final report

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Cost of feedlot dags to Australian beef industry

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Executive Summary

Australia is one of the world's largest producers of commercial livestock and top exporters of red meat and livestock. According to MLA estimates, the off-farm value of the Australian beef and cattle industry amounted to almost $17 billion in 2016-17 (MLA, 2017).

Dags are the build-up of mud and manure on the hides of cattle that can lead to operational and economic challenges to the industry. Prevention of dags by implementing appropriate feedlot pen management is widely considered to be the best currently available strategy to mitigate the impacts of dags. However, the capital and operational costs of feedlot management infrastructure mean that chemical and mechanical measures to prevent or remove dags are also an important option for the industry. In addition, despite best pen management practices, dags can cause problems, so alternative measures are also required.

MLA and other research bodies have funded a substantial number of projects over the past 30 years, with limited success in developing a suitable alternative to the current practice of extensive washing to breakdown and remove the dag material.

The objectives of this project were to:

1. Evaluate and quantify the cost of dags to the Australian beef industry, through an assessment of the cost to each impacted part of the supply chain, including:
    a. The magnitude of the problem, giving consideration to regional distribution of feedlot dags, annual variability in dag prevalence, and washing location (feedlot vs. processor).
    b. Cost to the feedlot sector, including performance loss, direct cleaning costs (infrastructure, labour, water use, WH&S costs, etc.), processor cleaning charges, and meat quality downgrades.
    c. Cost to the processing sector, including direct cleaning costs not charged back to supplier feedlots, impacts on processing efficiency (additional labour, reduced chain speed, etc.), cost of trim and potential microbial contamination, including potential for increased risk due to food safety recalls.
    d. Cost to the hide tanning sector as a result of incomplete dag removal and increased damage to hides.
2. Produce an estimate of the cost of dags per head to provide a threshold to inform the investment of future industry R&D funds and private funds into innovative commercial alternatives for dag management.

This project has involved working with a selection of five vertically integrated larger feedlot operators that have supply partnerships with abattoirs. We have also worked with a hide tanner willing to participate in this study. We conducted on-site interviews with personnel from each of these operations to generate comprehensive data sets on the timing and duration of historical dag cleaning practices, breeds of cattle prone to dag impacts, hide-shedding times and durations, costs of direct dag removal, costs of indirect impacts of dags such as lost productivity, and other information.

We have identified during this project that, despite the strong collection effort, data on the impact of dags is scarce and shows huge variability between contributors, across time and within business and market structures. The small size and the gaps in the data do not allow for statistical inference (neither parametric nor non-parametric).

The approach followed for estimating the magnitude of the dag problem was to calculate the attributable average cost of dag management per head for those businesses that provided us with data with a sufficient robustness and completeness that would allow replication. Data was grouped into seven major cost categories:

- Labour;
- Water;
- Effluent disposal;
- Energy;
- Infrastructure (CAPEX);
- Infrastructure (OPEX); and
- End product downgrades.

The findings suggested that, on average, the cost of dag management in the 2016 season would have amounted to approximately \$ 10.72 per head, comprised of a \$ 6.34 and \$ 4.38 cost borne by processors and feedlots respectively. The higher cost borne by processors suggests that the charge backs that processors are currently imposing on suppliers is, on average, insufficient.

Contributor interviews have surfaced an average variability of dag presence of approximately 33 per cent to 50 per cent and have stated that 2016 was a year of low dag presence. At face value, this would suggest the cost of dag management per head ranges from \$ 10.55 to \$ 16.02 per head depending on the prevalence of dags.

Taking this into consideration, the cost of dags to the Australian beef industry would sit between \$ 4 million and \$ 10 million, equivalent to between 0.02 and 0.05 % of the Australian beef and cattle industry value of production. In turn, this is equivalent to between 0.16 and 0.39 % of the feedlot industry's value of production.

The key limitations of this estimate are the absence and high variability of data and the strong reliance on anecdotal evidence. Of particular concern are the following:

- No *'hard'* data on the cost to the transport sector and to the tannery sector, although interviews would suggest that they are close to negligible;
- No valid estimate on the cost of energy for processors and on the cost of effluent disposal for feedlots;
- A limited number of data points based on very few records, which hampers generalisability; and
- The inability to establish a fact-based regional or seasonal pattern for costs aside from qualitative, non-observational commentary.

The project found that dags do incur a measurable cost on industry and that the cost is borne across the supply chain, especially by processors and feedlots. Moreover, the cost is not borne equally, with costs varying considerably between businesses depending on their location, operation, supply chain relationships and season.

The cost estimate provides a threshold to guide additional investment in dag management – by commercial developers of treatments, research organisations such as MLA and the feedlots and processors involved in the supply chain.

The outcomes of this project align with one of the key strategic challenges for the Australian beef industry: maintaining a premium integrity and quality image for the product while driving increased on-farm productivity gains.

The project makes two recommendations to guide future RD&E and investment in dag management:

1. Developing more reliable estimates on the costs of dags will require observational research
2. Dag management improvements need to be integrated with other improvements to provide sufficient incentive to be implemented.

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Abbreviations

ADG	Average Daily Gain (of livestock liveweight)
ALFA	Australian Lot Feeders' Association
BRD	Bovine Respiratory Disease
CFU	Colony-Forming Unit
DOF	(Days on Feed) means the difference between the exit date and the entry date of feedlot cattle
EC	Electrical Conductivity
EDP	Evening Dust Peak
ET	Endotoxin
G:F Ratio	(Gain : Feed Ratio) is synonymous with the feed conversion ratio
IBR	Infectious Bovine Rhinotracheitis
MLA	Meat & Livestock Australia
NLIS	National Livestock Identification Scheme
NPI	National Pollutant Inventory
ODTS	Organic Dust Toxic Syndrome
PM	Particulate Matter
PPE	Personal Protective Equipment
PSD	Particle Size Distribution
Pulls	Cattle which have been pulled from their home pen for treatment
PCV	Packed cell volume
SAR	Sodium Adsorption Ratio
TEOM	Tapered Element Oscillating Microbalance
TSP	Total Suspended Particulates
TWA	Time Weighted Average
µg/h	µg exposure per hour
WBC	White Blood Cell

1 Background

Australia is one of the world's largest producers of commercial livestock and the top exporter of red meat and livestock. According to MLA estimates, the off-farm value of the Australian beef and cattle industry amounted to almost $17 billion in 2016-17 (MLA, 2017). The beef industry has a complex supply chain with very diverse competitive structures across its different links. The output of the industry is exposed to several cyclical, geographical and political drivers that create unique risks to beef and livestock production, such as weather patterns, biological cycles, commodity price fluctuations, unharmonised biosecurity, welfare and access regulations, and regional production patterns. These affect the distribution and prevelance of dags across the supply chain and the degree to which the industry and individual businesses are incentivised to prevent them.

Dags are the build-up of mud and manure on the hides of cattle that can lead to operational and economic challenges to the industry. Prevention of dags by implementing appropriate feedlot pen management is widely considered to be the best currently available strategy to mitigate the impacts of dags. However, the capital and operational costs of feedlot management infrastructure mean that chemical and mechanical measures to prevent or remove dags are also an important option for the industry.

Dag removal can be carried out at the feedlot by soaking live cattle with water to soften the dags and then washing with a high pressure jet or hose (Greenwood, House and Fell, 1998; Haines *et al.*, 2000). Washing is also carried out at meat processing facilities, but this is generally as a food safety risk mitigation measure rather than to remove dags.

The costs associated with dag removal include:

- Direct cleaning costs at the feedlot;
- Direct cleaning costs at the abattoir - during daggy periods, dag contamination can result in penalty payments to the slaughter team, the need for extra staff to trim contaminated carcasses, loss of meat production, and dirty hides being delivered to local and overseas hide processors (Wescombe 1994);
- Indirect costs caused by reduced productivity;
- Reduced processing efficiency; and
- Reduced quality of carcass or hides.

MLA and other research bodies have funded a substantial number of projects over the past 30 years, with limited success in developing a suitable alternative to the current practice of extensive washing to breakdown and remove the dag material. This research has included:

- Mechanical or physical dag removal mechanisms such as shearing, hand raking, and the Rockdale Dedag Machine, which was found to be relatively effective at removing dags but was associated with increased risks to animal health and welfare and, subsequently, meat quality (Greenwood, House and Fell, 1998; Rowland, Phillips and Coates, 1999); and
- Chemical dag minimisation mechanisms, such as washing and detergents (Greenwood, House and Fell, 1998; Rowland, Phillips and Coates, 1999; Haines *et al.*, 2000).

More recently, a number of commercial entities have indicated they are interested in investment in research to address the dags issue. There is, however, currently no significant up-to-date information on the magnitude of the problem, the cost of current interventions, or the total cost to industry. This information is required as a basis for assessing potential solutions to the problem, and the likely return on any investment to address the issue. This project was designed to collect the information required to allow these assessments to be undertaken.

The project has involved working with a selection of five vertically integrated larger feedlot operators that have supply partnerships with abattoirs. We have also worked with a hide tanner willing to participate in this study. We conducted on-site interviews with personnel from each of these operations to generate comprehensive data sets on the timing and duration of historical dag cleaning practices, breeds of cattle prone to dag impacts, hide-shedding times and durations, costs of direct dag removal, costs of indirect impacts of dags such as lost productivity, and other information.

The outcomes of this project align with one of the key strategic challenges for the Australian beef industry: maintaining a premium integrity and quality image for the product while driving increased on-farm productivity gains.

2 Project objectives

The objectives of this project were to:

1. Evaluate and quantify the cost of dags to the Australian beef industry, through an assessment of the cost to each impacted part of the supply chain, including:
    a. The magnitude of the problem, giving consideration to regional distribution of feedlot dags, annual variability in dag prevalence, and washing location (feedlot vs. processor).
    b. Cost to the feedlot sector, including performance loss, direct cleaning costs (infrastructure, labour, water use, WH&S costs, etc.), processor cleaning charges, and meat quality downgrades.
    c. Cost to the processing sector, including direct cleaning costs not charged back to supplier feedlots, impacts on processing efficiency (additional labour, reduced chain speed, etc.), cost of trim and potential microbial contamination, including potential for increased risk due to food safety recalls.
    d. Cost to the hide tanning sector as a result of incomplete dag removal and increased damage to hides.
2. Produce a high-level cost benefit analysis (CBA) of two proposed interventions for dag management. The CBA should develop an evidence base for the potential investment of industry R&D funds or private funds into innovative commercial alternatives for dag management.

3 Methodology

3.1 Literature review

The project involved three stages: literature review, data collection and economic analysis. Literature from Australia and overseas was reviewed to both identify available cost data and scope how the project should collect and analyse additional data in the subsequent phase.

3.2 Data collection

3.2.1 Participant selection

The project team targeted larger, preferably vertically integrated, operators because these operators were more likely to have comprehensive data on the costs of feedlot dags to each stage of the industry. Six feedlots and each of their supply abattoirs were selected to participate in this project. We also identified suitable tanning and transport operators to contribute information on these parts of the supply chain.

3.2.2 Dataset requirements

The data to be collected was identified using the schematic diagram of the feedlot-abattoir section of the supply chain (Fig. 1) We aimed to address:

- Impacts of dags on cattle performance;
- Impacts of dags on Average Daily Gain (ADG), Dry Matter Intake (DMI), Feed Conversion Efficiency (FCE) due to dags;
- Requirements for cattle washing at the feedlot;
- Capital and operating costs of washing equipment at the feedlot;
- Post-washing cattle management requirements;
- Capital and operating costs of post-washing holding pens;
- Cattle transport - differences in costs of transport for “clean” cattle vs “daggy” cattle;
- Cattle washing at the abattoir;
- Additional capital and operating costs at the abattoir due to cleaning daggy cattle;
- Impacts of dags on slaughter and processing;
- Throughput delays at the abattoir;
- Impacts of dags on meat yield and quality;
- Extra labour in removing bruising caused when washing and trimming of any contaminated areas
- Carcass quality as affected by dags;
- Downgrading due to dark cutting;
- Yield reduction due to extra trimming of bruises;
- Impacts of dags on hide quality as affected by dags; and
- Defects to hides due to cuts caused in fleshing operation.

A spreadsheet was developed listing all required information to be obtained from each participant.

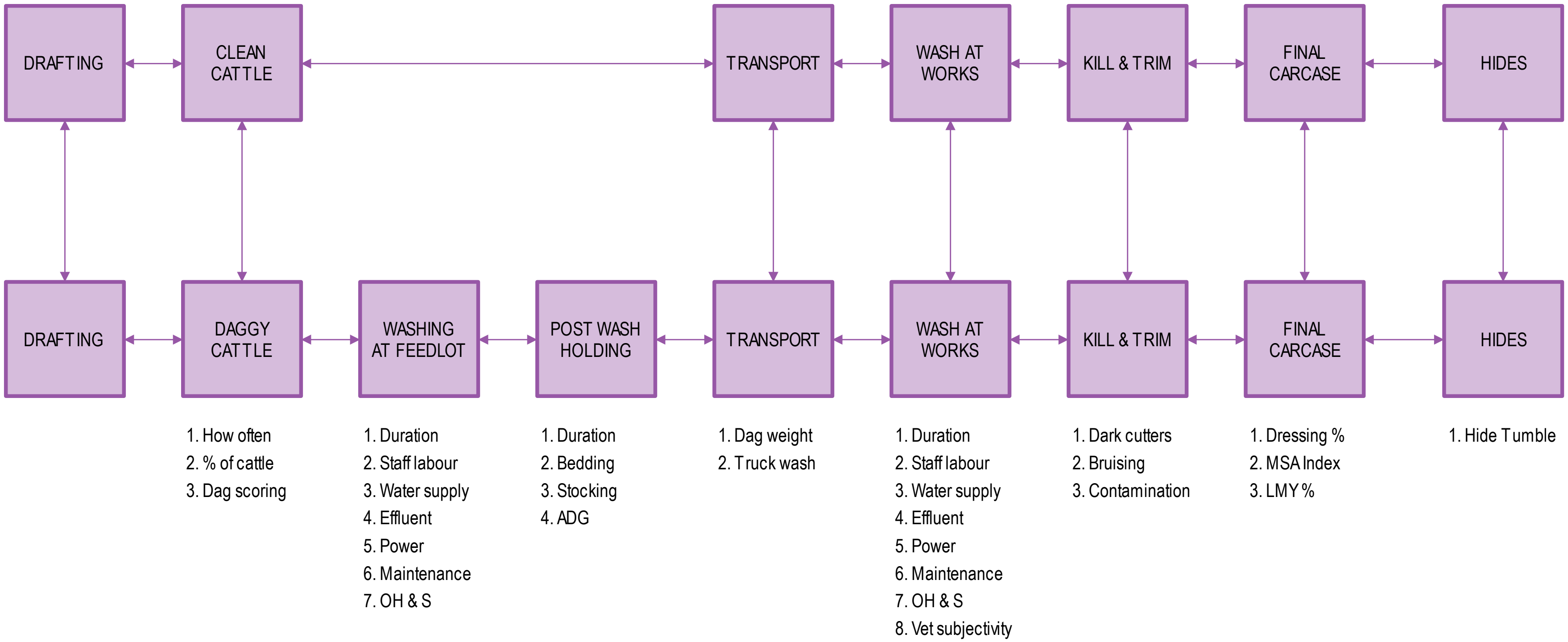

Fig. 1 – Feedlot – Abattoir Supply Chain (with and without dags).

