Dairy Australia

AGRICULTURE VICTORIA

Dairy Feedpads and Contained Housing

National Guidelines

Fourth Edition

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Foreword

The Australian dairy industry is historically recognised and remains today grazing based production systems whereby producers have relied predominantly on home-grown feed, with the support of supplementary feeding. Over time dairy producers have adopted and incorporated innovative feeding and housing solutions utilising a range of feeding infrastructure such as short-term use of earthen areas with troughs through to permanent concreted flood washed feedpads (with or without shelter facilities). This has enabled an extensive range of feedstock and by-products to be fed throughout the year with the ability to accommodate herds during periods of adverse weather, seasonal variability, and emergency events.

In more recent years, parts of the Australian dairy industry have invested significant time and effort in reviewing the farm's long term strategic direction and have commenced a transition journey into contained housing facilities with zero grazing. These significant investment decisions are being adopted to address a range of farming and regional specific challenges including climate adaptation, water availability, workforce efficiencies, improvement in environmental management, and enhanced animal health and production outcomes. A shift to an intensive farming system is a change of land use and therefore require more complex decision making, planning, development considerations and a longer-term vision to change and adjust farm practices and management.

The establishment of any feeding infrastructure or contained housing should not be a quick fix solution to address issues of feed utilisation and wastage or a reactive response to a poor season. Choosing the most appropriate feeding infrastructure and contained housing for the farm, and its locality, requires understanding the range of potential feeding and housing solutions commonly used in the industry (not just in Australia, but globally) and determining which farm system and associated infrastructure will best suit the farms future growth or proposed change.

These National Guidelines, written and peer reviewed by 28 subject matter experts and technical specialists from Australia and the United States, are intended to provide referral agencies, service providers and dairy producers across Australia with a clear and concise overview of all the elements that require consideration when undertaking the initial planning, development and longer-term management of these feeding and housing facilities.

The information in these National Guidelines is a collation of current planning and the best technical information available compiled to:

- assist the dairy industry to make informed decisions with respect to dairy feedpads and contained housing
- raise awareness of industry, government, and community expectations to minimise any adverse impact on the environment
- establish a key reference enabling new proposals to progress smoothly through the various development and planning stages relevant for each state
- demonstrate that the dairy industry has an ongoing commitment to support producers undertake farming system changes.

The review and upgrade of these guidelines to produce edition 4 was the result of two significant industry events, those being the national Dairy Manure Summit and the National Dairy Intensification Workshop.

These engagements with farmers and key stakeholders clearly identified the importance of these national guidelines and opportunities to strengthen key sections, particularly focusing on financial management, land capability assessment, farm emission, improved engineering designs and a better understanding of state planning and approval processes following the successful establishment of these farm systems across Australia.

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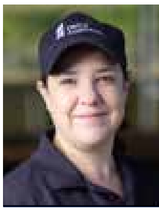

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Glossary

Term	Definition
Amenity	The comfortable enjoyment of life and property, particularly with regard to visual appearance, odour, dust, noise and light spill.
Basic feed-out area	A type of feedpad. Contains an area with a permanent compacted earthen feeding infrastructure shared by cows and vehicles which may be dry scraped. Can be relocated to another site on the farm (with effort) if necessary.
Batter	The uniform side slope of an excavation such as a pond, track, road or ditch.
Bedded pack	Deep layers of organic material (i.e. woodchips, straw, sawdust etc.) that form a bed and pack down over time.
Bedding	Organic or inorganic material or manufactured products used to provide a comfortable laying space to improve animal health and welfare. Bedding materials include sand, composted manure, woodchips, sawdust, straw and rubber mats.
Behavioural enrichment	The practice of providing animals under managed care with environmental stimuli to improve quality of life.
Brisket locator	A device at the front of stalls to assist the position of the cow when lying, preventing her from lying too far forward in the stall.
Buffer	The distance between the dairy complex or reuse areas and a sensitive natural resource (e.g. waterway, bore and water storage) to reduce the risk of potential environmental impacts. Buffers are measured from the outer perimeter of the dairy complex, or reuse areas unless otherwise indicated.
Bun stack	An above ground storage option for silage where the harvested feed is heaped on the ground, rolled and covered completely with plastic.
Bund	Watertight wall or embankment designed to prevent liquid entering and/or exiting an area.
Capital cost	One off investment cost - in this case, the costs associated with construction of feeding/ housing facilities and the purchase of any associated equipment.
Commodity shed	A row of flat-bottom, usually concrete, storage bays or bunkers that are covered with a high roof for storage of wet and dry feedstuff materials such as by-products, grains and meals etc.
Compost	A humus-rich soil conditioner produced by composting manure.
Compost bedded pack	A bedding system where an active composting process is maintained in the base of the bedding pack to promote a clean, dry, comfortable bedding surface.
Composting	A natural biological decomposition process that takes place under controlled self-heating and aerobic condition.
Contained	Where dairy cattle are contained for the purpose of access to water and feed e.g. hay, silage, grain or total mixed ration.
Contained housing	An integrated facility for feeding and housing cattle with zero grazing such as a freestall, loose housing or dairy dry lot.
Controlled drainage area	An area that collects and contains runoff from the dairy complex while excluding stormwater inflows.
Cow barrier	Structures used to prevent cows from standing in or on the feeding table. Common structures include elevated troughs, fences, hot wires, steel cables, head locks, neck rails and stanchions.
Cow brush	Rotating cylinder with hard bristles that cows can scratch themselves against.
Cross over	In a freestall, a walkway that joins two alleys.

Term	Definition
Cross ventilation	A negative pressure mechanical exhaust system that provides forced air movement laterally across the housing from side to side.
Curtain baffles	Curtain style structures that hang vertically from the ceiling to trap and force air down at fast-moving speeds to promote cooling to the space below.
Deep litter pack	A bedding system where new bedding material is continuously piled on top of the old bedding material to keep the surface clean and dry.
Dairy complex	Land where dairy cattle are milked, contained, loaded or unloaded; manure and effluent are stored and treated, cattle feed is prepared, handled or stored. The dairy complex does not include manure and effluent reuse areas.
Drain	A conduit for conveying stormwater water or effluent.
Drive alley	The area adjacent to the feeding table along which vehicles and machinery drive to deliver and push up feed. Cattle are not allowed access to the drive alley.
Dairy dry lot	An open, well-drained area with an earthen surface and a shade structure over part of the area, to protect animals from the sun and rain. A bedded area may be provided under the shade structure.
Effluent	*See manure*
Effluent reuse	The application of manure and recycled effluent onto land.
Erosion	The wearing away of the land surface by rainwater, water-flow or wind, removing soil from one point to another e.g. gully, rill or sheet erosion.
Far off dry period	The period from dry-off to 21 days before calving.
Feed alley	The alleys occupied by cattle when they are accessing feed. These alleys are located parallel to the feeding table.
Feed conversion efficiency (FCE)	The amount of feed required or consumed per unit of milk solids production.
Feeding table	The surface on which feed is placed when feeding cows on feedpads and in contained housing facilities.
Feedpad	An area used for supplementary feeding cattle where the surface is either formed, laid with a durable material or stocked at a rate that precludes vegetation. Examples of feedpad facilities include temporary feed-out area, basic feed-out area, formed earthen feedpad and concrete feedpad.
Five domains welfare model	A model for animal welfare that considers both the positive and negative aspects of nutrition, environment, health, behaviour and mental state and embraces the provision of positive experiences and desirable outcomes to determine the overall welfare state, rather than simply focusing upon limiting animal exposure to negative experiences.
Flexible feeding system	A feeding system that allows feeding on a feedpad as well as in paddocks. Useful in drought or wet conditions.
Flood	An overflow of water that submerges land that is usually dry. A 1% annual exceedance probability (AEP) flood is a large flood with an average recurrence interval (ARI) of 100 years.
Formed earthen feedpad	A type of feedpad. Has a compacted surface shared by cows and vehicles and regularly scraped. Fixed structures including purpose-built concrete troughs or nib wall or cable or hot wire +/- narrow cement strip for cows to stand on while eating +/- loafing areas, shade structures.
Freeboard	The elevation difference between the full pond and the crest of the bank. Freeboard protects the bank from wave action, riling, by-wash flows and overtopping under high-intensity rainfall and fast filling.
Freestall	A type of contained housing facility where cattle are allocated bedded cubicles (stalls), which they are free to enter to lie down as they please. They are used for long-term housing of cattle and may be an open-air, partially or fully-enclosed structure, with or without an additional loafing area for cattle to stand to utilise or occupy.
Geosythentic material	A thin flexible and permeable sheet of synthetic material used to stabilise soils.
Groundwater	All water below the land surface that is free to move under the influence of gravity.
Impermeable	Materials with a permeability no less than 1x10-9m/s. For design purposes this includes concrete, synthetic pond liners or suitable compacted clay liners.

Term	Definition
Landscaping	The use of plants, earthen banks or other features to provide visual amenity.
Leaching	The process whereby soluble nutrients (e.g. nitrogen) are carried by water down through the soil profile.
Levee bank	An earthen bank designed to confine or direct liquids and solids to or away from designated areas.
Loafing area	A formed surface adjacent to a feedpad, or within the contained housing facility. Its primary purpose is to provide a separate section away from the feeding table for cattle to stand, lie, ruminate or idle.
Longitudinal slope	The slope along the length of the feedpad, or contained housing facility, to facilitate drainage particularly for flushing alleys.
Loose housing	A type of contained housing facility where there is a large open bedding area, without individual stalls. These facilities are typically categorised by their management of the bedded area as a: • *Compost bedded pack* that is mechanically tilled at least twice daily; or • *Deep litter pack* where absorbent organic bedding is added regularly to the bedded area, but there is no mechanical tilling.
Manure	Livestock faecal and urinary excreta in a liquid, slurry, semi-solid and solid form. It can also include waste feed, bedding and soil. Liquid manure is typically referred to as *effluent*. *Effluent* is produced by cleaning the dairy shed and holding yards with water. Effluent may also include stormwater, residual milk and chemicals from cleaning dairy plant and equipment. Effluent may be recycled (i.e. recycled effluent) and used for washing manure from areas such as holding yards, alleys and housing facilities, or applied to land.
Manure management system	Integrated system designed to manage the manure stream from its point of generation through to its reuse onto land, or off-site export. It typically includes components to contain, treat, store and/or reuse manure.
Milking platform	The total hectares of land directly contributing to milk production and includes grazed and harvested forage (pasture and crops) and designated feeding and sacrifice areas. The milking platform is where the greatest nutrient inputs, manure deposition, nutrient cycling, pasture, crop and milk production and potential for nutrient losses, is occurring.
Natural ventilation	The provision of fresh air into a building space using natural air flow movements.
Neck rail	A rail to assist the position of cows in a stall so they have enough forward lunging space when they lie down.
Nib wall	A small concrete wall constructed along the perimeter of alleys to prevent manure from leaving the feedpad or contained housing facility or entering the feeding table.
Partial budget	A budget used to calculate the effect on profits of a proposed change in a portion of the operation by including only the costs and returns that change as a result of the proposed change in the operation. Because only a portion of the costs and returns are included, the partial budget only provides an estimate of the profitability of an alternative relative to current operations. It does not provide an estimate of the absolute profitability.
Partial mixed ration (PMR)	A method of feeding where feedstuffs, supplementary to what the cows will graze, are combined as a single mixed ration and fed in between bouts of grazing, so the mixed ration makes up only part of the cows' diet.
Photoperiodic manipulation	Subjecting cows to specific light and dark exposure periods to increase milk production.
Principle productivity area	*See milking platform*
Recirculation fans	Fans used to create fast air movement above cow resting places to promote cooling.
Regrouping	The mixing or comingling of cows that were not previously in the same group.
Sedimentation basin or pond	A pond structure that allows the settling out and storage of solid material from the effluent stream.
Sensitive use	A use that may be impacted by including odour, dust, and noise. It includes a dwelling, a dependant persons unit, a residential building, a hospital, a school, childcare centre, a caravan park and other uses involving the presence of people for an extended period. Sensitive use does not include recreational areas such as parks and sporting facilities.

Term	Definition
Separation distance	The distance between a dairy complex and a sensitive use. Separation distances are measured from the edge of the dairy complex to the nearest wall of a building associated with a sensitive use.
Shrink	The loss of feed that occurs during storage, handling and consumption, often due to unavoidable processes. Examples are trampling and soiling of pasture during grazing, silage effluent and volatiles, spoilage, contamination, handling losses, rejections/refusal to eat.
Side slope	The slope in the feed alley that directs manure and runoff away from the feeding table. The slope direction runs perpendicular to the feeding table. This is usually only associated with earthen feedpads.
Social licence	Refers to the acceptance granted to a company or organisation by the community and is based on trust and confidence.
Stall alley	In a freestall, these are walkways to enable the cows to access the stalls.
Stall divider	A looped rail that defines the width of the freestall and facilitates the lying direction of the cow.
Stall kerb	A small concrete barrier at the back of a stall used to prevent slurry manure from the alley contaminating the bedding.
Stalls	Individual resting spaces or beds in a freestall which cows are free to enter and leave as they please.
Standard Cattle Unit (SCU)	Equivalent to an animal with a liveweight of 600kg.
Stocking density	Feedpad: space per cow. Freestall: number of cows per stall. Loose housing: cows per square metre of bedded area.
Stockpile area	A bunded area with an impermeable base used for the temporary storage of manure or compost.
Stormwater	Rainfall runoff from building roofs, other hard surfaces and land.
Struvite	A crystalline mineral made up of magnesium, ammonium and phosphate that can precipitate out of wastewater and build up on the inside of pipes, pumps and other wastewater treatment equipment causing clogging and damage.
Surface waters	A waterway, any body of water above the ground, including streams, rivers, lakes, wetlands, reservoirs and creeks.
Temporary feed-out area	An area where feed is delivered to cows either on the ground, or in hay rings or tractor tyres. It could be located in a pastured or bare cropping paddock, a designated sacrifice paddock or along a laneway without a prepared surface. It can be readily relocated to other sites on the farm.
Thermoneutral zone	The ambient temperature range across which an animal is comfortable and doesn't need to expend energy to maintain its normal body temperature. For healthy cattle this is generally 0ºC to 25ºC.
Topography	The shape of the ground surface as defined by the presence of hills, mountains or plains, both natural and artificial, of an area, such as are required for a topographic map.
Total dissolved solids (TDS)	A measure of the inorganic salts and small amounts of organic matter dissolved in water. The main constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogen carbonate, chloride, sulphate, and nitrate anions.
Total mixed ration (TMR)	A method of feeding which involves mixing all diet ingredients together into a single ration so that, in theory, each mouthful the animal eats is nutritionally balanced.
Transition period	The period from four weeks pre-calving to four weeks post-calving, which is characterised by an increased risk of metabolic disease for the cow due to the physiological changes that are happening at this time.
Tunnel ventilation	A negative pressure mechanical exhaust system that provides forced air movement longitudinally through the housing from end to end.
Vegetated filter strip (VFS)	A vegetated area (typically grassed) separating a waterway from an area where organic matter is deposited. It is designed to reduce the nutrient concentration of runoff through particle trapping and by increasing infiltration into the soil.
Vegetative environmental buffer (VEB)	A dense multiple-row planting of trees or shrubs etc. for the purpose of improving air quality, to filter dust, noise and mitigate odour, along with providing a shelter belt and wind break.

