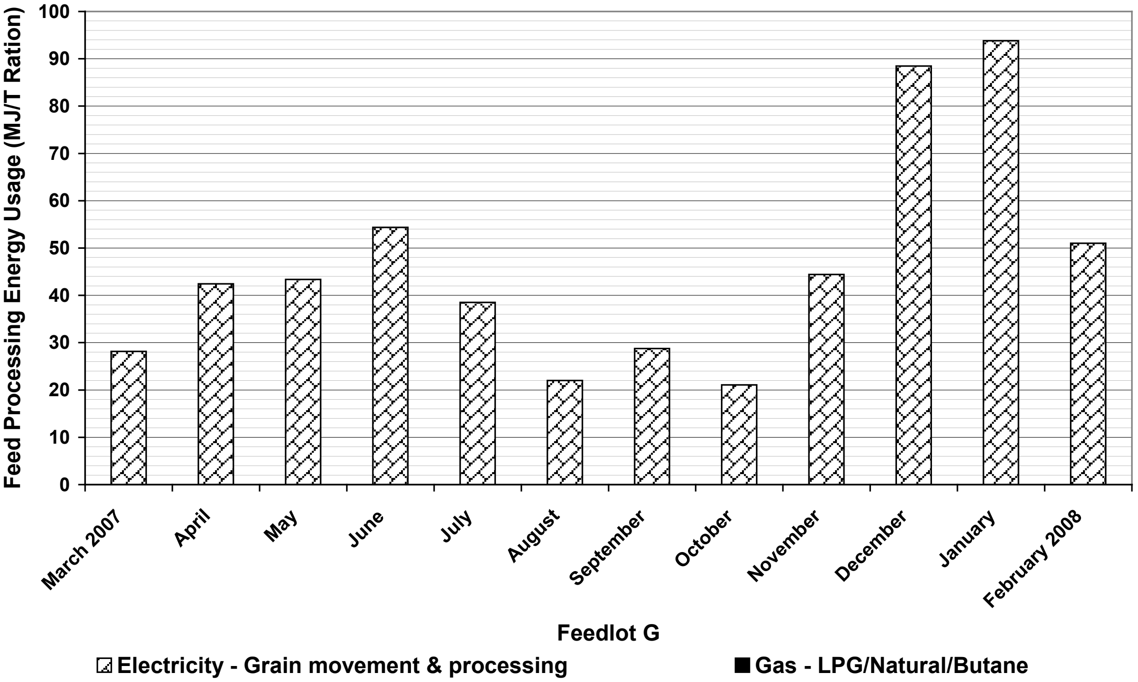

Figure 89 – Feed processing energy consumption for Feedlot G (MJ/t grain)

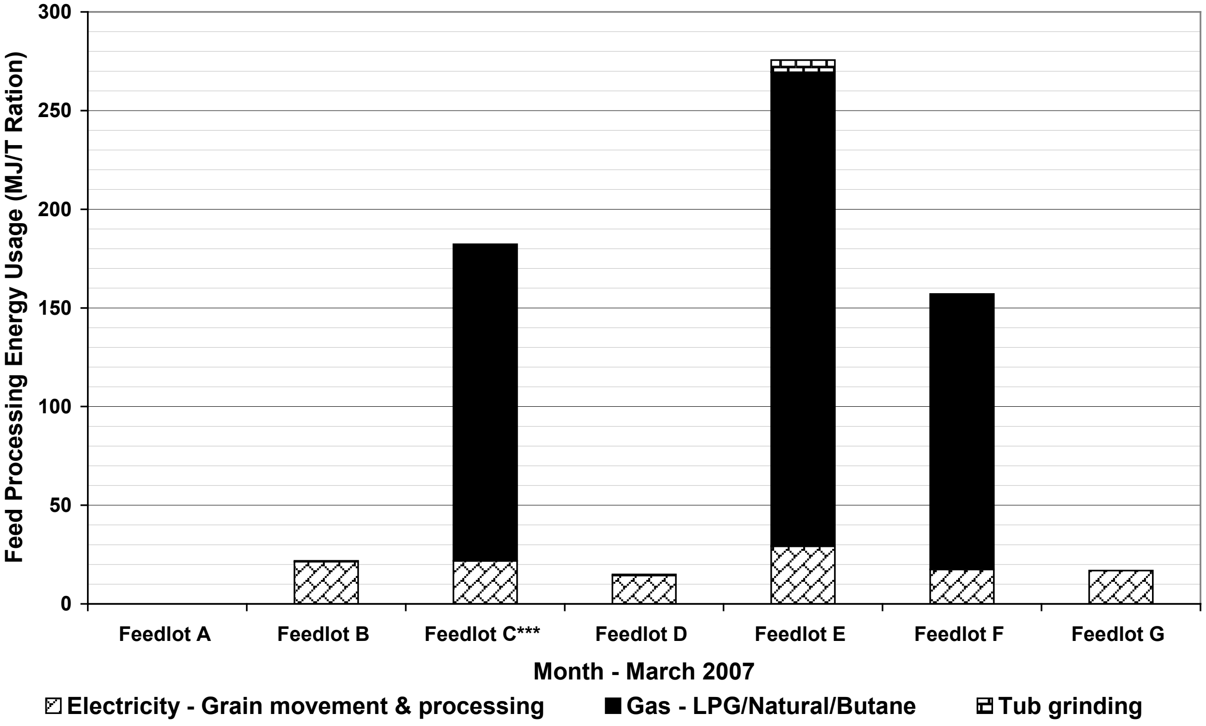

Figure 90 – Feed processing energy consumption for March 2007 (MJ/t ration)

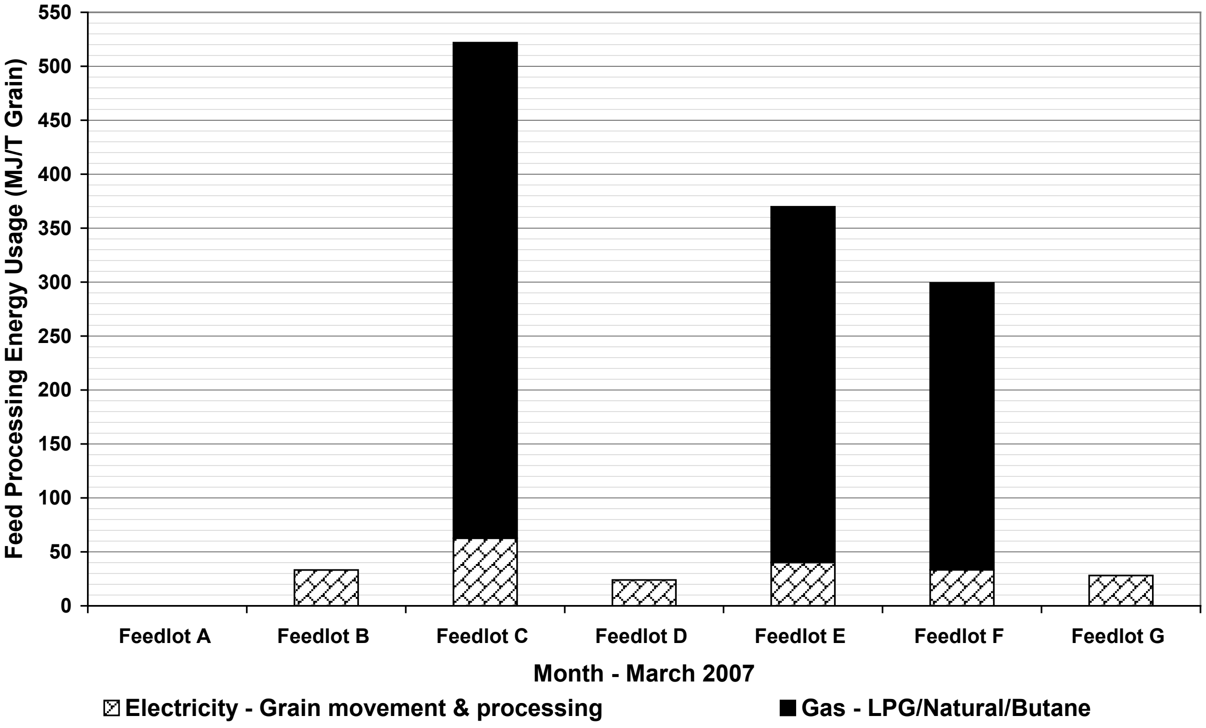

Figure 91 – Feed processing energy consumption for March 2007 (MJ/t grain)

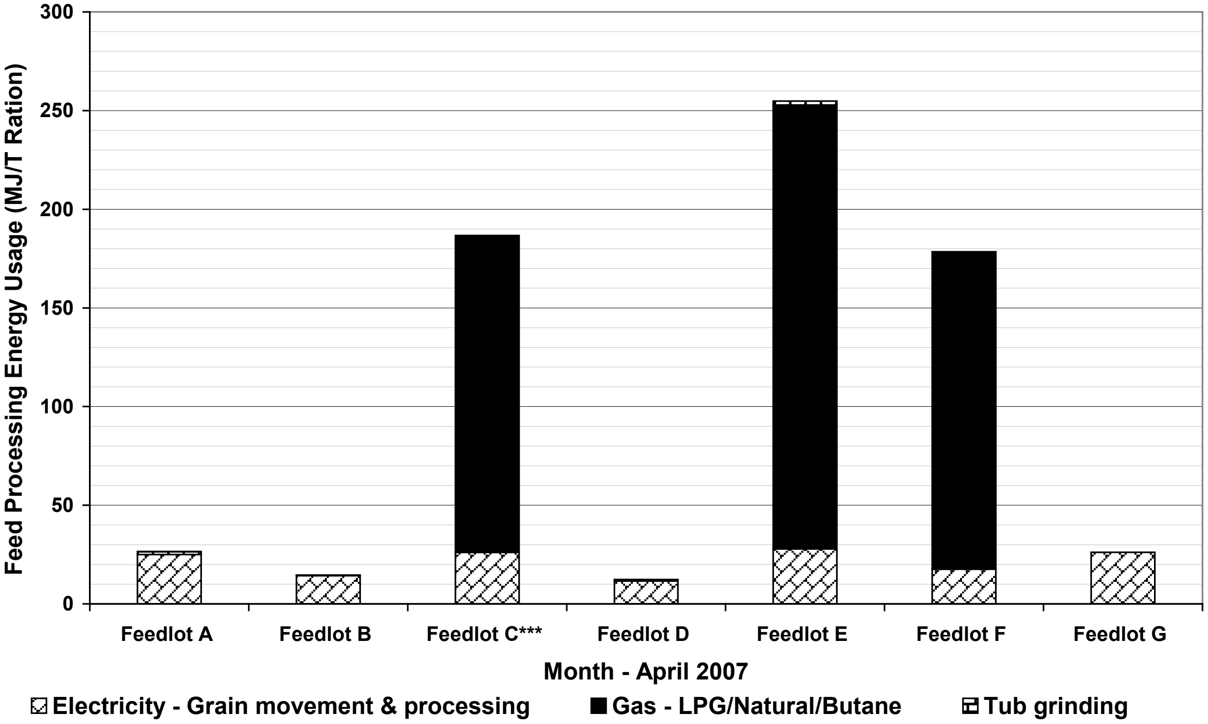

Figure 92 – Feed processing energy consumption for April 2007 (MJ/t ration)

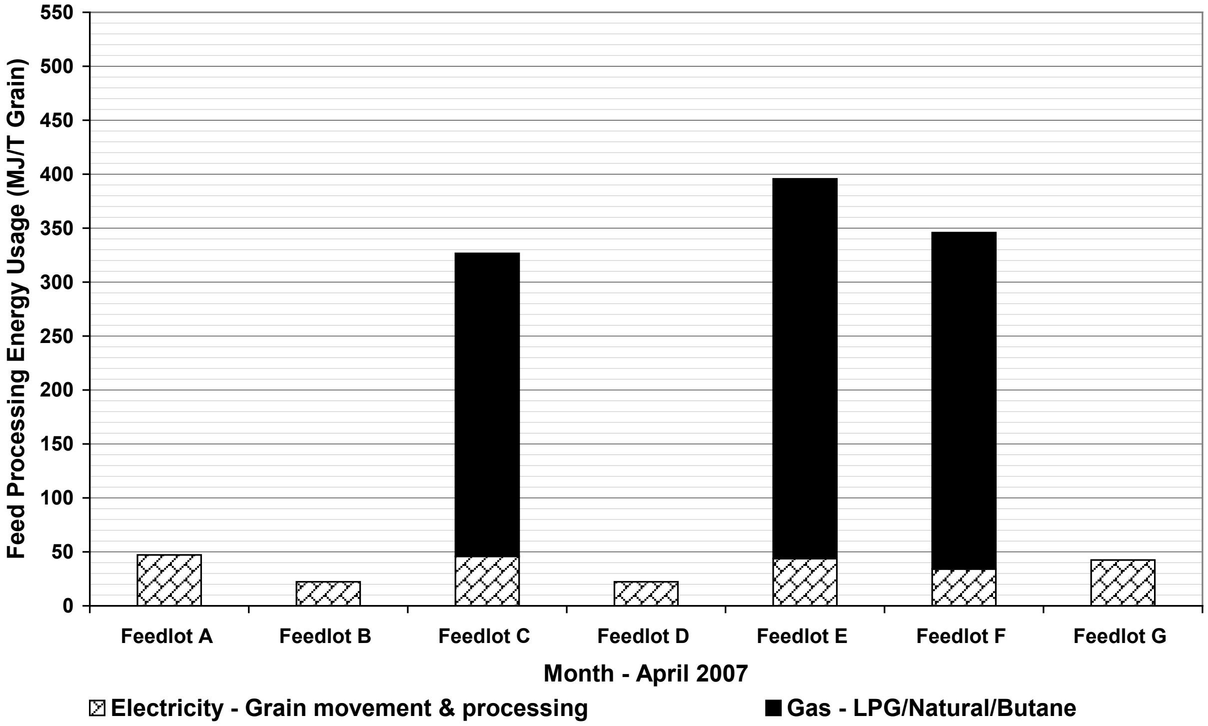

Figure 93 – Feed processing energy consumption for April 2007 (MJ/t grain)

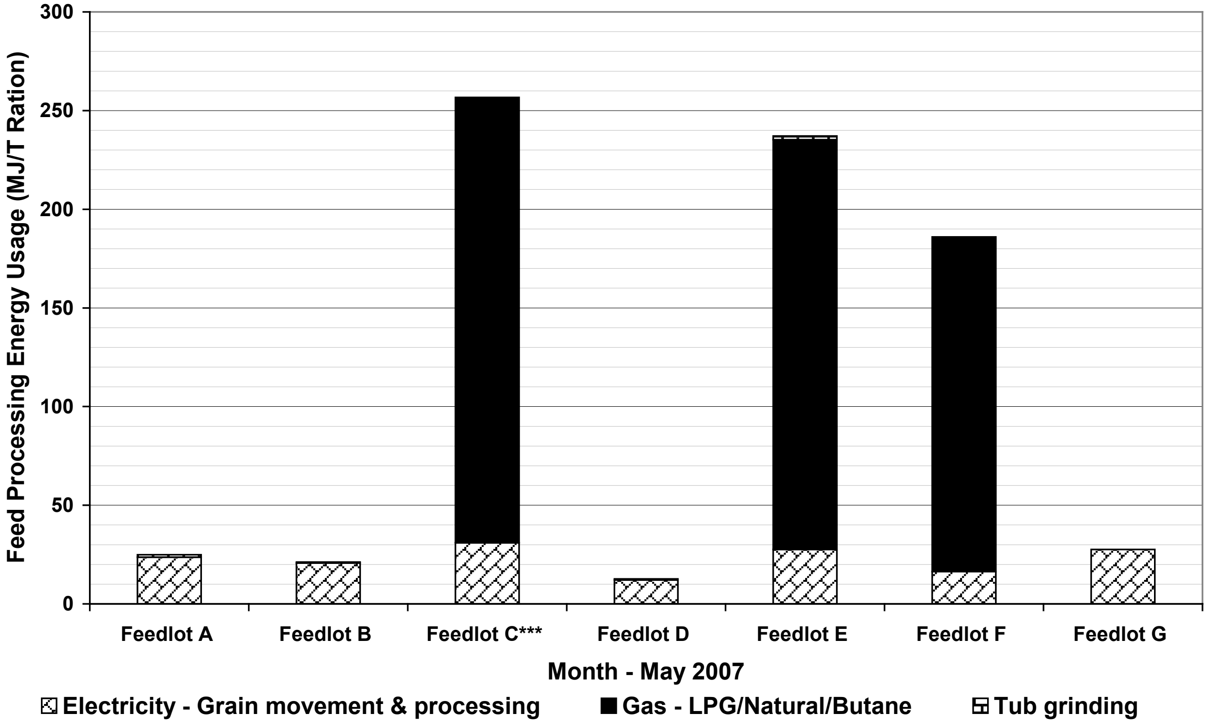

Figure 94 – Feed processing energy consumption for May 2007 (MJ/t ration)

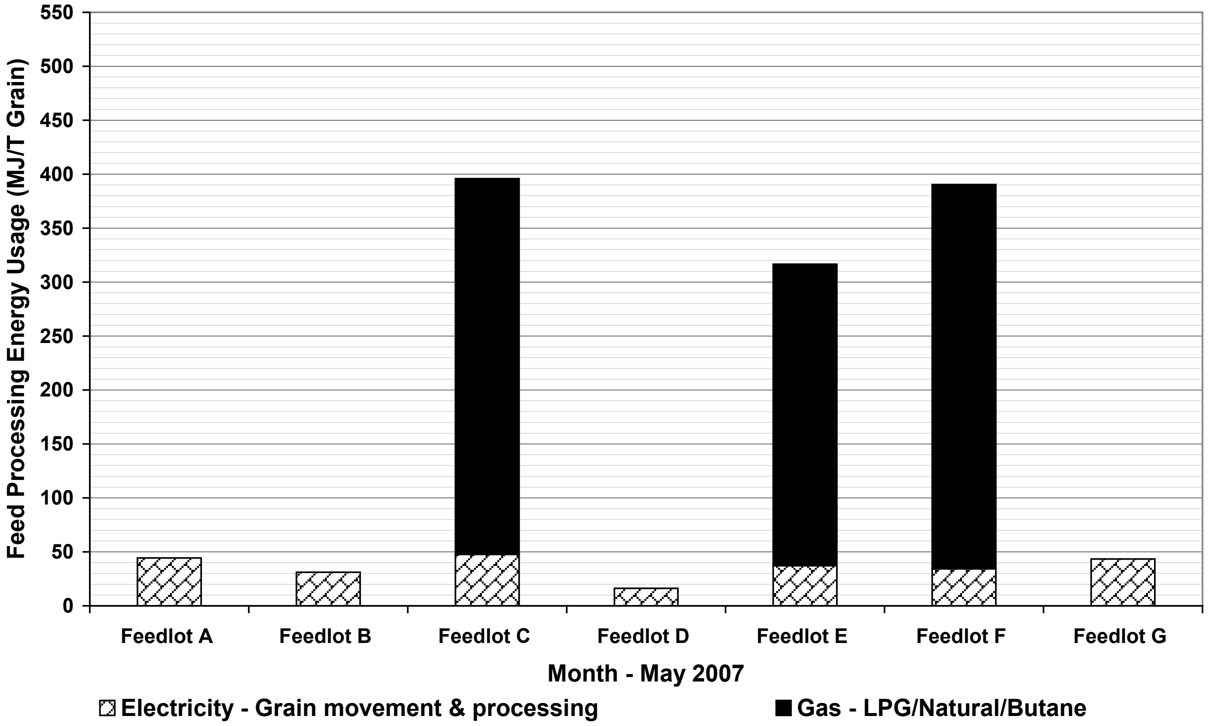

Figure 95 – Feed processing energy consumption for May 2007 (MJ/t grain)