3.2.3 Interviews

All feedlots and abattoir participants were visited by the project team and face-to-face interviews were held to obtain the information required. In most cases, a series of follow up emails and phone calls were conducted to fill data gaps.

Two main types of data were aimed to be collected during the site visits:

1. Historical records and anecdotal data on when cattle washing has been carried out due to dag problems, causes of dag formation, and dag mitigation and removal. Both ACIL Allen and Premise invested time with operators and staff on-site to ensure that the appropriate data was obtained. After completion of site visits, follow up communications were conducted to fill identified data gaps.
2. Records of costs of feedlot dags to operations, including:
    a. Costs to feedlot such as performance loss costs, direct cleaning costs (infrastructure, labour, water use and WH&S costs), processor cleaning charges and meat quality downgrades;
    b. Costs to processor such as direct cleaning costs not charged back to feedlots, impacts on processing efficiency (additional labour, reduced chain speed), water use, cost of trim and potential microbial contamination, including potential for increased risk due to food safety recalls.

When required, reasonable, plausible working assumptions based on the professional judgement of the project team were made and their implications have been disclosed in this report.

Transport and tanning operators were interviewed initially via telephone, with follow up emails and phone calls conducted to clarify information and fill information gaps.

3.2.4 Data compilation

For each participant, quantitative data was tabulated and quality data was documented in report form.

3.3 Economic analysis

The approach was to focus on providing a robust analysis of the direct economic impacts of the proposed recommendations using a cost benefit analysis (CBA) approach. The CBA framework included two main components (refer to Fig. 2):

- **Mapping of impacts** — this component sought to build a detailed understanding of the costs of managing dags to the different players in the supply chain and the potential benefits and costs that the proposed interventions may entail;
- **Quantification of direct impacts** — this component entailed quantifying the direct impacts (costs, benefits and transfers) of both the business as usual scenario, and each of the two potential interventions. This was refined to identifying the cost threshold for interventions to be economically viable when the required information on the interventions was not able to be provided.

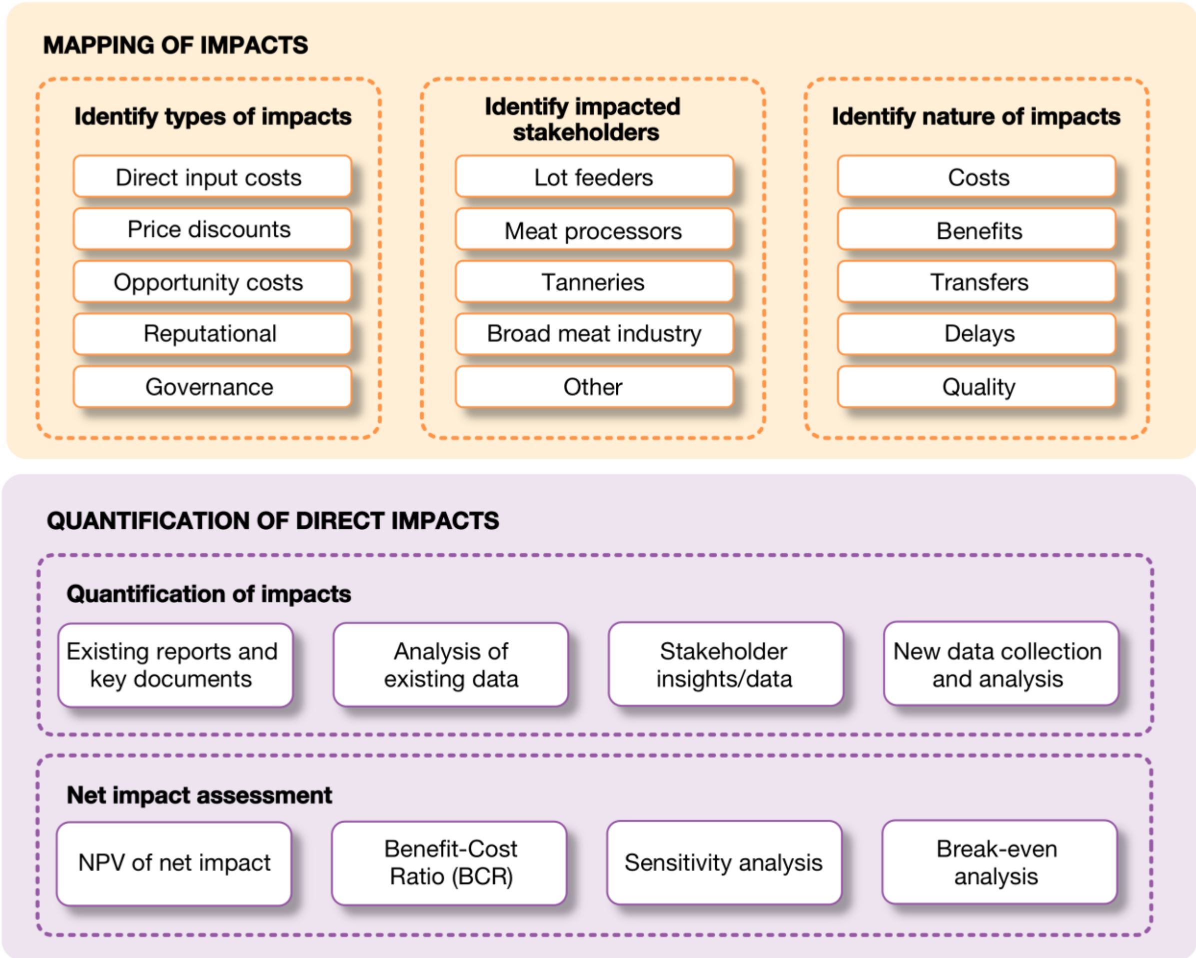

Fig. 2 – Analytical (cost-benefit) framework

3.3.1 Mapping of direct impacts

Based on the data collected and collated in Stage 2, the first component of our analytical framework entailed building a detailed understanding of the costs of dags to the Australian beef industry. This involved mapping:

- The costs to feedlots of dag management practices considering the regional and seasonal variations in these costs;
- The costs to meat processers that arise from the management of daggy cattle, including the potential biosecurity risks of inadequate dag management;
- The costs to the hide tanning sector of inadequate dag removal and hide damage;
- Other relevant explicit and implicit costs that arise from dag management in Australia.

The second component involved structuring a detailed understanding of the potential impacts of the technological approaches (interventions) that MLA is considering to address feedlot dag prevalence:

- The types of impacts associated with the potential interventions (e.g. economic, social and/or environmental);
- Who those impacts would accrue to (including feedlot sector, processing sector, hide tanning sector, government, the community in general and other stakeholders);
- The nature of the impacts that the proposed recommendations would bring about (e.g. whether they are costs, benefits or transfers); and

- When impacts would occur, and for how long.

3.3.2 Quantification of direct impacts (cost-benefit analysis)

Once the relevant cost and benefit data were sourced, collected and collated, we originally sought to quantify the net economic impact of the technological intervention using a CBA model. A CBA model brings together all relevant economic impacts into a consistent monetary value to assess the overall impact of the interventions.

The initial part of the economic analysis involved quantifying the dag management costs following the site visits to estimate their impact. The second component of the analysis proposed for this project involved structuring a detailed understanding of the potential impacts of the technological approaches (interventions) that MLA is considering to address feedlot dag prevalence to complete the CBA in full (last row of Fig. 2).

During the project we were advised the details on the proposed technologies that would provide the interventions to be included in the economic analysis would not be available. On this basis we still applied the CBA framework but limited the analysis to a breakeven analysis, which was agreed with MLA on 21 September 2017. This meant the project could establish an estimated cost threshold at which a new technology would not exceed the costs of dags identified. As a result, net present value (NPV), benefit cost ratio (BCR) of the intervention induced impacts incremental (i.e. compared) to the business as usual (i.e. no intervention) scenario and analysis of their individual sensitivities to cost drivers (variables) were not developed.

4 Literature Review

4.1 Introduction

Dags present challenges at all levels of the beef industry supply chain (Fig 3). These challenges include impacts on animal welfare, food quality and safety risks, and management costs. To date, little quantitative data is available on the magnitude of the impact of dags to the beef industry in Australia. This information is required before industry wide, cost effective solutions can be identified.

In order to quantify the extent to which dags impact the industry, a comprehensive understanding of the factors that may contribute to dag formation and how dags are currently managed is required. This literature review has been conducted to identify the combination of contributing circumstances (such as breed, climate, moisture, temperature, physiology, and pen management practices) in which dags become an issue to feedlot operators and provides preliminary information on the magnitude of the dag problem for the Australian Beef industry.

4.2 Background

4.2.1 Dag formation and composition

Dags are an accumulation of faecal and soil particles that adhere to hair in the coats of cattle. They are formed through a complex process involving grain sugars, which act as a binding agent between the manure, dirt, and hair. As dags dry, the product becomes increasingly difficult to remove (Slattery, Davis and Carmody, 2005). Dags tend to accumulate along the belly, brisket, tail, legs and sides of animals.

Dags arise in feedlot cattle and present major challenges across the entire beef supply chain (Fig. 3) due to:

- Concerns regarding the welfare and health of animals;
- Increased costs associated with the cleaning and processing of daggy cattle;
- Reduced performance and meat quality outcomes; and
- The potential to compromise food safety through carcass contamination.

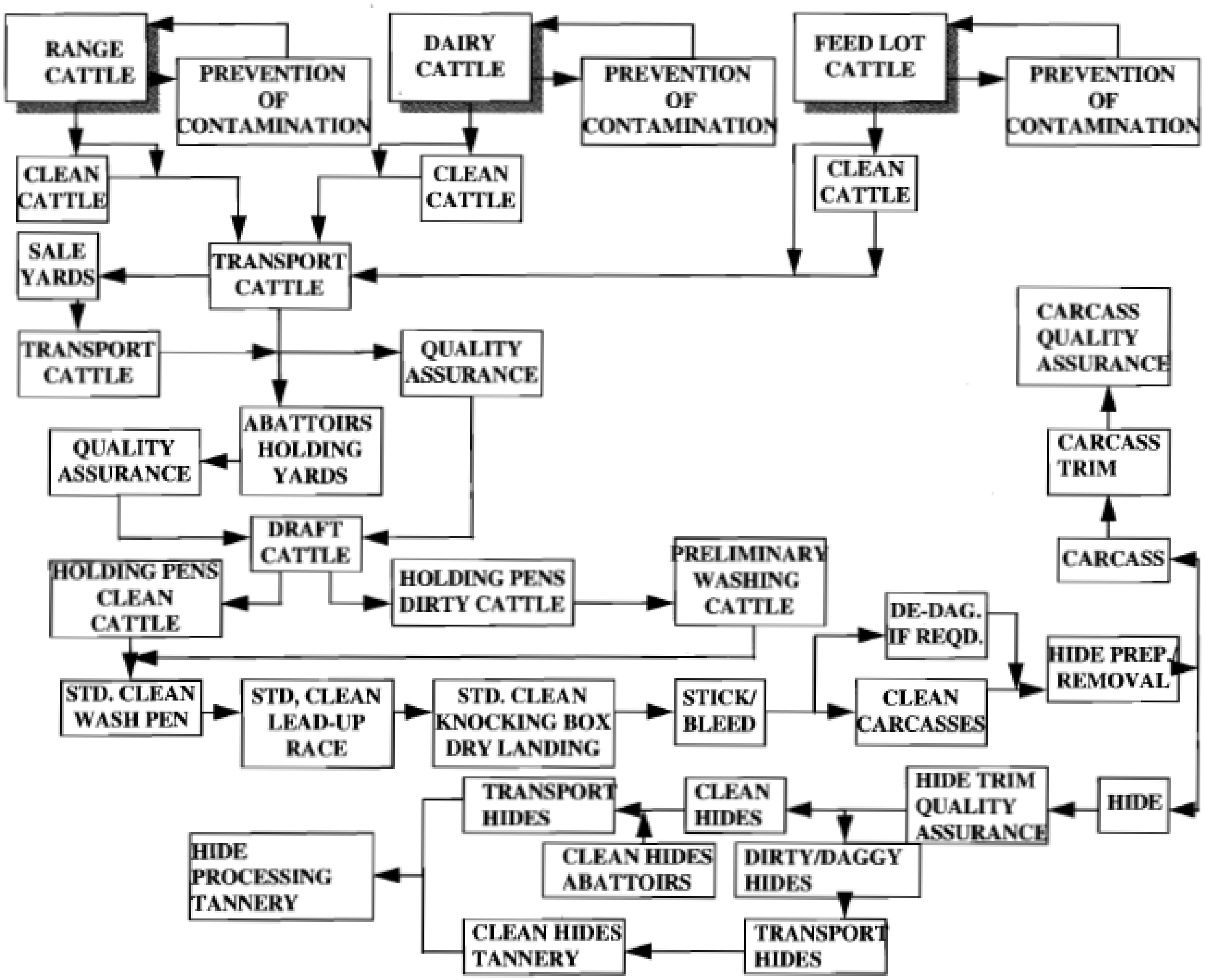

Fig. 3 – Schematic flow chart of beef supply chain. Source: Wescombe (1994)

4.2.2 Occurrence of dags

Dags usually develop in winter in climate zones where high winter rainfall and low rates of evaporation combine to prevent rapid drying out of feedlot pens. This is usually between the months of April and September on the eastern coast of Australia. Dags have been known to occur outside of these climate zones and time periods, but the severity is substantially lower, and there is little or no management required. For example, one feedlot located in Central New South Wales reports that dags are a problem for them every winter. In contrast, many feedlots located in areas dominated by summer rainfall, such as Dalby in Queensland, have fewer dag problems because pens generally dry out rapidly following rainfall events (Watts *et al.*, 2016).

The incidence of dags can increase from relatively minor to severe, with the worst cases seeing animals carry an average of 3.7 kg of dags per animal (Auer, Covington, Evans, Nat & Tozan, 1999). Dags are also more of a problem for longer hair breeds of cattle. *Bos taurus* cattle, which traditionally have long hair coats during winter, are the most commonly affected, although other breeds can also be impacted. This is discussed further in Section 4.3.1.

4.3 Factors that contribute to dag formation

4.3.1 Breed and physiology

The impacts of dags vary with different breeds of cattle. As mentioned in Section 4.2.2, *Bos taurus* breeds of cattle are impacted more severely by dags than *Bos indicus*. This relationship has been observed anecdotally by feedlot operators and has also been reported in the literature (Wescombe, 1994). The difference is generally accepted to be due to the difference in hair length. Compared with *Bos indicus* cattle, *Bos taurus* hair is longer and finer and this hair type is more susceptible to dags in winter when hair growth is stimulated by cooler temperatures. The fact that *Bos taurus* breeds are more suited to the cooler regions of southern Australia, where dags are more commonly a problem than in northern regions, is also a factor that may contribute to the observed relationship between dags and *Bos taurus* breeds.