Abbreviations

AMS	Automatic Milking Systems
BYDA	Before You Dig Australia Phone: **1100** **byda.com.au**
EfMP	Effluent Management Plan
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
DM	dry matter
DMI	dry matter intake
kg	kilogram
kL	kilolitre
KWe	Kilowatt-electric – One thousand watts of electric capacity
KWh	kilowatt hours
kPa	kilopascals
m	metres
mm	millimetres
ML	megalitres
TS	total solids
Wh	watt-hours

Introduction

The *National Guidelines for Dairy Feedpads and Contained Housing* were first conceptualised in 2019. At that time, the intent was to create a compete revamp of the first edition, created in 2010, but widen their footprint to be nationally relevant in addition to incorporating the best science and design from around the world. This has been achieved. The authorship for this edition is truly international and the information contained in these chapters is a distillation of current global best thinking and practice.

Across the following pages, the National Guidelines are arranged into 15 chapters. This resource is not intended to be solely read cover to cover and from the beginning. Rather, it is deliberately designed to be accessed, by relevant topic, depending on the present need of the farm team or their advisers. It is designed to be "dipped in and out of" depending on the task at hand. Further, the National Guidelines make extensive use of figures, photographs and tables to assist the reader in clear understanding of the content. Technical terms commonly used in this topic area are explained in the Glossary.

The intended audience for the National Guidelines is anyone with an interest or role in the decision making around establishing, modifying or using some type of feedpad or dairy cattle housing. It is equally relevant to farm owners, farm workforce members and advisers.

A look over the contents description reveals the breadth of topics covered. The National Guidelines are designed to comprehensively cover environmental planning, optimising animal welfare through good facilities design, maximising cow comfort through the various ventilation options, efficient energy use and generation plus feed delivery systems to maximise efficiency and productivity. The fourth edition contains expansive sections on amenity, environmental considerations and management of manure. Readers will also note the inclusion of a chapter on using automatic milking systems within cattle housing where an alternative to conventional milking is an option.

For farmers involved in the early stages of planning for a new piece of feeding or housing infrastructure, the National Guidelines offers them, along with their advisory team, the opportunity to significantly reduce the risk of poor planning and design decisions. People using this resource are really encouraged to read the relevant chapters, consider their plans, and then review their designs and approach based on a comparison against the information contained within the National Guidelines. The authors and review team for this resource have gone to extensive lengths to present design and use information which not only represents state of the art thinking, but also reflects optimised Australian and international facilities currently in use. Much of the usefulness of this publication lies within the time prior to the first concrete being poured on a building project.

The *Fourth Edition National Guidelines for Dairy Feedpads and Contained Housing* are an update to a truly world class publication and resource for the Australian dairy industry and should be highly applicable and relevant for many years into the future.

01

Dairy development definitions and planning pathways

Overview

This chapter explains the definitions, production system types and planning pathways relevant to developing or upgrading dairy feedpads and contained housing. It provides a clear framework for understanding when a dairy shifts from a grazing-based system to a more structured or higher-input feeding and housing system, and how that shift affects planning requirements, environmental responsibilities and day-to-day operations. When reviewing or planning changes to a dairy enterprise, it is important to understand the full range of system options available, as the suitability of each depends on climate, land capability, herd needs, infrastructure layout, nutrient management capacity and long-term farm goals.

A critical early step is recognising the difference between grazing production and higher-input feeding or housing systems because this distinction influences the level of design work, the approvals required, the need for specialist input and the overall scale and cost of the development. These thresholds vary between states and territories, so operators must confirm how their proposed system will be classified in the relevant jurisdiction. The purpose of this chapter is therefore not only to define system types but to help farmers, designers and consultants understand how new infrastructure integrates into the broader farm system, rather than viewing feedpads or contained housing as isolated structures.

1.1 Dairy production system definitions

Dairy farms across Australia operate along a broad range of production systems. These systems differ in how cows are managed, how feed is delivered, how infrastructure is used and how manure and nutrient loads are handled.

Planning frameworks in each state and territory recognise these differences, and the way a dairy is described within the planning system often depends on how much of the herd's daily feeding and housing is supported by constructed infrastructure rather than open paddocks. Although each jurisdiction uses its own terminology, the practical distinctions that matter for approvals are consistent nationwide.

A Pasture-based system is one in which cows obtain most of their feed by grazing pasture grown on the farm. Cows spend the majority of their time on paddocks, coming to the dairy and yards primarily for milking or short periods of supplementary feeding. Seasonal feeding, sacrifice paddocks, on-off grazing and short-term use of a feedpad do not alter the fundamental nature of this system. Manure is spread 'as excreted' across the landscape and effluent from the yards and dairy and supplementary feeding area is managed through a manure and effluent management system. Environmental risks are generally lower and more diffuse. In most planning schemes, this type of operation is treated as grazing or extensive animal production.

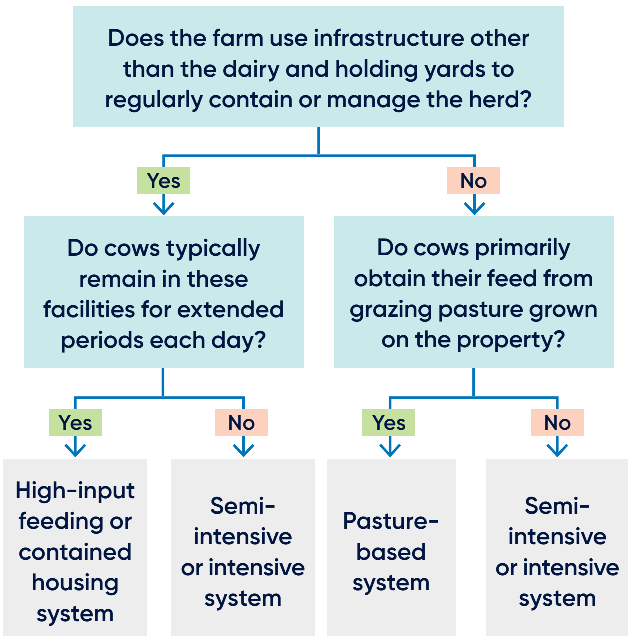
A Semi-intensive or hybrid shelter system continues to rely strongly on pasture but uses more supporting infrastructure to assist with feeding, herd movement or weather management. These farms may use feedpads, loafing areas or stand-off areas more regularly, particularly during wet periods, extreme heat, pasture shortages or periods of high milking demand. Partial Mixed Rations (PMR) may be fed to complement grazing. In these systems, a larger proportion of feed is brought to the cows, and cows may spend more of their day in constructed areas. Because of this shift, manure and effluent begin to accumulate at higher rates in specific locations, and planning authorities may require a more detailed assessment where the supporting infrastructure is used frequently or year-round. How these systems are defined within planning scheme varies and the use of these systems needs to be clearly defined with any approval generally aligning with the temporary use of this type of system.

A contained housing or higher-input feeding system is one where cows spend extended periods in purpose-built structures such as freestall, loose housing or dry lot systems. These systems use Total Mixed Rations (TMR) as the diet, meaning that all feed is mixed and delivered rather than grazed. All manure and effluent is fully collected within the built system and must be managed through properly designed storage, handling and reuse systems. Planning frameworks across Australia generally classify these systems in terms similar to intensive or high-input animal production because the animals depend heavily on infrastructure-based feeding and housing. Although terminology varies between states, the unifying feature is that feeding takes place within constructed facilities rather than on pasture and the feed is supplied entirely through mechanical means.

Across all systems, the aspects that most influence planning and environmental requirements are the proportion of feed that is imported, the amount of time cows spend in constructed areas, and the degree to which manure and effluent are concentrated. As the role of built infrastructure increases, the level of technical assessment and approval detail typically increases as well. These definitions provide the foundation for understanding the planning, environmental and operational pathways outlined in the remainder of the following sections.

> **Note**
>
> Within these guidelines, several terms carry specific meaning. These terms are provided in the Glossary. See also Chapter 8 for more details on these systems.

Figure 1. Defining the farm system



1.2 Making sound investment decisions for feeding and housing infrastructure

Overview

This chapter provides guidance on evaluating investment decisions in feeding and housing infrastructure and whether this aligns with your farm business goals and financial capacity. It covers business planning fundamentals, financial assessment, understanding risks, and preparing for discussions with lenders.

Introduction: Why this decision matters

Investing in feeding infrastructure such as feedpads, cattle shelters, or contained housing facilities represents one of the most significant financial decisions a dairy farm business will make. These investments can range from tens of thousands of dollars for basic feeding infrastructure solutions to multi-millions of dollars for comprehensive contained feeding and housing systems.

Before committing to such an investment, it is essential to understand whether the infrastructure fits your long-term business strategy, whether your business has the financial capacity to support it, and how to manage the associated risks. This chapter will guide you through the key considerations and provide a framework for making an informed decision.

Aligning infrastructure investment with your business strategy

Start with your long-term vision

Infrastructure investment should never be a reactive response to a single poor season or immediate challenge. Instead, it must align with your farm's long-term strategic direction. Understanding your strategy must come before assessing your financial position. Ask yourself:

- Where do you see your farm business in five, ten, or twenty years?
- What are your goals and how will this infrastructure help achieve them?
- Does this investment support or hinder business succession or transition plans, including engaging the next generation?
- How does this fit with your lifestyle and exit strategy goals?
- Are there alternative ways to achieve your objectives without this level of investment?

Being able to clearly articulate why you want to invest in infrastructure and how it aligns with your long-term strategy is critical for sound decision-making. This ensures the investment is driven by considered business planning rather than short-term pressures.

Develop a strategic business plan

A strategic business plan is your roadmap for the future. Dairy Australia's "Our Farm Our Plan" program provides a structured approach to developing your strategic plan, helping you work through critical business questions including your business vision, strengths and weaknesses, production and financial goals, and how major investments like infrastructure fit within your overall strategy. It is important that you get input from family members, business partners, advisors, and lenders when developing the business plan.

Taking time to develop or update your business plan before making infrastructure decisions ensures that investment choices are driven by strategy rather than circumstance.

Understanding your financial capacity

Before considering a significant infrastructure investment, you need a clear understanding of your farm's financial health. This involves examining your balance sheet, equity position, and cash flow capacity.

Understanding your balance sheet and equity

The balance sheet is a snapshot of what your business owns (assets) and what it owes (liabilities) at a particular point in time. The difference between these is your equity, which represents the true value you have built in the business.

Your **equity percentage** is calculated as:

Equity ÷ Total Assets × 100

A higher equity percentage indicates a stronger financial position and greater capacity to withstand adverse events. Farms with strong equity have more buffer to absorb production setbacks, market downturns, or unexpected costs. Maintaining adequate equity is fundamental to business resilience.

See section below on how a major investment can impact your financial position and how banks will assess your application and value your different asset types.

Using DairyBase to analyse your financial position

DairyBase is Dairy Australia's physical and financial analysis tool that allows you to analyse your farm's performance and compare your results against similar operations.

DairyBase data provides valuable context for evaluating your readiness for major investment and can support discussions with advisors and lenders.

Understanding your cash flow and debt servicing capacity

Having adequate equity is necessary but not the only critical factor to have for a major investment. You also need confidence that the business can generate enough cash flow to service any additional debt while meeting all operating expenses and maintaining reserves for unexpected events.

Debt servicing refers to the cash needed to make loan repayments. When evaluating a major investment, you need to consider how much additional debt servicing the business must cover and whether projected cash flows are sufficient.

A useful measure is **finance costs per kilogram milk solids**, which shows the burden of debt relative to production. Using our 800-cow example with $8.0 million total debt at 6.5% interest:

Finance costs before investment:
$234,000 interest ÷ 456,000 kg MS = $0.51/kg MS

Finance after investment:
$520,000 interest ÷ 560,000 kg MS = $0.93/kg MS

This represents an increase of $0.42/kg MS in finance costs. Because interest rates can change significantly, it's prudent to test your debt servicing capacity at rates 2-3% higher than current levels. For example, at an interest rate of 8.5% finance costs would increase to $1.21/kg MS - an increase of $0.70/kg MS from the pre-investment position.

Cash flow budgets across all phases

Developing detailed cash flow budgets is essential for understanding whether the investment will be sustainable. You need to prepare budgets for three distinct phases:

1 **Construction/transition phase:** This period typically involves disrupted production, one-off costs, and learning curves as you adapt to new systems. Many farms underestimate the working capital required during this phase.
2 **Early operational phase (years 1-3):** The Dairy Farm Monitor Project found that TMR farms required several years to optimise their new system. Your budgets should reflect realistic rather than optimistic assumptions about production levels and costs during this learning period. Allow for increasing herd numbers if the expectation is to milk more cows.
3 **Fully operational phase (year 4 onwards):** Once systems are optimised, budgets should reflect your target production levels and efficiencies.

Your cash flow budgets should be monthly and must be underpinned by sound physical budgets covering milk production, feed requirements (both homegrown and purchased), labour, water, energy, and other key resources.

Testing your assumptions through sensitivity analysis

No budget perfectly predicts the future. Sensitivity analysis involves testing how your investment performs under different scenarios. This helps you understand the true level of risk and identify whether additional buffers or contingency plans are needed. At a minimum, test scenarios including:

- Production changes (milk and fodder)
- Milk price variations (-10% to -20% from projections)
- Feed cost increases (particularly for purchased concentrates, forages and irrigation water).

Understanding performance under adverse conditions is essential for sound risk management. If your investment only works under best-case assumptions, it represents significant risk to your business resilience.

Planning your capital investment

Developing a comprehensive capital budget

A comprehensive capital budget must capture all costs associated with the investment, not just the obvious infrastructure components. Include:

- Infrastructure construction (buildings, concrete work, fencing)
- Effluent and manure management systems
- Feed storage and handling equipment
- Professional fees (engineers, consultants, planners)
- Council and regulatory approval costs
- Contingency allowance (typically 10-15% of construction costs)
- Additional working capital requirements.

Many farms encounter cost overruns because they underestimate the true scope of what is required. Engage experienced professionals early to develop realistic cost estimates.

Cost control is critical throughout the project. Having a clear project management plan, detailed specifications, and appropriate contingencies helps avoid budget blowouts that can undermine the investment's financial viability.

Considering a staged implementation

Where possible, consider whether staging the investment could reduce risk and improve outcomes. Staging allows you to:

- Test systems on a smaller scale before full commitment
- Manage cash flow requirements more effectively
- Adapt designs based on early experience
- Maintain some operational flexibility during transition.

While staging may not suit all projects, it's worth evaluating whether a phased approach could improve your risk profile without compromising your strategic objectives.

Understanding and managing investment risks

All major investments involve risk. Sound decision-making requires understanding what risks you face and how to manage them effectively.

Financial risks

Equity and leverage risk: Large infrastructure investments increase financial leverage, making your business more vulnerable to adverse events. Maintaining adequate equity buffers and having a clear plan to rebuild equity through retained profits is essential for long-term resilience.

Interest rate risk: Rising interest rates increase debt servicing costs. The Dairy Farm Monitor Project found that interest and lease costs more than doubled for many TMR farms between 2021-22 and 2023-24 due to larger debt and higher interest rates.

Cash flow risk: Ensure your business can service debt under adverse scenarios, not just best-case projections. Maintain conservative assumptions and adequate buffers.

Market and operational risks

Market volatility: Both milk prices and feed costs can change significantly. Model how your investment performs across a range of market conditions. Consider whether risk management tools such as forward contracting of feed or milk processor pricing programs can help stabilise your exposure.

Labour dependency: Contained housing systems require skilled labour and many tasks are very time sensitive. This creates dependency on finding and retaining capable and reliable employees. Invest in competitive employment conditions, training programs, and robust systems.