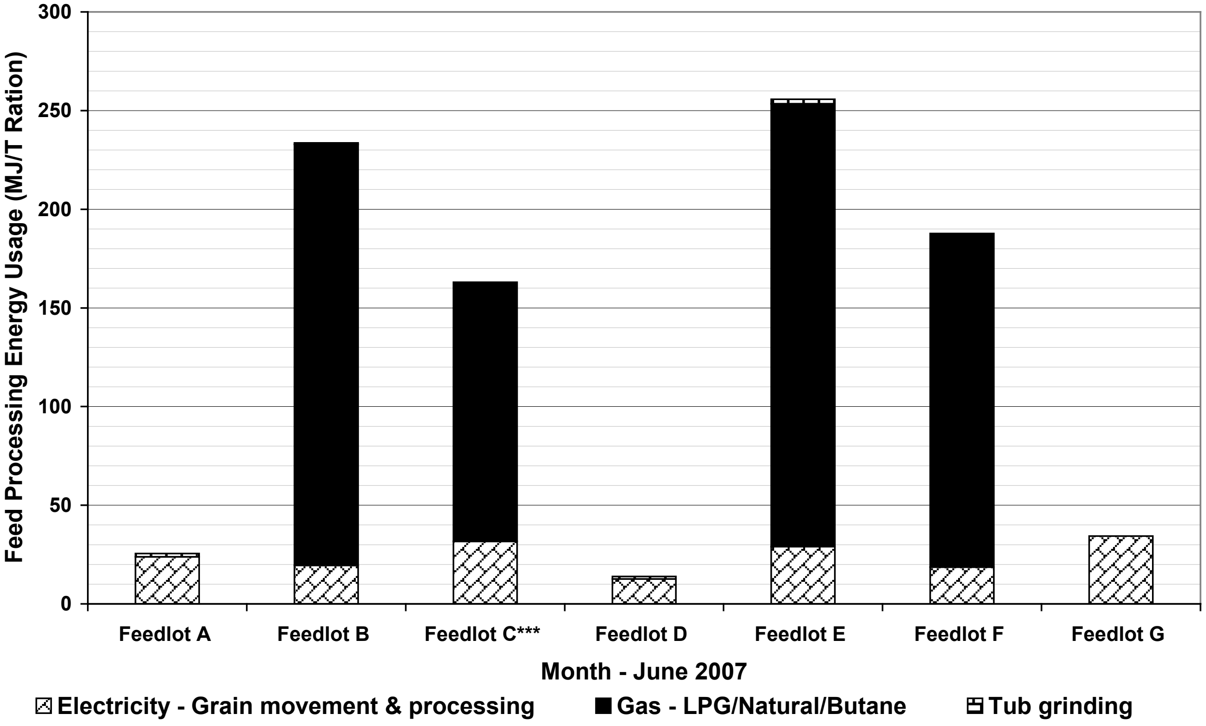

Figure 96 – Feed processing energy consumption for June 2007 (MJ/t ration)

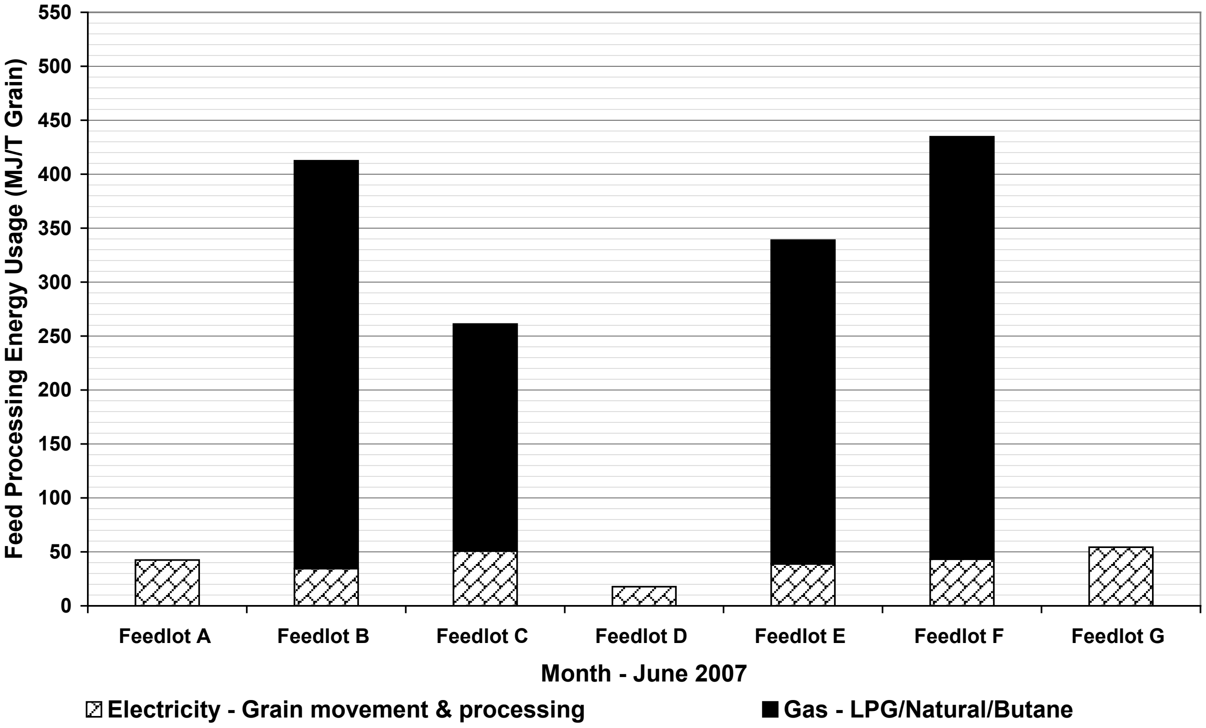

Figure 97 – Feed processing energy consumption for June 2007 (MJ/t grain)

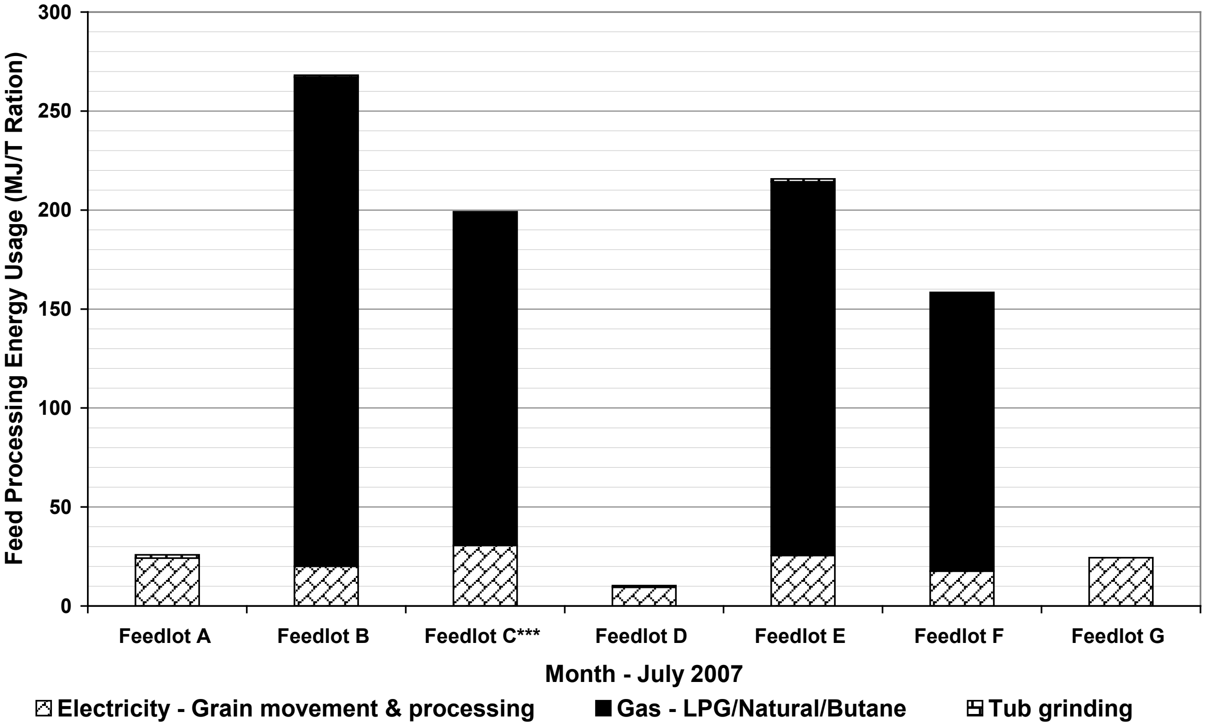

Figure 98 – Feed processing energy consumption for July 2007 (MJ/t ration)

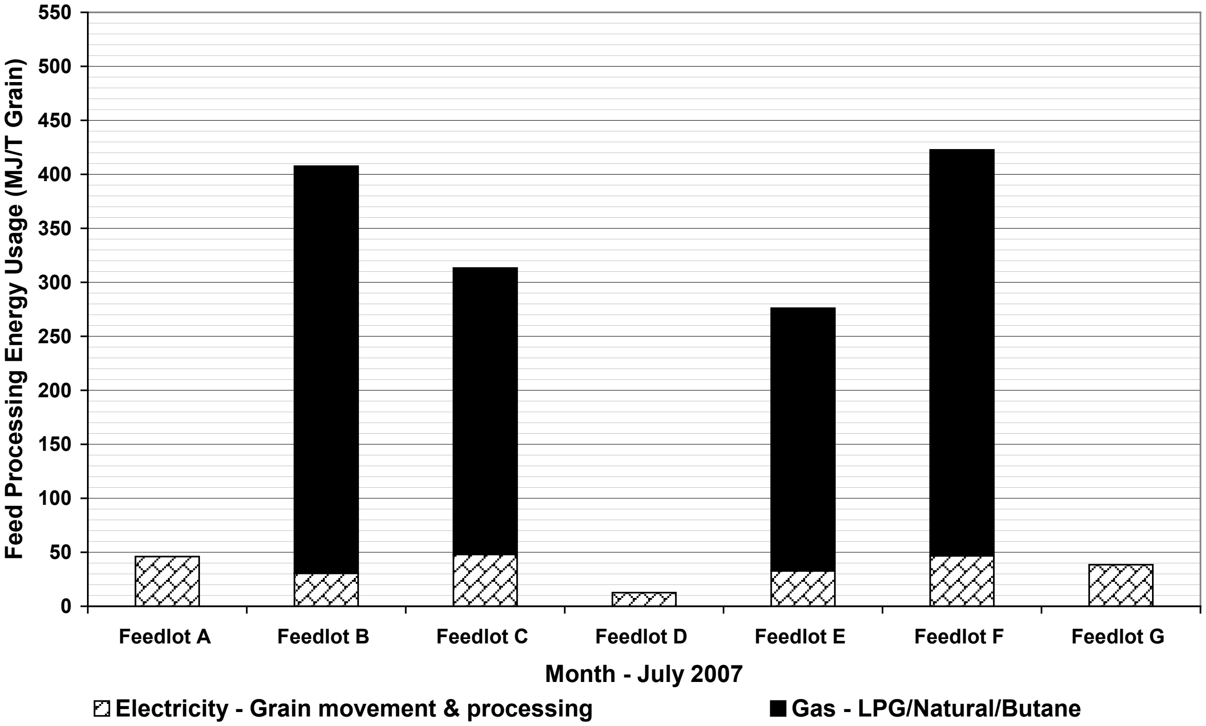

Figure 99 – Feed processing energy consumption for July 2007 (MJ/t grain)

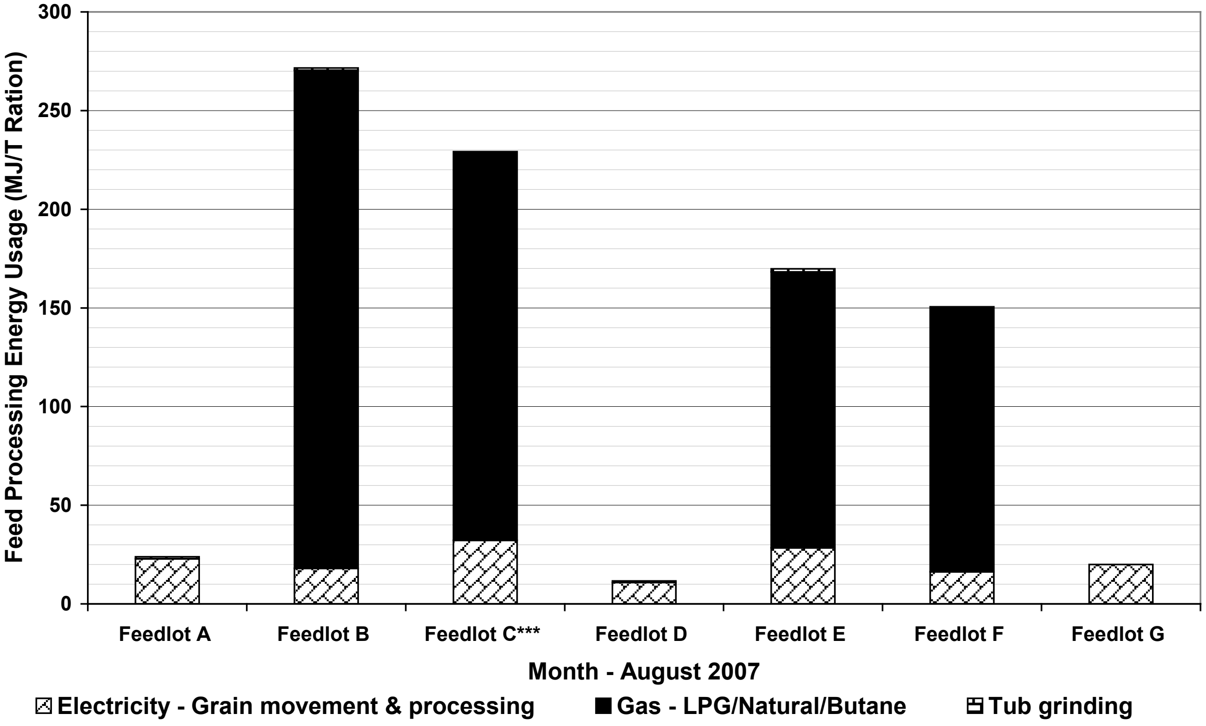

Figure 100 – Feed processing energy consumption for August 2007 (MJ/t ration)

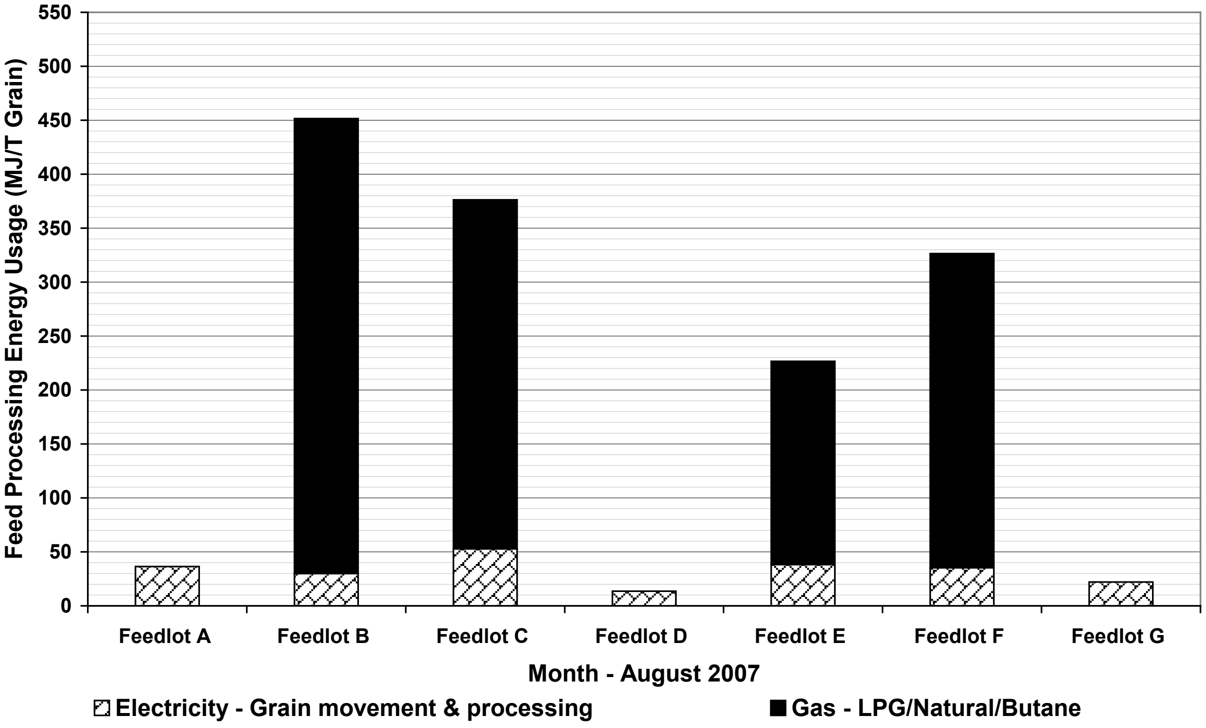

Figure 101 – Feed processing energy consumption for August 2007 (MJ/t grain)

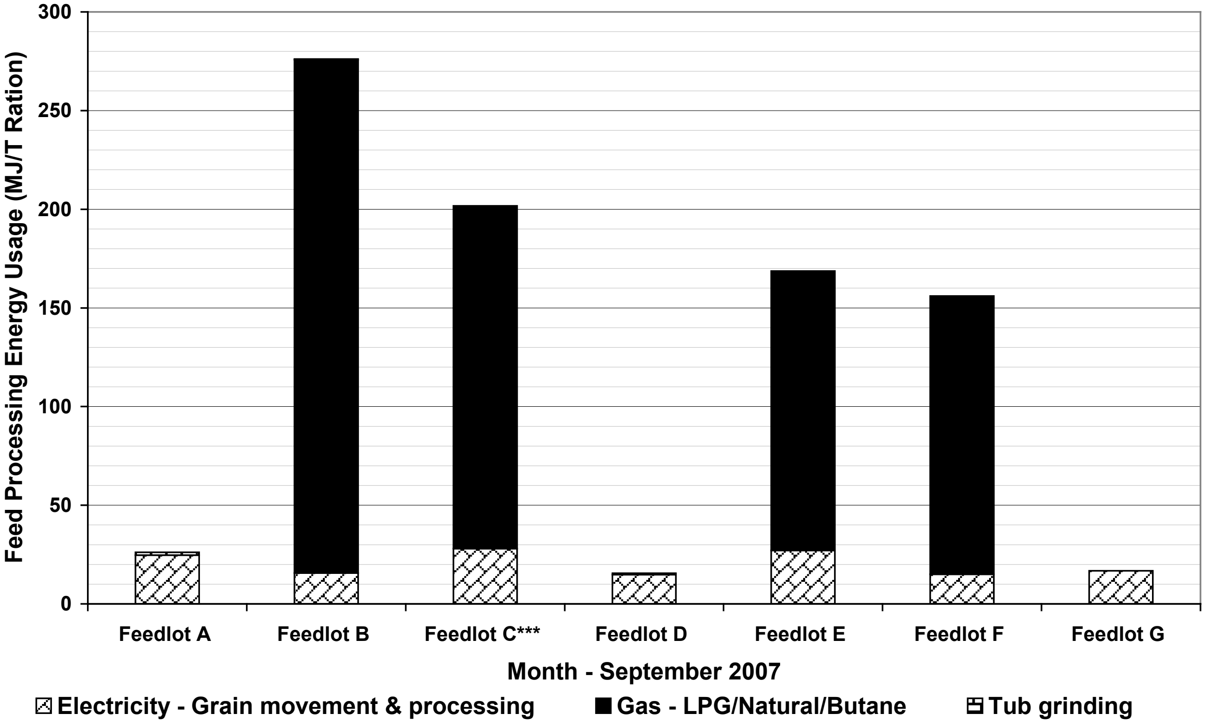

Figure 102 – Feed processing energy consumption for September 2007 (MJ/t ration)