To date, there is limited research linking aspects of physiology other than hair type to dag formation. According to Mader & Griffin (2015), heavier cattle experienced lower productivity during muddy conditions compared to lighter cattle, but this was found to be a factor of time animals spent on feed rather than any genetic physiological difference. There are several other behavioural studies that describe the effect of cold temperature and winter climates on animal behaviour and how these may be managed, however they do not provide tangible evidence of links between physiology and dag formation (Ito, Weary, & von Keyserlingk, 2018; Ray & Roubicek, 1971; Gonyou, Christopherson, & Young, 1979; Tucker et al., 2013).

4.3.2 Weather

Weather factors including temperature, moisture and wind, can have an impact on the incidence of dags. For example, rainfall has a significant impact on dag formation, with the prevalence and severity of dags increasing with the volume and duration of rain events. Watts *et al.* (2016) reports that it is more difficult to keep pen surfaces dry where annual rainfall exceeds 510 millimetres. In these circumstances, where pens remain wet for prolonged periods, management to prevent dags becomes highly challenging.

Temperature can also affect dag formation; cooler temperature stimulates hair growth, which can lead to dags and warmer temperature aids in rapid dag formation.

4.3.3 Climate

Overall, Australia has seven climate zones with three (subtropical, grassland, and temperate) having relevance to the geographic area considered in this study (Fig. 4). These three climate zones are described in Table 1. Dags will tend to form during (and after) longer periods of wet conditions when evaporation rates are low. This often coincides with cooler temperatures, which cause reduced evaporation from pen surfaces.

Table 1. Climate zones in South East Australia. Source: Australian Government, Bureau of Meteorology

Climate	Description
Subtropical	• High temperatures • High humidity • Distinct seasons: Wet: November-March, temperatures between 30-50°C Dry: April-October, average temperature ~20°C
Grassland	• Similar to subtropical climate, with less rainfall • Rainfall can often be summer-dominant
Temperate	• Distinct traditional four seasons • Rainfall can be either winter or summer dominant, depending on latitude • Cooler temperatures

Average annual evaporation in Australia is shown in Fig. 5. Evaporation can vary substantially in different parts of the country at different times of the year (Figs 5-7).

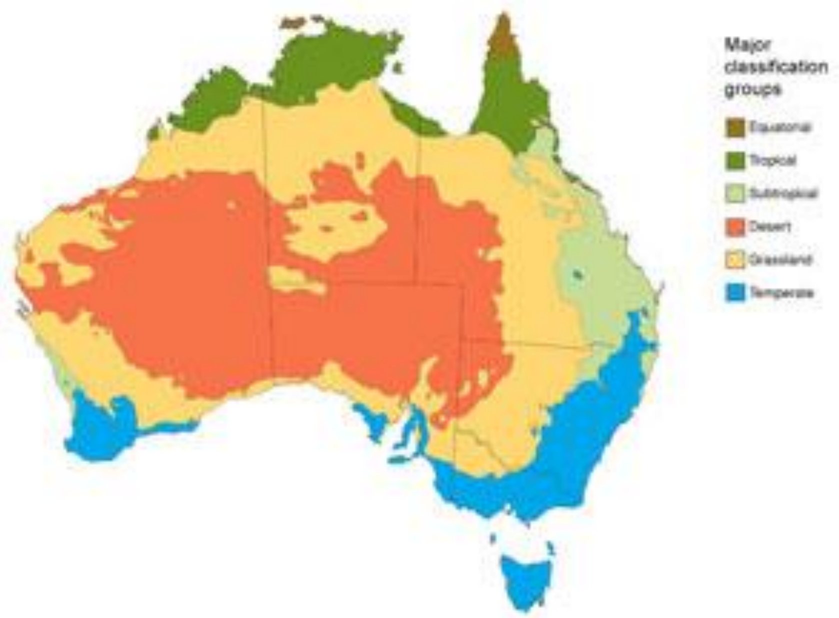

Fig. 4 - Climate classification groups in Australia. Source: Australian Government, Bureau of Meteorology, 2018

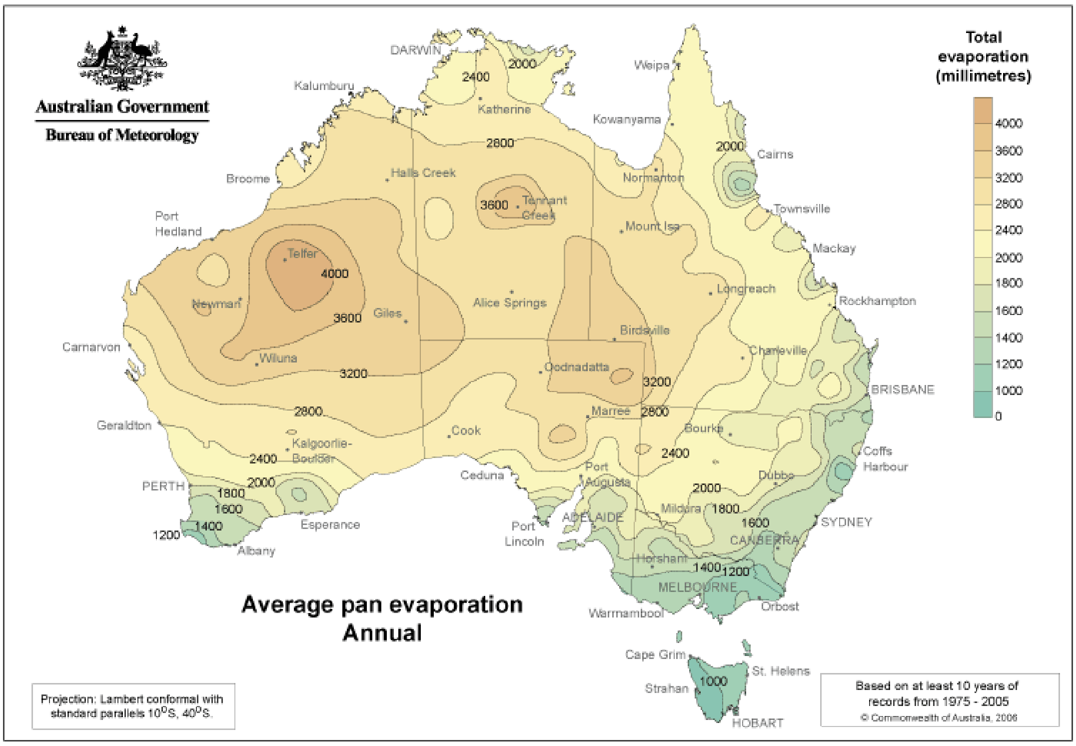

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Fig. 5 - Average pan evaporation in Australia annually. Source: Australian Bureau of Meteorology, Evaporation Index

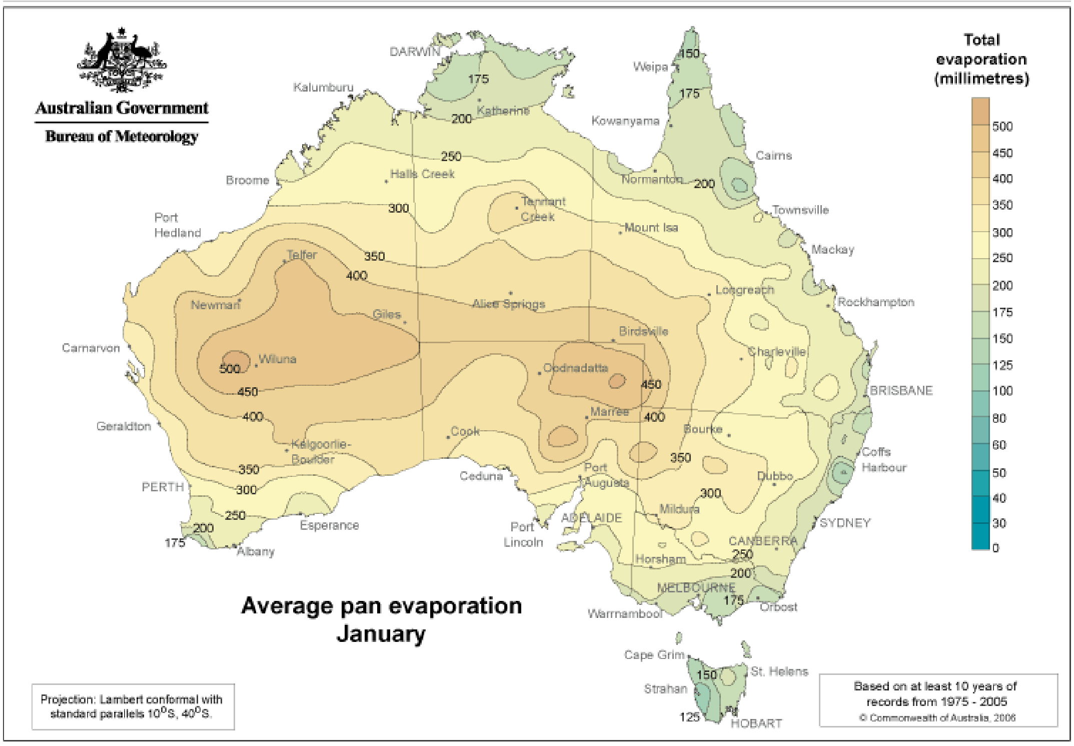

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Fig. 6 - Average pan evaporation in Australia in January. Source: Australian Bureau of Meteorology, Evaporation Index

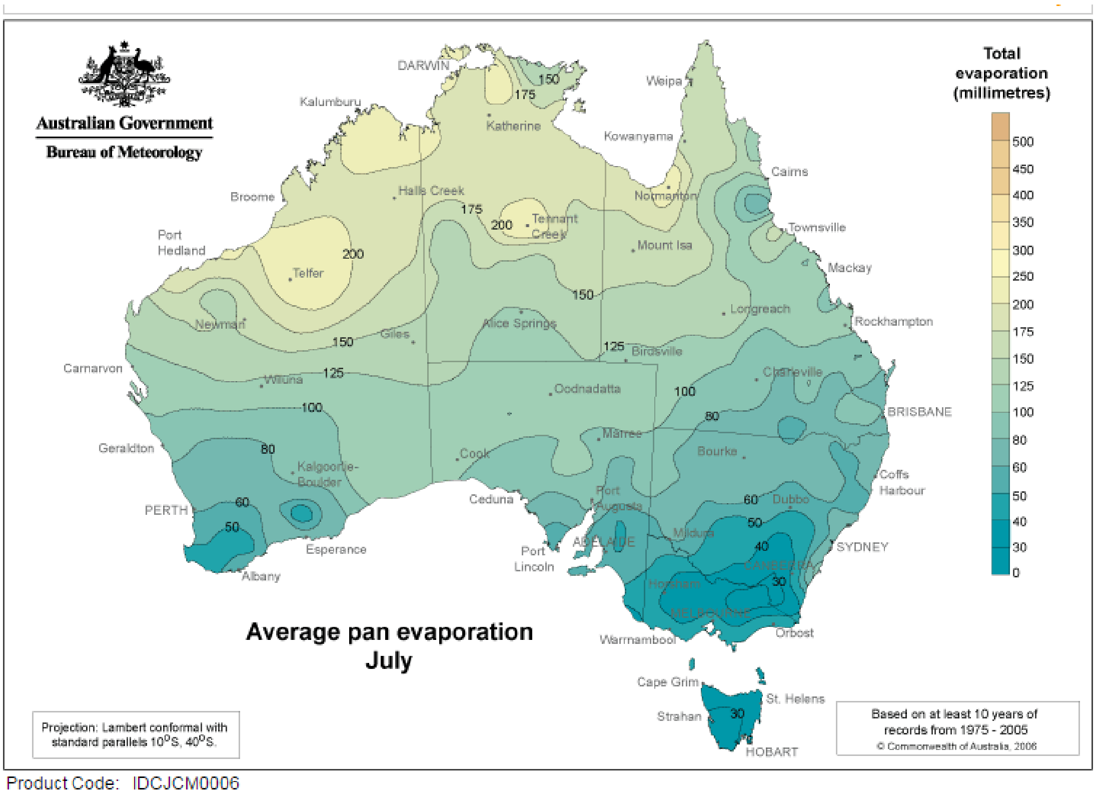

Fig. 7 - Average pan evaporation in Australia in July. Source: Australian Bureau of Meteorology, Evaporation Index

4.3.4 Cumulative impacts

In general, studies concerning dags do not consider the cumulative impacts that the factors above may have on dag formation. However, it is widely accepted that feedlot operations located in winter rainfall dominant areas and that feed *Bos taurus* cattle, will have the most severe incidences of dags during the dag risk period. Appropriate management is currently widely considered to be the most critical factor in reducing the incidence of dags. To be effective, pen management should consider all the contributing factors to the occurrence of dags and their cumulative impacts.

4.4 Assessment of dag severity

4.4.1 Dag scoring

There are several dag-scoring mechanisms, which all attempt to categorise the prevalence and severity of dags. Examples of these are provided in Appendix A – Mud Score Sheet. These mechanisms are used to monitor the effectiveness of current pen management and can guide the need for adjustment of existing practices.

Assessment of dag severity on cattle using the mud score sheet shown in Appendix A or another scoring reference can be subjective, with some operators classifying very severe dags with a lower score than would be given by a different operator. An example of a steer with a dag score of 5 is provided in Photograph 1.


Photograph 1 – Steer with a dag score of 5, depending on the assessor

4.4.2 Assessment of pen cleanliness

Feedlot operators may evaluate several characteristics to determine pen cleanliness. They include dag scores, drainage and pen surface for mud depth. According to Grandin (2016), mud at a depth of 11 cm results in reduced weight gain. Similarly, Smith Thomas (2013) reports that between 10 and 20 cm of mud can decrease feed intake by 8 – 15% and reduce gain by 14%. In severely muddy conditions (30 – 60 cm), intake may reduce by up to 30% and daily gain and feed conversion reduce by 25%.

According to the *Feedyard Assessment Guide* (Beef Quality Assurance, 2017), an operator should:

- Evaluate a minimum of 10 pens of cattle for cattle and pen conditions;
- Calculate the percentage of pens, where pens are maintained to help cattle have a dry resting area and eliminate wading through mud; and
- If 30% or more of pens are poorly maintained, or mud is present and preventative actions are not in place to manage conditions, reconsider pen management strategy.

4.5 Dag management

4.5.1 Feedlot pen management

Drainage

As mentioned previously, pen management is widely considered to be the most effective measure to reduce the incidence of dags and the severity of dags is greatest at feedlots where winter rainfall causes pen floors to remain wet for prolonged periods. Therefore, well designed pens that are maintained to encourage effective drainage will aid in increasing pen drying times and reducing the prevalence and severity of dags. Recent reports have indicated optimal pen surface moisture can be achieved by:

- Constructing pens on a slope of 3 - 3.5% (Watts, 2016);
- Integrating effective catchment and diversion drains into the feedlot design (Meat and Livestock Australia, 2012); and
- Optimising stocking densities to suit climatic and physiological conditions (McKeith *et al.*, 2012; Watts, 2016).