Transition challenges: The transition period to new feeding or housing systems can be a vulnerable time for your business. Herd health issues, production disruptions, equipment problems, and staff learning curves are common. Budget for realistic transition timeframes rather than expecting immediate results.

Management capability: More intensive systems demand high levels of technical knowledge and management capability. Invest in your own skills development and engage expert advisors where needed.

Risk mitigation strategies

Practical steps to manage investment risks include:

- Maintain conservative financial ratios with adequate equity buffers
- Use comprehensive sensitivity analysis to understand downside and upside scenarios
- Stage investments where possible to test systems before full commitment
- Carry enough feed inventory (including irrigation water) on hand to provide a buffer from extreme seasons or commodity price changes
- Diversify feed sources and consider forward purchasing strategies
- Build strong relationships with advisors and industry networks
- Maintain adequate insurance coverage
- Keep liquidity reserves for unexpected challenges
- Plan for animal health and biosecurity in intensive systems
- Avoid overstocking new infrastructure too quickly - allow time for systems and staff to adapt
- Have contingency plans ("Plan B") if things don't proceed as expected
- Review and update your business plan regularly.

Measuring investment performance

Establishing clear metrics and tracking them over time helps you evaluate whether the infrastructure is delivering expected returns and identify areas needing attention.

Return on Total Assets (ROTA)

ROTA measures how efficiently the business uses all its assets to generate profit.

Payback period

Payback period measures how long it takes for cumulative cash flows generated by the investment to equal the initial outlay. For major dairy infrastructure, payback periods of 10 to 15 years are common, though this varies depending on the scale and nature of the investment.

Growth in equity and net worth

Ultimately, successful investment should increase your business net worth over time. After making a large investment, net worth may initially remain flat as equity percentage falls and you work through the transition period. However, over time, improved profitability should rebuild equity and grow net worth. Tracking this annually provides a clear signal of investment performance. The cost of depreciating assets needs to be built into these calculations.

Preparing for discussions with lenders

When major investment requires external financing, lenders need confidence that your business can service the debt and that you have thoroughly evaluated the investment. Understanding what lenders look for significantly improves your chances of securing finance on favourable terms.

What lenders assess

Banks generally evaluate applications using five key criteria (the "five C's"):

Character: Your track record, management capability, and history. Strong historical performance, particularly through challenging periods, strengthens your application.

Capacity: Your ability to generate sufficient cash flow to service debt, assessed through historical financial statements, detailed cash flow projections, and stress-tested sensitivity analysis.

Capital: Your equity position and contribution to the investment. Strong equity provides buffer for both you and the lender.

Collateral: The security available to the lender. Banks apply specific lending ratios to different asset types (typically 60-70% for land, 50% for water, 40-60% for livestock, 25-50% for infrastructure). This means the security value may be substantially less than your asset values.

Conditions: External factors affecting your business such as climate, market conditions, and regulatory environment.

How banks calculate borrowing capacity

While your equity percentage indicates financial strength, banks calculate borrowing capacity differently. They:

- Apply specific lending ratios to each asset type (see table earlier in this chapter)
- Calculate total security value based on these ratios
- Typically lend up to 60% of total security value (loan to value ratio or LVR)
- Require minimum equity levels (often 40-55% depending on the lender and situation).

Infrastructure assets like contained housing typically contribute 25-50% of construction cost to total security value (due to limited comparable sales data and specialised nature). This gap between construction cost and security value can create borrowing constraints even when equity levels appear adequate.

Interest coverage requirements

Lenders assess serviceability using interest coverage ratios, calculated as:

Interest Coverage Ratio = EBIT ÷ Interest Expense

Most banks require minimum ratios of 1.25 for farming operations. However, they stress test using interest rates 1.5-2.5% higher than current rates to ensure your business can withstand rate increases.

Banks want to see that you can do better than just paying interest - you need demonstrated capacity to repay principal or reinvest in the business.

Documentation requirements

Approach your lender with comprehensive documentation including:

- Written business plan showing strategic alignment
- Three years of historical financial statements
- Current balance sheet
- Detailed capital budget
- Five-year cash flow projections covering all three phases
- Physical budgets supporting financial projections
- Sensitivity analysis across multiple scenarios
- Professional quotes or estimates
- Planning approvals or progress evidence
- Details of proposed financing mix (debt and equity).

How major investment impacts your financial position

When planning a major investment, it's essential to understand both how your equity position will change and whether you have sufficient borrowing capacity.

Banks assess your assets differently than you might value them on your balance sheet. Understanding these differences is crucial when planning major infrastructure investment:

Asset type	Typical bank lending ratio
Land	60-70% of market value
Water Rights	50% of market value
Livestock	60% (based on conservative long-term values, not current market)
Cash/Term deposits	100%
Machinery and plant	Variable, but normally 0% of book value
New Infrastructure (buildings, dairy, feedpads)	Variable, often 25-50% of construction cost minus depreciation
Overall security position	**Typically 50-60% of total asset value**

Infrastructure like concrete feedpads and contained housing facilities present particular asset valuation challenges. Banks typically value these at 25% to 50% of total construction cost, depending on factors such as:

- Comparable sales data (which is limited for specialised dairy infrastructure)
- Quality of construction and materials
- Functionality and flexibility of the design
- How well it fits with other infrastructure (e.g. milking plant)
- Size of property (what proportion of the overall value would be attributed to the infrastructure).

The example below demonstrates how these impacts may be calculated using an 800-cow farm considering contained housing infrastructure.

Category/Item	Before investment	After investment
Assets		
* Land and buildings (at market value)	$7,000,000	$7,000,000
* Water	$2,000,000	$2,000,000
* New infrastructure ($4 million investment @ 40% of its construction cost)	$0	$1,600,000
* Livestock	$2,000,000	$2,000,000
Existing plant and machinery	$900,000	$900,000
New plant and machinery	$0	$900,000
Feed inventory	$300,000	$300,000
* Cash (deposit for infrastructure)	$500,000	$0
Total assets at market value	**$12,200,000**	**$14,700,000**
Liabilities		
Bank debt	$3,500,000	$3,500,000
Existing machinery loans	$100,000	$100,000
New borrowing	$0	$3,500,000
New machinery loans	$0	$900,000
Total liabilities	**$3,600,000**	**$8,000,000**

Category/Item	Before investment	After investment
Equity position		
Equity ($)	$8,600,000	$6,700,000
Equity (%)	70%	46%
Bank security calculation		
Land and buildings (60%)	$4,200,000	$4,200,000
Water (50%)	$1,000,000	$1,000,000
New infrastructure (40%)	$0	$1,600,000
Livestock (60%)	$1,200,000	$1,200,000
Plant and machinery (0%)	$0	$0
Feed inventory (0%)	$0	$0
Cash (in term deposit) (100%)	$500,000	$0
Total Bank Security Value	**$6,900,000**	**$8,000,000**
Lending ratios		
Loan to Bank Security Ratio (ideally below 100%). Excludes machinery loans	52%	88%
# Loan to Market Value Ratio (ideally below 60-70%)	32%	56%

* Denotes assets that the bank will likely consider when determining equity and lending amounts.
# Excludes the cash asset.

Key observations:

- The farm's equity reduces from 70% to 46%, reducing financial resilience
- The loan to security ratio of 88% is below the limit that most banks could considering lending to but doesn't leave much room to move.
- The new infrastructure only adds $1.6m to security value (despite $4m construction cost), creating a $2.4m hit to equity. To proceed, the farm may need either additional equity contribution, reduced project scope, or alternative financing arrangements.

This example illustrates why understanding both your equity position (for financial resilience) and potential borrowing constraints (for financing feasibility) is essential when planning major investments.

A banker's perspective on applications

What separates strong from weak applications:

Strong applications demonstrate:

- Clear articulation of strategy and investment alignment
- Realistic budgets based on sound physical planning
- Comprehensive sensitivity analysis showing sustainable performance under stress
- Evidence of thorough due diligence and professional advice
- Detailed project management plans for large investments
- Understanding of both opportunities and risks.

Weak applications often:

- Treat infrastructure as a solution to immediate problems rather than strategic investment
- Present optimistic budgets without adequate stress testing
- Underestimate total costs or working capital requirements
- Lack project management detail and risk mitigation plans
- Show inadequate understanding of ongoing operational requirements.

Common mistakes to avoid:

- Approaching banks too late in planning
- Underestimating the gap between construction costs and security value
- Failing to account for transition challenges
- Inadequate contingency planning
- Not having a "Plan B".

Key takeaways and action steps

Bottom line: Infrastructure investment should only proceed when it clearly aligns with your long-term business strategy, your business has the financial strength to support it (both equity and cash flow), and you have thoroughly evaluated and prepared to manage the associated risks.

Strategic alignment:

- Develop your strategy before focusing on financial assessment
- Develop comprehensive business plans
- Ensure investment supports your long-term vision and succession plans
- Use the Farm System Evaluator tool strategic plan template to support your proposal.

Financial assessment:

- Understand your equity position and how the investment will impact it
- Model both your equity percentage and potential borrowing capacity constraints
- Calculate debt servicing under current and stress-test interest rates
- Develop detailed cash flow budgets covering construction, transition, and operational phases
- Use tools such as DairyBase to analyse your performance.

Risk management:

- Conduct sensitivity analysis across milk production, milk price, feed cost, interest rate, and fodder production scenarios
- Consider staged implementation where possible
- Plan for realistic transition timeframes and learning curves
- Maintain adequate buffers and avoid maximum leverage
- Have contingency plans.

Lender engagement:

- Start conversations 6-12 months before you need finance
- Prepare comprehensive documentation
- Understand the difference between your equity and bank security calculations
- Demonstrate thorough evaluation and professional engagement.

Next steps

- **Develop or update a business plan**
- **Prepare current balance sheet and understand both your equity and potential bank security position**
- **Visit farms that have made similar investments**
- **Engage appropriate professional advisors**
- **Develop preliminary budgets and test under multiple scenarios**
- **Review the Dairy Farm Monitor Project TMR research**
- **Start early conversations with your lender**

Glossary

Term	Definition
Earnings Before Interest and Tax (EBIT)	Gross Farm Income minus Total Operating Costs.
Equity (Total Equity)	Total Farm Assets Owned minus Total Liabilities.
Equity Percentage (Equity as % of Owned Assets)	(Total Equity/Total Farm Assets Owned) × 100.
Gross Farm Income	Total farm income, including cash and non-cash income (e.g., feed and livestock inventory changes).
Interest Coverage Ratio	A measure of the ability to meet interest payments from operating profit. Calculated as: EBIT ÷ Interest Expense. Banks typically require minimum ratios of 1.25 and test using sensitised interest rates.
Livestock trading profit	An estimate of the annual contribution to gross farm income by accounting for the changes in the number and value of livestock during the year. It is calculated as the trading income from sales minus purchases, plus changes in the value and number of livestock on hand at the start and end of the year, and accounting for births and deaths.
Loan to Security Ratio (LVR - Loan to Value Ratio)	The proportion of the bank's assessed security value that is borrowed. Banks typically lend up to 60% of security value for dairy farm infrastructure investments.
Net Farm Income	EBIT minus Total Finance Costs.
Number of milkers	Total number of cows milked for at least three months. In a seasonal calving herd this is normally the number of cows milked at 3-4 months after calving starts. For a split calving herd this is normally the number of cows being milked before starting to dry off the next group of cows. For a year-round calving herd, the average number of cows milked for the year plus 20% is normally fairly close.
Overhead Costs	All fixed costs incurred by the farm business that do not vary with the level of production. These include cash overhead costs such as employed labour and non-cash costs such as imputed owner-operator labour, family labour and depreciation of plant and equipment. It excludes interest, lease costs, capital expenditure, principal repayments, drawings, and tax.
Payback Period	The length of time required for the cumulative cash flows generated by an investment to equal the initial outlay.
Return on Equity (ROE)	A profitability measure showing the rate of return generated on the owner's equity invested in the business, after all operating and finance costs. Calculation: ROE (%) = (Net Farm Income after Interest and Lease Costs ÷ Owner's Equity) × 100.
Return on Total Assets (ROTA)	A measure of the profitability of the farm relative to its total assets. Calculation: Earnings before interest and tax (EBIT) ÷ total assets managed.
Security Value	The value banks assign to assets for lending purposes, which differs from market or book values. Banks apply specific lending ratios to different asset types (e.g. 60% for land, 25-50% for infrastructure).
Sensitivity Analysis	Testing how an investment or business performs under different scenarios by varying key assumptions such as milk price, feed costs, interest rates, or production levels.
Serviceability	The ability of a business to generate sufficient cash flow to meet debt repayment obligations.
Total Assets Managed	Sum of owned and leased farm assets.
Total Farm Assets Owned	Sum of Total Current Assets and Total Non-Current Assets.
Total Finance Costs	All interest paid on farm-related debt and lease payments on farm land (for leases longer than 12 months).
Total Liabilities	Average of current and non-current farm liabilities over the year.
Total Mixed Ration (TMR)	A feeding system where all dietary ingredients are mixed together and fed as a complete ration, typically associated with zero-grazing contained housing systems.
Total Operating Costs	Sum of all variable costs and total overhead costs (both cash and non-cash).
Total Usable Area	Total hectares managed minus the area of land which is of little or no value for livestock production e.g., house, shed area, laneways, channels. Often this makes up 10-15% of total area.
Total Variable Costs	Sum of herd, shed, and feed costs.

Further information and resources

Visit **dairyaustralia.com.au** and search for:

- **Farm Systems**
- **Our Farm Our Plan**
- **DairyBase**
- **Farm System Evaluator**
- **Dairy Farm Monitor Project**

For professional advice, consider engaging agricultural consultants, accountants, engineers, financial advisors, and legal advisors. Your regional Dairy Australia or state dairy organisation can provide referrals.

Disclaimer: The information in this chapter is provided as general guidance only. Every farm business is different, and decisions about major infrastructure investment should only be made after thorough evaluation of your specific circumstances with qualified professional advisors. Neither Dairy Australia nor the authors accept liability for decisions made based on this information.

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1.3 Long-term farm planning

Long-term planning is essential when considering the development or upgrade of feedpads, loafing areas or contained housing, because these changes alter how a dairy operation functions as a system. As feeding and housing practices intensify, the farm gradually shifts from a primarily pasture-based operation to one that relies more heavily on constructed infrastructure, stored feed and mechanised processes. This shift affects day-to-day operations, environmental risk pathways and how the property is viewed under planning legislation.

When cattle spend longer periods off pasture, manure and nutrients become more concentrated in defined areas rather than being dispersed across the landscape. Effluent capture, storage and reuse requirements increase, and more complex systems for capturing, conveying or storing manure and effluent may be needed. Feed storage and handling also become more substantial as reliance on imported fodder or mixed rations grows, resulting in increased vehicle movements, traffic generation and interactions with laneways, roads and neighboring land uses. Energy and water use often rise due to the operational needs of contained housing facilities, while monitoring, maintenance and biosecurity practices become more comprehensive.

These changes mean that intensification is not merely the addition of new buildings; it represents a transition in both land use classification and operational behavior. Planning frameworks treat this shift seriously, particularly where manure, effluent or farm activity increases to a level that creates potential impacts beyond the farm boundary. A long-term, whole-farm assessment allows the proponent to consider how new infrastructure will integrate with existing laneways, dairy sheds, feed systems, effluent and manure storage, cropping areas and nutrient reuse zones. It also provides the opportunity to anticipate future expansion and ensure that early decisions do not constrain or compromise long-term development.