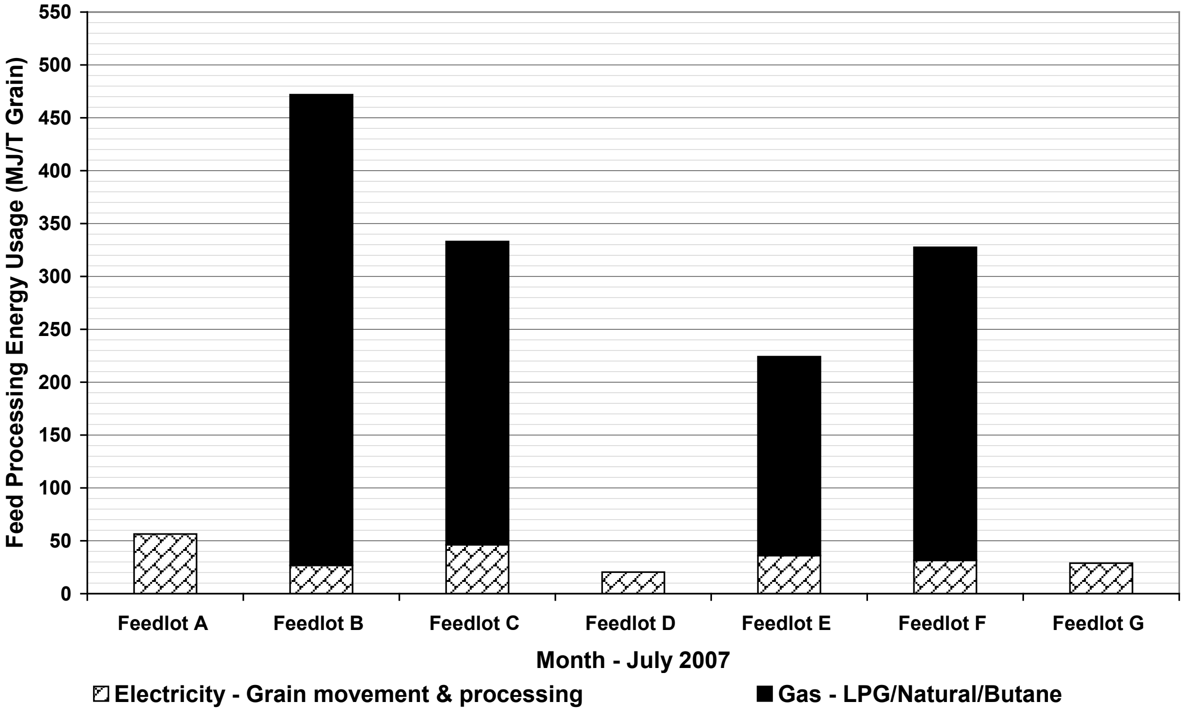

Figure 103 – Feed processing energy consumption for September 2007 (MJ/t grain)

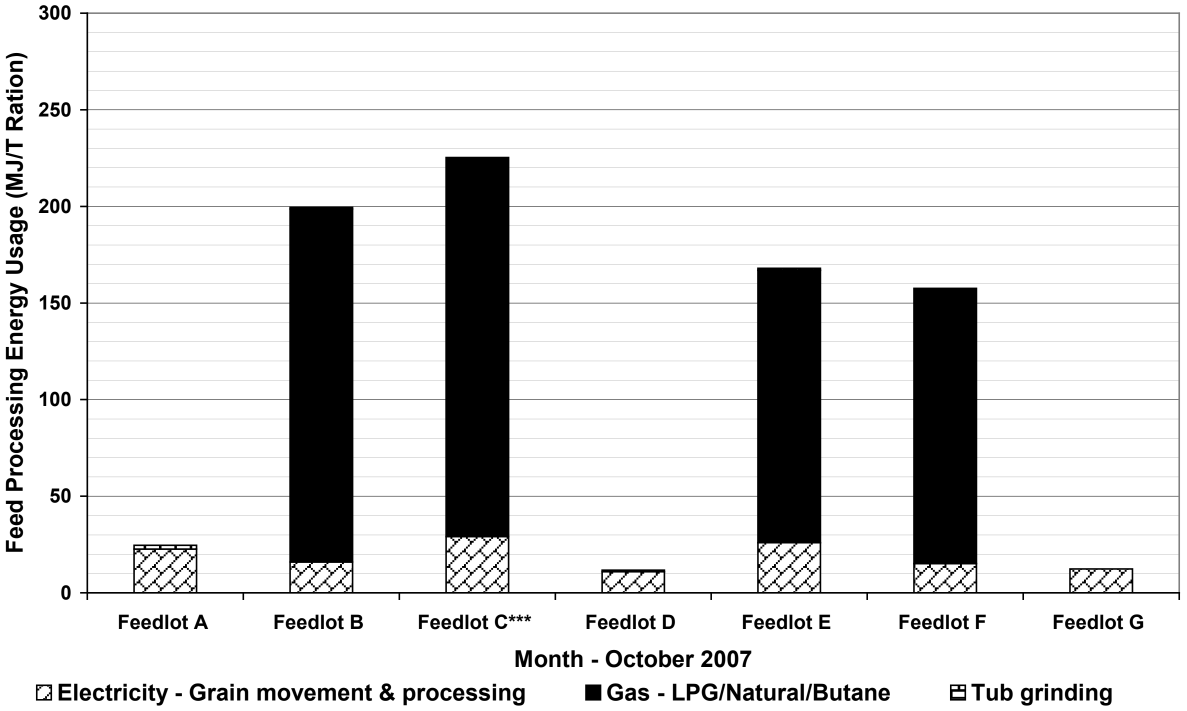

Figure 104 – Feed processing energy consumption for October 2007 (MJ/t ration)

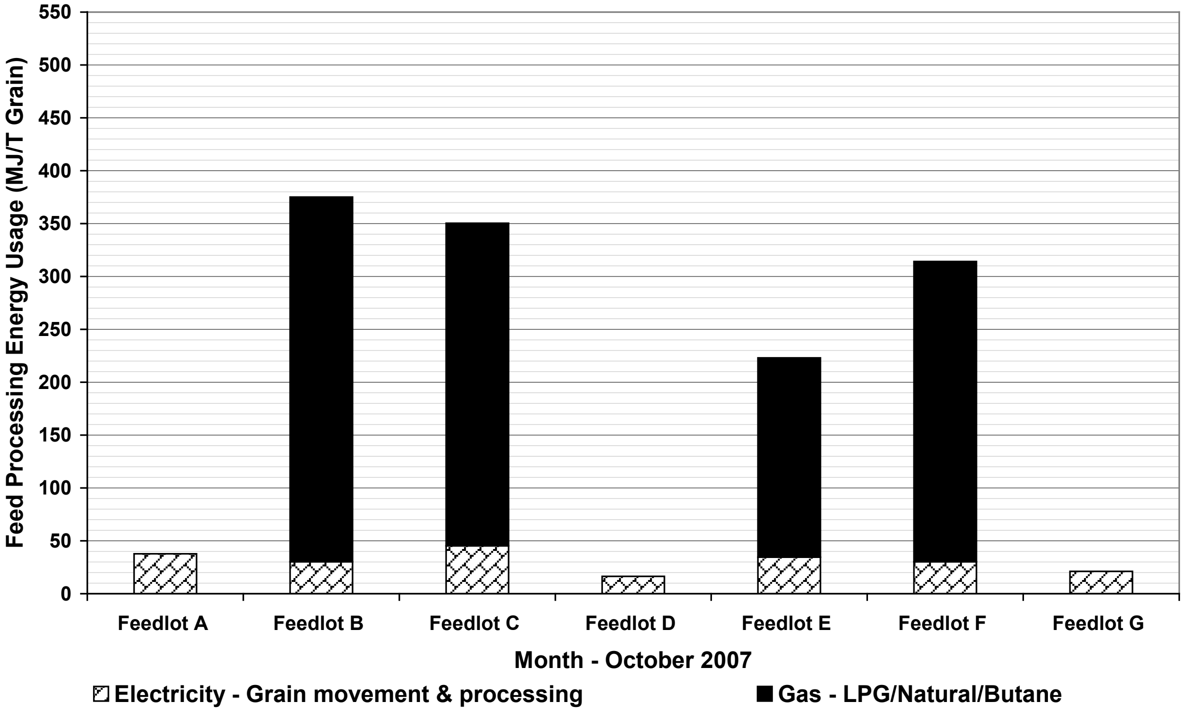

Figure 105 – Feed processing energy consumption for October 2007 (MJ/t grain)

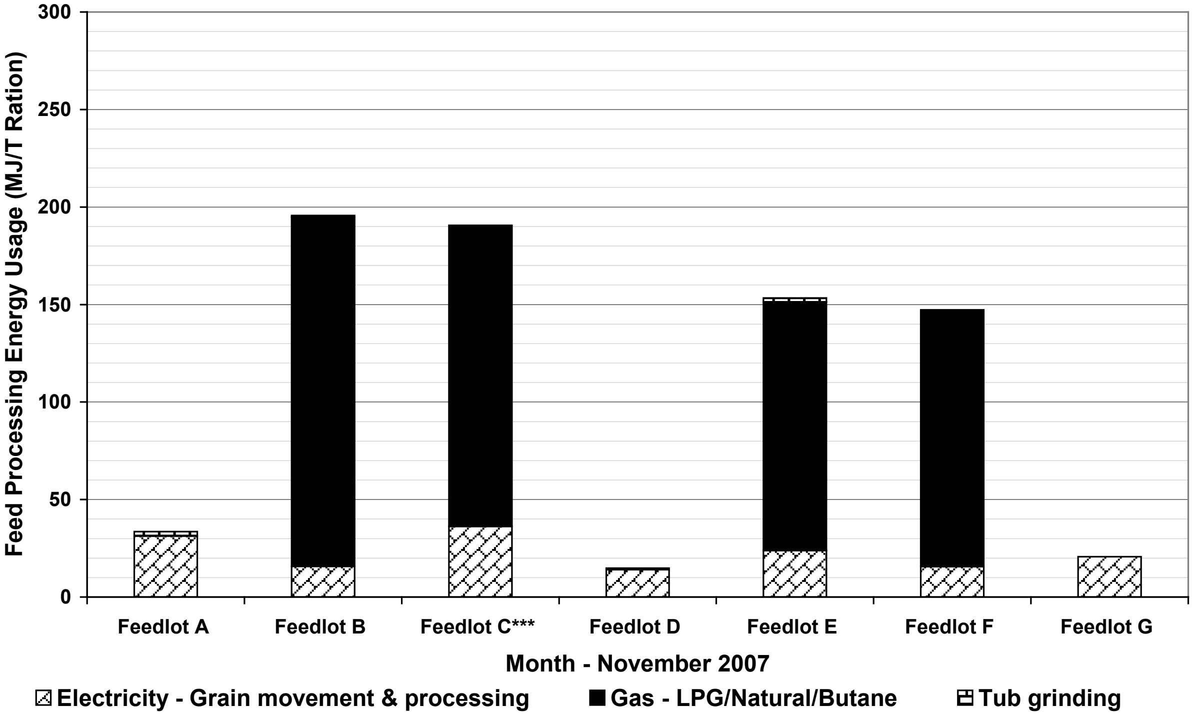

Figure 106 – Feed processing energy consumption for November 2007 (MJ/t ration)

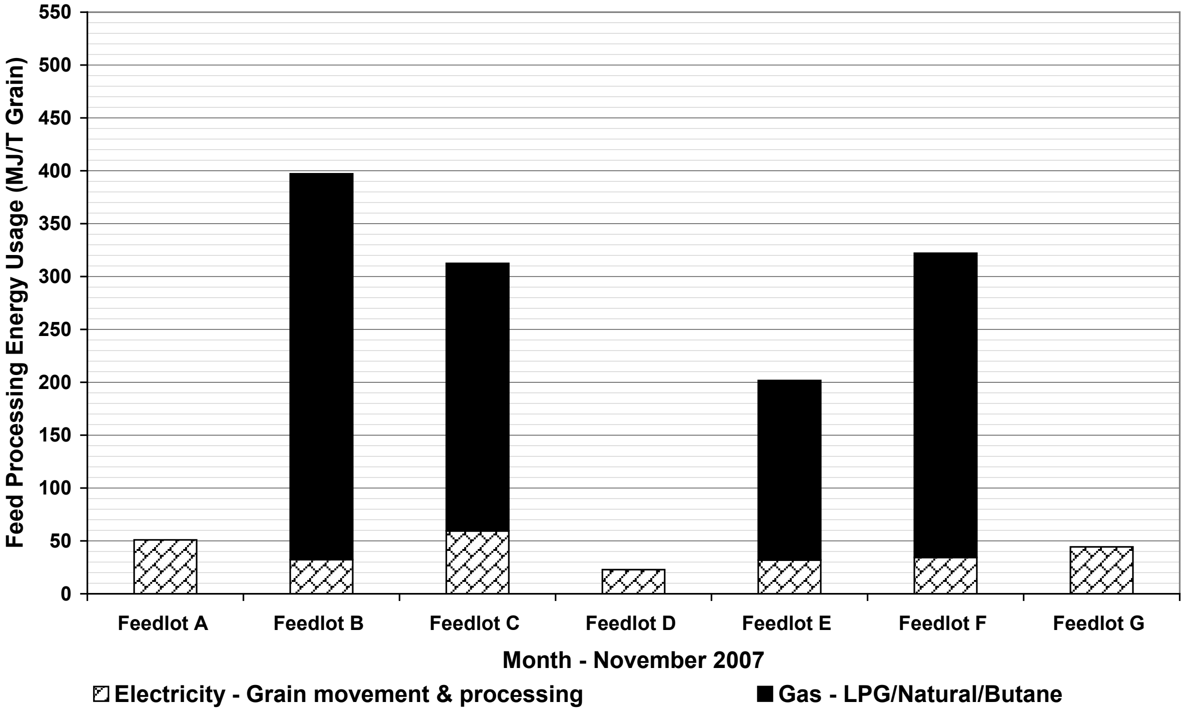

Figure 107 – Feed processing energy consumption for November 2007 (MJ/t grain)

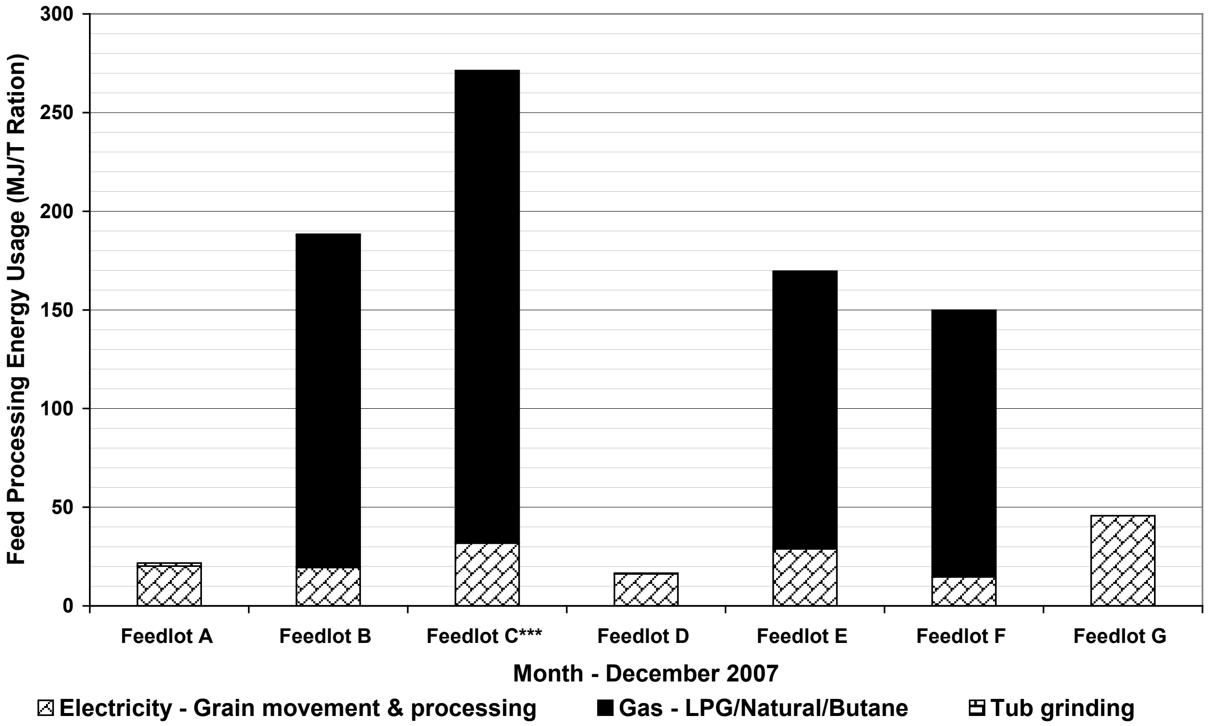

Figure 108 – Feed processing energy consumption for December 2007 (MJ/t ration)

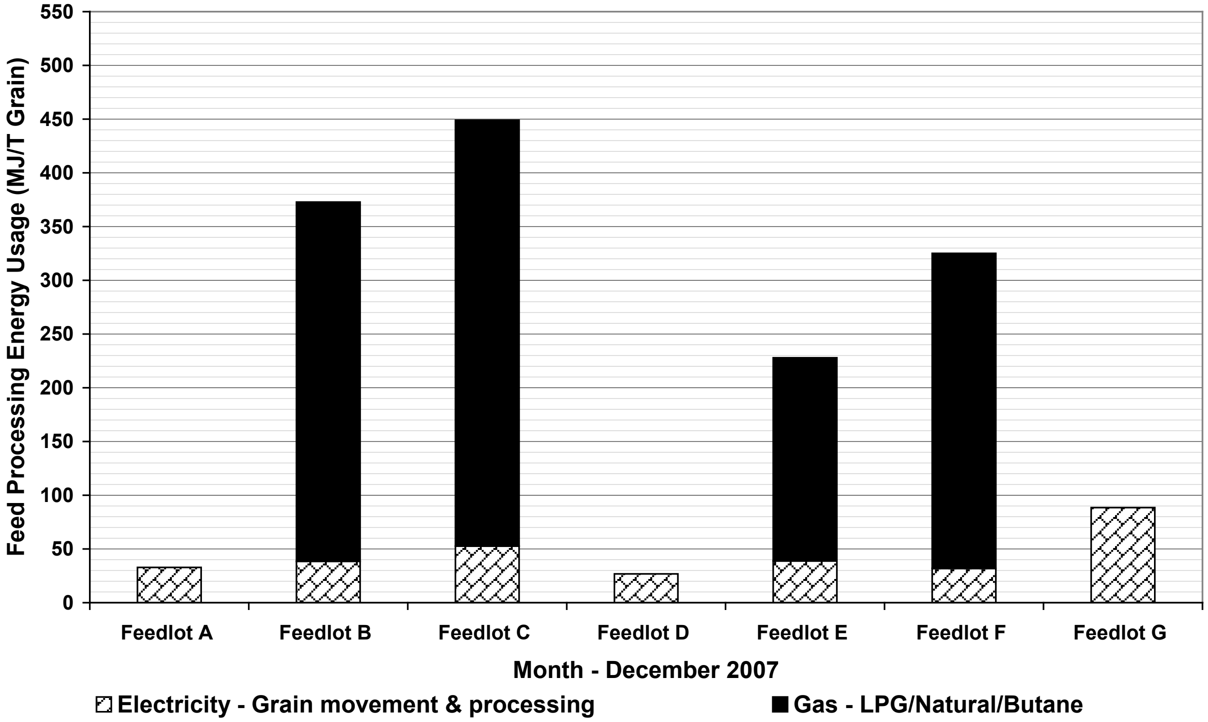

Figure 109 – Feed processing energy consumption for December 2007 (MJ/t grain)

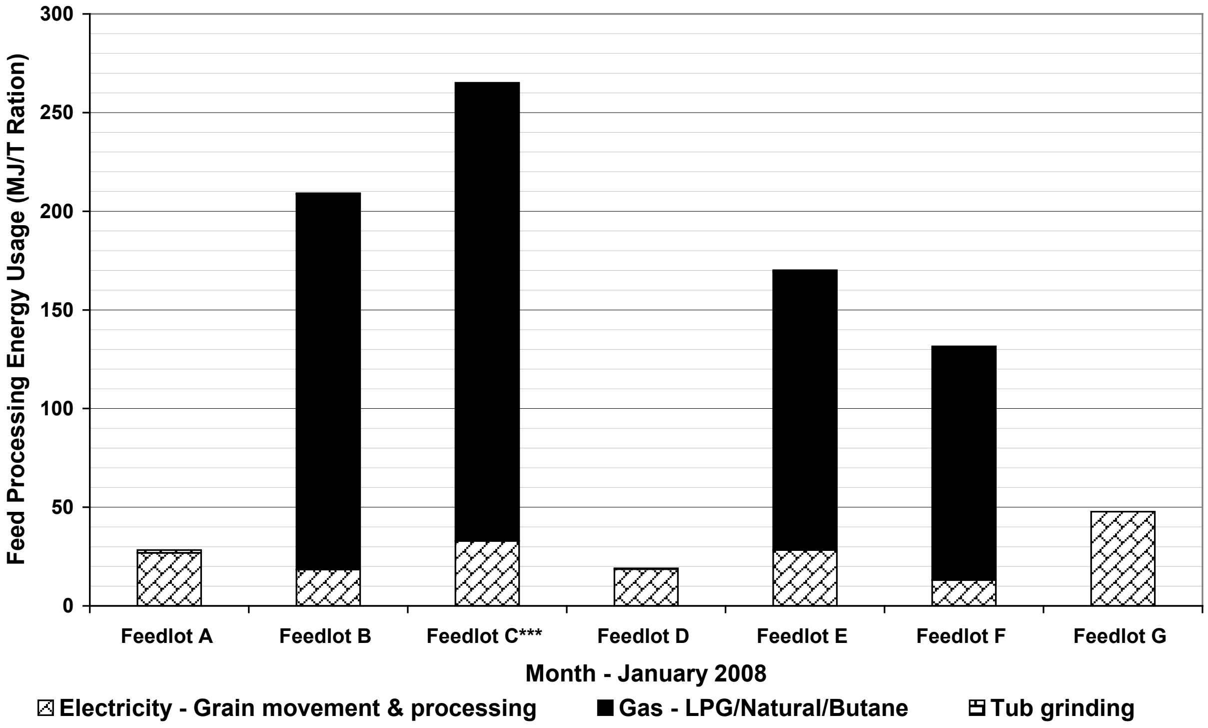

Figure 110 – Feed processing energy consumption for January 2008 (MJ/t ration)