Cleaning

In practice, most feedlots will aim to clean pens regularly and prior to conditions that encourage dag formation. Once these conditions occur, the built-up mud prevents staff and machinery from being able to access pens for cleaning or to improve drainage.

Covered pens

Some feedlots install infrastructure such as sheds to divert precipitation and keep pen floors dryer (Photographs 2 and 3). Covering pens has also been reported to improve cattle comfort, with benefits including winter temperature increases of 6°C and ADG increases of 100g (Condon, 2013).

Photograph 2 – Fully covered pens at a Tasmanian feedlot


Photograph 3 – Fully covered shed at a South Australian feedlot

Pen bedding
Feedlot operators can reduce dag formation by adding substrates, such as straw or woodchips, to a pen surface (Photograph 4). This activity acts to form a barrier between the animal and the muddy pen floor and encourages drainage of subsequent moisture.

The application of bedding depends on the management requirements of the operator, as well as climate and susceptibility to dags. Some businesses may apply wood chip year-round to covered pen areas, others may use wood chip on exposed pens for all cattle only during the dag risk period or only for pre-slaughter cattle. Some operations may undertake washing before laying the substrate.

The decision to install bedding of a particular type and at a particular rate and duration generally revolves around the costs associated with obtaining and spreading the bedding material. This includes purchase, equipment use and labour. However, there are other factors that also must be considered including:

- Applying wood chip presents slip hazards to pen riders, particularly after rain events;
- Bedding removal cost and labour requirements;
- Changed composting processes; and
- Environmental risks (Larney *et al.*, 2008).

Photograph 4 – Cattle in woodchip pen

4.5.2 Feedlot cattle washing

Dags attach to hair fibres and not to the epidermis of the skin. This makes them difficult to remove. Dag removal can be carried out at the feedlot by soaking live cattle to soften the dags and then washing with a high pressure jet or hose (Greenwood, House and Fell, 1998; Haines *et al.*, 2000). The soaking process can take up to 8 or 9 hours to be effective. This can lead to animal health and welfare issues due to stress induced during the cold water soaking phase. Similarly, the high pressure washing process can also take several hours and requires direct intensive inputs of labour, energy, and water that are costly to feedlot operators.

Some feedlots elect to wash cattle prior to dispatch to meat processing facilities (Photographs 5 and 6). Washing may be automated or manual, which ultimately effects the volume of water used. Information available on the volume of water used in Australia is limited. Anecdotally, some operations report clean water usage of approximately 1,700 L per head is required for approximately 25 % of outgoing cattle, which equates to about 1.2 L/head/day (Davis & Watts, 2011). Costs of water used for washing vary depending on flow rate, holding periods, proportion of stock requiring washing, and the ability to use recycled water.


Photograph 5 – Cattle being washed at a feedlot – soaking stage


Photograph 6 – Cattle washing at a feedlot – hosing stage

Anecdotal evidence suggests that, after washing, cattle are held in clean pens, which are often roofed and lain with a bedding material such as wood chip (Photograph 7). Ideally, washing occurs 1 - 2 weeks ahead of slaughter to overcome any impacts of pre-slaughter stress on meat quality (Section 4.8.2).

Photograph 7 – Washed cattle held in a woodchip pen

4.5.3 Managing dags during transport

There is some question whether dags form during transport. Anecdotally, there is not enough time during during transport from feedlot to abattoir for dags to form. Furthermore, animals should not be able to lie down during transport, which would prevent establishment of dags. Trucks that contain waste may contribute to dags along the belly, brisket and legs.

4.5.4 Cattle washing at the abattoir

Cattle washing is carried out at meat processing facilities regardless of whether or not the cattle have been washed to remove dags at feedlots prior to dispatch. This is because there are regulatory requirements and accreditation standards for clean animals to be presented for slaughter to avoid contamination and minimise food safety risk. These are discussed further in Section 4.7.

Cattle washing can involve either manual hosing and/or soaking. Cattle subjected to a soaking period are sprayed with water over a longer period, enabling dags to become moistened and easier to remove (Wescombe 1994). Although manual hosing can be an effective method of removing excess dirt/mud and faeces prior to slaughter, it has limited success in cleaning the more inaccessible areas of the animal such as the underside, brisket and the inner-flanks. It has also been demonstrated that hosing for a short duration does not remove dags accumulated on the animal (Wescombe 1994).

Most abattoirs in Australia move cattle in small groups (5-20 head) via a wash pen from the holding areas to the slaughter area. The wash pen has a combination of overhead, wall and floor mounted jet sprays, which attempt to remove any dust, mud, and faeces from the hide of livestock prior to slaughter (Wescombe 1994).

Wescombe (1994) has suggested that effective cleaning chemical solutions could be developed that would adhere to the hides of cattle for a desired period of time and would effectively reduce or prevent the formation of dags on cattle. Many chemical products have been tested for adherence to cattle hides over a period of several months. However, there was no microbiological evaluation of the hides during that period and, as chemical residues are a problem, more research and development in this field is required (Wescombe 1994). The use of chemicals as a mechanism to reduce dags is discussed further in Section 4.6.

4.6 Dag removal

Feedlot operators may implement a number of strategies to mitigate the risk of dags. Most current feedlot sites in Australia are designed and constructed with appropriate drainage and other preventative infrastructure. Furthermore, they implement management measures to minimise the impacts of dags. Some feedlots also implement further preventative action prior to and during dag risk periods. Some of these are discussed below.

4.6.1 Enzymes

Enzymes are proteins that increase the rate of chemical reactions. Slattery et al (2005) investigated the use of enzymes for removing feedlot dags. Dags were found to break down after 8 hours of incubation with enzymes, with cellulase being the most effective enzyme for dag decomposition.

The effectiveness of enzyme solutions is variable, with Cassells & Haritos (2009) identifying a range of enzymes with no impact on dag removal. This is potentially due to the variability in dag consistency and porosity and can hamper trials of potential new enzymes for dag removal. Despite this, new enzyme systems for dag removal have been, and continue to be, investigated. These include enzymes that target the interaction between dags and cattle hair as well as biomass degrading enzymes.

4.6.2 Other chemicals

Chemical products for dag removal can be used during washing or prior to slaughter. Chemical products that have been tested include sodium hydroxide, trisodium phosphate, acidified chlorine, and phosphoric acid (Meat Industry Services, 2006). Cargill Meat Solutions in the USA have adopted a 1.5% sodium hydroxide wash, followed by steam vacuuming in all of their plants. De-hairing chemicals can also be used prior to hide removal.

4.6.3 Mechanical dag removal

A number of mechanical systems have been evaluated for the removal of dags (Table 2). These range in effectiveness, with some still in use in some feedlots, but none that have been widely commercialised.

Table 2. Mechanical dag removal systems.

System	Description	Evaluation
Rockdale Robotic Dag Removal System (RRDRS)	Uses a hydraulic crush and robotic arms which hold rotating perforated drums on each end. These drums rotate along the sides of the animal and dags are pulled into the holes, parting them from the hair.	Technology was ineffective at removing all dags, and the associated capital associated was prohibitive (Rowland, Phillips and Coates, 1999).
Rockdale Dedag Machine	Similar to RRDRS	Handling procedures for this machine are associated with higher than average cortisol levels, which indicates the process causes animal stress (Greenwood, House and Fell, 1998).
Parke Rota Shear	An air driven handpiece which can be used pre- or post-slaughter to shear risk-areas.	An effective method despite uneven hair combing which would affect susceptible hides tanned (Rowland, Phillips and Coates, 1999).
Jarvis de-dagging tool	A tool used post-slaughter to remove large contamination particles.	Not commercialised at present (Rowland, Phillips and Coates, 1999).

4.7 Cattle washing regulations, accreditations, and standards

4.7.1 Industry Animal Welfare Standards

The *Industry Animal Welfare Standards Livestock Processing Establishments: Preparing meat for human consumption 2nd edition* (Edge, 2009) supports existing Australian standards and guidelines relating to the livestock processing industry. These standards aim to assist livestock processors to demonstrate compliance with regulatory standards in the industry. According to Part 5, causing animal stress must be minimised when washing animals by avoiding using high pressure hoses on sensitive areas of the animal and minimising exposure to cold temperatures.

4.7.2 Australian Standards

The *Australian standard for hygienic production and transportation of meat and meat products for human consumption (AS4696:2007)* (Commonwealth of Australia, 2007) replaced several earlier standards and aims to ensure that meat and meat products for human consumption comply with food safety requirements and are wholesome. Under Part 8, reasonable steps must be taken to present animals for inspection in a clean condition; animals that are not clean are not to be passed for slaughter or are to be passed for slaughter subject to conditions to prevent contamination of other animals, carcasses, or carcass parts. Under Part 20, facilities for cleaning animals prior to slaughter need to be provided at processing facilities. The Standards also state that only potable water can be used for the production of meat and meat products, but that animal washing, other than the final wash, can be performed with non-potable water (Standard 21.6 (a) (i)).

4.8 Impacts of dags on cattle performance and productivity

4.8.1 Feedlot impacts

The need for infrastructure and increased time and labour to manage dags at feedlots increases the costs for feedlot operators. In addition to these costs, feedlot profits can be reduced by impacts of dags on cattle performance.

Studies investigating the direct relationship between dags and cattle performance are limited. Dags may directly impact weight gain by causing stress to the animal. This stress may be inflicted simply because animals are unable to rest and lie down (Smith Thomas, 2013). Reduced lying time causes a physiological response, which lowers white blood cell count and increases non-esterified fatty acids and thyroxine levels (Tucker *et al.*, 2007; Webster *et al.*, 2008). Stress also increases the likelihood that animals may become sick (Carroll and Forsberg, 2007) especially when combined with conditions that create an environment for bacterial infections such as foot rot (Smith Thomas, 2013; Halfman, 2017). Poor health can also reduce ADG through supressed appetite.

A number of studies have shown that conditions related to the occurrence of dags can also negatively impact performance. For example, Morrison *et al.* (1970) assessed the impacts of mud, wind, and rain, on beef steer performance and concluded that wind had a negligible impact on performance, but mud and prolonged rain negatively impacted weight gain. Moreover, while mud was reported to seriously reduce animal performance, prolonged rain was shown to have performance impacts that are somewhat independent of the mud effect. The causes for this were not hypothesized by Morrison *et al.*, (1970), but Degen and Young (1993) indicate that the presence of mud and wet hides may increase heat exchange from the animal to the environment and make locomotion more difficult. This means that more energy is expended for the animal's maintenance requirements, and less is available to be used in body mass production. Dijkman and Lawrence (1997) provide further support to the impacts on locomotion, showing that animals walking in mud are slower, and use more energy than when walking on concrete. Mud can also increase health problems such as lameness (Mckeith *et al.*, 2012).

Hahn (1985) conducted an experiment to determine the relative effects of winter weather on beef cattle growth and feed conversion. The results indicate that, in the most extreme cases, wet weather can reduce average gain by 0.01 kg and increase feed requirements by 0.08 kg. This translates to (on average) an extra 6 days required to grow to specification and a 3% increase to feed costs.

4.8.2 Meat processing industry impacts

Increased labour requirement

In addition to the requirement to have additional personnel to assist with washing dag affected cattle prior to slaughter, the presence of dags increases the cost of processing due to increasing labour associated with additional trimmers and reduction of chain speeds. A 1997 report by Van Donkersgoed et al., estimated this reduction at 10-12%.

Carcass quality

The major impact of dags on carcass quality is thought to be caused from exposing animals to stress shortly before slaughter. Consumers prefer meat to be a bright red colour because it is perceived to be of higher quality than dark coloured meat. The bright red colour of meat is caused by generation of lactic acid in the muscle during post-mortem glycolysis. Stress (from activities such as washing or prolonged exposure to conditions post-washing) causes a cascade reaction in the body, which results in the depletion of glycogen, the energy substrate for the glycolysis process (Muchenje *et al.*, 2009) (Apple *et al.*, 1995) (Ferguson and Warner, 2008). The reduced levels of lactic acid in the resulting beef causes 'dark cutting'.

According to the Australian Meat Processor Corporation (AMPC), who conducted a study investigating the causes and contributing factors to dark cutting (Ponnampalam *et al.*, 2016), 10% of beef in Australia is impacted by dark cutting, equating to a potential $36 million loss to the industry.

Preston *et al.*, (2016) investigated the impacts of pre-slaughter washing on dark cutting and found that the overall incidence of dark cutting was slightly higher than the AMPC report, at 13%. However, this was higher in pasture finished (23.8%) than grain finished (2.1%) cattle. They concluded that each wash in lairage increased the dark cutting incidence by 2%, but that this was not related to the duration of the washing, nor the number and duration of high-pressure hose washes and belly washes. They further postulate that washing may cause changes in behaviour, such as increased mounting, that can lead to dark cutting.

Contamination

In addition to impacts of dark cutting, the meat processing industry can be impacted by dags due to microbial contamination. While primarily a concern to human health, contamination can also reduce product shelf life (Pipek *et al.*, 2005). Bell (1997) found high levels of contamination on parts of carcasses where opening cuts were made, or parts of the hide contacted during hide removal. Several other reports, such as McEvoy *et al.*, (2000) and Arthur *et al.*, (2008, 2010) conclude that there is a direct relationship between the degree of hide contamination and risk of carcass contamination. Water temperatures in pre-slaughter washing should be controlled, with Bell (1997) suggesting that cold temperature pre-slaughter washing is ineffective in removing microbial contamination and aided in spreading contaminants.

Microbial contamination is dependent on slaughter conditions and the requirements for reducing contamination risks at the abattoir are outlined in AS4696:2007. Australian processors wash carcasses as a preventative measure to reduce microbial loading, using procedures such as steaming or applying a lactic acid spray. Pipek et. al (2004) found that a combination of steam treatment followed by a 2% lactic acid spray was effective in reducing microflora. Factors affecting the success of microbial load reduction include infrastructure and delivery, such as water pressure (Harris & Savell, 2009).

Other actions to combat contamination within processing facilities include regular monitoring and reporting of contamination. This allows practices to be reviewed and altered (for example, by increasing abattoir staff) as levels of contaminants increase.

4.9 Hide quality impacts

Dags can cause reductions to hide quality because the hide may be damaged while trying to remove remaining flesh and selvedge from the hide during the tanning process.

4.10 Existing economic data on cost of dags

4.10.1 Antecedents

There is little data on the cost of feedlot dags to the Australian beef industry. To our knowledge no previous study has approached this topic in its entirety. This may be due to the industry not perceiving the issue as critical. Two main reasons may be behind this behaviour. Firstly, feedlot operators may perceive a low benefit / cost ratio from addressing this issue. As such, faced with the prospect of small uncertain marginal gains, the operators may be inclined to focus on other areas of pen management. Secondly, the current alternatives for dag management that involve bedding or shedding both entail relatively high capital outlays that may deter operators from undertaking them if they discount the present at a higher rate than the future (i.e. they show present-bias). Present-bias has been shown to be prevalent in many industries (Benhabib, Bisin, & Schotter, 2010). We understand that this may be due to operators underestimating both the implicit and explicit costs of dag management and potentially attributing dag costs to other operations in the pen. We expect this work can help shed light on these issues and potentially shift this observed behaviour. If the removal of dags becomes compulsory due to market requirements the matter becomes part of the cost of doing business.