A carefully considered long-term plan leads to a more resilient and efficient farming system. It ensures that the environmental and community expectations associated with more intensive dairy operations are identified at the outset and addressed through appropriate siting, design, management and documentation.

When planning any new feedpad, loafing area or contained housing facility, it is important to consider the development within the context of the whole farm system rather than as a single piece of infrastructure. Future needs such as dairy upgrades, maternity and calf raising areas, commodity and feed storage, water storage capacity, silage layout, laneway networks, manure storage expansion, energy demand and traffic movements should be assessed together to ensure the proposed system does not limit long-term growth or create operational bottlenecks. Taking a whole-farm approach early in the planning process reduces the risk of outgrowing the design, avoids duplicated expenditure and helps to ensure that new infrastructure strengthens the efficiency, resilience and sustainability of the entire farming operation.

1.4 Early planning for feeding and housing investment

Analyse drivers for change

The first step before purchasing or constructing infrastructure or making a farm system change is clearly understanding and being able to articulate the key motivators for change, the desired objectives, and anticipated outcomes. It is critical at this stage to consider the long-term vision for the property.

Use Farm System Evaluator – an on-line decision tool to help identify the most suitable farm system and infrastructure

A useful starting point is the Farm System Evaluator, an online decision-support tool developed by Dairy Australia and Agriculture Victoria to help farmers assess their readiness for different feeding and housing systems. The tool guides users through the key drivers for change, compares the implications of alternative farm system pathways and focuses on twelve key performance indicators for the business.

Working through the tool early in the process helps clarify whether the proposed direction is appropriate and what level of investment or system change is required.

Consult a financial adviser

Consulting a financial adviser, lender or potential investment partner early in the process is an important step once the preferred direction for the farm has been identified. These discussions help clarify the economic rationale for the development, confirm the scale of investment required and ensure that the proposal is financially viable before detailed design work begins.

A benefit–cost analysis or similar assessment can provide confidence that the long-term gains justify the capital expenditure. It is also valuable at this stage to identify the key points at which finance may need to be released to manage cashflow throughout the various stages of the project.

Test concepts and options

Testing ideas with trusted advisers, business partners or other farmers who have already adopted similar systems can provide valuable insights. Visiting farms that operate comparable infrastructure allows proponents to see how the facilities functions day-to-day, understand labour and management requirements, and consider whether the proposed system will fit the property, climate and herd.

Consult specialists

Engaging professional consultants, industry specialists or government officers early in the process can help refine the concept and identify issues that may not be immediately apparent. Discussing ideas with trusted advisers, industry bodies and experienced practitioners allows a balanced view from a range of informed opinions ensuring opportunities, challenges and benefits are considered,

Where consultants or designers will play a formal role, it is essential that the relationship is clearly documented from the outset. A written agreement should set out the scope of work, responsibilities, deliverables, timelines, costs, payment arrangements and any relevant insurance or safety requirements. Clear documentation supports good communication, reduces the risk of misunderstanding and provides appropriate protection for all parties involved in the project.

Consult system designers

Input from system designers can help determine how proposed feeding or housing infrastructure will integrate with existing laneways, dairy sheds, water systems, commodity storage, paddocks and surrounding land uses. Considering these relationships at the outset ensures that site layout, access, nutrient management and service connections are efficient, workable and consistent with planning requirements.

The Australian Dairy Industry has access to a list of accredited Effluent System Designers who have completed Agriculture Victoria's and Dairy Australia's national Design Livestock Effluent Systems training and therefore have access to relevant design toolkits and technical information.

agriculture.vic.gov.au/livestock-and-animals/dairy/managing-effluent/effluent-system-designers

Develop timeline schedules

An aspect of project management that is often underestimated is timelines, given the amount of work required to take the proposed concept through construction to operation. Complexities can arise depending on the development type, chosen site, planning requirements and assessments, locality complexities and separation distances from sensitive land uses such as neighbours and waterways, and the coordination of multiple professional services. Timelines for larger investments can take a minimum of ten months and even longer should the development attract objectors.

1.5 Core documentation required for dairy development

As dairy farm systems become more advanced and incorporate higher levels of feeding, housing and operational management, the documentation required to support planning and environmental approvals becomes more detailed. Authorities generally expect a clear explanation of how the increased operational requirements—such as feed handling, labour, housing, manure and nutrient generation, storage, reuse and overall farm activity—will be managed. The purpose of this documentation is to demonstrate that the proposal has been thoroughly considered and that any risks associated with intensification have been appropriately addressed.

A Statement of Environmental Effects, Environmental Impact Statement, Review of Environmental Factors or equivalent assessment document describes the proposed development, its construction, commissioning and operation, and the way in which it may affect the surrounding environment and community. It explains how the development will function within the broader farm system and considers matters such as changes to drainage patterns, effluent and manure handling processes, traffic and feed delivery movements, and any potential odour, dust or noise impacts. The level of assessment required varies between jurisdictions and depends on the scale and complexity of the proposal as well as the sensitivity of the surrounding area.

A Manure and Effluent Management Plan, required with any application, provides the technical details behind the design of the manure and effluent system. It describes how effluent will be collected and conveyed, how storage structures have been sized according to herd numbers and local climatic conditions, how solids will be managed including their application to land in accordance with a nutrient budget. This document demonstrates that the system has been designed to safely manage the increased loads associated with more structured feeding and housing arrangements.

Other documents may also be required as part of approval conditions. A Construction Management Plan generally outlines how construction activities will be managed to minimise risks such as erosion, sediment movement, dust, noise, traffic disruption and impacts on water quality. It also describes how temporary works, stockpiling, contractor movement and site access will be controlled during the build phase.

An Environmental Management Plan (EMP) outlines how environmental risks will be managed once the facility is operational. It includes procedures for monitoring effluent storage levels, maintaining pumps and infrastructure, managing nutrient applications within approved limits, responding to incidents or complaints and meeting any regulatory conditions or reporting obligations. This plan is a working document that guides day-to-day management and ensures the dairy continues to operate in accordance with its approvals.

Together, these documents demonstrate that the proposed development is well designed, technically robust and capable of operating in an environmentally responsible and sustainable manner over the long term.

1.6 Overview of the planning pathway

Although each state and territory has its own legislation and approval processes, most dairy developments involving new feedpads, loafing areas or contained housing follow a similar overall pathway. The process begins when an application is lodged with the responsible authority. The authority first checks that all required information has been provided and that the proposal is clear and complete. This early stage often determines whether additional supporting documents are needed before the assessment can progress.

Once accepted, the application is generally referred to other government agencies that have a role in land use planning, environmental protection, water management or public health. Most jurisdictions also require the proposal to be advertised or notified so that neighbours and the community are aware of the project and have the opportunity to provide feedback. The length and form of public exhibition vary, but the purpose is consistent: to ensure transparency and give interested parties the chance to raise any concerns.

If the assessment authority or referral agencies require clarification or additional technical information, they may issue a request for further information. This step is common where proposals involve new or expanded feeding or housing systems, because the authority must be satisfied that issues such as effluent storage, nutrient reuse, drainage, traffic movement and amenity impacts have been properly addressed.

Once all information has been provided, the authority assesses the application, considers agency advice and community submissions, and then decides whether the proposal should be approved or refused. If approved, the permit or consent will usually contain conditions that must be followed during both construction and operation. These may include requirements for erosion and sediment controls, environmental monitoring, infrastructure maintenance, reporting, or limits on how the system is operated. Additional permissions, such as building or construction permits, may still be needed before works can commence.

Most jurisdictions also provide an avenue for appealing decisions or conditions if the applicant or an affected party believes the assessment did not properly consider the evidence. The details of these appeal pathways differ across states and territories and are explained further in Chapter 3, which outlines the specific requirements for each jurisdiction.

02

Planning controls, overlays and surrounding land use

Selecting an appropriate site for feedpads, loafing areas or contained housing is one of the most important decisions in the development process. A well-chosen site reduces environmental risk, supports animal welfare and operational efficiency, and simplifies the approvals process. Conversely, a poorly chosen site can require extensive engineering, complex management systems and greater regulatory scrutiny. This chapter outlines the key factors to consider when evaluating a potential development site, and how these factors influence the design and approval requirements described in later chapters.

2.1 Zoning, overlays and surrounding land use

Every dairy development must be compatible with the planning zone and any overlays that apply to the land. A preliminary review should identify whether the proposed use is permitted, whether a planning permit or development approval is required, and whether additional approvals are triggered by overlays such as flood, bushfire, heritage, erosion, salinity or water-protection controls. Surrounding land uses such as neighboring houses, towns, community facilities, tourist accommodation or sensitive agricultural industries should also be considered, as they influence siting decisions and potential amenity impacts. Specific approval triggers and zoning requirements for each state and territory are outlined in Chapter 4.

Planning schemes may also include overlays that identify land subject to specific environmental or natural resource constraints such as salinity, acid sulfate soils, drinking water catchments, erosion-prone land, geotechnical hazards or strategic agricultural land. These constraints can influence the suitability of a site or require additional investigation to demonstrate that the development will not compromise the environmental or resource values of the area. In regions with multiple intensive farms, authorities may also consider cumulative impacts, particularly where several operations contribute to odour, dust, nutrient loading or traffic in the same locality.

2.2 Climate and meteorology

Local climate plays a major role in determining the suitability of a site and the type of infrastructure required. Key factors include rainfall, storm frequency, evaporation rates, temperature extremes and prevailing wind directions. These conditions influence effluent storage sizing, drainage requirements, orientation and the likelihood of odour or dust affecting neighboring properties. Understanding the site's wind climate is particularly important when considering proximity to sensitive receptors.

2.3 Topography, slope and drainage

Topography determines how water moves across the landscape and affects the extent of earthworks required for construction. Moderate, uniform slopes generally support efficient drainage and reduce the risk of clean water entering the dairy complex. Steep or uneven slopes may require significant cut and fill, retaining structures, or detailed engineered drainage systems. Early identification of natural flow paths helps avoid locations where runoff may concentrate or flow toward waterways or neighboring land.

2.4 Soils, groundwater and land capability

The soil and groundwater conditions of a site influence how well it can support feedpads, loafing areas, contained housing and the associated effluent and manure management systems. Basic soil characteristics—such as texture, structure, drainage behaviour, salinity and sodicity—affect the stability of foundations, the performance of effluent storages and how nutrients can be safely applied to surrounding land. Shallow groundwater or seasonally wet soils may increase the level of design consideration needed but do not necessarily prevent development.

For most proposals, a straightforward description of the soil profile and general groundwater conditions is sufficient at the site selection stage. Where the site presents more complex issues—such as highly permeable soils, very shallow groundwater, saline or sodic profiles, or areas prone to waterlogging—more detailed assessment may be required to confirm suitability and to guide the design of storages, drainage and nutrient reuse areas. These investigations and design requirements are outlined in Chapter 5, which covers site investigations, earthworks and the technical information needed to support construction.

Choosing a site with soil and groundwater conditions that can comfortably support the proposed infrastructure will reduce the need for extensive engineering and long-term management. Where constraints exist, they can often be managed through appropriate design and construction, but early identification helps avoid unexpected costs and delays.

2.5 Surface water, waterways and flood risk

The relationship between the proposed development and surface water features is critical. Sites located close to waterways, drains, channels, dams or wetlands require careful consideration to avoid nutrient runoff, flooding impacts or unauthorised discharge. Flood-prone land can limit construction timing, damage infrastructure and increase the likelihood of manure or effluent reaching surface waters. Preliminary site assessment should include identification of natural drainage lines and evaluation of the site's ability to maintain safe buffer distances.

Note

Additional requirements may apply in designated water supply catchments, irrigation districts or drainage board areas. These authorities often regulate setbacks from channels, drains and storages, and may require specific controls such as nutrient load limits, drainage licensing or buffer zones to protect public water infrastructure.

2.6 Amenity and sensitive receptors

Amenity considerations relate to how the development may affect neighboring land through odour, dust, noise, light spill or visual impact. Identifying sensitive receptors early allows the proponent to choose a site where impacts are naturally minimised through distance, topography or vegetation. At the siting stage, the focus is on mapping receptor locations and understanding prevailing wind and traffic patterns. Detailed design and management measures that address amenity impacts—such as odour management, dust suppression, noise reduction and lighting controls are generally required in an application.

In addition to dwellings, schools and community facilities, sensitive receptors may also include tourism accommodation, short-stay rentals, campgrounds, recreation facilities, health and aged-care services and worker accommodation. Some jurisdictions regard sensitive agricultural uses—such as viticulture, horticulture or certified organic production—as receptors where dust, spray drift or odour may compromise operations.

2.7 Biosecurity and emissions

Biosecurity and emissions risk should also be considered when selecting a site for feedpads or contained housing. Dairy systems can generate localised emissions such as odour, dust, noise, light spill and increased vehicle movement, and these are best managed when the site provides adequate separation from neighboring dwellings, public facilities and other sensitive uses.

Similarly, biosecurity risks increase where cattle, people and vehicles move through confined or high-traffic areas, especially near boundaries or shared access points. Choosing a site that supports controlled access, clearly defined traffic routes and appropriate distance from neighbouring livestock enterprises reduces the likelihood of disease transfer, conflict with other land users or off-site amenity impacts.

2.8 Biodiversity and heritage

All proposed development sites must be assessed for potential impacts on biodiversity and cultural heritage. Matters to consider include remnant native vegetation, threatened species or communities, waterways with ecological value, and areas of Aboriginal or historic heritage significance. In many jurisdictions, specialist assessments may be required to demonstrate that impacts have been avoided or minimised and to determine whether offsets or management plans are needed.

2.9 Access, roads, services and traffic

The suitability of a site also depends on its ability to support increased vehicle movements, feed deliveries, milk collection and staff access. Road condition, visibility at entry points, bridge load limits, and available turning space should be assessed. The availability and reliability of services such as electricity, stock water, telecommunications and fire access are also important. Traffic generation and service requirements must be considered in any system change and described in an application.

2.10 Confirming site suitability

A suitable site reduces the complexity of approvals, supports cost-effective construction and simplifies long-term environmental compliance. Where initial assessment identifies elevated risks—such as steep topography, shallow groundwater, proximity to waterways or close neighbours—the proponent should consider alternative locations or be prepared for enhanced design and management measures and significant conditions of consent. The site evaluation process forms the foundation for the planning pathway described in Chapter 3 and ensures the chosen location can safely and sustainably support the proposed system.

In regions with multiple intensive livestock operations, the assessment of site suitability may also need to include consideration of cumulative impacts. These can include combined odour or dust loads, shared traffic routes, aggregate nutrient contributions to catchment or cumulative effects on neighbours' amenity.

03

Application process and approvals

Overview

Dairy feedpads, loafing areas and contained housing systems require careful planning to ensure they comply with land use, environmental and building requirements in each state and territory. Although approval processes differ across jurisdictions, the overall pathway is broadly consistent nationwide.

This chapter outlines the typical steps involved in seeking approval for new or upgraded dairy infrastructure, including when approvals are likely to be needed, the types of information authorities expect, and how applications are assessed.

The process begins well before lodgement, with concept development, site confirmation and consultation with the relevant authorities. Once a proposal progresses to lodgement, the responsible authority will assess the application, consult referral agencies and consider any community feedback before issuing a decision and associated conditions. Additional approvals are often required following a planning decision, and these must be obtained before construction can begin.

Construction preparation, detailed investigations, staging considerations and commissioning requirements are also considered in this section.

3.1 Overview of approvals and dairy developments

Dairy developments involving feedpads, loafing areas or contained housing usually require several types of approval, although the exact combination varies across jurisdictions. Most projects begin with **planning or development approval,** which confirms that the proposed land use, infrastructure and siting are appropriate for the location. This approval considers zoning, overlays, potential environmental impacts and the relationship with neighboring properties.