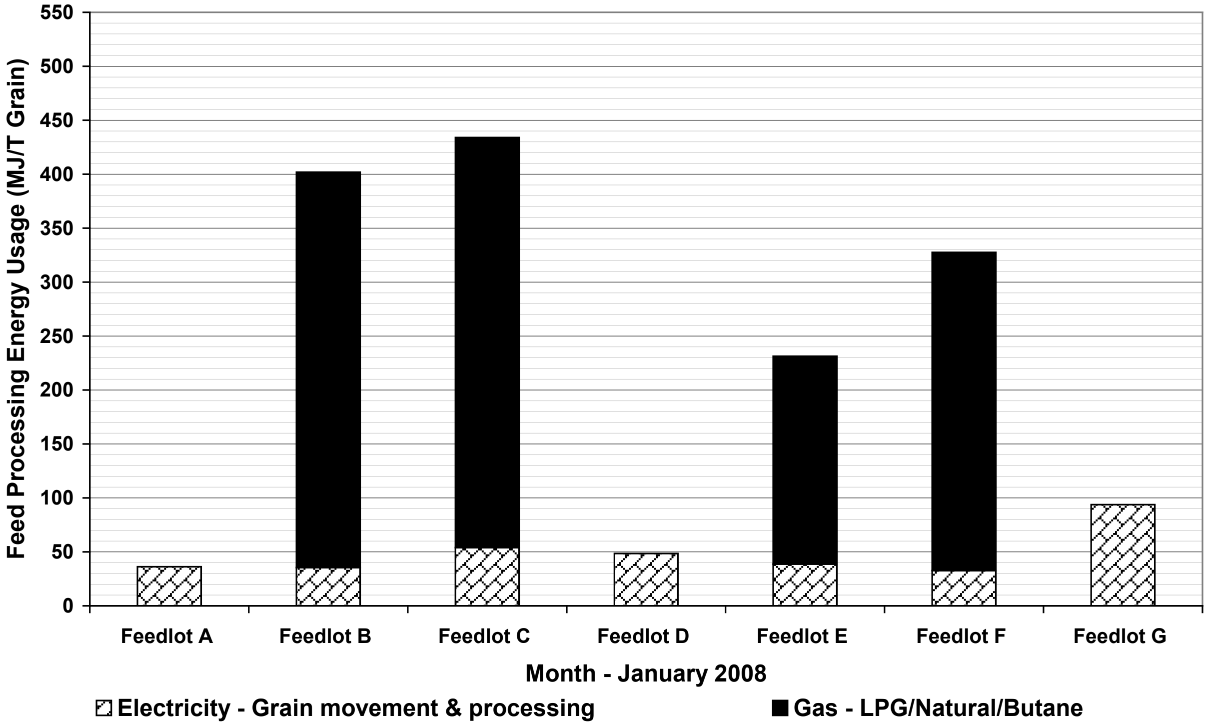

Figure 111 – Feed processing energy consumption for January 2008 (MJ/t grain)

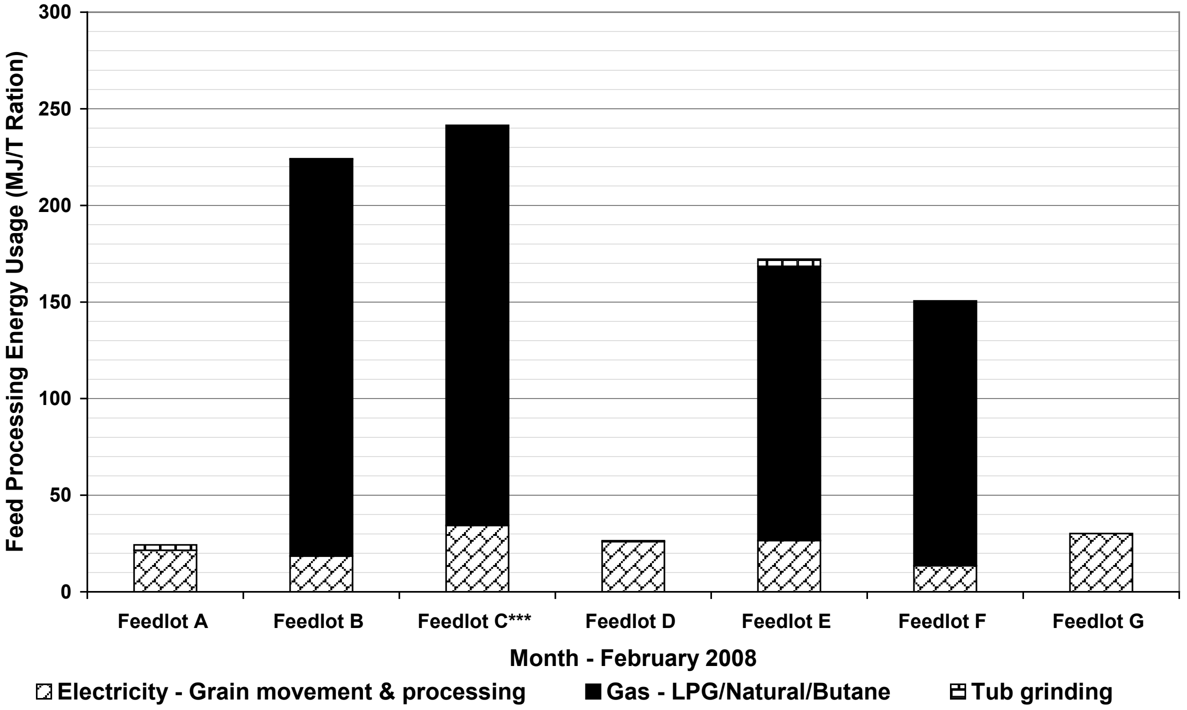

Figure 112 – Feed processing energy consumption for February 2008 (MJ/t ration)

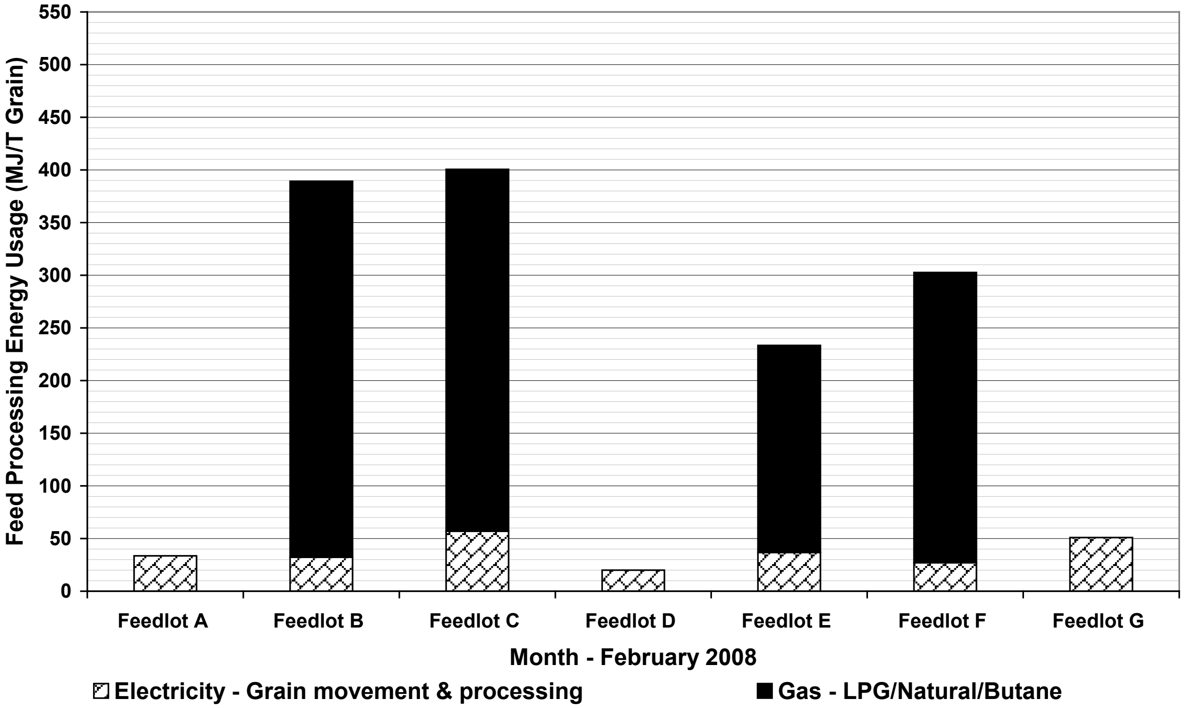

Figure 113 – Feed processing energy consumption for February 2008 (MJ/t grain)

Appendix C.2 – Feed delivery energy usage

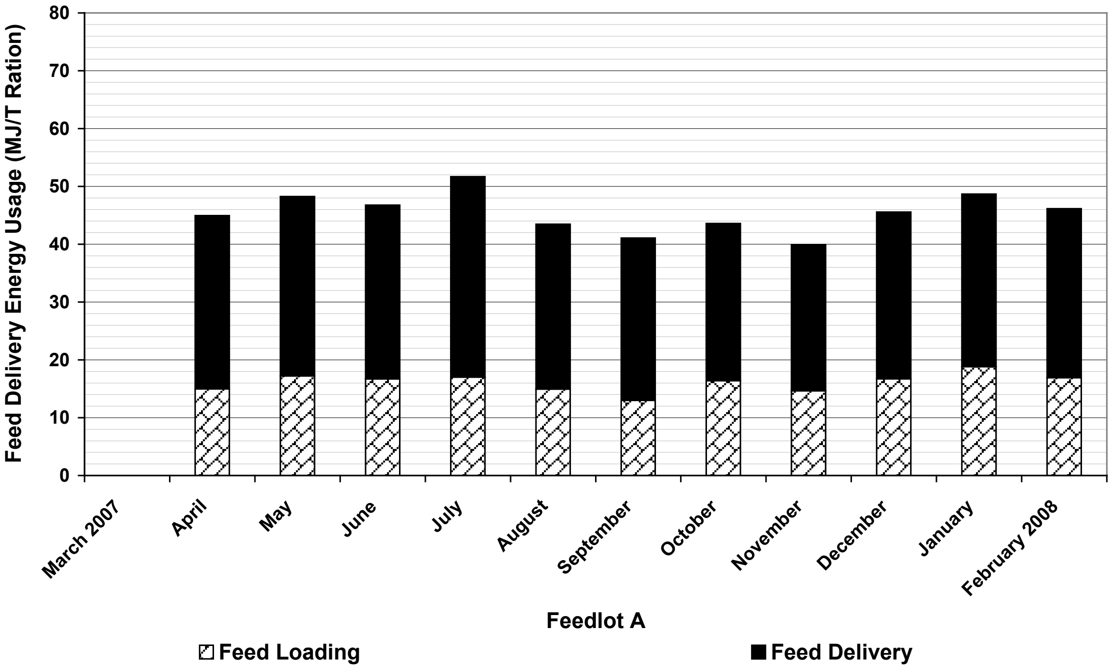

Figure 114 – Feed delivery energy consumption for Feedlot A (MJ/t ration)

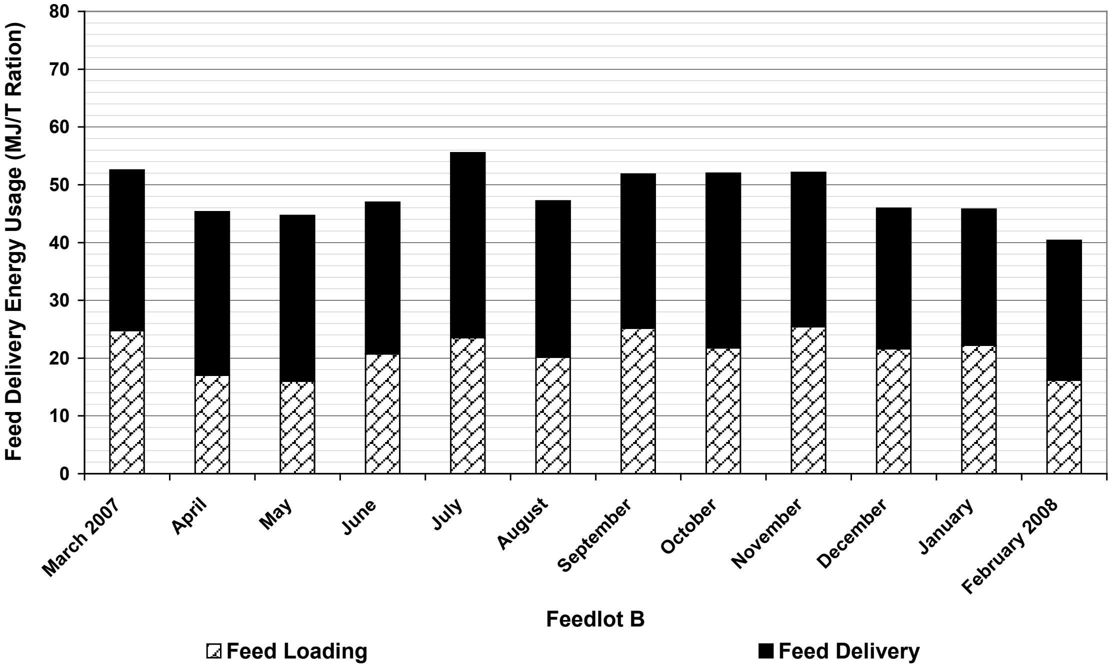

Figure 115 – Feed delivery energy consumption for Feedlot B (MJ/t ration)

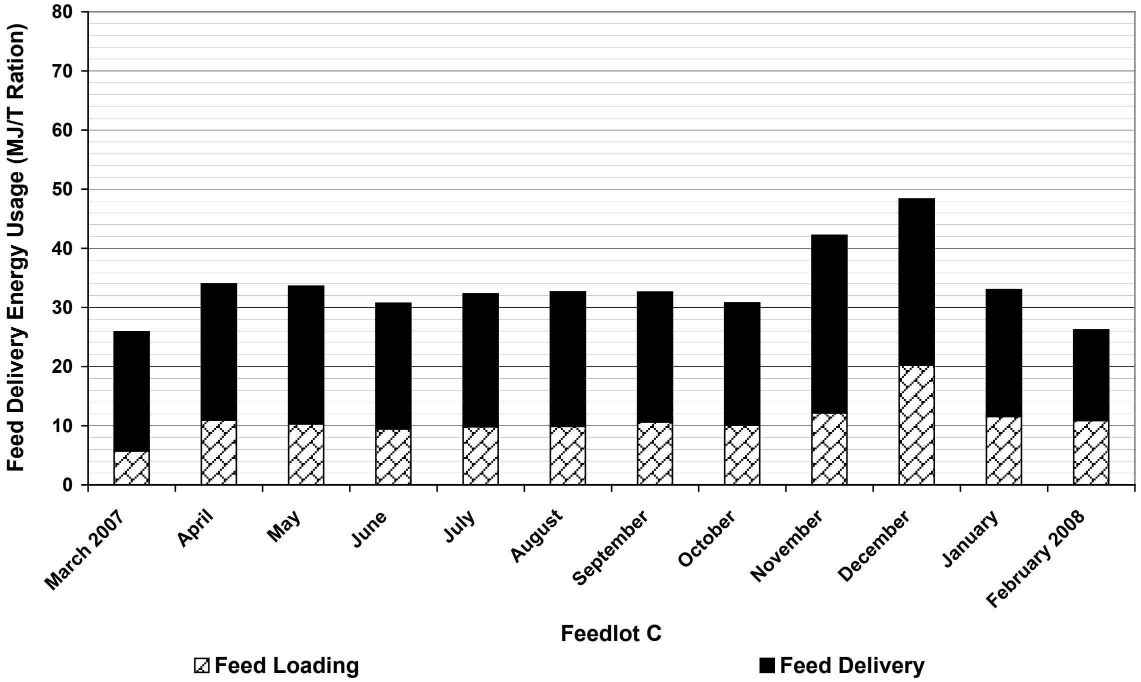

Figure 116 – Feed delivery energy consumption for Feedlot C (MJ/t ration)

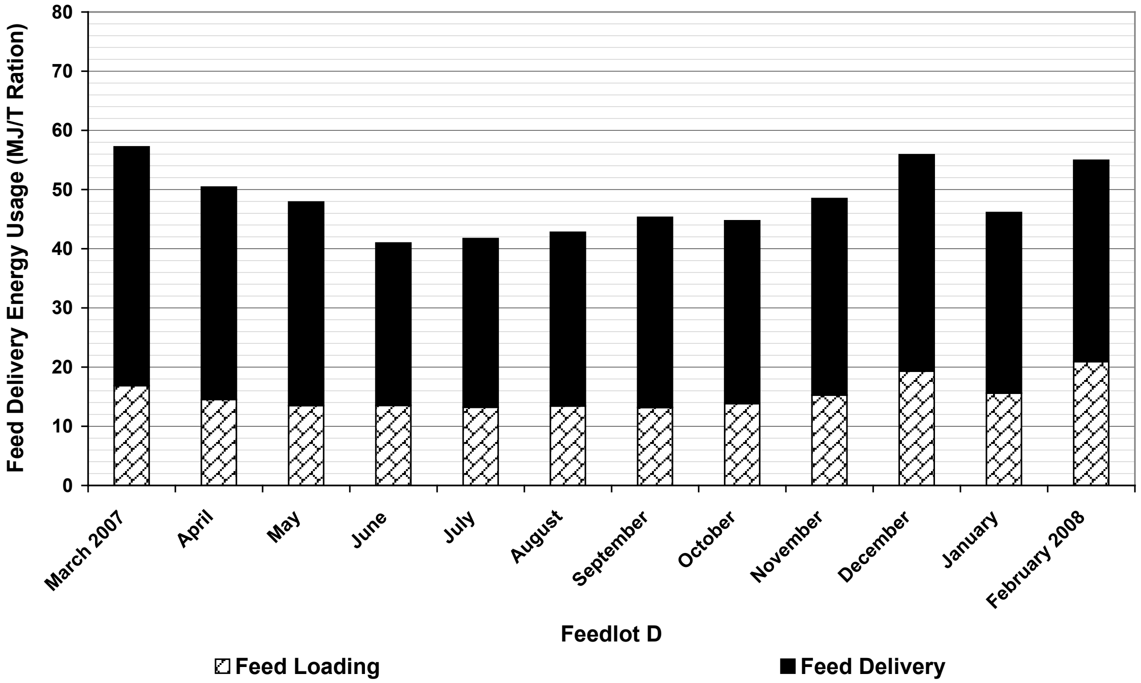

Figure 117 – Feed delivery energy consumption for Feedlot D (MJ/t ration)