4.10.2 Implicit costs

Dags can impact live-weight performance at the feedlot, as more energy is expended for the animal's maintenance requirements, and less is available to be used in body mass production (refer to Section 4.8.1).

Dag removal is a stress factor for cattle before processing which can increase the risk of obtaining low quality meat due to "dark-cutting" (refer to Section 4.8.2). Dark cutters may suffer price discounts ranging from 5 per cent up to 20 per cent of the carcass weight (Gazzola, 2001). Preston et al (2016) found dark cutting impacts 2.3% of grain finished cattle (2.3%) and that washing increased the incidence of dark cutting by 2%.

In addition, there is a potential to compromise food safety than can lead to bacterial contamination (e.g. *E Coli* or *Salmonella*). Indeed, a high prevalence of dags increases the risk of faecal contamination of the carcass especially in the brisket and shank areas where the cattle are dressed. Hence, processors must incur higher costs (both direct and through performance losses) to deal with dags. While robust data is not available, anecdotal evidence points to labour costs of $1,900 per day (in constant 2015 dollars) and a water usage of around 40 kilolitres per day to clean approximately 500 cattle (Wescombe, 1994). Finally, damaged daggy hides may be unsuitable for high quality leather goods, imposing additional costs to the tanning industries as a consequence of the reduction of locally sourced adequate raw material.

4.10.3 Explicit costs

In local feedlots, dag removal via washing can consume a material amount of intensive resources. There are also significant opportunity costs associated with dag management, as inputs deployed to this task are prevented from undertaking other equally important duties in the pen. The bulk of this work will be aimed at quantifying these explicit costs and estimating the implicit costs of dags to the whole of industry.

Table 3 presents a schematic of both the potential explicit (direct) and implicit dag management costs that may arise in the different stages of the supply chain.

Table 3. Potential sources of the costs of managing dags

Cost	**Unit of measure**
Feedlot costs (washing)	
Labour	Hours per head
Water supply	Litres per head per day
Effluent treatment CAPEX	Investment in $
Effluent treatment OPEX labour	$ per cubic metre
Effluent treatment OPEX utilities	$ per cubic metre
Power supply	$ per MWh
Power consumed	MWh
Maintenance CAPEX	Investment in $
Maintenance OPEX wash labour	Hours per square metre
Maintenance OPEX wash utilities	Hours per square metre
Maintenance OPEX drain labour	Hours linear metre
Maintenance OPEX drain utilities	Hours linear metre
Cattle movement cost	$ per hour
OH & S	$ per hour
Feedlot costs (post-washing)	
Duration on bedding post wash	Days post wash
Duration bedding pens required/year	Months/weeks
Bedding cost	$per tonne (delivered)
Truck loading	Hours
Transfer bedding to pen	Hours
Bedding distribution	Hours
Loss of production pen area	Square metres (or cattle number)
Loss of ADG rate (post washing) (this may increase)	Kilograms per day
Pen cleaning time (diff from normal)	Hours
Pen maintenance cost (diff from normal)	$per animal
Cattle movement cost	$per hour
Stocking density	SCU per pen

Disposal cost (diff from normal)	$per cubic metre
Transport	
Transport cost	$per kilometre per kilogram
Truck washing	$per minute
Truck washing	Additional time
Abattoir costs (washing)	
Labour	Hours per head and staff required
Dag scores	Score
Compliance	Compliance costs
Water supply	Litres per head per day
Effluent treatment CAPEX	Investment in $
Effluent treatment OPEX labour	$per cubic metre
Effluent treatment OPEX utilities	$per cubic metre
Power supply	$per MWh
Power consumed	MWh
Maintenance CAPEX	Investment in $
Maintenance OPEX wash labour	Hours per square metre
Maintenance OPEX wash utilities	Hours per square metre
Maintenance OPEX drain labour	Hours per linear metre
Maintenance OPEX drain utilities	Hours per linear metre
Charge out costs of washing	$per SCU (if charge washing to the feedlot)
OH & S	$per hour
Abattoir (post-washing)	
Dark cutting penalty	$per cwt
Dark cutting due to dags	$per cwt
Dark cutting frequency	% of animals processed
Bruising trim weight	Kilograms trimmed per bruise
Bruising (number)	Average number bruises for each site
Bruising trim cost	$per kg

Carcass contamination	$per cwt
Carcass contamination	% of animals processed
Dressing percentage	%
MSA Index	Index
LMY percentage	%
Tanneries	
Grading loss (downgrading)	$per kilogram
Grading loss (rejection)	$per kilogram
Fleshing costs (if required)	$per kilogram

5 Results–Data Collection

5.1 Participant selection

Six supply chains were selected for evaluation. They were selected to represent a range of climatic conditions and operational practices. We targeted operators located in regions likely to be impacted by dags on a regular or semi-regular basis.

Participants are not identified in this report, but the feedlot-abattoir supply chains represented are as follows:

- Supply Chain A –Queensland
- Supply Chain B –NSW
- Supply Chain C –NSW
- Supply Chain D –NSW
- Supply Chain E –Victoria*
- Supply Chain F –South Australia*

*NB: Cost estimates for Supply Chain E and F are not presented in the section 6 due to insufficient data provided by the businesses interviewed.

5.2 Dataset requirements

5.2.1 Feedlots

Qualitative and quantitative data was collected at feedlots. This included:

- Standard washing procedure – time of year cattle are washed and duration of washing times
- The proportion and severity of cattle affected by dags
- Length of time between washing and transport to processors
- Labour:
  - Cattle movements (to and from washing facilities)
  - Wash facility handling
  - Washing

    - Wash facility maintenance
- Post-washing procedure and related resources
- Effectiveness of washing procedures
- Impact of washing on dark cutting and bruising
- Capital costs
- Water usage
- Power consumption
- Maintenance to related facilities
- Bedding in post-wash facilities

An example of the data collection sheets used to obtain feedlot data is provided in Table 4.

Table 4. Feedlot data collection sheet

Parameter	**Unit**
Prevalence of dags pre-wash	percentage per affected period
Dag score (average)	score
Dag score (median)	Score
Capital	$
Water Usage	megalitre/washing day
Power Consumption	
Maintenance	$per washing period
Washing at feedlot	
(average) length of process	hours
Post-wash holding (if in effect)	
Duration	days
Bedding	$

In some instances, feedlots did not record resources committed to cattle washing and this information was obtained anecdotally or extrapolated. For example, pump meter measurements were used to obtain water use where water usage records were unavailable.

Data on performance and health impacts caused by dags has been omitted from this report because the performance impacts of dags alone (and not the conditions pertaining to them, such as mud and shivering) were insubstantial.

5.2.2 Processing facilities

Data collected at processors included:

- Standard washing procedure – time of year cattle are washed and duration of washing;
- Labour required to wash cattle and associated handling and maintenance;
- Effectiveness of washing procedures;
- Cost of microbial contamination and product recall;
- Volume of additional trim product – processors cannot record volume of trimmed product due to speed and multifaceted nature of carcass contamination source;
- Risk management protocol – other strategic steps taken to reduce contamination;

- Impact of severe dags on processing efficiency;
- Other observations – i.e. vet subjectivity;
- Dag score sheets - the proportion of cattle affected by dags and the severity of dags;
- Capital costs;
- Water usage;
- Power consumption;
- Maintenance to related facilities; and
- Rates of dark cutting, bruising, obtained by relevant operator

An example of the data collection sheets used to obtain processing facility data is given in Table 5.

Table 5. Processing facility data collection sheet

Parameter	**Unit**
Washing at works	
(average) length of process	hours
Vet subjectivity	Y/N
Kill and trim	
Dark cutting prevalence	% of dark cutters
Dark cutting grade	(average) AUS-MEAT colour
Bruising	(average) AUS-MEAT score
Carcass contamination	(average) kg

In a number of circumstances, water volumes were not accurately recorded at processors. Estimates based on operational experience and total water usage volumes were provided by operators in these cases.

5.2.3 Hide processor and transport industry

An example of the data collection sheets used to obtain hide processing and cattle transport industry data is given in Table 6.

Table 6. Hide processor and transport industry data collection sheet

Parameter	**Unit**
Transport	
Impact of dags	Y/N
Additional time cleaning truck	Hours/truck
Other – e.g. additional maintenance	
Hides	
Hide grading loss	(average) grade
Number of hides processed	(average) per annum
Weight of hide	(average) kg

Weight-based transport costs in and out of the facility	Y/N; $/kg
Proportion on grain-fed hides, compared to grass-fed	Percentage
Proportion of hides salted	Percentage
Process associated with non-salted hide processing	Anecdotal
Proportion of hides non-salted having dags	Percentage
Operational costs for non-salted hides	
Operational costs associated with removing dags from non-salted hides i.e. labour, infrastructure, deductions	
Other risks – i.e. biosecurity	

5.3 Interviews

The raw data collected from site visits is summarised in Appendix C. It is presented as a matrix that allows direct comparison between operations. The data collection process revealed a series of qualitative findings which are included in Appendix D. Data obtained through phone and in person interviews and from follow up correspondence are presented in the sections below.

5.3.1 Supply Chain A (Queensland)

Feedlot A and Processor A are subsets of a vertically integrated supply chain. This relationship means that there is no direct charge back to feedlots for daggy cattle.

5.3.1.1 Feedlot A

Feedlot A intermittently experiences dags. Relative to other winter rainfall dominant feedlots, rainfall is summer dominant. Dags are severe for a shorter period of time than is reported in more southern feedlots.

Feedlot A experiences dags from July through to September. Between 625 and 1,056 head of cattle are washed weekly. The washing process involves exposing cattle to a low-pressure soak immediately prior to transport. No high-pressure washing is included.

5.3.1.2 Abattoir A

Abattoir A processes cattle from a number of national operations predominantly located in Queensland. Feedlot A is one of their suppliers, The daggy period at Abattoir A is defined as the period from June to August. According to Abattoir A, approximately 4% of cattle are impacted by dags during this time.

5.3.2 Supply Chain B (New South Wales)

5.3.2.1 Feedlot B

Feedlot B is located in New South Wales, and washed approximately 10,560 cattle in 2017. According to Feedlot B, all cattle are impacted during the dag risk period. However, only cattle that are sent to processors with high charge back costs for washing are washed at the feedlot. This equates to 40% of feedlot cattle. . Feedlot washing takes place approximately 5 days prior to dispatch to the processing plant. The remaining 60% of cattle are sent unwashed to a processing facility that does pass the washing cost back to the feedlot

5.3.2.2 Abattoir B

Abattoir B operators indicate that their daggy season is between June and August, depending on local rainfall. It was estimated that 100% of cattle processed displayed average dag scores of 1-2 in 2017. In 2016, which was a wetter year, 100% of cattle processed displayed average dag scores of 3-5. According to Abattoir B, dags intermittently occur outside the dag period. However, because cattle hair is generally shorter during these times of the year, dags are easier to remove.

5.3.3 Supply Chain C (New South Wales)

5.3.3.1 Feedlot C

The dag risk period at Feedlot C is generally from April to September. According to Feedlot C, 100% of cattle are impacted by dags during this period.

Dags also continue to impact animals during the summer period but are less severe due to less muddy conditions and shorter hair type.

Feedlot C has implemented a number of strategies for reducing the impacts of dags at the feedlot.

5.3.3.2 Abattoir C

At abattoir C, approximately 50% of cattle are dag affected to some degree during the dag risk period. The abattoir utilises mechanical dag removal.

5.3.4 Supply Chain D (New South Wales)

5.3.4.1 Feedlot D

Feedlot D has not washed cattle for the past two years. Washing is restricted by water and resource availability. All cattle are washed at the processing facility. Costs are not passed back to the feedlot.

Feedlot D turns off approximately 1,000 head each week, which are all severely affected throughout the dag risk period (May to September). According to Feedlot D, there is little or no occurrence of dags in summer.

5.3.4.2 Abattoir D

Abattoir D processes both grain and grass-fed cattle and they are sourced from a range of suppliers.

5.3.5 Supply Chain E (Victoria)

5.3.5.1 Feedlot E

Feedlot E has operable washing infrastructure. However, the operator believes that utilising the infrastructure would be poor practice due to animal welfare hazards, and does not wash cattle.

5.3.5.2 Abattoir E

Abattoir E's dag risk period is from May to September and dags impact both grain-finished and grass-fed cattle to varying degrees.

5.3.6 Supply Chain F (South Australia)

5.3.6.1 Feedlot F

Feedlot F's dag risk period is between May and September. This site currently does not have the infrastructure required to wash cattle for dag removal.

The operation uses a combination of straw and sand to reduce animal injuries and mortalities, which has substantially improved weight gain per animal. It is believed that application of straw earlier in the dag period may reduce dag load.

5.3.6.2 Abattoir F

Abattoir F observes a dag period from June to September. It is estimated that 50% of Abattoir F's cattle have a dag score 5 during the dag period.

6 Results – Economic Analysis

6.1 Collection of data for this engagement

As expected, the collection of data on the costs of dag management has proven to be challenging. The project team has consulted with a large array of industry representatives and some key themes have emerged with respect to the impact of dags:

- Data on the cost of dag management is scarce and most contributors did not have processes in place to capture this data that would allow for time-based analyses;
- A significantly large proportion of the data is anecdotal and, as such, better suited for different methods such as overt observational research;
- There is a large variability in the prevalence of dags arising from climatic conditions, pen management, soil composition, work practices, etc.;
- Contributors considered dags to be an important driver of cost, however on average they understood that its management is less critical than that of other operations; and
- As the last point in the chain before the kill, processors are more likely to bear the costs of dag management. In fact, in some vertically integrated businesses, feedlots do not perform any washing.

There are two noticeable characteristics of dags that must be taken into consideration as they provide a contextual basis for interpreting the estimations of cost that follow:

- Dag management is an unavoidable task of beef production and the potential avoided costs by implementing adequate dag management largely exceed its direct costs; and

- Dags are a salient feature of hides. Research (Tobler & Weber, 2013) shows that salient events tend to be overweighted, so industry players may assign dag management a larger cost than what it actually has.

The interaction of these characteristics creates a situation in which businesses spend less effort in documenting and understanding the process but tend to overestimate its impact on long-term profitability (i.e. when seasonal variations are factored out). The scarce availability and reliability of data created the need for establishing a substantive number of assumptions to undertake quantitative analysis on costs. In this sense, the quantitative factors have to be understood in the context of the qualitative factors that accompany the analysis.

6.2 Cost of dags to the Australian Beef Industry

6.2.1 Approach

Despite the strong collection effort, data on the impact of dags is scarce and shows huge variability between contributors, across time and within business and market structures. The small size and the gaps in the data do not allow for statistical inference (neither parametric nor non-parametric).