Some proposals also require **environmental approvals or licences**, triggered by herd size, effluent storage volumes or overall risk. These approvals ensure the development protects soil, water, air quality, biodiversity and amenity, and may include monitoring, reporting and operational conditions. The thresholds differ between states and are summarised in Chapter 4.

Before construction begins, most developments also need **building** or **construction approval** to verify engineering standards, structural integrity and compliance with any planning conditions. Depending on the proposal, additional permits may be required, such as road access approvals, works on waterways, or adjustments to water use licences.

Because requirements vary, once the development type (contained, grazing etc) and scope (concept plans) is known, early consultation with the responsible authority and building certifiers is essential to confirm which approvals apply and the order in which they must be obtained.

3.2 Understanding whether approval is required

Whether a proposal requires approval depends on how the development is classified under local or state planning schemes. These schemes distinguish between grazing-based systems and systems that rely more heavily on constructed infrastructure and imported feed (Chapter 1). Developments involving new feedpads, loafing areas or contained housing often trigger the need for a permit because they increase the concentration of cows, feed, traffic and effluent handling within a defined footprint.

Expansions to existing facilities or significant changes to feed or housing practices may also require approval, particularly where they increase herd numbers, alter runoff pathways, change the volume of effluent generated or modify the land use classification.

Approval triggers may also relate to overlays, environmental sensitivity, proximity to waterways, flood risk, salinity risk, heritage constraints or the presence of nearby sensitive receptors. These elements reinforce why early site selection, described in Chapter 2, is important in determining the approvals pathway. The detailed requirements for each jurisdiction are provided later in this chapter (Part 3.5).

3.3 Typical approval pathway

While the level of detail will vary depending on the scale and complexity of the proposal, early understanding and planning provides a clear direction on site opportunities and constraints, the regulatory requirements that apply, the expertise needed to prepare the application, and the likely flow and timing of the decision-making process. Well-prepared applications reduce delays by minimising the need for authorities to request further information.

Planning

The planning stage begins by identifying potential sites, confirming the intended production system, and preparing preliminary layout concepts that reflect operational requirements and environmental performance expectations. Stages of the development and their timing are also important to define.

At this point, proponents are encouraged to meet with the responsible authority and any other relevant agencies to confirm approval triggers, assessment criteria and documentation requirements. These early discussions often occur through a pre-lodgement meeting and, for larger or more complex developments, may include advice on community engagement expectations or the need to prepare a Scoping Report and lodgment to the State Planning Department for the Environmental Assessment Requirements.

Preparation

A development proposal is then documented in a report (EIS, SEE, REF) that clearly describes the proponent, the site, the nature and scale of the proposed development, and how the system will operate. This includes information on herd numbers, feeding and housing arrangements, site layout plans, manure and effluent management systems, nutrient reuse strategies, and any planning overlays or environmental considerations relevant to the property. The report should also identify potential environmental and amenity impacts, outline how these will be managed, and describe the monitoring or intervention measures proposed. Once the report and supporting technical documents are complete, the relevant application forms and checklists are prepared and lodged in the format required by the authority.

Lodging the application

Lodgement begins the formal approval process. Most jurisdictions operate under statutory timelines, and the responsible authority coordinates referrals to other agencies, manages notification or public exhibition processes where required, and issues the final decision. Local government is usually the decision-making authority, although regional planning panels or state ministers may determine applications of regional or state significance.

Information and referral stage

After the application is lodged, the authority first checks whether all required information has been provided. If satisfied, fees are confirmed and the assessment period formally begins. The application is then referred to any agencies with responsibilities that may be affected by the proposal, such as those overseeing environmental protection, water resources, road safety, heritage or biodiversity. The proposal is also advertised or publicly notified, which may include letters to neighbours, publication on the authority's website or notices in local media.

Referral agencies may respond with no objection, no objection subject to conditions, or an objection. They may also request further information if additional detail is required to assess the proposal. When this occurs, the authority will advise the proponent in writing, outline the information needed and specify the timeframe for response. Assessment timeframes may pause during this period. Once additional information is provided, it is circulated to referral agencies for review.

The responsible authority then considers the referral responses, any public submissions and the internal assessment before reaching a decision.

Pathway to a decision

The authority may approve the application as submitted, approve it with conditions or refuse it. For approvals, the proponent may either accept the conditions or seek a review of them. If the development is approved and the conditions are accepted, the proponent must observe any statutory appeal period that may apply. Following this, additional approvals—such as building permits, construction certificates, environmental licences or road access permits—must be obtained before construction and operation can commence.

If a proposal is refused, or if the applicant disagrees with the conditions of approval, appeal mechanisms may be available depending on the jurisdiction. Third-party appeal rights may also apply in some circumstances.

Disclaimer

These guidelines support but do not override federal, state or local legislation, regulations, planning schemes or policy frameworks. Authorities may assess applications in a manner or scope beyond that described here. Dairy operators must also comply with workplace health and safety, animal welfare, biosecurity and environmental protection obligations at all times.

3.4 Information commonly required in an application

The level of detail required in an application is influenced by the scale of the development, the sensitivity of the site and the potential for off-site impacts. Authorities generally expect information that clearly explains the proposed development, demonstrates an understanding of the site's environmental and amenity context and outlines how potential impacts will be managed.

Applications typically include a description of the proponent and property, the system type, herd numbers, feed and housing arrangements, infrastructure layout and staging. Site and environmental information are required to describe zoning, overlays, surrounding land use, climate, soils, groundwater, surface water, biodiversity and heritage. Technical information on manure and effluent management must demonstrate how ponds and storages have been designed, how drainage is managed, how nutrient reuse areas have been identified and how potential risks such as odour, dust, noise and runoff will be mitigated specific to the site and development.

Plans and drawings commonly include site location plans, layout plans, drainage plans and any details required for ponds, storages or structures. Supporting documents may include an Environmental Impact Statement, Review of Environmental Factors or Statement of Environmental Effects, a Manure and Effluent Management Plan, nutrient budgets, odour or noise assessments where required, traffic assessments and/or construction-and operation phase management plans.

3.5 Preparing and submitting a complete application package

A well-prepared application package is one of the most effective ways to shorten assessment timeframes and reduce the likelihood of formal requests for further information. While the specific documents required will depend on the scale of the proposal and the expectations of the assessment authority, most dairy developments benefit from an approach that clearly explains the proposed system, demonstrates how environmental and amenity risks will be managed, and provides all technical information in a structured and easy-to-navigate format.

The application should begin with a clear description of the project, including the purpose of the development, the proposed feeding or housing system, the number and class of animals involved, and how the new infrastructure integrates with the existing farm layout. Authorities look for evidence that the proponent understands how the system will operate day to day, how traffic, feed delivery and effluent movement will be managed, and how these activities relate to surrounding land uses. Including a simple narrative supported by clear layout plans and site maps helps establish this context.

Reports and technical documents should be prepared by suitably qualified professionals and presented in a consistent, orderly manner. Manure and effluent system designs, nutrient budgets, soil assessments, drainage plans and engineering drawings are central to demonstrating that the development can operate safely and sustainably. These documents should show how storage volumes have been calculated, how clean and dirty water are separated, how manure solids and liquid effluent will be reused, and how the development aligns with national and state-based design guidance. A well-organised set of drawings, including location plans, site plans, cross-sections and hydraulic schematics, makes assessment substantially more efficient.

Authorities also expect applications to clearly address environmental risks such as odour, dust, noise, water quality, soil protection and stormwater management. Where relevant, the application should explain how buffers have been determined, how odour risk has been considered, and what measures will be used to minimise impacts on neighboring land uses. If the development involves significant changes to animal movement, staff access or visitor entry points, the application should also describe any updates to the farm's biosecurity procedures.

A key feature of a strong application is clarity. Each report should support the next, and the full package should tell a coherent story about how the development was designed, why it is suitable for the proposed site, and how it will be constructed and operated in a compliant manner. Many proponents benefit from including a short covering letter or application summary that explains what is included, how the documents relate to each other and how the proposal meets the requirements of the relevant planning scheme or development code. This simple step helps assessors navigate complex packages and minimises misunderstandings.

Finally, before lodgment, the full package should be reviewed against any published checklists, referral requirements or pre-lodgment advice provided by the assessment authority. Title searches, site plans, specialist reports and design documents should all be up to date, consistent and internally aligned. Submitting a complete, well-structured package reduces delays, improves confidence for both regulators and financiers, and provides a clear pathway for the subsequent construction and commissioning stages.

3.6 Receiving and understanding conditions of consent

Once a development approval or permit has been issued, it is essential to take the time to thoroughly understand the conditions of consent before commencing any works. These conditions form the basis on which the project may lawfully proceed and often set requirements that apply before, during and after construction. Failing to comply with conditions, even unintentionally, can result in delays, additional costs, or formal enforcement action.

Conditions may include pre-construction requirements such as submitting amended drawings, obtaining a building permit, providing a sediment and erosion control plan, confirming engineering certifications or installing temporary environmental controls. It is important to identify these early so that construction is not delayed by unmet prerequisites.

During construction, conditions may specify hours of work, dust management, noise or traffic, protection of drainage lines and native vegetation, and procedures for stockpiling materials or handling stormwater. For projects involving feedpads or contained housing, regulators may impose requirements to maintain clean and dirty water separation, protect watercourses, and ensure that effluent containment structures are built to approved design levels and compaction standards.

Operational conditions generally set out how the facility must be managed once completed. These may relate to herd capacity, manure and effluent management, pasture utilisation, buffer distances, odour control, monitoring frequency, and record keeping. Some jurisdictions also require commissioning reports, certification of infrastructure, or confirmation that all pre-operational work has been completed before commissioning the new system.

Understanding conditions of consent at the outset helps to plan construction sequencing, contractor responsibilities, and the timing of finance draws or equipment orders. The conditions should be read alongside the approved plans, engineering documents and any supporting assessments to ensure a consistent interpretation across the project team. Discussing the conditions with council officers or the relevant regulator can also assist, particularly where language is ambiguous or where conditions may overlap with other approval requirements.

A clear and shared understanding of the consent conditions reduces compliance risk, supports smoother project delivery, and ensures the system operates as intended once commissioned.

3.7 Construction and pre-commissioning

Once approvals have been granted and any associated conditions have been understood, the development moves into the construction and pre-commissioning stage. This phase is often the most resource-intensive, as it brings together contractors, equipment suppliers and technical specialists to turn the design into a functioning component of the farm system. Clear coordination, good documentation and consistent oversight are essential to ensure the work is completed safely, meet the approved plans and perform as intended once cattle enter the system.

Construction typically begins with establishing the site, confirming survey levels, marking out key structures and reviewing the approved drawings with the contractor team. Earthworks and drainage are usually the first physical activities. These early tasks set the foundations for the long-term performance of the feeding or housing area, so careful attention to site preparation, fall control, subgrade compaction and drainage installation is critical. Even small deviations at this stage can affect effluent flow paths, roofing alignment, or the effectiveness of clean/dirty water separation.

As structures such as feedpads, housing system structures, effluent channels, ponds and traffic areas take shape, construction quality must be monitored against the certified plans and engineering specifications. Many dairy developments involve multiple contractors—earthworks, concrete, plumbing, roofing, electricians, steel fabricators—and ensuring that each understands where their work integrates with the next reduces the risk of delays, rework or non-compliance. Regular site meetings, construction diaries and photographic records offer practical ways of tracking progress.

Throughout construction, the proponent must ensure that the conditions of approval are being met. These may include sediment and erosion controls, dust or noise management, working hours, protection of waterways, and constraints around vegetation removal or cultural heritage. Councils and regulators may undertake inspections during this period. Maintaining transparent communication and keeping all documents readily available helps avoid unnecessary disruptions.

As the project nears completion, the focus shifts from building the physical structures to ensuring that the system works safely and reliably in practice. This pre-commissioning stage involves confirming that pumps, scrapers, augers, rainfall diversion systems, stormwater controls, slopes, water troughs, fans, lighting and traffic flow arrangements perform as designed. Any commissioning required for effluent storage, lined ponds, pumps or automation equipment should be conducted according to manufacturer or engineering guidance. This is also the time to finalise operational procedures, update the farm biosecurity plan to reflect new entry points and movement patterns, review safety procedures, and ensure that all staff understand how to operate the new system.

Once final inspections have been completed and any required certification or sign-off has been provided by engineers, building surveyors or the approval authority, the system can transition into operation. Beginning with a short settling-in period—where cattle numbers are increased gradually and staff monitor performance closely—helps identify and resolve any minor issues early. A well-managed construction and commissioning phase not only supports compliance but also ensures the new infrastructure integrates smoothly into the broader farm system and delivers the production, animal welfare and environmental benefits intended.

04

State and territory planning and environmental resources

Dairy feedpads and contained housing developments are assessed under local, state and territory legislation. Although the principles of good design, environmental protection and community amenity are consistent nationally, the triggers, approval pathways, terminology and referral requirements differ between jurisdictions.

This chapter summarises the relevant planning and environmental frameworks for each state and territory, providing a clear starting point for determining the approvals that may apply to a proposed development. It does not replace local or state legislation. Instead, it assists proponents, designers and consultants to navigate the regulatory landscape by identifying the most relevant Acts, regulations, assessment triggers and supporting guidance.

Users should confirm requirements directly with the responsible authority, as planning schemes and environmental legislation are updated periodically and some developments may require more detailed assessment than what is outlined here. This chapter should be read in conjunction with Chapter 3, which explains the national approval process and the documentation typically required for dairy development proposals.

4.1 National guidelines, standards and codes

A number of national standards and technical resources apply to dairy farming and should be considered when developing or upgrading feedpads or contained housing systems. These documents do not replace state or local planning requirements but provide the foundational expectations for animal welfare, biosecurity, environmental protection, construction and livestock traceability across Australia.

Animal Welfare Standards

Australian Animal Welfare Standards and Guidelines for Cattle provides guidance for all people responsible for care and management of all cattle within Australia. Considerations of the objectives, standards and information within this document should be factored into any design and operating system.

animalwelfarestandards.net.au/welfare-standards-and-guidelines/cattle/

The *Australian Animal Welfare Standards and Guidelines for Cattle* set out the minimum expectations for the care and management of dairy cattle. These standards should be considered when designing feeding areas, housing, laneway systems and handling facilities.

Australian Animal Welfare Standards and Guidelines – Land Transport of Livestock are nationally agreed standards and apply to all persons involved in the livestock transport process. These should be referred to when proposing facilities that incorporate the holding, loading and unloading of livestock to ensure facilities comply with these requirements.

Land-transport-of-livestock-Standards-and-Guidelines-Version-1.-1-21-September-2012.pdf (animalwelfarestandards.net.au)

Biosecurity

Biosecurity Under the Commonwealth Emergency Animal Disease Response Agreement (EADRA), all dairy farmers must maintain an up-to-date property biosecurity plan and manage risks associated with animal movements, visitor access and potential disease transmission. When planning new or expanded feeding or housing systems, these obligations should be integrated into the design and operation of the facility. Particular consideration is needed where manure or effluent is exported off-farm, where visitor and vehicle movements increase, or where larger numbers of animals are accommodated in a single location. Planning should also account for Emergency Animal Disease (EAD) preparedness, including procedures for Death, Destruction and Decontamination (DDD), to ensure that facilities can support rapid and effective response actions if required.

Visit **dairyaustralia.com.au** and search for biosecurity.