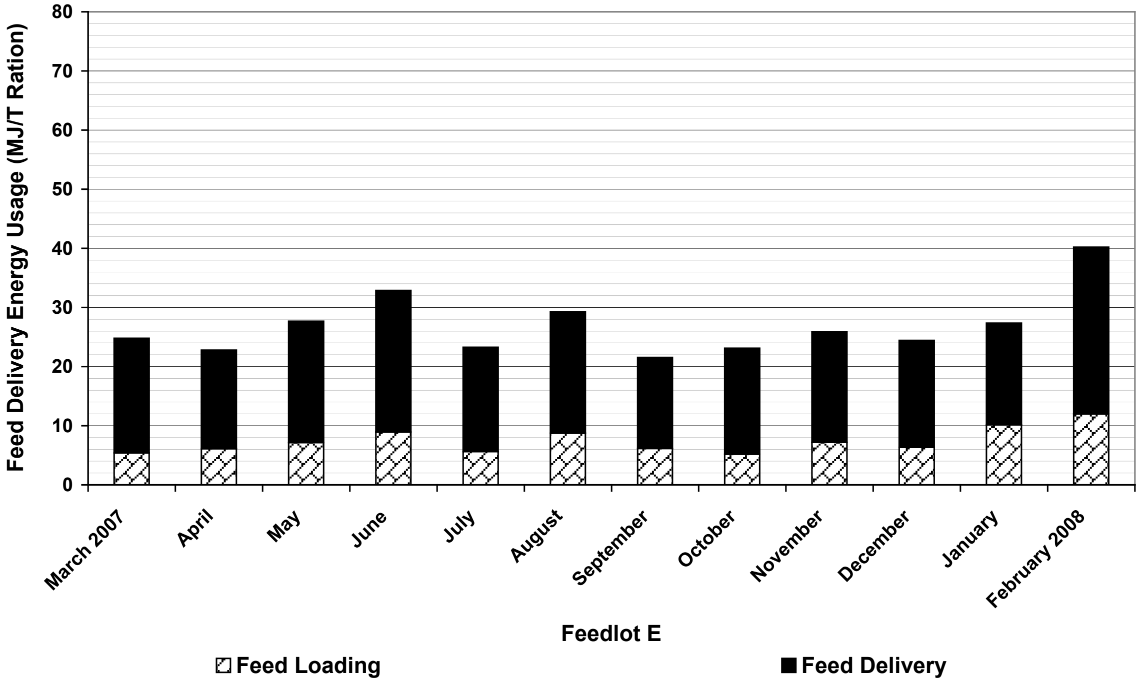

Figure 118 – Feed delivery energy consumption for Feedlot E (MJ/t ration)

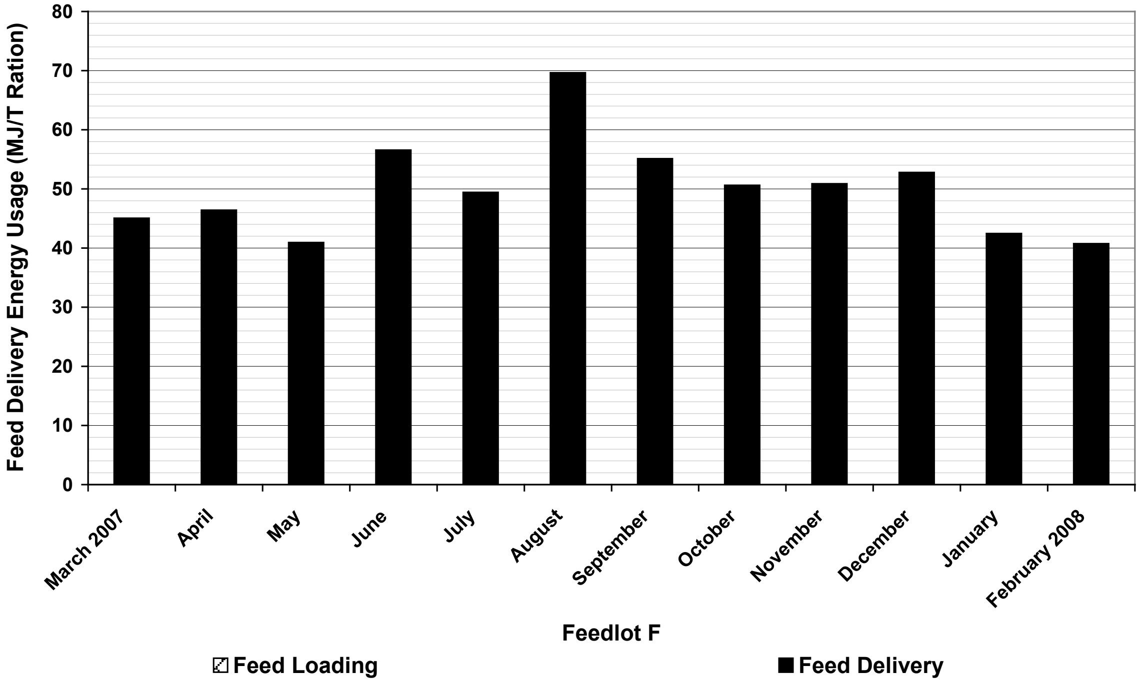

Figure 119 – Feed delivery energy consumption for Feedlot F (MJ/t ration)

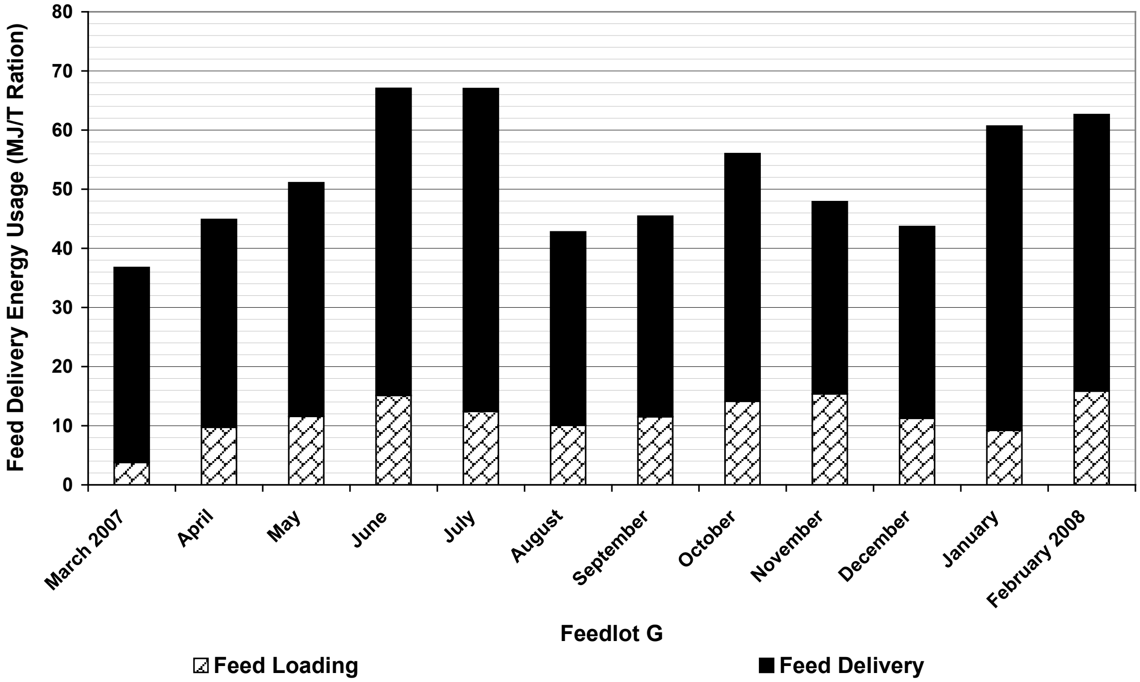

Figure 120 – Feed delivery energy consumption for Feedlot G (MJ/t ration)

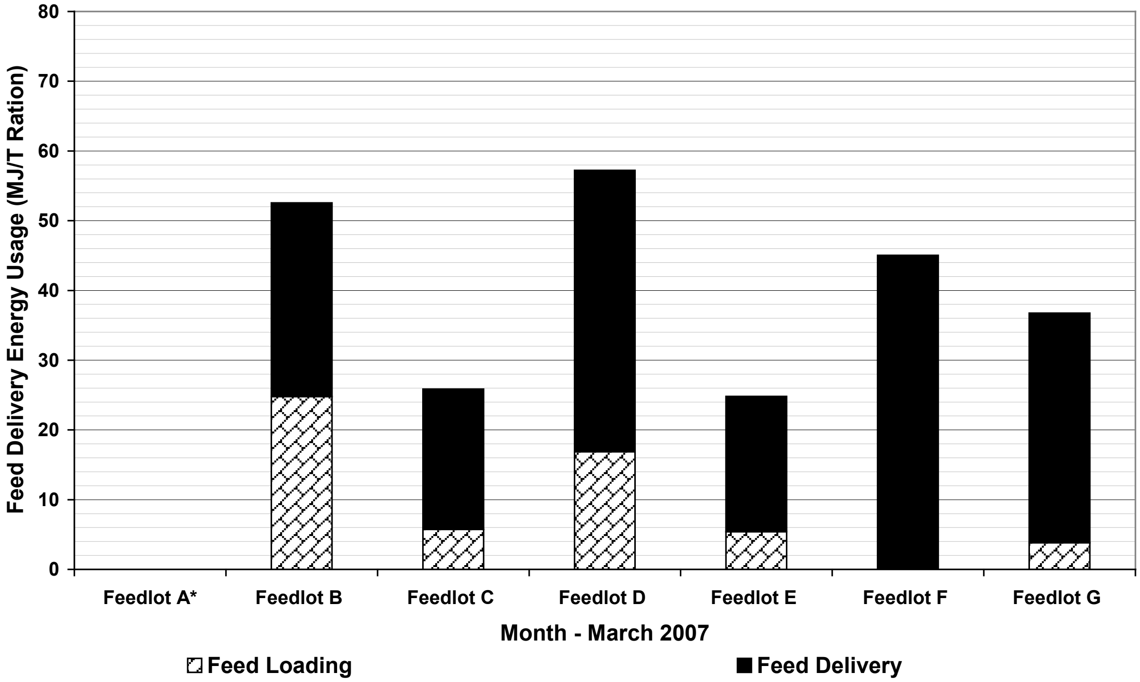

Figure 121 – Feed delivery energy consumption for March 2007 (MJ/t ration)

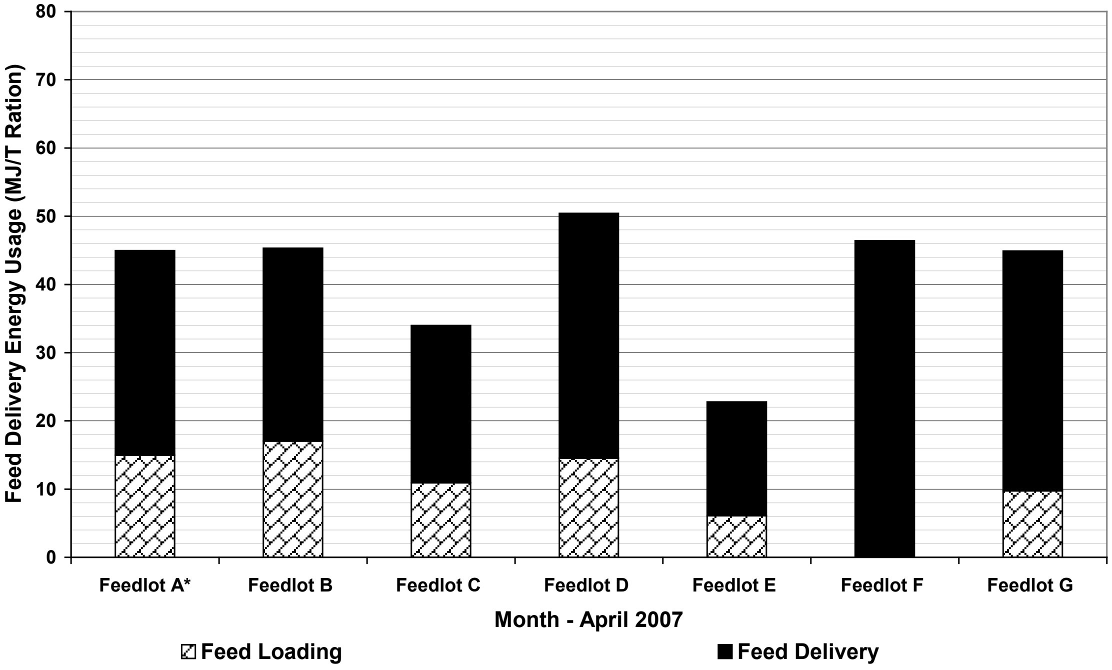

Figure 122 – Feed delivery energy consumption for April 2007 (MJ/t ration)

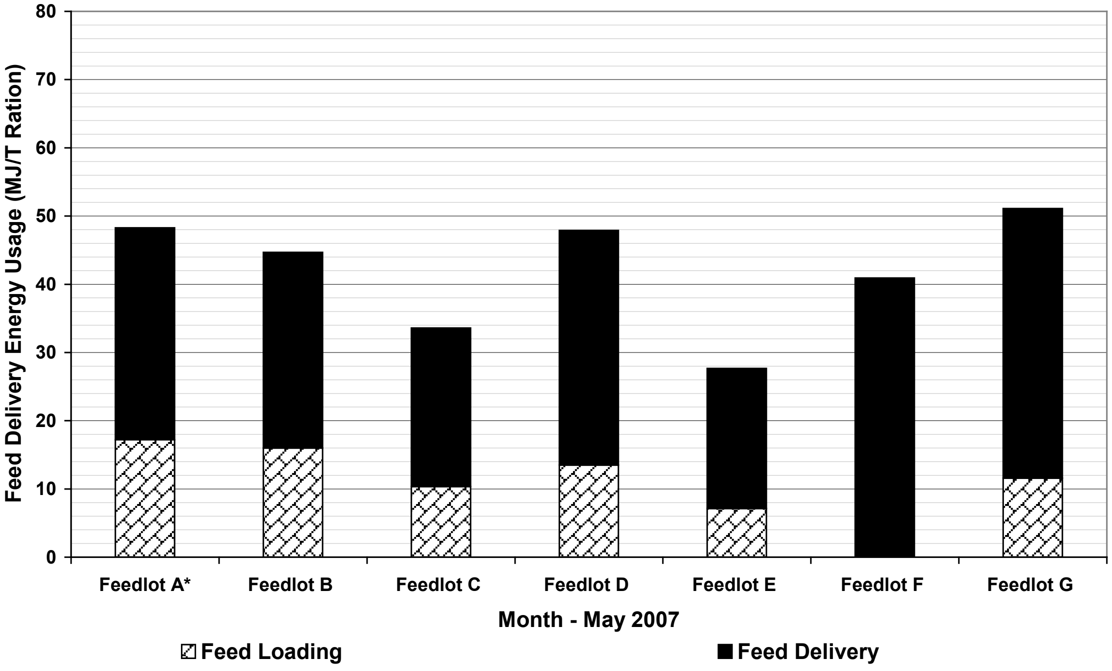

Figure 123 – Feed delivery energy consumption for May 2007 (MJ/t ration)

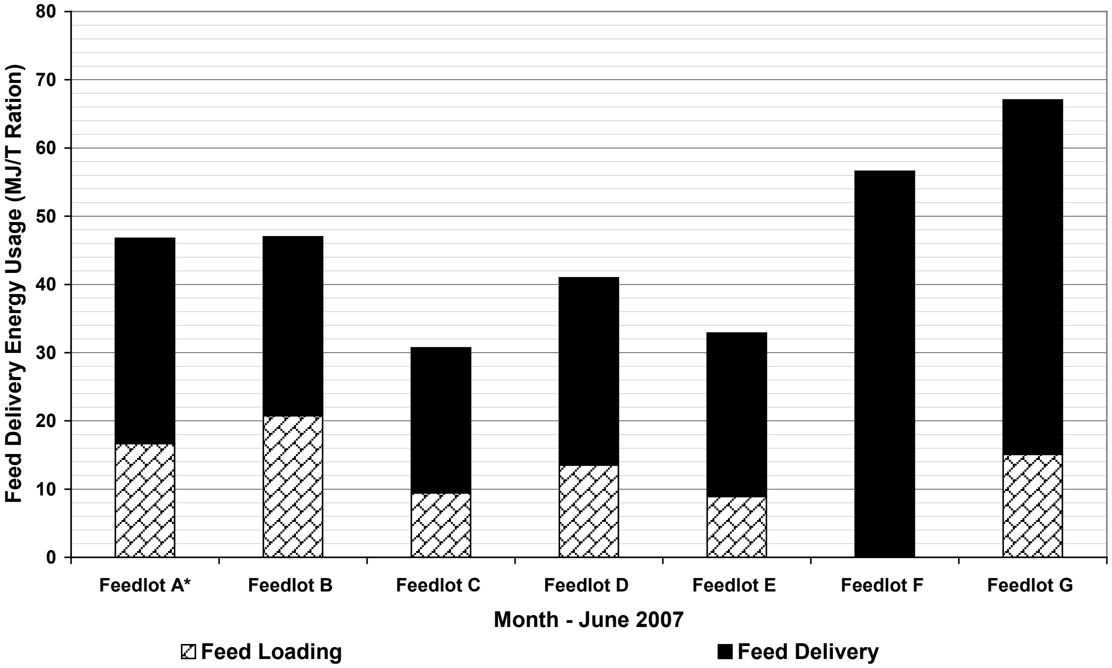

Figure 124 – Feed delivery energy consumption for June 2007 (MJ/t ration)

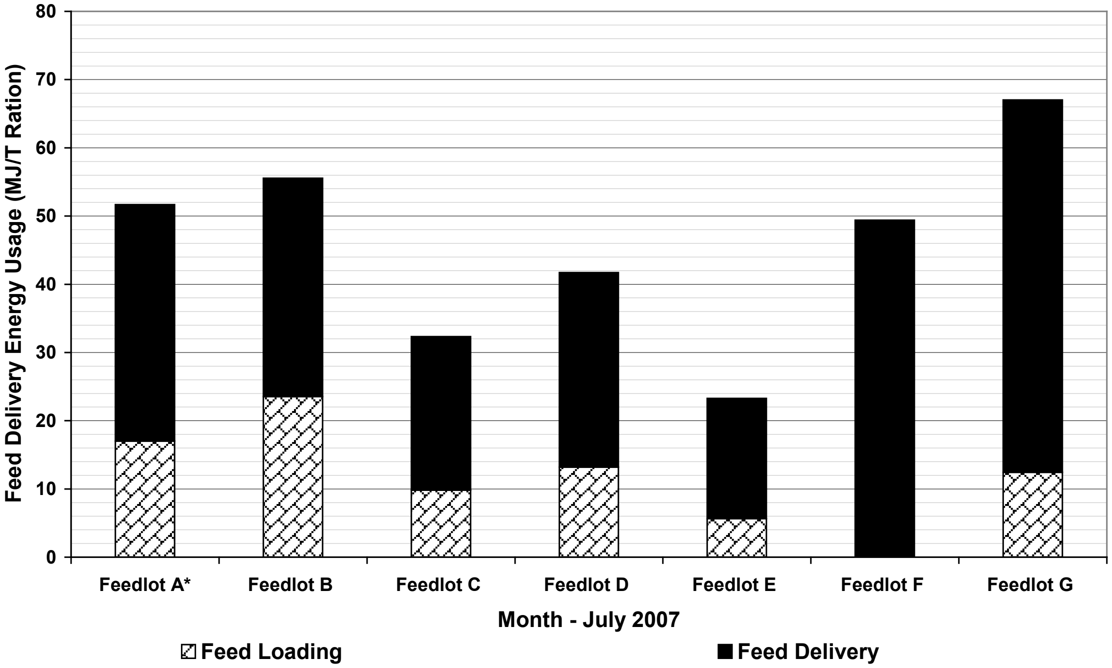

Figure 125 – Feed delivery energy consumption for July 2007 (MJ/t ration)