The approach followed for this estimate was to calculate the attributable average cost of dag management per head for those businesses that provided us with data with a sufficient robustness and completeness that would allow replication. It must be noted that some of this data is not based on records but on visual observation and interviews. Data was grouped into seven major cost categories:

- Labour;
- Water;
- Effluent disposal;
- Energy;
- Infrastructure (CAPEX);
- Infrastructure (OPEX); and
- End product downgrades.

For those categories where data was missing, the average cost of the category was inputted. Due to lack of information, it was not possible to estimate the cost of energy for processors nor the cost of effluent disposal for feedlots.

6.2.2 Estimates and variability

The table below shows the point estimates by cost category for both feedlots and processors. Costs are shown for four of the six supply chains visited because insufficient data was sourced from two to provide a sufficiently robust estimate.

Table 7. Estimate of the cost of dag management by cost category by business

	Processors	**Feedlots**

	A	B	C	D	Mean	A	B	C	D	Mean
Labour	$0.57	$0.68	$0.56	$0.42	$0.56	$0.22	$0.44	$1.44	$0.70	$0.70
Water	$2.83	$2.83	$3.85	$1.82	$2.83	$2.79	$0.31	$1.60	$1.57	$1.57
Effluent disposal	$1.67	$1.67	$1.67	$1.67	$1.67	NA	NA	NA	NA	
Energy	NA	NA	NA	NA		$0.57	$0.57	$0.57	$0.57	$0.57
Infrastructure (CAPEX)	$0.33	$0.50	$0.16	$0.33	$0.33	$0.33	$0.55	$2.00	$0.83	$0.93
Infrastructure (OPEX)	$0.29	$0.30	$0.28	$0.29	$0.29	$0.73	$0.32	$0.06	$0.18	$0.32
End product downgrades	$0.50	$0.50	$0.50	$0.50	$0.50	$0.49	$0.08	$0.29	$0.29	$0.29
Total	**$6.19**	**$6.48**	**$7.01**	**$5.03**	**$6.18**	**$5.13**	**$2.28**	**$5.96**	**$4.14**	**$4.38**

Note: For those categories were data was missing, the average cost of the category was imputed.
Source: Project Team

This suggests that on average the cost of dag management in the 2016 season would have amounted to approximately $10.56 per head. This cost is comprised of a $6.18 cost borne by processors and a $4.38 expense endured by the feedlots. The figures also suggest that the $1.50 to $5 per head dag cleaning charge backs that processors are currently imposing on suppliers are, on average, insufficient to cover actual costs.

To assess the dispersion in the data, Fig. 8 presents a scatterplot of the point estimates by category and by contributor. The variability of the data is very large, and for most categories the size of the sample does not allow the calculation of formal dispersion metrics (such as the standard deviation or variance).

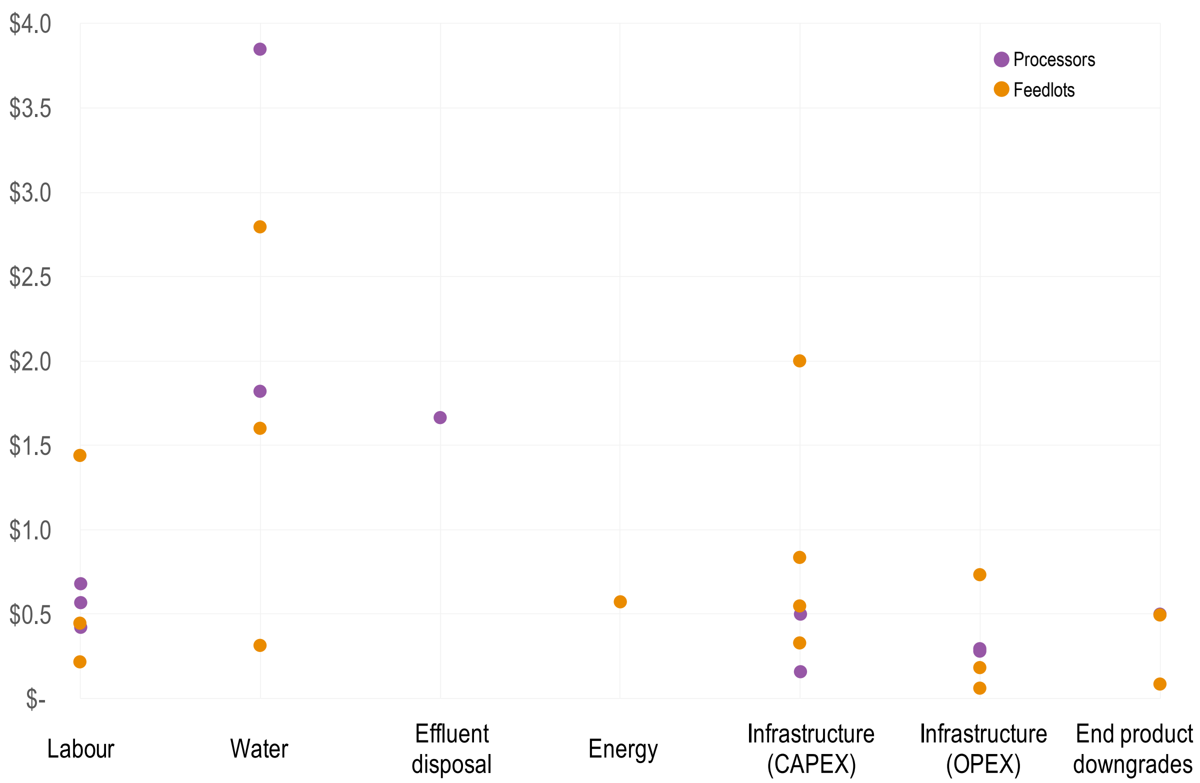

Fig. 8 - Point estimates by cost category and by contributor

6.2.3 Grain-fed cattle turnoff

Data from the Australian Lot Feeders' Association (ALFA) shows that cattle turnoff from Australian feedlots amounted to approximately 2.6 million head in 2016 (see Table 8 for details).

Table 8. Grain-fed cattle turnoff in 2016

State	Quarter 1	Quarter 2	Quarter 3	Quarter 4	2016 total
New South Wales	206,195	231,453	226,828	155,492	**819,968**
Victoria	43,549	58,383	40,351	31,980	**174,263**
Queensland	329,172	350,577	367,528	408,315	**1,455,592**
South Australia	19,845	28,031	8,118	11,411	**67,405**
Western Australia	32,965	44,060	27,279	11,108	**115,412**
Total	**631,726**	**712,504**	**670,104**	**618,306**	**2,632,640**

6.2.4 Total cost of dags and sensitivity testing

Contributor interviews have surfaced an average variability of dag presence of approximately 33 per cent to 50 per cent and have stated that 2016 was a year of low dag presence. At face value, this would suggest the cost of dag management per head ranges from $10.55 to $16.08 per head depending on the prevalence of dags.

Table 9. Cost of dag management in different years ($per head)

	Cost to processors	Cost to feedlots	Total cost to industry
High dag year	$9.52	$6.56	$16.08
Average dag year	$7.93	$5.47	$13.40
Low dag year	$6.18	$4.38	$10.56

Taking this into consideration the cost of dags to the Australian beef industry would sit between $4 million and $10 million per annum (Fig 9). This is equivalent to between 0.02 per cent and 0.05 per cent of the Australian beef and cattle industry value of production. In turn, this is equivalent to between 0.16 per cent and 0.39 per cent of the feedlot industry's value of production. These figures are based on the assumption dags occur 5 months per year and that not all of the cattle slaughtered are affected by dags during that time. This equates to between 15 and 23 per cent of the 2.6 million feedlot cattle slaughtered incurring direct dag management costs.

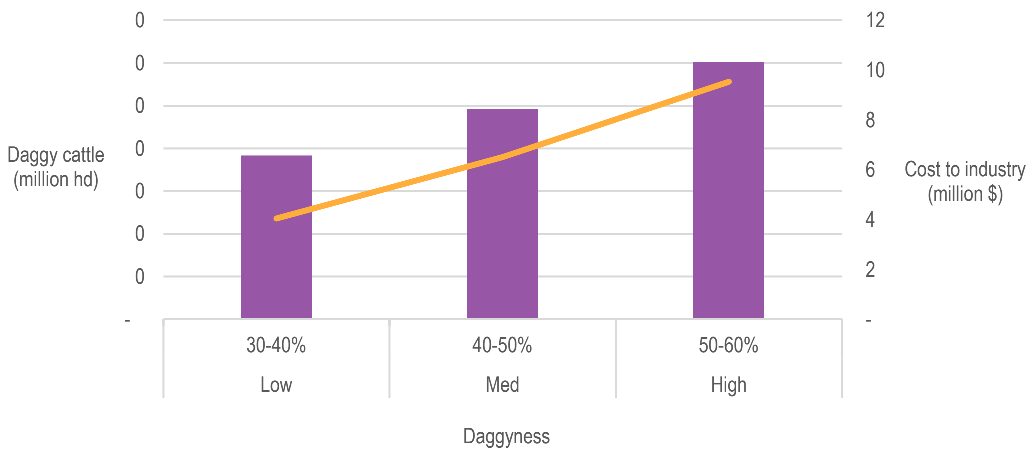

Fig. 9 - Cost of dags to industry in different years

The breakdown of the impact of each cost item is presented in Table 10 below.

Table 10. Estimates of cost to the Australian beef industry by cost category (in $ 000's)

Cost category	Low scenario	High scenario
Labour	$0.474	$1.117
Water	$1.661	$3.914
Effluent disposal	$0.629	$1.482
Energy	$0.216	$0.509
Infrastructure (CAPEX)	$0.539	$1.270
Infrastructure (OPEX)	$0.231	$0.543
End product downgrades	$0.297	$0.699
Total	$4.045	$9.534

6.2.5 Limitations

The key limitations of this estimate are the absence and high variability of data and the strong reliance on anecdotal evidence. Of particular concern are the following:

- No *'hard'* data on the cost to the transport sector and to the tannery sector, although interviews would suggest that they are close to negligible;
- No valid estimate on the cost of energy for processors and on the cost of effluent disposal for feedlots;
- A limited number of data points based on very few records, which hampers generalisability; and
- The inability to establish a fact-based regional or seasonal pattern for costs aside from qualitative, non-observational commentary.

7 Discussion

The objectives of this project were to evaluate and quantify the cost of dags to the Australian beef industry and produce a high-level cost-benefit analysis (CBA) on two proposed interventions for dag management.

7.1 Cost of dags to the Australian Beef Industry

Cattle dags are a part of beef production in Australia and overseas that can be mitigated but not completely avoided at all times and in all circumstances. Dags create a number of challenges for feedlots and other parts of the beef supply chain:

- Concerns regarding the welfare and health of animals;
- Reduced performance and meat quality outcomes;
- Increased costs associated with the cleaning and processing of daggy cattle; and
- The potential to compromise food safety through carcass contamination.

7.1.1 Framing costs and collecting data

The first step of this project was to break these challenges down across the feedlot/processor/tannery parts of the beef supply chain to where dags occur and are managed so that sufficient primary data could be collected to estimate the cost of dags to the industry.

Australian and overseas literature highlight the cause of and ability to (cost effectively) manage dags is determined by:

- Location – particularly seasonal conditions (rainfall) and climate (sustained wetness and low evaporation) combine to increase the likelihood of dag occurrence;
- Site layout – exposure, slope, pen substrate and bedding and other characteristics all influence the degree to which dags in cattle are experienced;
- Management – the location-site layout characteristics combine with individual business preferences and circumstances; other constraints (such was water availability/disposal) to create a range of management options (that can often be limited);
- Supply chain relationships – willingness and need to accept cattle with dags and charge for cleaning;
- Saliency – when dags are present they are a bigger/immediate problem and people may believe dags rather than other constraints are limiting performance.

The literature also noted that dags are not always present in many businesses and dag management utilises systems, labour and resources from across the business that are used for other purposes. This means dag costs are not clearly accounted for beyond specific dag infrastructure (such as dag washing facilities) making dag management costs hard to estimate. This is true for all four challenges and the animal welfare/health, and reduced performance/meat quality in particular.

The project used the literature and Premise's industry knowledge to develop a data collection form that condensed and simplified these considerations. The form was tested before use. Before each visit the form was sent to the participant and the team worked with them and used their own observations to complete the form. Additional information was sought and provided after the interviews.

The six supply chains visited where deliberately chosen to increase the probability of primary data being available. The businesses within each supply chain were vertically integrated and were known to have experienced dags in the past. Unfortunately, the visits were conducted in the dry winter of 2017 which meant that dags were not as prevalent as expected.

The result of the data collection confirmed one of the project's hypotheses – businesses in the supply chain have limited primary data on the cost of dags and much of the available information is anecdotal. It is unlikely improving the data collection process (a better form) or timing (a wetter and daggier year) would have significantly increased the volume of data collected – the absence of data is the key constraint.

7.1.2 Key findings from data collection

Nonetheless the visits generated significant amounts of data and insights for the project and future dag research and management. The key findings are:

- Dags are a concern and cost on businesses and therefore impact the industry;
- The impact of dags is not uniform and varies year by year and business by business;
- There is considerable innovation occurring to develop better dag management tools and processes;
- Effective pen management makes a significant difference to dags, but dags are unlikely to provide sufficient incentive to completely redesign pens given the significant cost;

- Food safety is managed by all abattoirs visited through washing cattle and/or slaughtering techniques;
- Some abattoirs charge to wash daggy cattle;
- There is limited data, given the embedded nature of dag management, so any future research on the cost should be based on detailed observation and data collection;
- The lack of available data could be improved by providing feedlots and processors with the tools (such as data collection sheets) to ensure that future assessments can conduct more conclusive analyses with less variability.

7.1.3 The cost of dags

The average cost of dags in 2016 for the supply chains visited in 2017 is approximately $10.56 per head. This figure is comprised of a $6.18 cost borne by processors and a $4.38 expense endured by the feedlots. There is a high degree of variability for both, with costs ranging from $5.20 to $7.35 for processors and $4.14 to $5.13 for feedlots.

The cost of dags to industry would stand between $10.56 and $16.08 per head. This is equivalent to between approximately $4 million and $10 million per year depending on the prevalence of dags. There are several data limitations and assumptions needed to arrive at these estimates. These are that the estimated time when dags are prevalent (5 months of the year), the proportion of cattle requiring dag management (35-55%) and the lower and upper costs ($10.56-16.08) can be uniformly applied across the number of feedlot cattle slaughtered annually to provide the estimated range. As expected, strong uncertainty and present bias are playing a role in the extent to which operators are recording costs associated to dag management.

7.2 The benefit of dag interventions

The second project objective was to develop a high-level cost benefit analysis for two potential interventions to improve dag management. Information on the interventions was not available. While this meant the objective was not fully addressed there are a number of findings which inform future dag management and R&D on potential interventions.