Engineering and environmental design references

Beef Cattle Feedlots: Design and Construction describes the principles and engineering involved in the design of feedlots, associated facilities and in their construction.

Beef Cattle Feedlots: Waste Management Design and Utilisation identifies the management of waste (Manure and Effluent) generated within a site and its utilisation to enhance crop production. These documents have been prepared specifically for the beef cattle industry and are connected with most States Intensive Animal guidelines and Codes of Practice. Currently, most States have not incorporated specific intensive dairy definition within their planning schemes and as a result, contained dairy systems will often be treated or reviewed in line with both state and national guidelines for feedlots. It must be recognised that dairy feedpads and intensive dairy systems **are not** beef cattle feedlots, being systems that are operated for different outcomes and with different management strategies, however in many proposals will share similarities with some facilities utilised. These documents serve as an invaluable resource for technical information pertaining to common infrastructure. They also address system variances as necessary, offering valuable insights for planning and licensing purposes.

mla.com.au/research-and-development/feedlot/design-and-management/feedlot-design-manual/

mla.com.au/research-and-development/feeding-finishing-nutrition/Lotfeeding-intensive-finishing/odour-and-waste-management/manure-handbook/

Effluent and Manure Management Database for the Australian Dairy Industry is a repository of reliable and scientifically validated technical data on dairy effluent management adaptable to all dairying regions in Australia. This is a key reference document for Effluent Designers and Planners.

Visit **dairyaustralia.com.au** and search for effluent system management resources.

Construction and building requirements

The *National Construction Code (NCC)* sets the minimum requirements for buildings and structures across Australia. Part H3 (Farm Buildings and Sheds) outlines the specific performance and fire safety requirements for farm structures, including dairy feedpads, commodity storage areas and animal housing facilities. These requirements should be considered during detailed design and prior to seeking building approvals.

ncc.abcb.gov.au/editions/ncc-2022/adopted/volume-two/h-class-1-and-10-buildings/part-h3-fire-safety

bwanational.com.au/post/understanding-the-ncc-farm-buildings-and-farm-sheds

Livestock identification and traceability

The National Livestock Identification System (NLIS) Traceability Standards outline the mandatory requirements for identifying cattle and maintaining movement records. Where new yards, handling systems, entry points or expanded housing areas are proposed, proponents should ensure that NLIS obligations—such as scanning, recording and updating movements—can be met efficiently and accurately.

integritysystems.com.au/globalassets/isc/pdf-files/cattle-traceability-standards.pdf

National Guidelines for Dairy Feedpads and Contained Housing (this document) provides the industry and related bodies with up to date and key components of feedpads and contained housing systems.

4.2 State and territory requirements

Every new feedpad, loafing area or contained housing facility must meet the planning rules (or exemption requirements) of the State or Territory in which the property is located. While this guideline explains the technical and environmental aspects of good design, the legal requirements for getting a development approved are set by each jurisdiction, and by the local council responsible for the area. Understanding these rules early makes the whole process smoother, faster and far less costly.

Each State and Territory has its own planning laws and local planning schemes. These determine what can be built in each zone, which overlays apply to the land (such as flood, bushfire or water protection) and what information must be provided with an application. Councils also have their own requirements, and these may include additional assessments or referral steps. Most of these planning rules can be viewed using government online mapping tools, and in some places—such as Victoria and NSW—the Navigating Farm Developments tool makes it easier to bring this information together in one place.

Development applications are lodged either through a State planning portal (ACT, NSW, NT, SA) or directly with the local council (QLD, VIC, TAS, WA). Once lodged, the application is checked to make sure all required information has been provided. It may then be referred to other government agencies for advice, particularly where water, roads, biodiversity or public health requirements are involved. Talking with council and relevant agencies early in the process helps avoid surprises and reduces the chances of receiving a 'Request for Further Information' later on.

Before lodging, Proponents should obtain a current title search and title plan to confirm ownership and identify any easements or restrictions that could affect the proposal. Checking this information at the design stage avoids delays, redesign and additional cost during the assessment phase.

The following sections outline the planning and development requirements for each State and Territory. They provide a practical overview to help Proponents understand what is generally required before submitting an application. These requirements can change over time, so users should always confirm current rules, policies and guidance with their local council or State planning authority.

Summary of specific planning requirements by State/Territory

State	Class	Requirements
Australian Capital Territory	Intensive Animal Farming (No dairy-specific category)	No specific triggers identified for dairy operations. Proposals are assessed case-by-case under the Territory Plan.
New South Wales	Intensive Livestock Agriculture	> 50 cows – requires Development Approval with a Statement of Environmental Effects to be submitted with application. > 800 cows, Development Approval is considered to be a designated development and an EIS is required. Secretaries Environmental Assessment Requirements (SEARs) must also be detailed in application. Application may also trigger Regional or State significant development if project value exceeds trigger. Facility also requires an EPA licence to operate.
Northern Territory	Intensive Animal Husbandry	No dairy-specific thresholds identified. Assessment is based on scale, environmental sensitivity and water extraction requirements.
Queensland	Intensive Animal Husbandry	Applications are made as impact assessment applications and are code assessable. There are varying triggers depending on the number of cattle and their weight and the site. < 150 Standard Cattle Unit (SCU) may be self-assessable or exempt. > 150 SCU, development permit and environmental authority required. *Note: Council may also have its own local definition of intensive animal husbandry that should also be referred to.*
South Australia	Planning and Land Intensive animal husbandry, dairies and associated activities Services – PlanSA	> 100 cow milking sheds and facilities (including housed facilities with AMS) located within water protection area > 200 cows per day (average over 12-month period) within a prescribed water catchment area requires EPA licence and Development Approval. > 500 cows per day over any period of 12 months requires EPA licence and Development Approval.
Tasmania	Intensive Animal Husbandry	No specific dairy thresholds identified.* Assessment depends on location, catchment, nutrient management capacity and whether conditions in the State Policy on Water Quality Management 1997 or planning scheme overlays are triggered.
Victoria	Intensive Animal Husbandry	Up to 1,000 head capacity: planning permit may not be required however application must be lodged with Council and approved. > 1,000 head capacity: planning permit required. > 5,000 head capacity, EPA licence required.
Western Australia	No specific dairy definition	Nil. ***Note:*** *Cattle feedlot considers > 50 cattle/ ha over a total of 500 animals where the 'watering and feeding of cattle occurs'* *Site is defined as prescribed where it has a design production facility of 500 animals or more situated less than 100m from a watercourse, and on which the number of cattle per ha exceeds 50.*

****Note:*** *Policy or requirements are under review at the time of printing.*

Australian Capital Territory

The planning system in the Australian Capital Territory (ACT) is governed by the *Planning and Development Act 2007*, the *Planning (General) Regulation 2023*, and the *Territory Plan 2023*. Together, these instruments set the rules for land use, development assessment, zoning and permitted activities. The Territory Plan divides the ACT into zones, each with specific policies outlining what types of development are allowed, prohibited or require assessment.

The ACT Planning and Land Authority (ACTPLA) is responsible for administering development applications, assessing proposals against the Territory Plan and ensuring compliance with planning requirements. Public consultation is a standard part of the ACT system, meaning neighbours and community members may have opportunities to comment on a proposal before a decision is made.

The ACT does not have a dairy-specific planning category. Proposals are instead assessed under the definition of Intensive Animal Farming, which includes animal production that takes place inside buildings or structures, or where animals are held in defined areas for extended periods. This use is generally permitted only in Broadacre (NUZ1) and Rural (NUZ2) zones.

At the time of writing, there are no specific thresholds, limits or licensing requirements for higher-input dairy systems under ACT planning or environmental legislation. Applications are therefore assessed on their merits, with consideration of site suitability, environmental protection measures and potential impacts on surrounding land uses.

Type	Link
Act	**Planning and Development Act 2007 | Acts** **legislation.act.gov.au/a/2007-24**
Regulation	**Planning (General) Regulation 2023 | Subordinate laws** **legislation.act.gov.au/sl/2023-20/**
Codes or other planning instrument	**Territory Plan 2023 | Notifiable instruments** **legislation.act.gov.au/ni/2023-540** **District Strategies - Environment, Planning and Sustainable Development Directorate - Planning** **planning.act.gov.au/professionals/our-planning-system/district-strategies**
Planning Website	**Planning - Environment, Planning and Sustainable Development Directorate - Planning** **planning.act.gov.au**
Application Portal	**Lodge a DA - Environment, Planning and Sustainable Development Directorate - Planning** **planning.act.gov.au/applications-and-assessments/development-applications/lodge-a-da**
Spatial Data	**ACTmapi viewer** **actmapi.act.gov.au/home.html**
Title Information	**ACTLIS** **actlis.act.gov.au/titleSearch**

Other useful sites:	
EPA	**Environment Protection Authority - Access Canberra** **accesscanberra.act.gov.au/city-services/environment-protection-authority**

New South Wales

Planning legislation in New South Wales (NSW), is governed by the *Environmental Planning and Assessment Act 1979* (EP&A Act), *Environmental Planning and Assessment Regulation 2021* and the related State Environmental Planning Policies (SEPPS). Each local Council also administers its own Local Environmental Plan (LEP) and in many areas a Development Control Plan (DCP). Together, these instruments form a risk based planning framework that guides land use, development assessment and environmental protection throughout NSW.

The Local Environmental Instrument provides the following definitions with relation to Dairy in NSW:

Dairy (pasture-based) - *a dairy that is conducted on a commercial basis where the only restriction facilities present are milking sheds and holding yards and where cattle generally feed by grazing on living grasses and other plants on the land and are constrained for no more than 10 hours in any 24-hour period (excluding during any period of drought or similar emergency relief).*

Note: Dairies (pasture-based) are a type of extensive agriculture. Specifically, **extensive agriculture** is defined as any of the following:

- *a dairy (pasture-based) where the animals generally feed by grazing on living grasses and other plants on the land as their primary source of dietary requirements, and any supplementary or emergency feeding, or temporary agistment or housing for weaning, dipping, tagging or similar husbandry purposes, of the animals.*

Dairy (restricted) - *a dairy that is conducted on a commercial basis where restriction facilities (in addition to milking sheds and holding yards) are present and where cattle have access to grazing for less than 10 hours in any 24 hour period (excluding during any period of drought or similar emergency relief). It may comprise the whole or part of a restriction facility.*

Note: Dairies (restricted) are a type of intensive livestock agriculture.

Specifically, ***Intensive livestock agriculture*** *is defined as the keeping or breeding, for commercial purposes, of cattle, poultry, pigs, goats, horses, sheep or other livestock, and includes any of the following: dairies (restricted), feedlots, pig farms, poultry farms, but does not include extensive agriculture, aquaculture or the operation of facilities for drought or similar emergency relief.*

Under NSW planning law, higher-input dairy systems—such as feedpads, loafing areas and contained housing—are generally assessed as Intensive Livestock Agriculture unless the operation clearly remains pasture-based. This classification determines whether a proposal can proceed with a standard Development Application (DA) or whether a higher level of assessment is required.

The *Environmental Planning and Assessment Regulation 2021*, Schedule 3 identifies when a proposal is considered 'Designated Development' meaning it must be supported by an Environmental Impact Statement and comply with the Secretaries Environmental Assessment Requirements (SEARs). Under Clause 22, '*Development for the purposes of a dairy is designated development if the dairy accommodates more than 800 head of cattle for the purposes of milk production.*'

The Environmental Protection Authorities *Protection of the Environmental Authorities Act 1997* Schedule 1 identifies premises that require an operating licence. Clause 22 identifies **dairy animal accommodation**, as accommodation (a) of animals used for the production of milk (dairy animals), and (b) in freestall complexes, feedpads, loading (loafing) pads, milking sheds or stand-off areas, but not in pasture, calving areas or calving sheds and requires facilities with a capacity to accommodate over 800 dairy animals at any one time to be licensed.

In some limited cases, development for feedpads in NSW may be exempt from requiring a Development Approval however the change in use from a pasture-based system to an restricted system will trigger a Development Approval and where buildings are proposed a Construction Certificate.

NSW dairy developments may also require approval under a range of complementary legislation, depending on site characteristics. These may include (but are not limited to) *the Protection of the Environment Operations Act 1997, Water Management Act 2000, National Parks and Wildlife Act 1974*, and the *Roads Act 1993*. Early use of the NSW Planning Spatial Viewer and the Development Referrals Guide helps identify which authorities may need to be consulted or provide formal referral responses.

The new, award winning MyFarmPlanner tool provides assistance to applicants to identify relevant planning requirements, overlays, referral agencies and assessment expectations for dairy developments in NSW.

The Spatial Mapping system and Development Referrals Guide provides helpful information in understanding where applications may require other approvals and referral.

Type	Link
Act	Environmental Planning and Assessment Act 1979 No 203 - NSW Legislation legislation.nsw.gov.au/view/html/inforce/current/act-1979-203
Regulation	Environmental Planning and Assessment Regulation 2021 - NSW Legislation legislation.nsw.gov.au/view/html/inforce/current/sl-2021-0759
Codes or other planning instrument	State Environmental Planning Policies | Planning planning.nsw.gov.au/policy-and-legislation/state-environmental-planning-policies
Planning Website	planning.nsw.gov.au
Application Portal	DPIE Login b2clogin.com
Spatial Data	NSW Planning Portal Spatial Viewer planningportal.nsw.gov.au/spatialviewer/#/find-a-property/address
Title Information	
Six Viewer	SIX Maps hmaps.six.nsw.gov.au
NSW Land Registry Services	nswlrs.com.au
Other options (private)	nswlrs.com.au/services/record-searches/how-to-find-an-information-broker

Other useful sites:	
Development Referrals Guide	planning.nsw.gov.au/sites/default/files/2023-10/development-referrals-guide.pdf
Development Application Documents	planning-circular-ps-22-004-application-requirements-for-development.pdf amazonaws.com planning.nsw.gov.au/sites/default/files/2023-02/application-requirements.pdf
Environmental Guidelines for the Dairy Industry*	dpi.nsw.gov.au/__data/assets/pdf_file/0003/249033/Environmental-management-guidelines-for-the-dairy-industry.pdf dpi.nsw.gov.au/dpi/animals/dairy/development-and-environmental-guidelines
Environmental Guidelines – Use of effluent by irrigation	epa.nsw.gov.au/-/media/epa/corporate-site/resources/epa/effguide.pdf
Intensive Livestock Development	planning.nsw.gov.au/sites/default/files/2023-03/planning-guidelines-intensive-livestock-agricultural-development.pdf
Land Use Conflict Risk Assessment Guide	dpi.nsw.gov.au/__data/assets/pdf_file/0018/412551/Land-use-conflict-risk-assessment-LUCRA-guide.pdf
EPA	Licensing and Regulation epa.nsw.gov.au/licensing-and-regulation
EPA feedlot odour assessment technical information	epa.nsw.gov.au/sites/default/files/240189-local-government-air-quality-toolkit-beef-cattle-feedlots-guidance-note.pdf epa.nsw.gov.au/sites/default/files/20060440framework.pdf epa.nsw.gov.au/sites/default/files/20060441notes.pdf

**Note: Under review at the time of writing*

Northern Territory

Planning in the Northern Territory is governed by the *Northern Territory Planning Act, 1999, Planning Regulations 2000* and the *Northern Territory Planning Scheme 2020*. The Planning Scheme provides the overall strategic framework for land use development including zoning, overlays, development requirements and planning definitions. It also defines which types of development are permitted or require assessment.