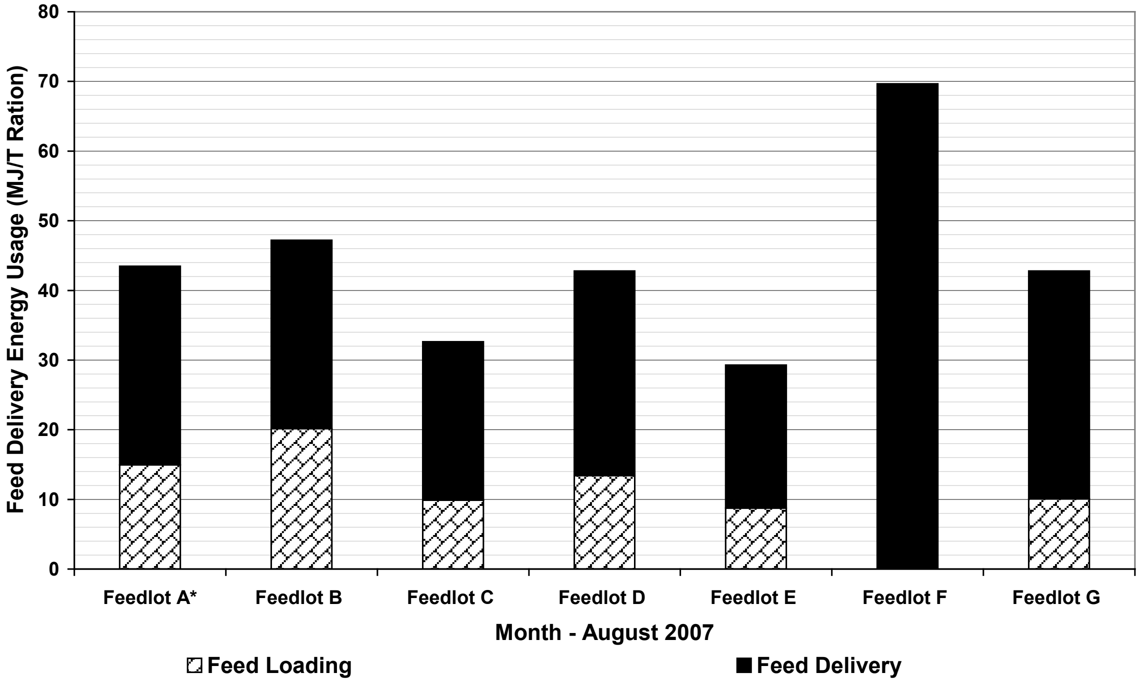

Figure 126 – Feed delivery energy consumption for August 2007 (MJ/t ration)

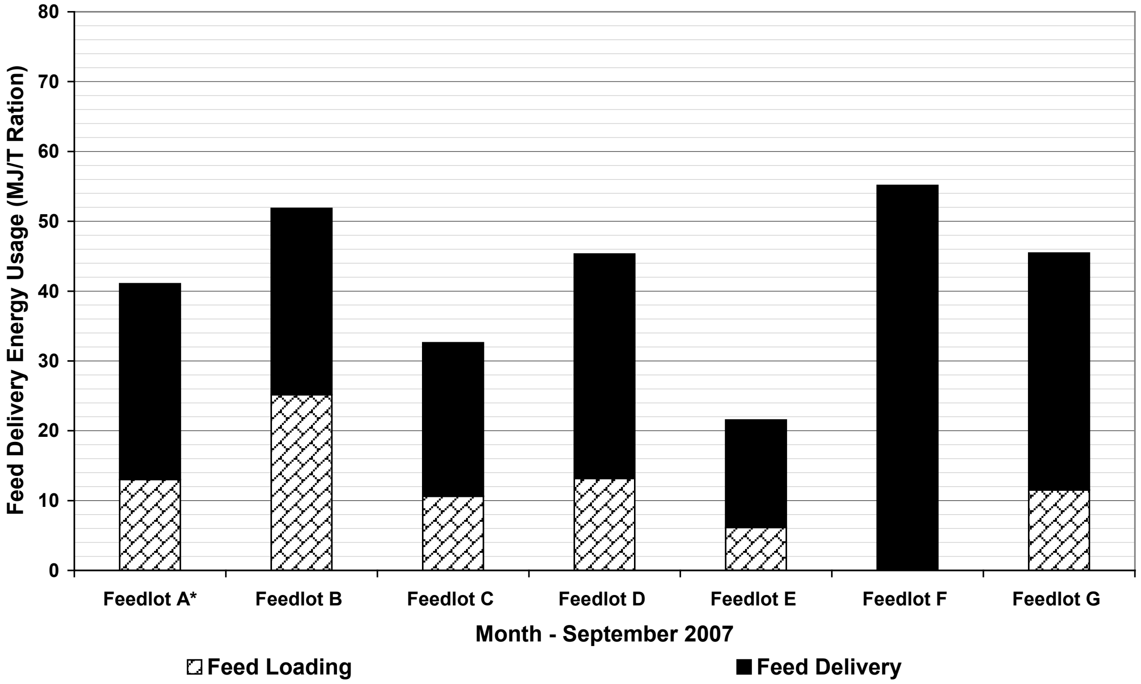

Figure 127 – Feed delivery energy consumption for September 2007 (MJ/t ration)

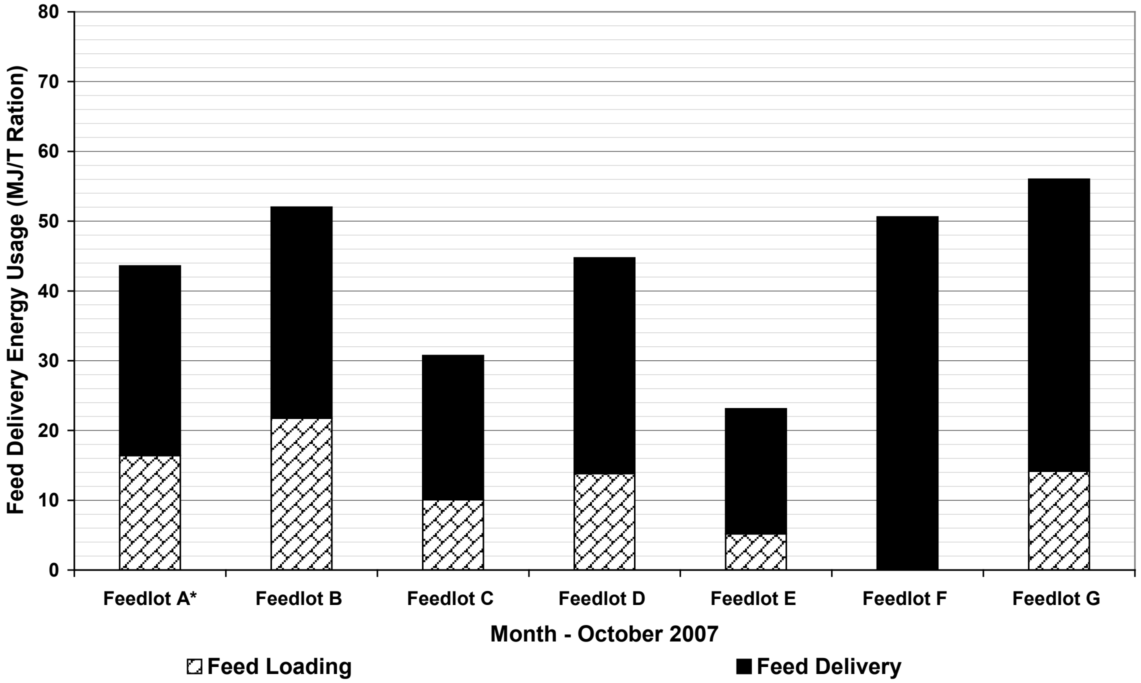

Figure 128 – Feed delivery energy consumption for October 2007 (MJ/t ration)

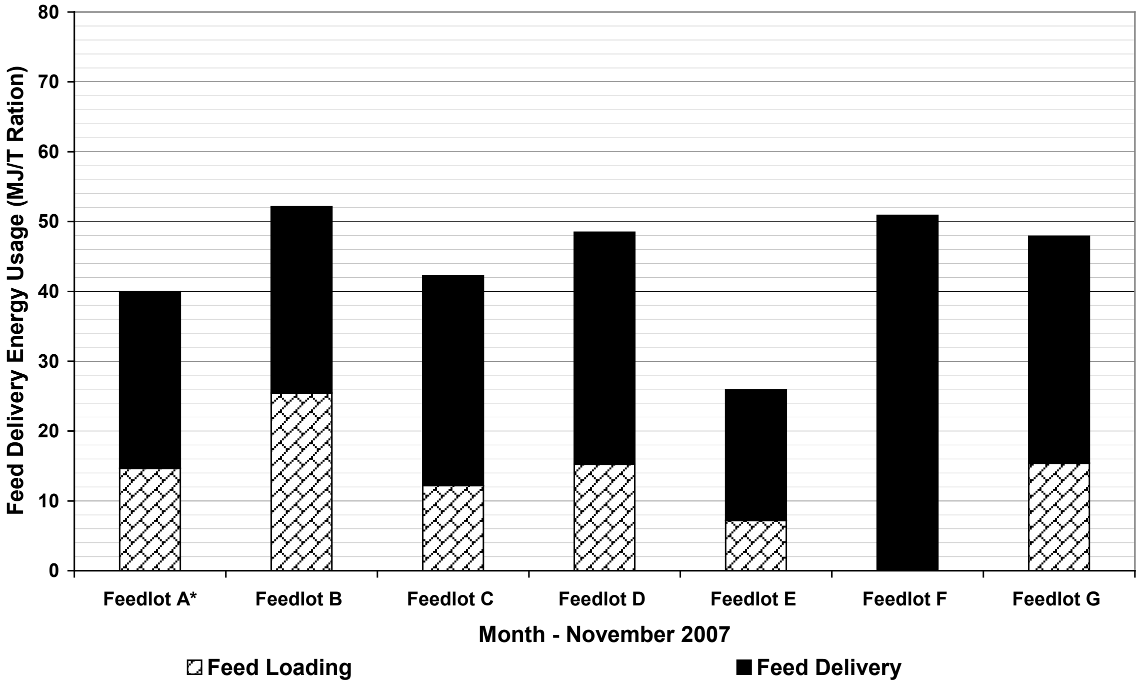

Figure 129 – Feed delivery energy consumption for November 2007 (MJ/t ration)

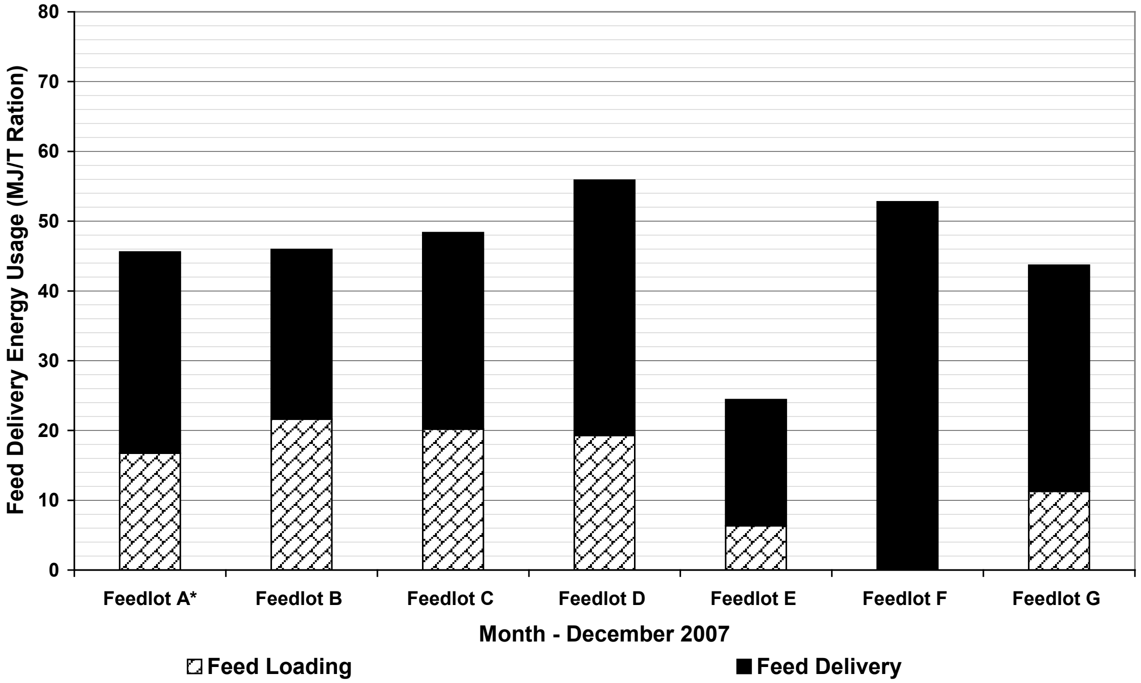

Figure 130 – Feed delivery energy consumption for December 2007 (MJ/t ration)

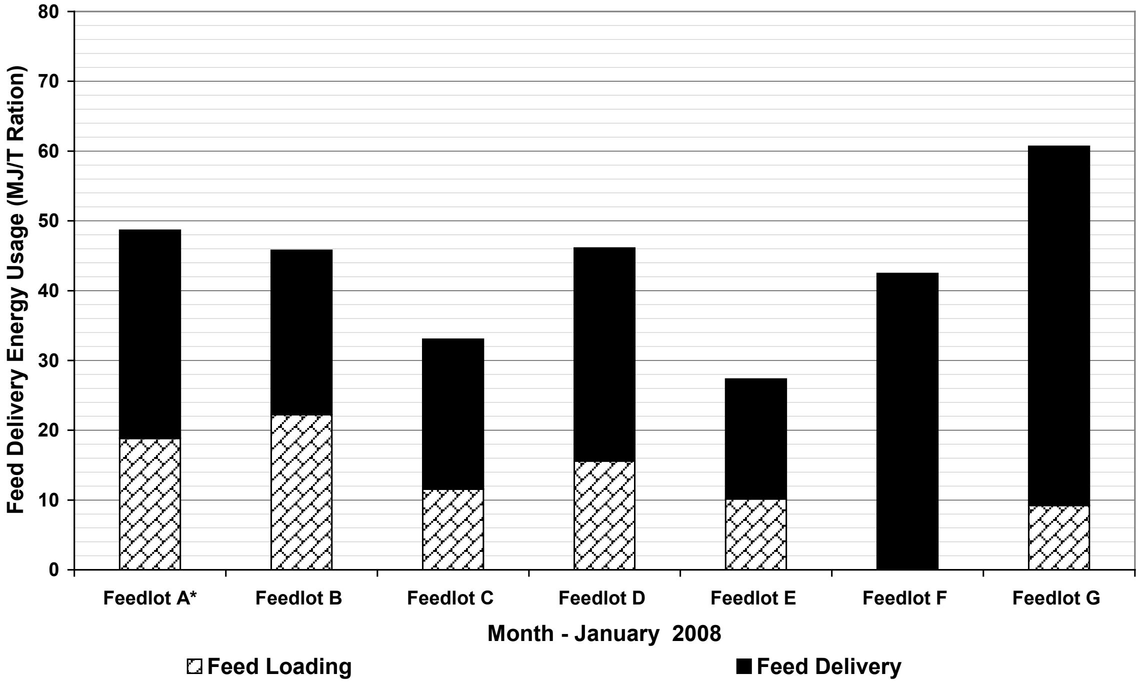

Figure 131 – Feed delivery energy consumption for January 2008 (MJ/t ration)

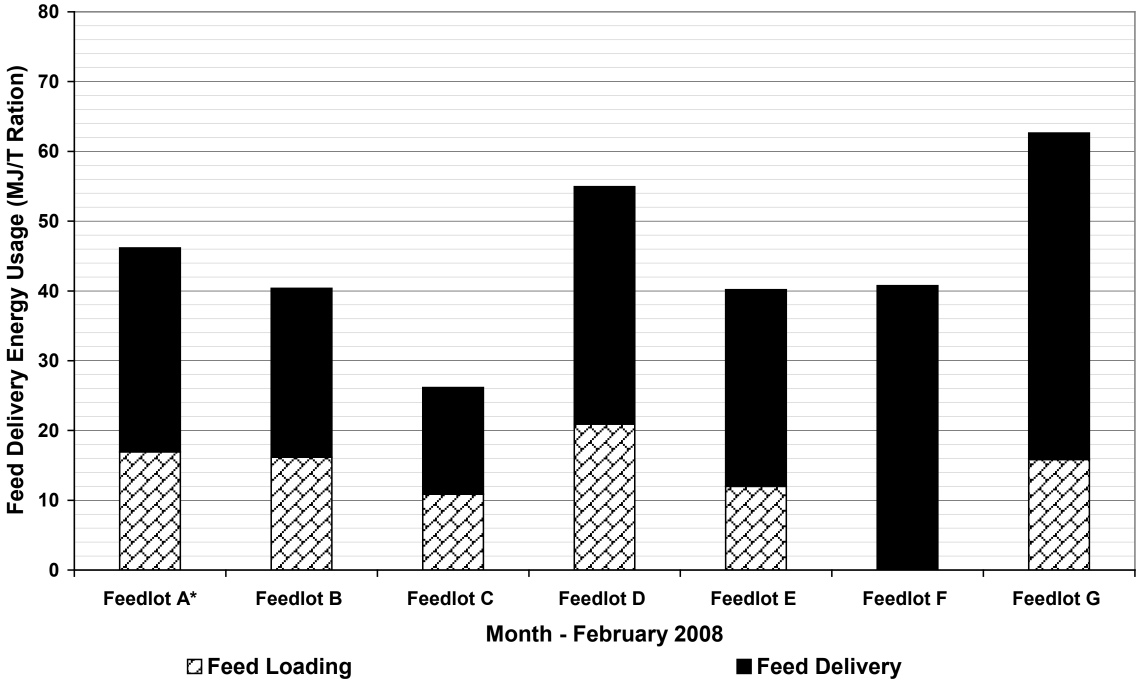

Figure 132 – Feed delivery energy consumption for February 2008 (MJ/t ration)

Appendix D – Waste management energy usage

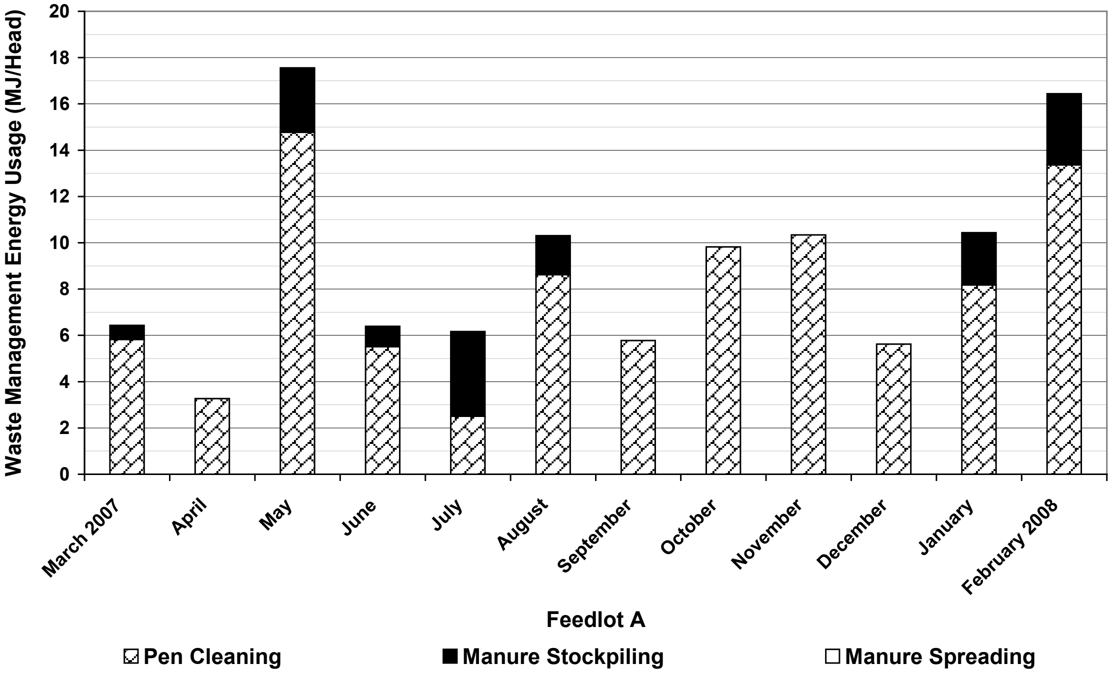

Figure 133 – Waste management energy consumption for Feedlot A (MJ/head-on-feed/month)