Firstly, the estimated costs suggest that over the long-run the weight of dags on the cost structure of the industry is presumably less than proportional to what anecdotal evidence (in some particular years) suggests. This strengthens the argument that saliency bias may be playing a role in industry perception. This should not be interpreted that the issue is not important or cannot be managed more effectively. However, when undertaking analysis on future technologies to address dags more cost effectively, MLA should take into account that industry perceptions may not necessarily correspond exactly with balance sheet impacts.

In terms of any interventions that reduce the impact of dags the costs estimated represent a threshold at which feed lotters and processors will commercially assess whether to adopt the associated technologies and practices or not. This in turn provides a signal to those developing the interventions on pricing. A particular intervention’s economic threshold will be less than the estimates, unless it replaces all the costs currently incurred.

8 Conclusions/Recommendations

The project found that dags do incur a measurable cost on industry and that the cost is borne across the supply chain, especially by processors and feedlots. The cost is not borne equally with costs varying considerably between businesses depending on their location, operation, supply chain relationships and season.

Based on the data available the estimated cost is approximately $10.56 to $16.08 per head which equates to between $4 million and $10 million per year for the industry depending on the prevalence of dags. The cost is based on direct costs.

The cost estimate provides a threshold to guide additional investment in dag management – by commercial developers of treatments, research organisations such as MLA and the feedlots and processors involved in the supply chain.

The cost estimate has a low level of reliability. This is driven by a number of factors:

- The prevalence of dags varies year on year due to climate;
- Dag management is linked to other business decisions – so while dags may be a trigger (salience bias) it may not be sufficient in its own right to incentivise businesses to change;
- The estimate is based on limited data.

8.1 Recommendations

Based on these conclusions there are two recommendations arising from this project:

- Better cost data will require observational research; and
- Future research should focus on integrated solutions rather than intervention bolt-ons.

8.1.1 Recommendation 1: Better cost data will require observation research

The key finding of this project is that the data required to develop a reliable estimate of costs is not readily available. While including animal performance costs and the opportunity cost of diverting existing resources to dag management could increase the cost estimate there is much to be gained from developing better estimates for the data this project sought since the data is direct and tangible.

The best way to achieve this is through observation research on dag management in a limited number of businesses. This would require time and motion studies to accurately record when dags occur, how they are managed (and linked to other decisions and actions) and what resources are required.

Given such studies are expensive to establish and operate there is potential to integrate other research objectives using a monitor feedlot/abattoir style of approach.

Feedlot and processors could record basic business and performance related information on a data collection sheet to monitor the costs of dag management. Information that would be useful to record includes:

- Labour required to wash cattle (hr per pen or per head)
    - Additional time required to wash daggy cattle (hr per pen or per head)
- Water usage to wash cattle (Ml per pen or per head)
- Energy required to wash cattle (MWh per pen or per head)
- Capacity of washing facilities (head per pen)

8.1.2 Recommendation 2: Focus on integrated solutions

A specific intervention focused only on dag management will only succeed if it is affordable, observably effective and readily implementable. At the same time the study found that dag management is linked to and can be constrained by other parts of the business - pen management and waste disposal for example. These are improvements that have much greater benefits than dag management alone, but are also much more complicated and expensive solutions that are only occasionally implemented.

This suggests more effort is required to scope dag management as an integrated solution (Recommendation 1) and then to tactically communicate the associated improvements. For example, the dairy industry has developed dairy effluent design standards whose extension is targeted to farmers intending to renew their milking sheds or are facing market/social/regulatory pressure to do so.

9 Key Messages

- The project found dags do incur a measurable cost on industry and that the cost is borne across the supply chain, especially by processors and feedlots. The cost is not borne equally with costs varying considerably between businesses depending on their location, operation, supply chain relationships and season.
- Based on the data available the estimated cost of dags on the feedlot industry is approximately $10.56 to $16.08 per head which equates to between $4 million and $10 million per year for the industry depending on the prevalence of dags. The cost is based on direct costs.
- This cost of dags on the feedlot industry is equivalent to between 0.02 and 0.05 % of the Australian beef and cattle industry value of production. This is equivalent to between 0.16 and 0.39% of the feedlot industry's value of production.
- The cost estimate has a low level of reliability. This is driven by a number of factors:
    - The prevalence of dags varies year on year due to climate;
    - Dag management is linked to other business decisions – so while dags may be a trigger (salience bias) it may not be sufficient in its own right to incentivise businesses to change;
    - The estimate is based on limited data.
- The cost of dag management in the 2016 season is comprised of $6.34 and $4.38 cost borne by processors and feedlots respectively. The higher cost borne by processors suggests that the charge backs that processors are currently imposing on suppliers is, on average, insufficient.
- Key findings from the data collection:
    - Dags are a concern and cost on businesses and therefore impact the industry;
    - The impact of dags is not uniform and varies year by year and business by business;
    - There is considerable innovation occurring to develop better dag management tools and processes by individual companies;
    - Effective pen management makes a significant difference to dags, but dags are unlikely to provide sufficient incentive to completely redesign pens given the significant cost;
    - Food safety is managed by all abattoirs visited through washing cattle and/or slaughtering techniques;
    - Some abattoirs charge to wash daggy cattle;
    - There is limited data, given the embedded nature of dag management, so any future research on the cost should be based on detailed observation and data collection;
    - The lack of available data could be improved by providing feedlots and processors with the tools (such as data collection sheets) to ensure that future assessments can conduct more conclusive analyses with less variability.
- The key recommendations of the project are that:
    - Developing more reliable estimates on the costs of dags will require observational research. Feedlots and processors are best equipped to collect this data, but should be informed of the data to be collected to improve the reliability of extrapolating costs across the whole industry
    - Dag management improvements need to be integrated with other improvements to provide sufficient incentive to be implemented.
- The cost estimate provides a threshold to guide additional investment in dag management – by commercial developers of treatments, research organisations such as MLA and the feedlots and processors involved in the supply chain.

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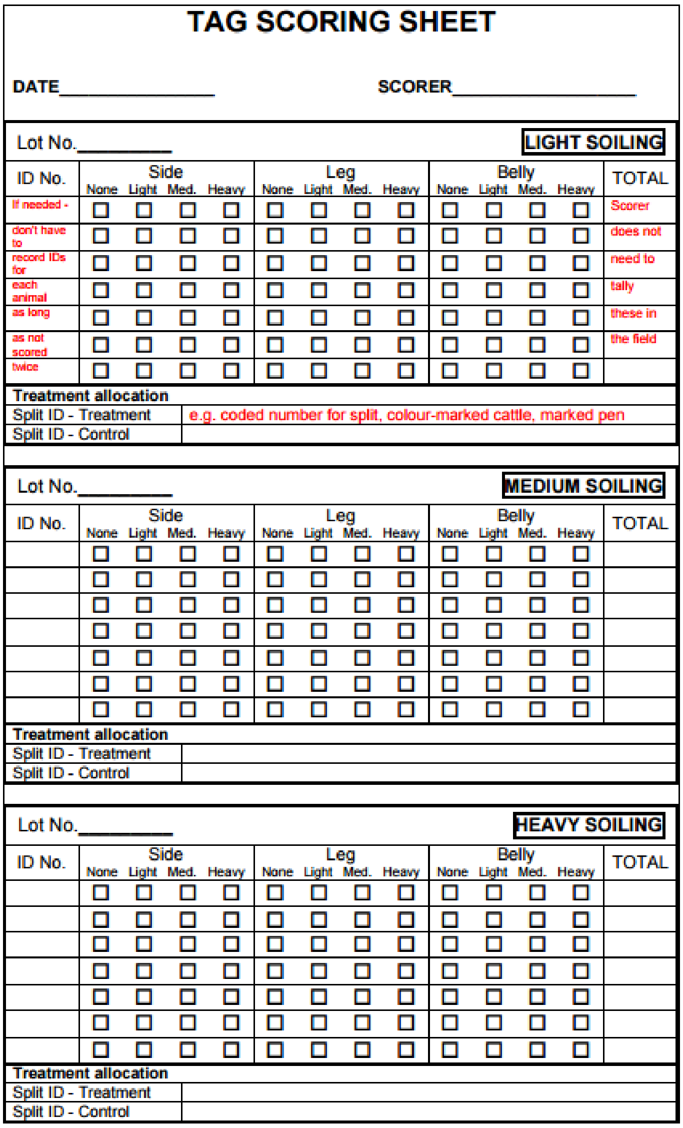
11 Appendix A – Mud Score Sheet

Mud Score	Description	Image
1	no dag, clean hide	
2	small lumps of manure attached to the hide in limited areas of the legs and underbelly	
3	small and large lumps of manure attached to the hide covering larger areas of the legs, side and underbelly	
4	small and large lumps of manure attached to the hide in even larger areas along the hind quarter, stomach and front shoulder	
5	lumps of manure attached to the hide continuously on the underbelly and side of the animal from brisket to rear quarter	



TAG SCORING SHEET

DATE_______________ SCORER_________________

Lot No.__________ **LIGHT SOILING**

ID No.	Side None	Side Light	Side Med.	Side Heavy	Leg None	Leg Light	Leg Med.	Leg Heavy	Belly None	Belly Light	Belly Med.	Belly Heavy	TOTAL
If needed -	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Scorer
don't have to	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	does not
record IDs for	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	need to
each animal	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	tally
as long	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	these in
as not scored	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	the field
twice	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Treatment allocation	
Split ID - Treatment	e.g. coded number for split, colour-marked cattle, marked pen
Split ID - Control	

Lot No.__________ **MEDIUM SOILING**

ID No.	Side None	Side Light	Side Med.	Side Heavy	Leg None	Leg Light	Leg Med.	Leg Heavy	Belly None	Belly Light	Belly Med.	Belly Heavy	TOTAL
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Treatment allocation	
Split ID - Treatment	
Split ID - Control	

Lot No.__________ **HEAVY SOILING**

ID No.	Side None	Side Light	Side Med.	Side Heavy	Leg None	Leg Light	Leg Med.	Leg Heavy	Belly None	Belly Light	Belly Med.	Belly Heavy	TOTAL
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	

Treatment allocation	
Split ID - Treatment	
Split ID - Control	

Fig. 10 - Dag/tag scoring sheet (Source: Cobbold (2008))

Note that in practice animals are often given a score which quickly appropriates the information collected from Fig. 10 . This is described in Table 11.

Table 11. Appropriated version of a dag score sheet

Score	Incidence/Severity of dags
0	Nil
1	Low
2	Moderate
3	Heavy

Other sources, such as Busby & Strohbehn (2008) define mud scores as:

1 = no tag, clean hide;
2 = small lumps of manure attached to the hide in limited areas of the legs and underbelly;
3 = small and large lumps of manure attached to the hide covering larger areas of the legs, side, and underbelly;
4 = small and large lumps of manure attached to the hide in even larger areas along the hind quarter, stomach, and front shoulder; and
5 = lumps of manure attached to the hide continuously on the underbelly and side of the animal from brisket to rear quarter

12 Appendix B – Fact Sheet

Cost of Feedlot Dags to the Australian Beef Industry

What are dags?

Dags are the build-up of mud and manure in hard nodules on the hides of long-haired cattle. They are difficult to remove and can lead to operational and economic challenges to the Beef industry.

Dag prevention and removal

The implementation of appropriate feedlot pen manure management is widely considered to be the best currently available strategy to mitigate the formation of dags. Manual, chemical and mechanical measures to prevent or remove dags are also an important option for the industry.

Dag removal can be carried out at the feedlot by firstly soaking live cattle with water to soften the dags and secondly by washing the cattle with a high pressure jet or hose (Greenwood, House and Fell, 1998; Haines *et al.*, 2000). Similar soaking and washing is also carried out at meat processing facilities, but this is ultimately a food safety risk mitigation measure rather than to remove dags.

Impact of dags

Feedlot Industry	Processing Industry	Tanning Industry
• Increased requirements for dag washing infrastructure • Increased clean water usage and effluent generation • Time and additional labour cost for dag management • Reduced cattle performance	• Increased labour requirement • Increased clean water usage and effluent generation • Reduced carcass quality • Contamination risk	• Reduced hide quality and value

Costs associated with dag removal

Explicit costs	Implicit costs

• Direct cleaning costs at the feedlot
• Direct cleaning costs at the abattoir during dag risk periods
    • Penalty payments
    • Extra staff to trim contaminated carcasses
    • Loss of meat production
    • Dirty hides delivered locally and overseas
	• Indirect costs caused by reduced productivity;
	• Reduced processing efficiency; and
	• Reduced quality of carcass or hides.

What is the cost of dags to the Australian Beef Industry

The cost of dag management in the 2016 season was approximately $10.56 per head – comprised of a $6.18 cost borne by processors and a $4.38 expense endured by the feedlots. There was high variability in the data used in the analysis (Fig. 1).

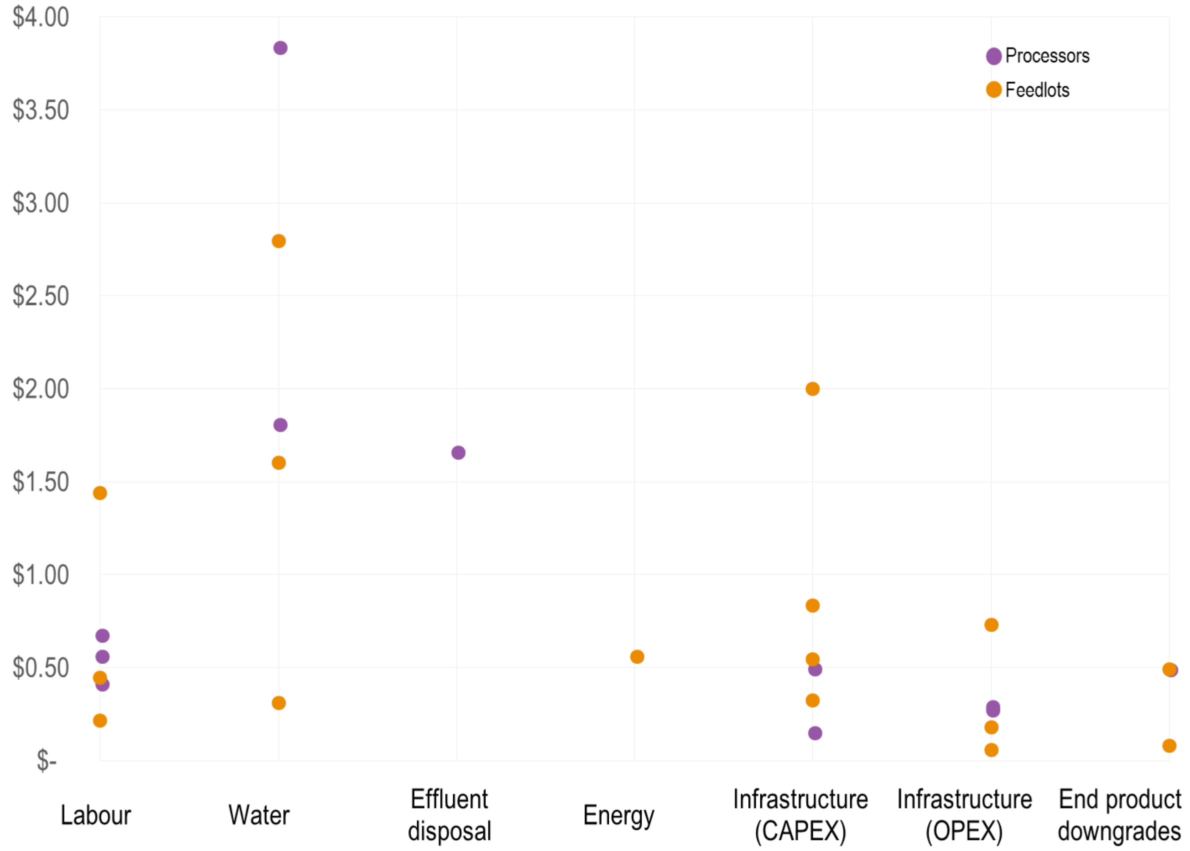


Fig. 11 - Point estimates by cost category and by contributor ($/head)

The average range of dag presence is approximately 33 % to 50 %, suggesting that the cost of dag management ranges from $10.55 to $16.08 per head depending on dag prevalence (Fig. 2). Taking this into consideration, the cost of dags to the Australian beef industry is between $4 million and $10 million per annum. This is equivalent to between 0.02 % and 0.05 % of the Australian beef and cattle industry value of production and between 0.16 % and 0.39 % of the feedlot industry's value of production.