The *NT Planning Scheme* defines **Intensive animal husbandry** as the *breeding, keeping and feeding of animals, including poultry and pigs, in sheds, stalls, ponds, compounds or stockyards; or (b) aquaculture; as a commercial enterprise.*

The scheme does not contain any dairy-specific definitions (pasture or contained) as a result, when planning a project within the Northern Territory it is important to undertake consultation with local authorities to gain detailed information on application requirements.

Type	Link
Act	**Legislation Database** **legislation.nt.gov.au/en/Legislation/PLANNING-ACT-1999**
Regulation	**Legislation Database** **legislation.nt.gov.au/en/Legislation/PLANNING-REGULATIONS-2000**
Codes or other planning instrument	**NT Planning Scheme 2020** **nt.gov.au/property/land-planning-and-development/our-planning-system/nt-planning-scheme**
Planning Website	**Land planning and development** **nt.gov.au/property/land-planning-and-development**
Application Portal	**Development Applications Online** **ntlis.nt.gov.au/planning**
Spatial Data	**NT Land Information Search** **ntlis.nt.gov.au/land/info/app/planningdetails**

Other useful sites:	
EPA	**NTEPA** **ntepa.nt.gov.au**
Cattle Industries Livestock Development division	**Contact Livestock Industries Development division** **nt.gov.au/industry/agriculture/livestock-and-animals/cattle/contact-livestock-industries-development-division**
Development Requirements Guide	**nt.gov.au/__data/assets/pdf_file/0004/914872/nt-planning-scheme-part-5-development-requirements.pdf**
Development Application Documents	**Development+referrals+guide+-+2023+final.pdf** **planning-circular-ps-22-004-application-requirements-for-development.pdf** **amazonaws.com**

Queensland

The planning framework in Queensland is established under the *Planning Act 2016* which is the primary legislation governing land use planning, development assessment and appeals. The Act is supported by the *Planning Regulation 2017* which sets out additional procedural requirements, assessment benchmarks, referral triggers, infrastructure charges and the types of development that require assessments. State, Regional and Local Planning Schemes also guide land use decisions, zoning and development controls.

Queensland does not have specific intensive dairy definitions or requirements and as a result is likely to be triggered within intensive animal definitions. **Intensive animal feedlot** being an activity *includes keeping cattle or sheep in a 'feedlot'*. A feedlot is defined as a *confined yard or enclosure that contains watering and feeding facilities where the animals are fed only by hand or mechanically and are not allowed to graze within the enclosure. This activity does not include keeping cattle or sheep:*

- *in a drought-declared area, if the animals are only fed their nutritional requirements,*
- *on a feed pad in a paddock,*
- *for no longer than is necessary for,*
  - *sale, slaughter or transport*
  - *weaning*
  - *animal husbandry (branding, dehorning, desexing, vaccinating)*
  - *milking*
  - *shearing.*

The licensing requirements define cattle as *including beef and dairy cattle of all ages* and the total number referenced within the trigger is based on a SCU which is a measurement based on live cattle weight. EG 650 to 700kg cattle are equal to 1.12 SCU. Facilities that operate over 150 SCU require a Development Permit under the *Planning Act 2016* and an Environmental authority (EA) issued under the *Environment Protection Act 1994*. The property must also be registered with Biosecurity Queensland.

Type	Link
Act	**Planning Act 2016 - Queensland Legislation - Queensland Government legislation.qld.gov.au/view/html/inforce/current/act-2016-025**
Regulation	**Planning Regulation 2017 - Queensland Legislation - Queensland Government legislation.qld.gov.au/view/html/inforce/current/sl-2017-0078**
Codes or other planning instrument	**dsdmipprd.blob.core.windows.net/general/spp-july-2017.pdf planning.statedevelopment.qld.gov.au/planning-framework/plan-making/regional-planning**
Planning Website	**planning.statedevelopment.qld.gov.au**
Application Portal Infrastructure designations portal Regional interests development assessment portal	**planning.dsdmip.qld.gov.au/signin?returnUrl=%2Finfrastructure-designation&reason=authorisation planning.dsdmip.qld.gov.au/signin?returnUrl=%2Frida&reason=authorisation**
Spatial Data	**planning.statedevelopment.qld.gov.au/planning-framework/mapping**
Title Information	**titlesqld.com.au**

Other useful sites:	
Forms	**planning.statedevelopment.qld.gov.au/planning-framework/development-assessment/development-assessment-process/forms-and-templates**
Planning for Healthy Agriculture	**qff.org.au/wp-content/uploads/2016/11/QFFToolkit.pdf**
Development Application Documents	**business.qld.gov.au/industries/farms-fishing-forestry/agriculture/animal/health/welfare/codes**
Effluent Management Guidelines for Dairy Sheds in Australia	**webarchive.nla.gov.au/awa/20130904200000/http://www.environment.gov.au/water/publications/quality/dairy-sheds-australia-paper16a.html**
Emission estimation technique manual for intensive livestock – beef cattle	**dcceew.gov.au/sites/default/files/documents/beef.pdf**
Guideline for Stormwater and environmentally relevant activities	**des.qld.gov.au/policies?a=272936:policy_registry/pr-gl-stormwater-guideline-era.pdf**
Dept of Agriculture and Fishing, QLD	**business.qld.gov.au/industries/farms-fishing-forestry/agriculture/animal/industries/cattle/environment**

South Australia

South Australia's planning system operates under the *Planning, Development and Infrastructure Act 2016* and its associated *Planning, Development and Infrastructure (General) Regulations 2017*. These instruments together with the *Planning and Design Code*, establish the processes, assessment pathways and rules for planning, building and land division across the state.

The Planning and Design Code defines **intensive animal husbandry** to include feedlots, dairies and their related facilities being defined as *the commercial production of animals or animal products where the animals are kept in enclosures or other confinement and their main food source is introduced from outside the enclosures or area of confinement in which they are kept*. Because there is no separate intensive dairy definition in South Australia, dairy feedpads or contained housing proposals are usually assessed under this land use category.

Most dairy-related proposals are lodged as an 'Agricultural building' which means *a building used wholly or partly for purposes associated with farming, commercial forestry, intensive animal husbandry, dairying or horticulture, or to support the operations of that use, but does not include frost fans or a building used wholly or partly for any of the following:*

1. *The processing or packaging of commodities;*
2. *The housing of animals for the purposes of **intensive animal husbandry**; and*
3. *The purposes of a **dairy.***

For intensive animal husbandry developments, Schedule 8 of the Planning, Development and Infrastructure (General) Regulations 2017 sets out the documentation requirements to accompany a development application. Referral to the Environment Protection Authority (EPA) is triggered when an operation meets the EPA licence definition for cattle feedlots or other confined feeding systems—namely operations that:

- hold not less than an average of 500 cattle (requiring an EPA licence) over any 12-month period; or
- hold not less than an average of 200 cattle per day over any 12-month period where the site is located within a Water Protection Area (also EPA-licensable).

These triggers exclude operations carried out at abattoirs, slaughterhouses, saleyards, or short-term emergency or drought feeding.

Development in South Australia is assessed for both the physical works and the use of the land. Applications are lodged online through the PlanSA portal, with local councils acting as the initial receiving authority. Applications are then referred to any relevant agencies (including the EPA, SA Water or Environment Department) for assessment and recommended conditions. Following planning approval, additional permits or licences may be required, such as an EPA Licence or Authorisation prior to operation.

Type	Link
Act	**Planning, Development and Infrastructure Act 2016** **legislation.sa.gov.au/lz?path=%2FC%2FA%2FPlanning%20Development%20and%20Infrastructure%20Act%202016**
Regulation	**Planning, Development and Infrastructure (General) Regulations 2017** **legislation.sa.gov.au/lz?path=%2FC%2FR%2FPlanning%20Development%20and%20Infrastructure%20(General)%20Regulations%202017**
Codes or other planning instrument	**plan.sa.gov.au/resources/planning/planning_and_design_code**
Planning Website	**plan.sa.gov.au/development_applications/getting_approval/the_approval_process/why_you_need_approval**
Application Portal	**plan.sa.gov.au/development_applications/lodge_an_application/lodge_online**
Spatial Data	**SAPPA the South Australian Property and Planning Atlas** **sappa.plan.sa.gov.au**
Title Information	**sailis.lssa.com.au/home/auth/login**
Other useful sites:	
Code of Practice for Milking Shed Effluent*	**epa.sa.gov.au/files/4771456_milking_shed.pdf**
Guidelines for Wastewater Lagoon Construction	**epa.sa.gov.au/files/4771372_guide_lagoon.pdf**
*Environment Protection (Water Quality) Policy 2015**	**Environment Protection (Water Quality) Policy 2015** **legislation.sa.gov.au/lz?path=%2FC%2FPOL%2FENVIRONMENT%20PROTECTION%20(WATER%20QUALITY)%20POLICY%202015**
EPA Website	**ask.your.epa.sa.gov.au**

**Note: Under review at the time of writing*

Tasmania

Tasmania's planning system is governed by the *Land Use Planning and Approvals Act 1993* (LUPAA) and its associated *Land Use Planning and Approvals Regulation 2014*. The Tasmanian Planning Scheme, established in 2017 under LUPAA, includes the State Planning Provisions (SPP), a standardised set of statewide planning rules—and each council's Local Provisions Schedule (LPS), which applies zoning, overlays and local variations. Together, these instruments guide how land can be used and what types of development require approval.

Development applications for dairy feedpads or contained housing are lodged with the relevant local council. Council assess the application against the Planning Scheme, SPPs and any relevant overlays, and may refer it to the Tasmanian Planning Commission for matters of broader significance.

Under the State Planning Provisions**, Intensive Animal Husbandry** is defined as *a use of land to keep or breed farm animals, including birds, within a concentrated and confined animal growing operation by importing most food from outside the animal enclosures and includes a feedlot, poultry farm or piggery.* Intensive animal husbandry is a discretionary use in many zones, meaning it requires public notification and assessment of representations before a decision is made.

In addition to the planning requirements, the Tasmanian dairy industry is regulated by the *Dairy Industry Act, 1994, Dairy Industry Regulation 2014* and the *Farm Dairy Premises Code of Practice*. All facilities (including those associated with the dairy e.g. housing) must maintain a license and meet their obligations under the Farm Dairy premises Effluent Management Code of Practice, 2025 which is administered by the Tasmanian Dairy Industry Authority (TDIA).

Other permits to construct dams and any pond exceeding 1ML may also be required as part of the application process. Intensive Animal Husbandry is considered a Level 1 Activity which remains Authorised by Local Council unless the Environment Protection Authority determines the significance to be that of a Level 2 activity and assesses the activity under their Act. At the time of writing, Tasmania is undertaking a review of their planning system with relation to Intensive Dairy Development.

Type	Link
Act	**legislation.tas.gov.au/view/html/inforce/current/act-1993-070**
Regulation	**legislation.tas.gov.au/view/whole/html/asmade/sr-2014-141**
Codes or other planning instrument	**planning.tas.gov.au/other-resources/Tasmanian-planning-scheme**
Planning Website	**stateplanning.tas.gov.au**
Application Portal	Contact Council
Spatial Data	**portal.planbuild.tas.gov.au/external/enquiry** **security.thelist.tas.gov.au/cas/login?service=https://www.thelist.tas.gov.au/app/login**
Title Information	**nre.tas.gov.au/land-tasmania/the-list/properties-titles**

Other useful sites:	
Dairy Industry Act 1997	**legislation.tas.gov.au/view/html/inforce/current/act-1994-036**
Dairy Industry Regulation 2024	**legislation.tas.gov.au/view/whole/html/asmade/sr-2024-076**
Tasmanian Dairy Industry Authority	**tdia.tas.gov.au/resources/regulation**
Effluent Management	**tdia.tas.gov.au/resources/effluent-management**
Dam Works Permit Guidelines	**nre.tas.gov.au/water/dams/dam-works-codes**

Victoria

The Victorian planning system is governed by the *Planning and Environment Act 1987*, which establishes the framework for planning schemes, development assessments, and appeals. Under the Act, local councils are responsible for preparing and maintaining Municipal Planning Schemes, which set out policies and provisions for land use and development within their jurisdictions. The Victoria Planning Provisions are a state-level set of planning policies and controls that guide the preparation of these local schemes to ensure consistency across the state. The Victorian planning system emphasizes community engagement, environmental sustainability, and orderly development. Development applications are assessed against relevant planning schemes, and decisions can be appealed to the Victorian Civil and Administrative Tribunal (VCAT).

Intensive Animal Production within Clause 73.04 of the Victorian Planning Scheme is defined as *land used for animal production where the animals' food is imported from outside the immediate building, enclosure, paddock or pen*. It does not include: an abattoir or sale yard; or grazing animal production, pig farm, poultry farm or poultry hatchery. The definition of an **Intensive Dairy Farm** is defined as *land used for intensive animal production where cattle are kept or bred for the production of milk*. In some cases, development for feedpads may be exempt from a Planning Permit however the change in use from a pasture-based system to an intensive system will trigger a Planning and Building Permit.

The Environment Protection Authority (EPA) issues operating licences for *Primary Industry – waste solely to land (B01a) for operating a piggery, cattle feedlot, sheep feedlot, goat feedlot or dairy freestall that a) has more than 5,000 animals (of any combination of pigs, cattle, sheep or goats) concentrated for the purposes of agricultural production; and b) discharges or deposits waste to land*. This licence is issued under Schedule 1 of the *Environment Protection Regulations 2021* in conjunction with the *Environment Protection Act 2017*. Other permissions may also be required for associated site activities, including dam construction. tyre storage, or connection to roads.

Applications for a Planning Permit are lodged directly to Local Council, often through a specified Planning Portal. Once accepted, applications are referred to relevant Authorities for assessment and comment. Victorian Councils also have access to a dedicated Agricultural Planning and Advisory Service with extensive experience in agricultural applications who will provide independent assistance and advice. Once approved and relevant conditions are met, Building Permits can be obtained from qualified building certifiers or Council.

Type	Link
Act	**Planning and Environment Act 1987** **legislation.vic.gov.au/in-force/acts/planning-and-environment-act-1987/155**
Regulation	**Planning and Environment Regulations 2015** **legislation.vic.gov.au/in-force/statutory-rules/planning-and-environment-regulations-2015/006**
Codes or other planning instrument	**planning.vic.gov.au/planning-schemes/browse-planning-schemes**
Planning Website	**planning.vic.gov.au**
Application Portal	Contact Council
Spatial Data	**Geocortex Viewer for HTML5** **mapshare.vic.gov.au/vicplan** **LASSI - Land and Survey Spatial Information** **maps.land.vic.gov.au/lassi**
Planning Reports	**planning.vic.gov.au/planning-schemes/planning-property-report**
Navigating Farm Developments	**Navigating farm developments – online planning tool** **agriculture.vic.gov.au/farm-management/planning-and-farm-development/navigating-farm-developments-online-tool**
Title Information	**landata.vic.gov.au/tpc_menu.aspx**

Other useful sites:	
Planning and advisory service	**Ag Vic Planning and Advisory Service** **agriculture.vic.gov.au/farm-management/planning-and-farm-development/agvic-planning-and-advisory-service?SQ_VARIATION_821691=0**
Animal Production Guidelines	**agriculture.vic.gov.au/farm-management/planning-and-farm-development/information-for-applicants/animal-production-other-industries**
Dairy Food Safety Victoria	**dairysafe.vic.gov.au/publications-media/regulations-and-resources/guidelines/475-victorian-dairy-licence-handbook/file**
Managing Effluent	**agriculture.vic.gov.au/livestock-and-animals/dairy/managing-effluent**
EPA	**epa.vic.gov.au**

Western Australia

In Western Australia, the planning application system is established under the *Planning and Development Act 2005* and its associated regulations. Local governments prepare and administer Local Planning Schemes, which set out land-use zones, development requirements and assessment pathways for their areas. Most agricultural proposals, including dairy developments, require a Development Application to the relevant local government, which assesses the proposal against its Local Planning Scheme, State Planning Policies and any applicable development controls. Public consultation is commonly required, particularly where a proposal involves new infrastructure or changes to land use.