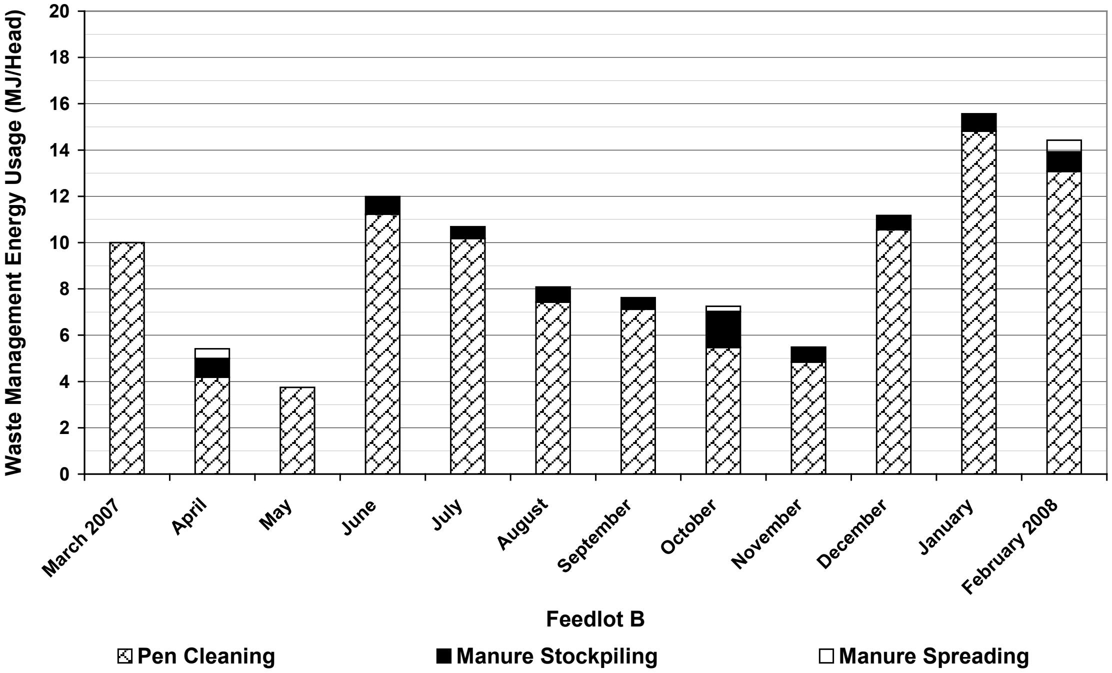

Figure 134 – Waste management energy consumption for Feedlot B (MJ/head-on-feed/month)

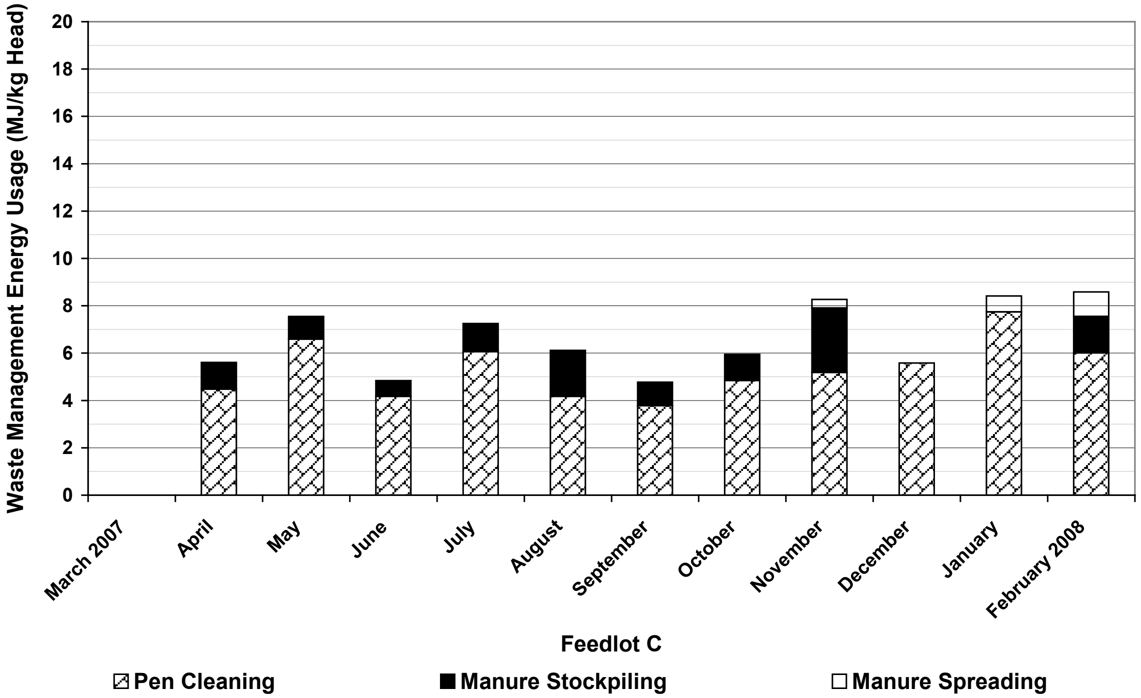

Figure 135 – Waste management energy consumption for Feedlot C (MJ/head-on-feed/month)

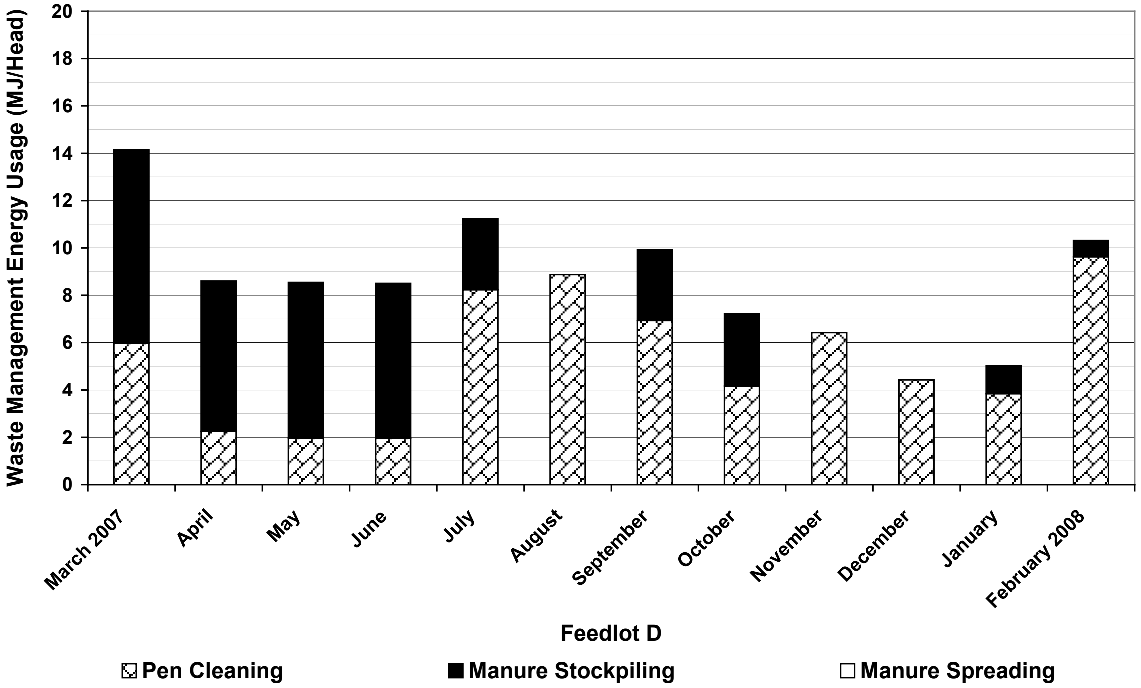

Figure 136 – Waste management energy consumption for Feedlot D (MJ/head-on-feed/month)

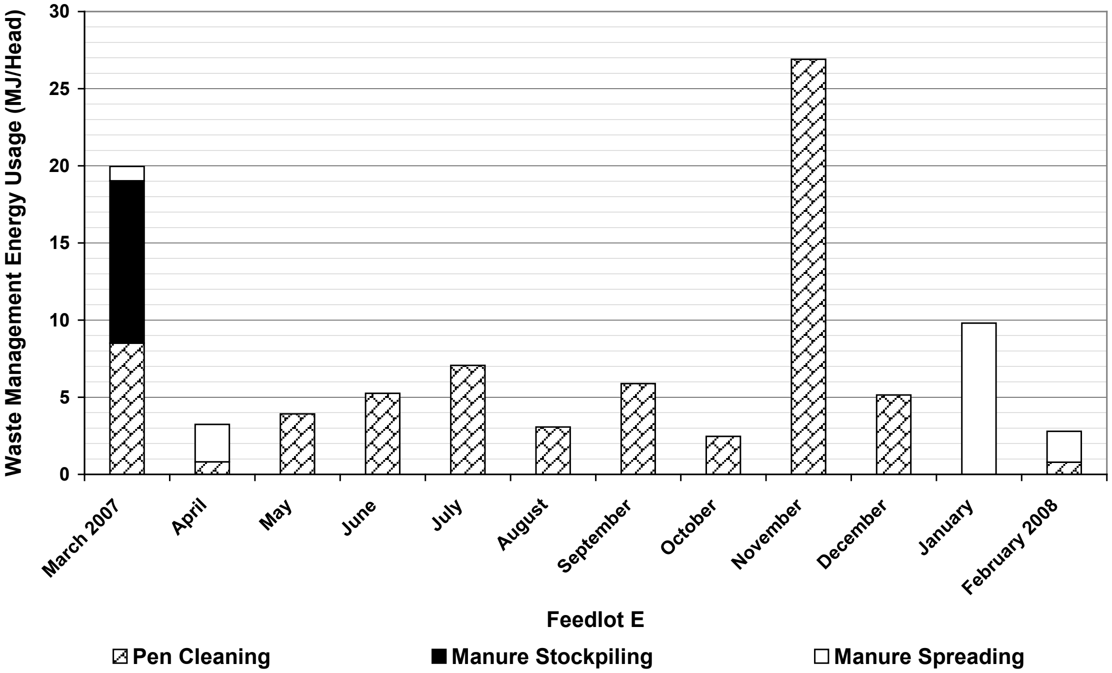

Figure 137 – Waste management energy consumption for Feedlot E (MJ/head-on-feed/month)

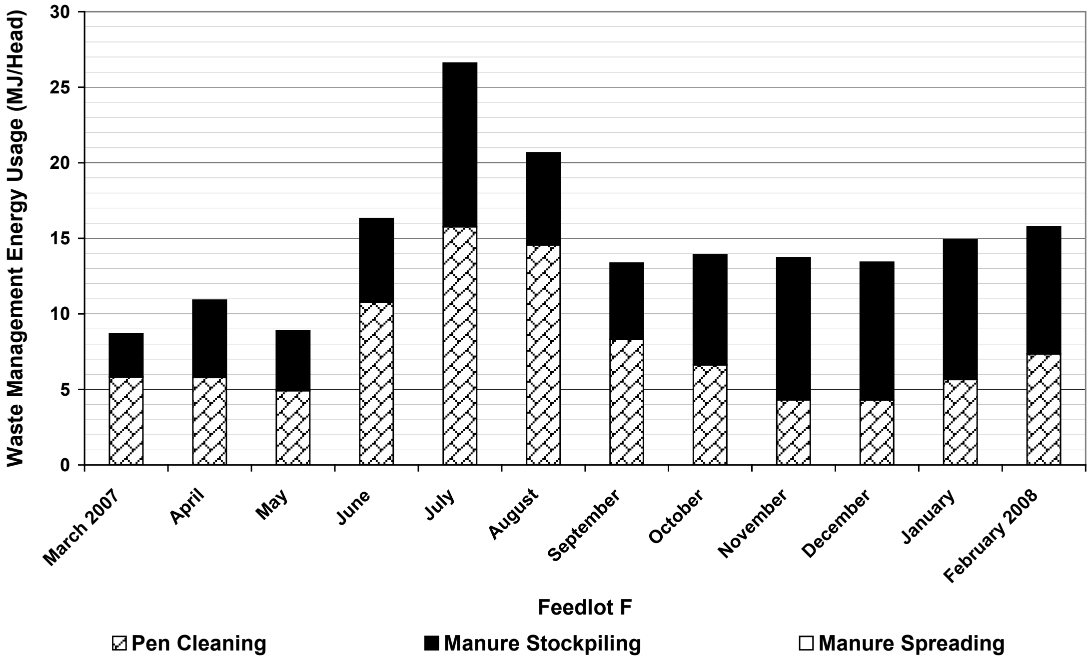

Figure 138 – Waste management energy consumption for Feedlot F (MJ/head-on-feed/month)

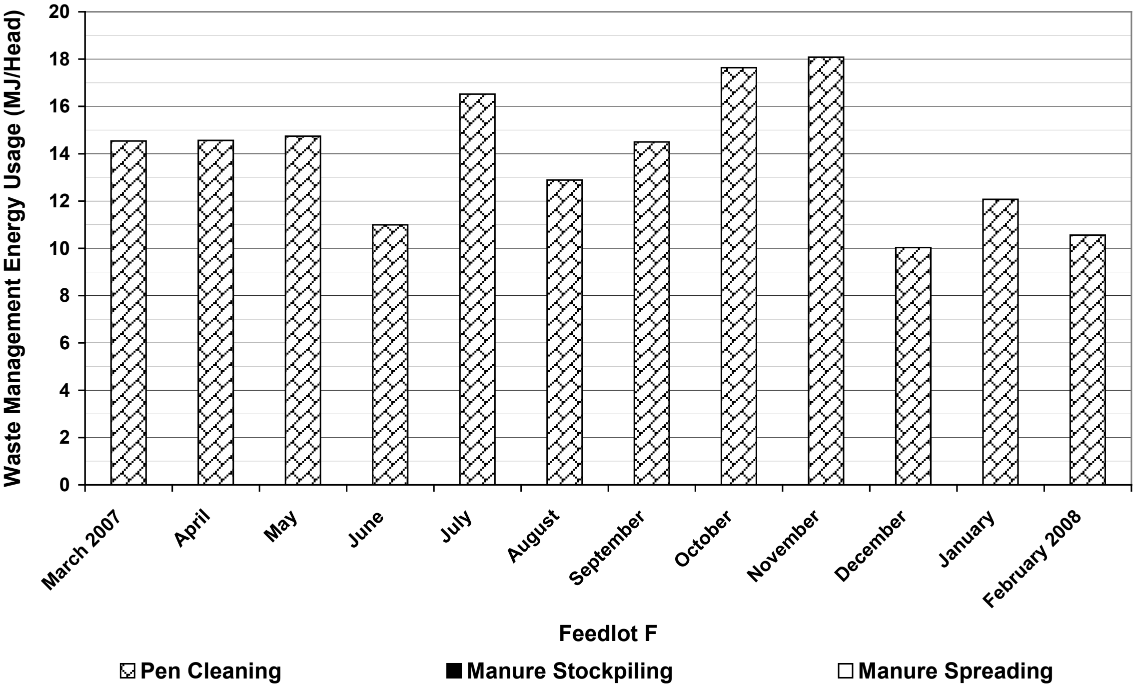

Figure 139 – Waste management energy consumption for Feedlot G (MJ/head-on-feed/month)

Appendix E – Cattle washing energy usage

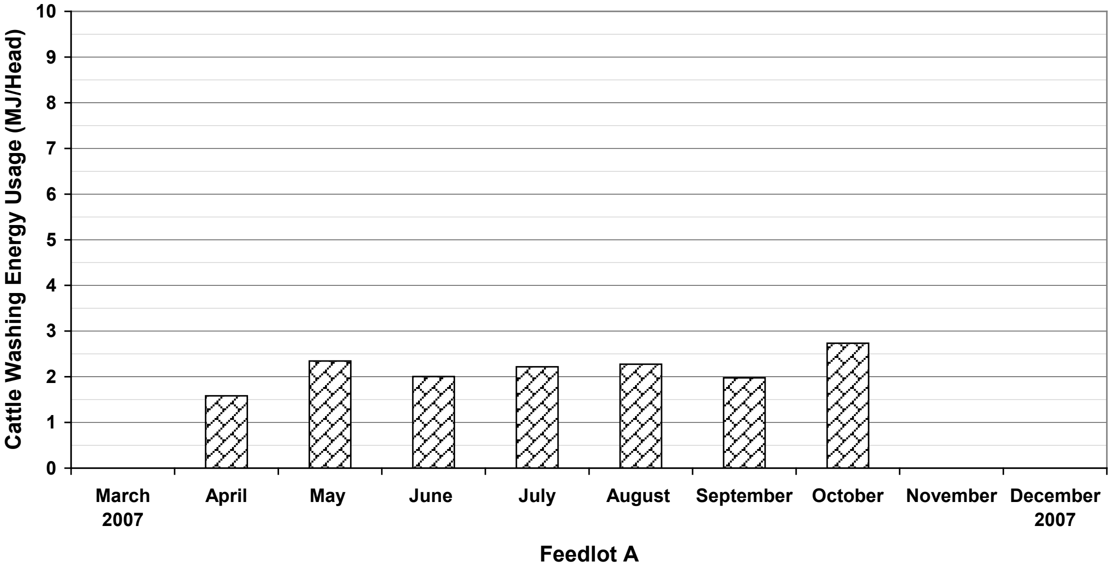

Figure 140 – Cattle washing energy consumption for Feedlot A (MJ/head washed)

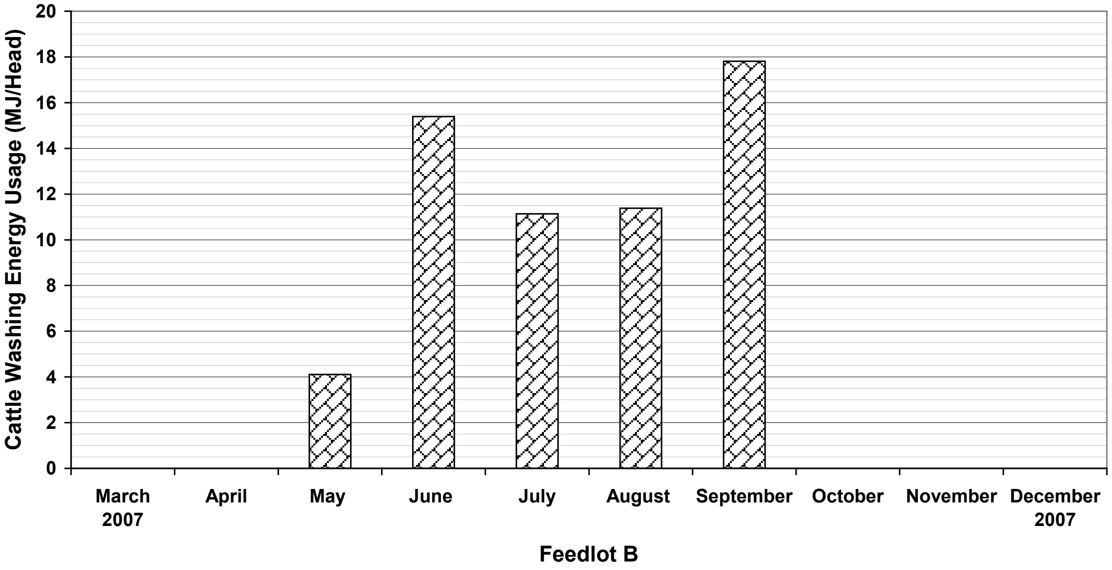

Figure 141 – Cattle washing energy consumption for Feedlot B (MJ/head washed)

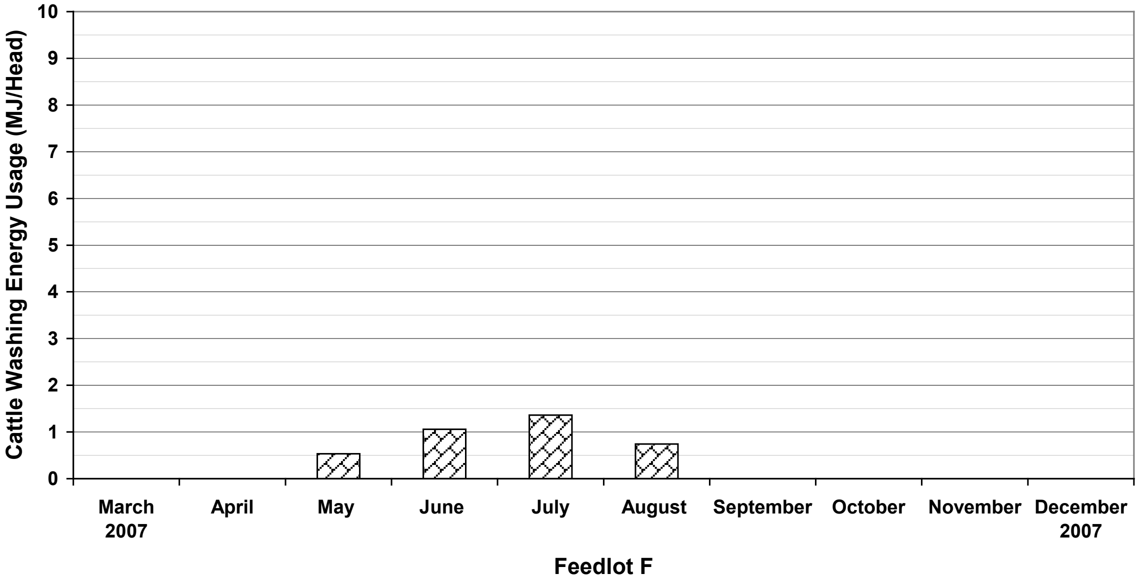

Figure 142 – Cattle washing energy consumption for Feedlot F (MJ/head washed)