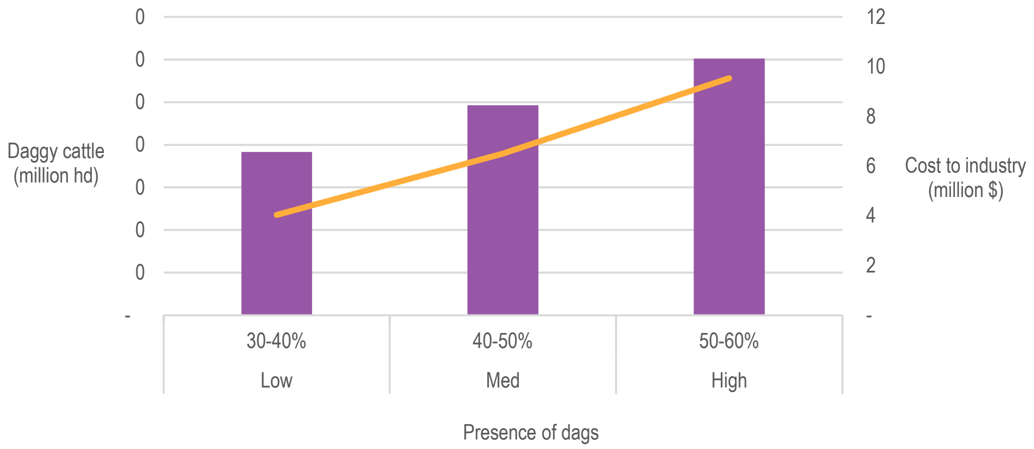


Fig. 12 - Cost of dags to industry in different years

Key points

- Dags incur a small but highly variable cost to industry but a significant cost to some individual producers.
- The estimated cost of dags on the feedlot industry is approximately $10.56 to $16.08 per head ($4 million and $10 million per year).
- $6.34 and $4.38 per head cost borne by processors and feedlots respectively.
- The impact of dags is not uniform;
- There is on-going innovation occurring to develop better dag management tools and processes;
- Effective pen design and manure management makes a significant difference to dags, but adoption is variable;
- Food safety is managed by all abattoirs visited through washing cattle and/or slaughtering techniques;
- Some abattoirs charge to wash daggy cattle;
- There is limited data, given the embedded nature of dag management, so any future research on the cost should be based on detailed observation;
- The lack of available data could be improved by providing feedlots and processors with the tools (such as data collection sheets) to ensure that future assessments can conduct more conclusive analyses with less variability.
- Dag management improvements need to be integrated with other improvements to provide sufficient incentive to be implemented.
- The cost estimate provides a threshold to guide additional investment in dag management – by commercial developers of treatments, research organisations such as MLA and the feedlots and processors involved in the supply chain.

References

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13 Appendix C – Data spreadsheet

	Feedlot A	Feedlot B	Feedlot C	Feedlot D	Feedlot E	Feedlot F	Processor A	Processor B	Processor C	Processor D	Processor E	Processor F
COST OF DAGS IN THE AUSTRALIAN BEEF INDUSTRY												
Does the enterprise wash	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y
Dag period	July-Sept	June-Aug	Apr-Sep	Apr-Sep	May-Sep	May-Sep	Jun-Aug	Jun-Aug		May-Sep	May-Sep	June-Sep
Proportion of cattle affected	25-33%	40%	100%	100%	100%	100%	4	this year 100% 1/2, last year 100% 3-5	50%			
Number of head processed per week	2500-3200	~950-1300	1000.00	1000	1000	1100	4800.00	4200	2500	5500	2660	1050 (4 days)
FEEDLOT												
Feedlot Washing Procedure												
Duration:		40 min prep + 20 min return. 5-10 min/hours to check cattle over 8 hour period	8 hours	8hours - havent washed due to environmental constraints for 2 years	N/A	N/A						
Low pressure (mins)	40	8 (washing length, labour only required for loading/unloading accounted for below										
High pressure (mins)												
Additional (handling etc, mins)	20	1										
Number washed/day	60	110	250	200								
Time of washing prior to lairage	Within 24 hours	5 days	7 days	1								
Number of washing days in 1 week		4/wk for 6 weeks in	4									
Resources												
Capital	$ 100,000	$ 102,446	$ 900,000	$ 300,000								
Water												
Volume (ML/day)	1	1	1									
Cost ($/MG)	190+ pumping costs/chlorination/bore s/transfer stations		$100									
Fresh/Recycled	R	R	F									
Power												
Maintenance												
Time taken (hours/week)		1.5 x 4 washing days (1hre x 3 staff daily to clean nozzles and prepare wash + 2-3 staff x 2hrs on sat to give thorough clean. Nozzles cost $45 yeach- 25 per year. Engine service costs ~ $250/year	1									
Labour Units		3	1									
Utilities	screen replacement		4 days to clean facilities and jets, 1 day to pump maintenance	$2000 - road maintenance + cleaning sed pits with bobcat								
Labour												
Hourly rate Y/N	Y	Y	Y									
Standard ($/hr)	32.5	22.7-23.50	30									
Overtime ($/hr)	40											
Salary Y/N												
Number of labour units	2		1.5									
Post-washing Procedure												
Bedding	N/A	Recycled timber	Shed and woodchip	Woodchip		Barley Straw						
Cost		17.50/m2- cover 2/3 pen area and 2 hours of staff time to spread	$10000 every 4-6 weeks	(((2 x 50 x 60) + (2 x 35 x 60)) x		cost to bale						
Performance impacts:												
Washing- ADG (kg/day)	0.25		neg									
Washing- Feed intake (kg/day		1.5	neg									
Mud- ADG (kg/kg)		0.1	sig.									
Other				compost downgrades from $18 to $10/t, 40kg body weight	40kg heavier this year- mud effects?	increased by 25%- more a mud depth thing						
Other												
Does the processor charge a dirty cattle fee? (Y/N)	N	Y	N	Y		Y						
If yes, what is this value? ($/hd)		$1.50 for one processor and $21 for other		$ 3		? (possibly $5)						
If no, why not?	Integrated business		Managed internally by processor									
TRANSPORT												
Volumetric (Vol) or Weight Loading (WL)	Vol	WL	WL	WL	Vol		N/A	N/A	N/A	N/A	N/A	N/A
Approximate average dag weight (kg/hd)	3.5	~9-12	neg	6	5	4						
Approximate maximum dag weight (kg/hd)	20									20		
PROCESSOR												
Pre-slaughter washing												
Duration:												
Low pressure (mins)							~60-180	3-7HOURS		4	10.5hrs	
High pressure (mins)							~90-120 (potentially an additional 120 if severe)			3min/animal		
Additional (handling etc, mins)							neg.					
Washing facility capacity (head)							80					
Total number of washing days per week							5 days - 6 hours/day				4	
AQIS subjectivity							Y	Y		Y	Y	Y
Resources												
Capital								$ 125,000				
Water										plus additional fees to process water with nutrient loading		
Volume (ML/day)									1	1	34.2KL	450 kL/day reclaimed + 300kl potable water (in summer 200+133 respectively)
Cost ($/day)												
Fresh/Recycled							R	R		R	R	F + R
Power												
Maintenance							Cleaned 10-20 times/day, 15-20 min duration			cleaning pipes out 3x a day	blockages 3x a weekl	
Time taken (hours/week)								4				270 hours/winter + 3-min/winter day
Labour Units								1				
Utilities								ball fittings				
Labour												
Hourly Rate Y/N							3 * 22.474 + 1 * 22.47					
Standard ($/hr)												
Overtime ($/hr)												
Salary Y/N								Y			Y	
$/unit								$ 13,655.95			60000	
Number of additional labour units							4	5		1	3	2 staff for 8 hours - washers + 2 on slaughter floor (legger and trimmer)
Other												
Does the processor charge a dirty cattle fee? (Y/N)							Y	Y	Y- reserves right but never imposed		N	
If yes, what is this value? ($/hd)							$ 5	$ 1.50	$ 20			
If no, why not?											Cost internalised	
Post-slaughter												
Percentage of dark cutters								NEG	neg			
Incidence of bruising								NEG	neg			
Increase of trimming (kg/hd)								0.5		0.75 (up to 1kg)		
Other risk mitigation strategies to combat contamination												
							7 second hot water wash	knife sterilisers and automated blade sprays, additional labour	de-dagger tech, additional labour, carcase wash, steam vacuum		Additional labour, steriliser	
											$1500 confirm micro test, $760K product value lost, yield lost- $9.60/kg, loose 1/2 tail x 664 x 4 days	can slow chain by 1 hour- costs them overtime- up to once a week but NOT CONFIRMED

14 Appendix D - Subjective findings from data collection

After conducting site visits to six feedlots, the resounding observation was that less washing was occurring than expected. Interestingly, 50% of the selected feedlots were not washing. Over 33% were not washing due to restricted resources and lacking, or inoperable infrastructure. One operation was considering investing in a washing facility, however were exploring other practices to minimise dag prevalence.

Further sampling across eight feedlots supported, if not strengthened the argument that Australian feedlots did not undertake washing procedures. Of the secondary interviews, conducted via teleconference, 88% did not wash cattle. Of this 89%, 14% had occasionally undertaken light soaking to improve processors ability to remove dags, and 28% had attempted to remove dags via shearing. 28% did not wash due to an integrated supply chain business structure. 14% had considered investing in washing infrastructure, however had not due to welfare implications caused by severe weather conditions, and instead invested in shed infrastructure and bedding.

All feedlots interviewed reflected that they only washed due to pressure from processing facilities. Merely having dags was of no implication to these enterprises, however the conditions pertaining to dags significantly affected the performance of cattle and business profitability. A number of operations reported at least 40kg difference in live weight in winter periods compared to summer.

Investing in dag management infrastructure such as cattle washes was of notable cost, largely in water, labour and infrastructure costs. Additionally, infrastructure use was variable, therefore return on investment varied substantially between sites.

Concluding the site visits, it was clear that feedlots saw improving pen maintenance and accessibility as an avenue to reduce dag prevalence, with other more substantial opportunities including increased feed intake and weight gain, therefore increasing the volume of saleable product through the processing facilities throughout daggy periods.

All operations felt that dag management or preventative measures, while ideal, would not eliminate dags, however they also believed that there was strong value in reducing the severity of dags affecting beef cattle.

All stock transporters contacted reported that there were no significant impacts of dirty or muddy cattle to their businesses. They each independently noted that feedlots had daggy cattle rather than grass-fed stock, but dags did not, in their belief, cause an increase in workload for transport companies. Commonly, the attitude was that some cattle would be dirty, and that was *"taken with a grain of salt".* One operator sited that daggy cattle were of no concern, however curfewing stock to manage effluent discharge while in lairage was a substantial concern. This operator quoted incidences where drivers were fined for effluent spillage when cattle were not appropriately managed prior to loading.

Six processing operations were interviewed to attain the impact of dags to their business. Operators quickly identified that washing cattle was an action to reduce the risk of carcass contamination. Any incidence of positive microbial testing would have a significant impact on these enterprises, long-lasting past additional microbial testing or additional labour to extend washing time.

One enterprise stated that if one potential positive test is detected, it costs $1,500 to confirm if the sample is positive. If this sample is then confirmed positive *"we lose the sale value of one shipping container of product- 700 cartons- around $760,000 assuming the value of bulk pack trim, excluding the* *costs to return the product and additional handling".* This product must then be sold at a discounted rate to a heat treatment processor.

This cost does not account for long-term loss of business. According to one operation, returning a potential positive was documented to happen, on average, 10 times per year. 80% of these incidences occur during daggy periods.

The site visits reflected that due to the multifaceted causative nature of dark cutting, the costs could not be isolated to washing for dags prevention singularly. One operation reflected the increase in bruising, however noted that since updating infrastructure this had largely been accounted for. Two operations referenced the observations made by Preston (2016);

- *"Of 1,437 pasture-fed cattle, dark cutting incidence was 24%;*
- *Of 1,447 grain-finished cattle, dark cutting incidence was 2%; and*
- *The proportion of behavioural changes in washing and lairage increased dark cutting by up to 12%."*

From the interviews, a range of 0.5 – 1 kg of saleable product per animal may be additionally trimmed in daggy periods. This volume was estimated as trimming occurs in several locations in a processing facility, and for a range of reasons. All processors interviewed expressed that there was some subjectivity in the industry standard, which is defined in *The Australian Standard for the Hygienic Production and Transportation of Meat and Meat Products for Human Consumption* (AS 4696:2007). Clauses 8.4 and 8.5 state that:

- "8.4 *Reasonable steps are taken to present animals for inspection in a clean condition;*
- 8.5 *Animals that are not clean are not passed for slaughter or are passed for slaughter subject to conditions that ensure they do not contaminate animals, carcasses and carcass parts during slaughter, dressing, post-mortem inspection and disposition."*

This variation means that there is not a standard level of cleanliness for processors to wash to, and the decision to undertake additional washing is at the discretion of what supervisors may classify as "conditions that ensure they do not contaminate animals...".

All processors highlighted that cattle washing was, at times, ineffective at removing all dags. Processors have a series of risk management strategies to reduce the risk of carcass contamination, including additional labour units in washing, trimming and legging areas of the facility. Worse-case scenario, an operation will reduce the chain speed of an operation. To achieve target production volumes, processors are required to pay overtime.

Furthermore, processors highlighted that the rate which they charge does not cover the costs of washing cattle, however felt they were not in the position to increase this rate in the fear of becoming uncompetitive.

All feedlot and processors acknowledged that pre-slaughter washing for dag removal has animal welfare and social license implications, and support finding alternative methods to remove or reduce dag loads.