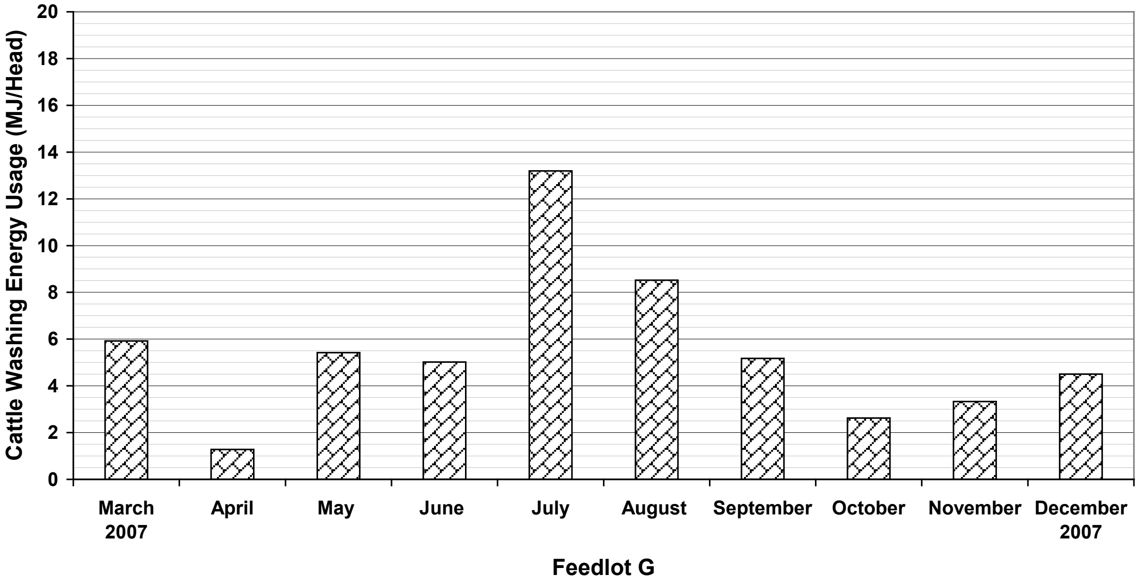

Figure 143 – Cattle washing energy consumption for Feedlot A (MJ/head washed)

Appendix F - Administration and minor activities energy usage

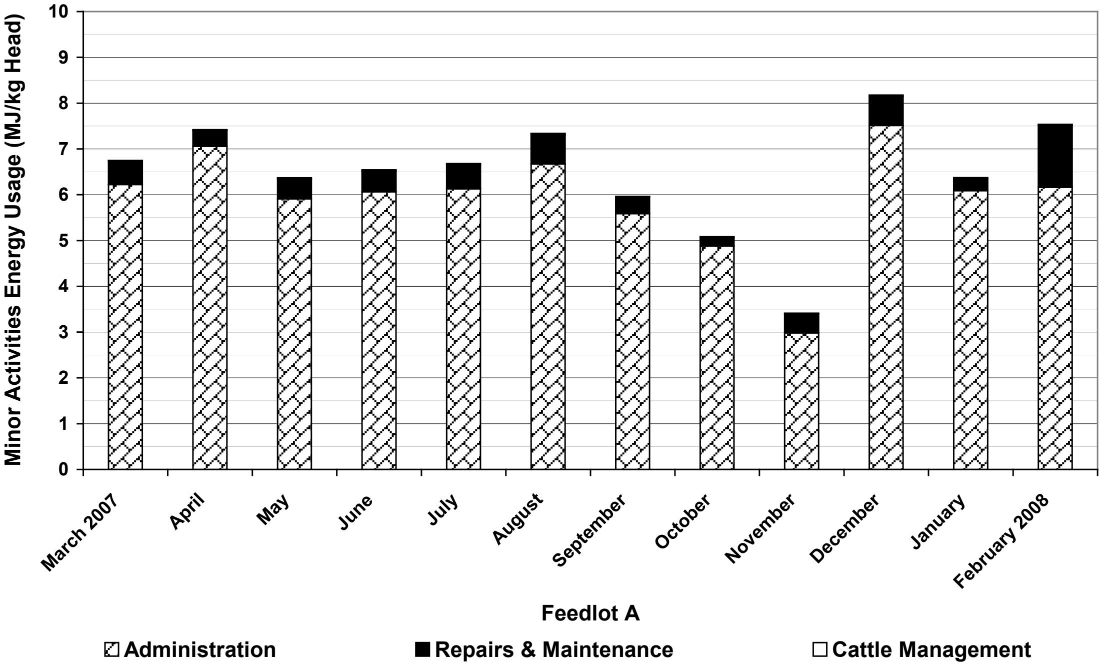

Figure 144 – Administration and minor activities energy consumption for Feedlot A (MJ/head-on-feed/month)

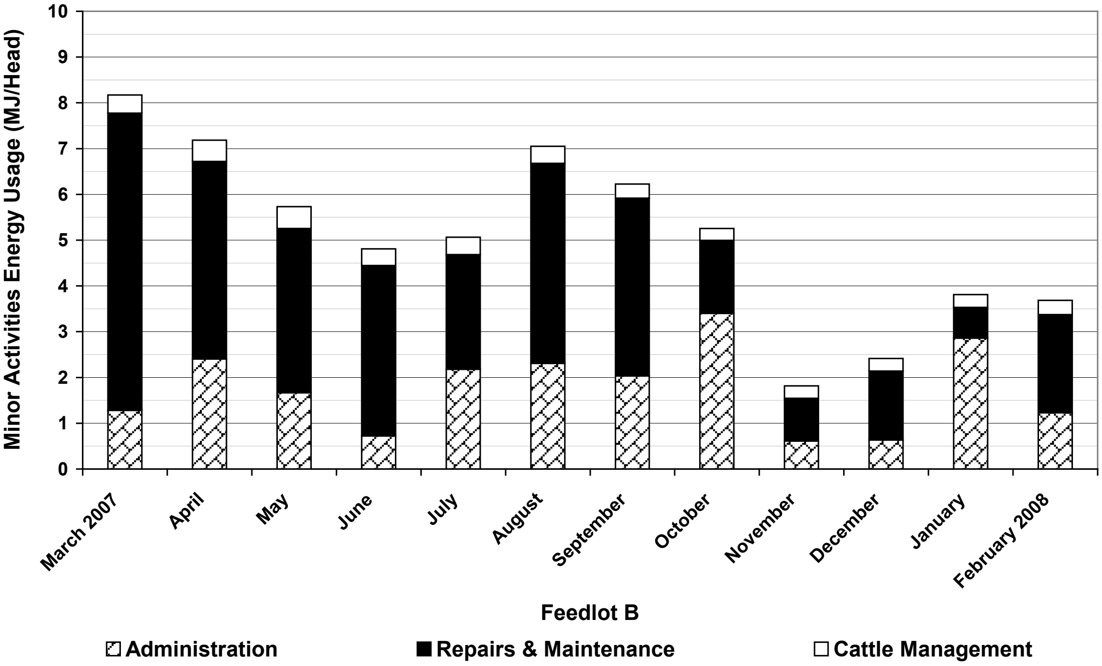

Figure 145 – Administration and minor activities energy consumption for Feedlot B (MJ/head-on-feed/month)

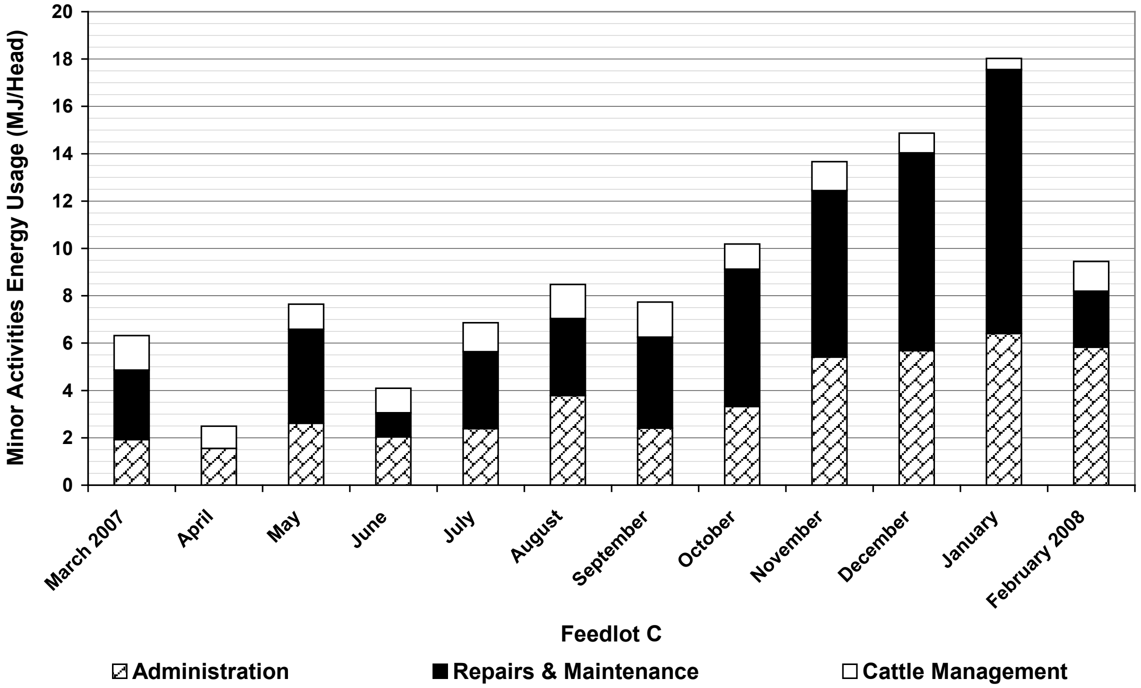

Figure 146 – Administration and minor activities energy consumption for Feedlot C (MJ/head-on-feed/month)

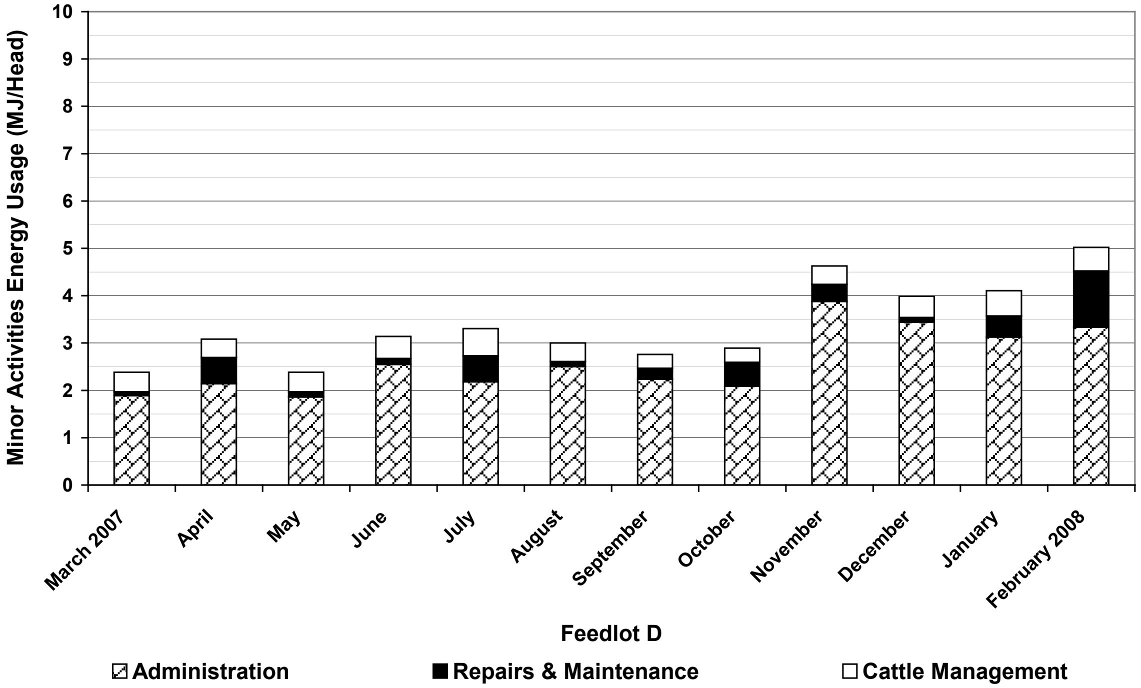

Figure 147 – Administration and minor activities energy consumption for Feedlot D (MJ/head-on-feed/month)

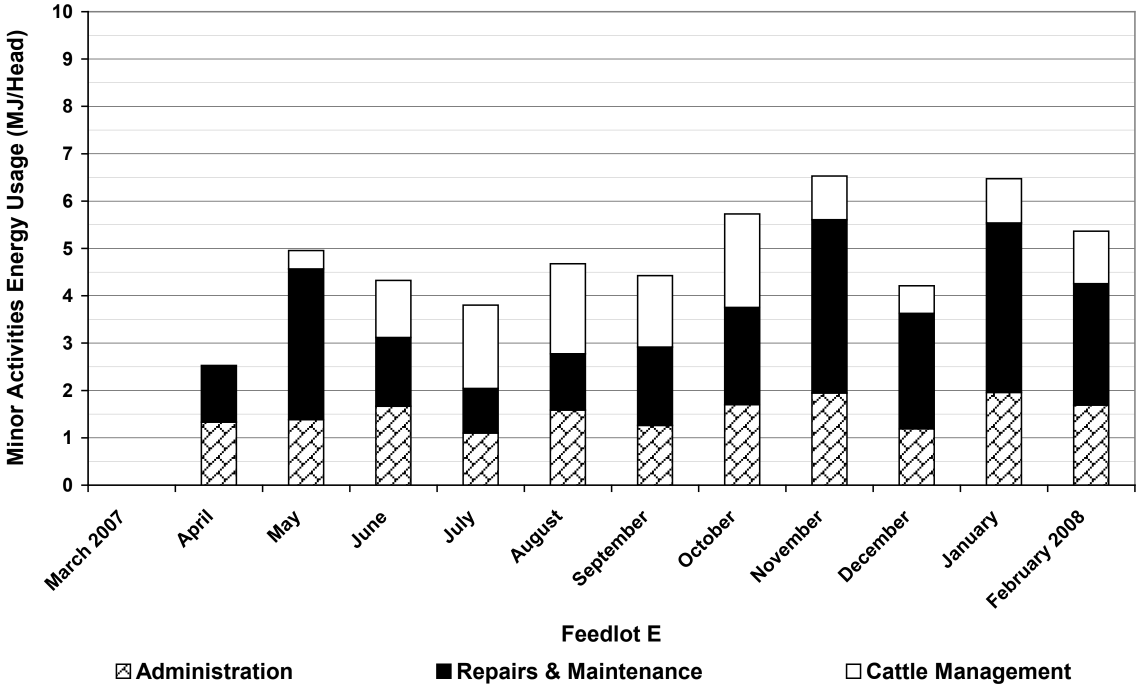

Figure 148 – Administration and minor activities energy consumption for Feedlot E (MJ/head-on-feed/month)

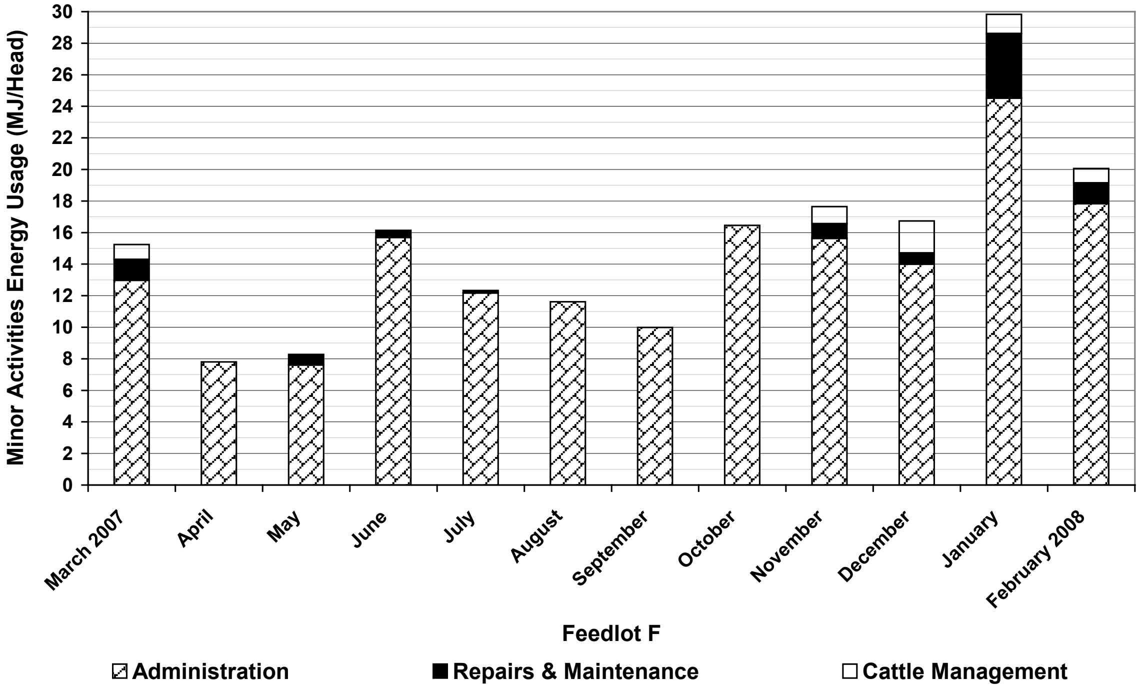

Figure 149 – Administration and minor activities energy consumption for Feedlot F (MJ/head-on-feed/month)

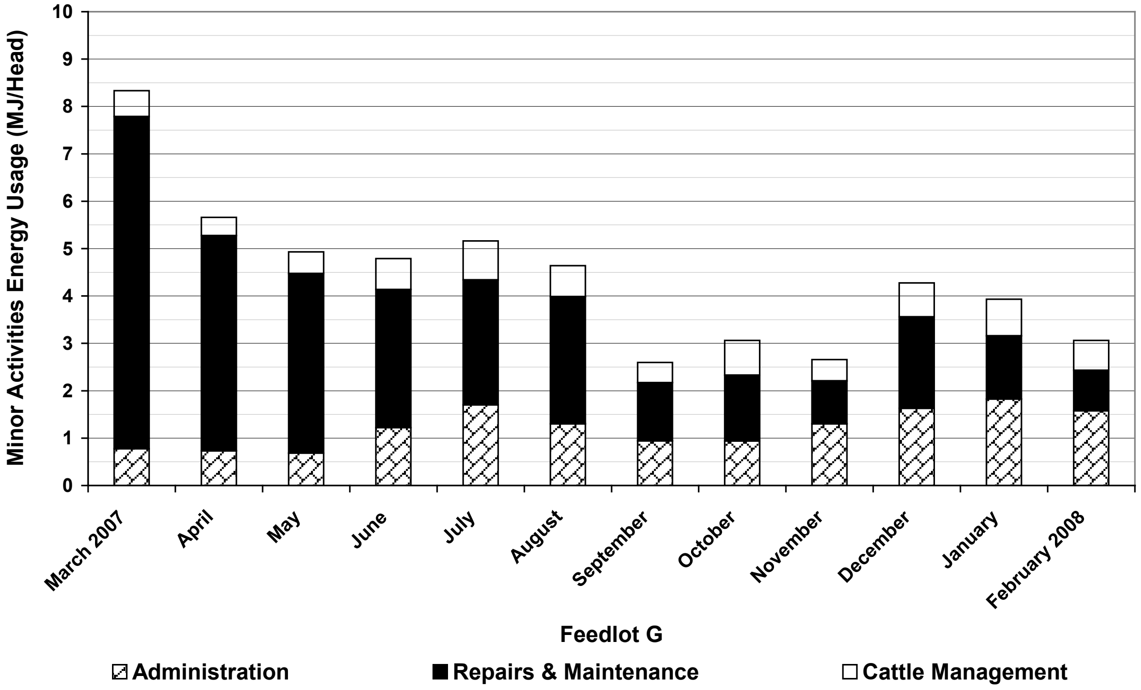

Figure 150 – Administration and minor activities energy consumption for Feedlot G (MJ/head-on-feed/month)