Dairy farms are not currently listed as a prescribed premises under Schedule 1 of the *Environmental Protection Regulations 1987*, meaning they are not subject to automatic environmental licensing in Western Australia. However, other prescribed premises categories may be relevant to dairy housing or feedpads. Of particular note:

- *Cattle feedlot (Category 1 or 68): premises on which cattle are watered and fed at densities greater than 50 head per hectare and with a design capacity of 500 head or more, with the category determined by proximity to a watercourse.*
- *Compost manufacturing and soil blending (Category 67A): premises processing 1,000 tonnes or more per year of organic material, which may be relevant where manure solids, bedding or other organic materials are processed on-site.*

Because WA does not currently define intensive dairy as a specific land use, proposals are typically assessed using broader definitions such as intensive animal husbandry or by comparing to feedlot definitions. Proponents must therefore engage early with the local government to confirm how the development will be classified and what information will be required.

The value of the proposal also influences the assessment pathway. Most applications valued at less than $5 million are decided by local government (except in Perth and Peel). Larger or more complex proposals may be determined by the Western Australian Planning Commission (WAPC) through the State Development Assessment Unit.

Type	Link
Act	**Planning and Development Act 2005** **legislation.wa.gov.au/legislation/statutes.nsf/main_mrtitle_722_homepage.html** **Building Act 2011** **legislation.wa.gov.au/legislation/statutes.nsf/main_mrtitle_12333_homepage.html**
Regulation	**Planning and Development Regulations 2009** **legislation.wa.gov.au/legislation/statutes.nsf/main_mrtitle_11033_homepage.html** **Building Regulations 2012** **legislation.wa.gov.au/legislation/statutes.nsf/law_s43955.html**
Codes or other planning instrument	**wa.gov.au/organisation/department-of-planning-lands-and-heritage**
Planning Website	Check with Council **planning.wa.gov.au/significant-development-pathway/significant-development-applications**
Application Portal	Contact Council
Spatial Data	**espatial.dplh.wa.gov.au/planwa/Index.html?viewer=planwa**
Title Information	**map-viewer-plus.app.landgate.wa.gov.au/index.html**

Other useful sites:	
Application Requirements	**wa.gov.au/government/document-collections/planning-development-application-forms-and-fees**
Code of Practice for Dairy Farm Effluent Management WA	**wa.gov.au/government/publications/code-of-practice-dairy-farm-effluent-management-wa**
Agribusiness Development Guidelines - Preparing a Solid Waste Management Plan	**ABD Guidelines_Preparing a Solid Waste Management Plan.pdf agric.wa.gov.au**
Agribusiness Development Guidelines - Land application of solid animal by-products	**ABD Guidelines_Land Application of Solid Animal By-Products.pdf agric.wa.gov.au**
DPIRD	**agric.wa.gov.au/agribusiness-food-trade/agribusiness-development**
Industry Licence Systems	**wa.gov.au/service/environment/environment-information-services/licences-and-works-approvals-prescribed-premises**
EPA Referral	**epa.wa.gov.au/step-step-through-proposal-assessment-process**

4.3 Using this information in your application

The information in this chapter should be used as a practical reference when preparing a development application. The first step is to confirm how the proposed system will be classified under the relevant State or Territory planning framework, as the terminology varies between jurisdictions and may influence whether the project is treated as a grazing operation, a higher-input dairy system or an intensive animal enterprise.

Once the classification is clear, proponents can identify which approval triggers apply. These may relate to herd size, the type or scale of infrastructure proposed, nutrient storage or reuse practices, the proximity to waterways or boundaries, or the potential for environmental or amenity impacts. Understanding these triggers early helps ensure that the correct level of assessment is prepared.

It is also important to understand which agencies will be involved in the assessment. Even modest developments can require input from water authorities, environmental regulators, road or transport agencies, heritage specialists or agricultural departments. Gathering accurate property information at the start of the process—such as title details, easements, overlays, groundwater or flood constraints, and applicable buffer requirements—helps confirm whether the proposed site is suitable and whether alternative layouts may be needed.

The quality of supporting documentation is central to a smooth assessment. Effluent system designs, nutrient budgets, site plans, drainage layouts and engineering drawings should be prepared by appropriately qualified professionals and clearly demonstrate that the proposal can operate safely and sustainably. The documents produced during the assessment phase should also explain how the system manages biosecurity, environmental protection, neighbour amenity, traffic movements, and day-to-day operational requirements. Once approval is granted, further permissions are often required before construction can commence. These may include building permits, road access approvals, dam works permits, environmental licences or specialist operational approvals such as TDIA licensing in Tasmania.

When used together, these resources support a well-designed and thoroughly considered application. They also help ensure that new dairy feeding or housing systems align with regulatory expectations across both planning and environmental frameworks.

4.4 Important reminders for proponents

Early engagement with the local Council or relevant authority is one of the most effective ways to avoid delays. A pre-lodgement meeting provides an opportunity to confirm assessment pathways, clarify documentation requirements and identify any sensitive or complex issues before significant design work is completed. Clear, complete and well-structured documentation significantly reduces the likelihood of Requests for Further Information, which are a common cause of prolonged assessment timeframes.

The dairy and intensive agriculture sectors currently face limited national capacity in specialist services. Only a small number of practitioners have the experience needed to design systems and prepare detailed applications that meet regulatory expectations across multiple jurisdictions and securing their availability often requires considerable lead time. Proponents should plan well ahead, particularly for large or complex proposals—to ensure that key technical work can be completed without delaying the overall project timeline.

Early engagement and clear scoping with consultants help secure availability, reduce design iteration and improve the quality and consistency of the final submission.

Effluent and manure system designs, nutrient management plans and engineering drawings should be prepared by suitably experienced professionals and tailored to the specific site and herd numbers. These documents should explain how environmental risks will be managed, how infrastructure integrates with the broader farm system and how the development will maintain compliance with planning and environmental obligations. It is equally important to demonstrate how the proposal will manage dust, odour, noise, traffic and other amenity considerations for neighbouring land uses.

Finally, proponents should remember that this Guideline is intended to complement the legislative requirements that apply in each jurisdiction. Authorities will rely first on State and Territory legislation, planning schemes and regulatory instruments when determining a development application. Using the Guideline alongside these frameworks helps ensure a clear, consistent and well-supported proposal, but it does not replace statutory obligations or remove the need to verify current requirements with the responsible authority.

05

Site investigation and earthworks

Introduction

Site investigation and earthworks for dairy feedpads and contained housing facilities should consider the following:

- Site and soil attributes are assessed at a desktop and visual inspection level before any ground disturbance.
- Soil materials are suitable for the purpose, meeting appropriate engineering standards.
- Site plans and designs inform any proposed earthworks.
- Construction methods and requirements are identified before earthworks are undertaken.
- Design and construction protect environmental features such as surface waters and groundwater, and nearby sensitive uses.

5.1 Preliminary desktop investigation

For information related to the development application and approval process see *Chapter 2 Planning requirements – development applications and approvals*.

Any potential development site should not be disturbed until desktop due diligence is carried out in full, covering overlays, services and environmental site conditions. Some of these factors include, but are not limited to, the following:

Local and state planning zones and overlays: flooding, heritage (natural, cultural or indigenous), natural resources (surface water, groundwater, soil) and native vegetation. See *Chapter 2 Planning requirements – development applications and approvals*.

Site levels, slope, drainage and stormwater: should be reviewed with available electronic information. Contours may be obtained from state databases while other more detailed information including Light Detection and Ranging (LiDAR) may be accessible. Levels, slopes and drainage should be understood to determine:

- Stormwater from neighbouring land flowing onto or across a proposed development site.
- The direction and discharge point for stormwater from the proposed development site, specifically noting where drainage water passes across site boundaries.

Where detail is not available electronically, site survey for levels should be carried out in the outset of field investigations.

Surface waters: sites must consider any area where waterways, watercourses, drainage paths or passive flow paths occur within or in close proximity to proposed development areas. Infrastructure must be positioned with adequate buffer distances or protection measures from these features.

Groundwater: conditions for most states are available via electronic databases or hydrogeological map sheets including Australian Geological Survey Organisation Mapping, Waterconnect, WaterNSW Real-time data and Visualising Victoria's Groundwater.

All groundwater information collected at a desktop level should be verified from field measurement of stock and domestic bores, irrigation bores or state monitoring bores. Geotechnical investigation pits or boreholes should be used for detection of shallow or perched groundwater. Groundwater considerations:

- Areas with high water tables, where groundwater is found within 1.0 metre of the finished floor level of proposed ponds or from the base of foundations. Standing water and capillary rise will impact pond lining and foundations, regardless of salinity quality.
- Beneficial use groundwater, where adequate protection measures are required, regardless of depth. This is particularly important in landscapes with permeable soil and rock.

Geology: information available electronically and in hard copy should be accessed and reviewed from state database information or from geological map series data. Where proposed development sites are located in areas of permeable geological formations such as deep sands or fractured rock, special design considerations will be required for construction of effluent ponds, manure stockpiles and freshwater storage dams to achieve an impervious standard.

Soil management overlays specific to sites can be obtained from state databases or local council. Examples of soil management overlays include, but are not limited to the following:

- Salinity (natural soil salinity, irrigation induced or from high water tables).
- Potential acid sulphate soils should not be uncovered, avoiding impacts to surface waters and groundwater.
- Sodic or dispersive soils where soil exchangeable sodium percentages are 6.0% or greater, or where soils disperse upon immersing in fresh water.
- Potentially contaminated land.

Dial Before You Dig (DBYD) and engagement of a Services Locator: Note: DBYD is limited to public land. The location of services within property boundaries is the responsibility of the landowner.

Some local council areas require permits before proceeding with site investigations. Inquiries should be made with local councils before commencing any earthworks.

It is also critical to ensure that national and state guidelines are consulted for the geotechnical investigation, erosion, soil management and sediment control, effluent pond and farm dam construction and operation. These guidelines will form part of the approval process from your local council prior to issuing a works approval for construction.

5.2 Land capability assessment

Introduction

A Land Capability Assessment (LCA) establishes if land can safely support a proposed development and defines the environmental considerations and constraints which restrict or limit the proposed use. An LCA provides the necessary information for an Environmental Management Plan or Environmental Impact Statements to demonstrating how environmental constraints from site development and operation will be avoided, managed and monitored. A LCA is intended to provide all environmental information which a regulatory authority will require to carry out a detailed environmental assessment.

LCA for dairy development embraces similar principles to those for domestic and industrial wastewater management, tailored to agriculture and dairy. Environmental sensitivities and risks are based on the developments proposed scale and method of operation.

Dairying regions around Australia have their own unique sets of land capability considerations, which may support dairy operations or provide challenges in how systems require management to ensure adequate environmental protection outcomes are met.

LCA aims, approach and critical considerations

LCA for dairy development should:

- **investigate a site's physical limitations,** or environmental and land capability constraints for the proposed development type
- **consider planning elements** associated with site selection, design and management, specifically overlays and other sensitivities impacting the proposed development type
- **evaluate the environmental constraints** using a risk-based approach
- **detail whether the environmental constraints can be managed or modified** to ensure sustainable environmental outcomes are achievable
- **conclude on the suitability of the site** for the intended use, and
- **support regulatory bodies** in the process of approval.

In compiling an LCA, there may be several areas of specialisation which are outside of the LCA consultant area of expertise, requiring specialist consultant engagement. The LCA assessor and specialist consultants must be suitably qualified and hold adequate levels professional indemnity insurance covering their field of engagement.

A three-step approach should be considered in preparing an LCA:

1 Initial site inspection and desktop review

2 Field investigations, by the LCA consultant and specialist environmental consultants, and

3 LCA reporting, including the evaluation of site suitability along with recommendations.

Information collected by LCA assessors and specialist consultants may overlap throughout reporting (for example, both an Effluent Management Plan and LCA may provide details on surface waters). The LCA assessor must ensure that information from several parties is consistent, avoiding inconsistent information being passed on for assessment.

Critical LCA considerations for dairy development

Critical LCA considerations for early dairy development include, but are not limited to the following:

- **Site drainage and seasonal water tables:** Dairy developments should be planned around principles of good drainage. Proposed development sites should be sited on land which is well-drained. Poor surface and profile drainage or seasonally high-water tables causing capillary rise and saturation of the upper profile will impact:
  - Building foundations, particularly within reinforced concrete, where groundwaters contain salts, even at low concentrations
  - Integrity of earthen effluent ponds, including flocculation of clay lining, potential effluent-groundwater interaction and/or impacts on synthetic lining from upwards pressure and buoyancy
  - Sustainable irrigation of effluent and reuse of nutrients, arising from poor field drainage and waterlogged soil conditions.
- **Slope and fall for effective flood washing:** Dairy developments which include feedpads and contained housing with gravity washdown require at least 1% fall for effective floodwashing, allowing low-energy, minimal-labour systems to be adopted. Where falls of >1% exist, natural landscape characteristics should be used to support the design. Where engineered earthen pads are required, large volumes of earth must be available to support major earthworks for pad construction to be achieved.

- **Borrow pit sites, haul distance and void use for effluent or freshwater storage:** Soils close to development sites are preferred to borrow for earthen pads. The void created is typically used for effluent or fresh water containment. To ensure borrow pits can remain as close as possible to development areas to reduce haul distance and earthworks costs, local soil and geotechnical information should be reviewed early in the planning process to support sound decision making and prevent major changes in site planning, layout and development type.
- **Effluent conveyance:** Gravity fall should be advantageously used for effluent drainage and transfer, reducing energy and pumping costs. Levels from the point source to the zone of containment should be carefully designed by altering surface levels and matching results of geotechnical investigations to achieve efficiency and compliance. Further consideration of effluent flow or pumping into the irrigation network should be considered.
- **Future development:** Development plans should include additional land area for future expansion. LCAs should consider land further afield of the proposed development area to allow for proportional increases in facilities including contained housing, effluent systems and new dairies.

The LCA process

1 Preliminary desktop review and site inspection

Preliminary desktop review to support an LCA should cover land capability considerations and potential limitations listed in Table 1. Draft plans by dairy design consultants are required for initial review to ensure the LCA is prepared relative to the site plan and method of operation. Key priorities for desktop review are to:

- Obtain and utilise publicly available land capability information to define a sites location, geographic position and potential land capability constraints that may affect a sites suitability.
- Understand land capability considerations and limitations which are sufficiently detailed to describe a site and regions land capability limitations, allowing LCA assessors to formulate conclusions and accept the associated risks, following field verification.
- Confirm land capability considerations and limitations which are insufficiently detailed following desktop review, supporting decisions for engagement specialist consultants.
- Guide the client through the initial LCA process for their project, moving to more detailed stages of investigation where required.

The above process highlights areas of land capability where information is limiting. The process may also influence adjustment to preliminary site plans, which are necessary prior to the engagement of specialist consultants undertaking detailed investigations. If any element of doubt exists regarding the quality and reliability of information sourced from desktop review, further evidence should be sourced by supportive investigations by suitably qualified consultants.

Figure 2. Using farm topography mapping to assist with infrastructure siting

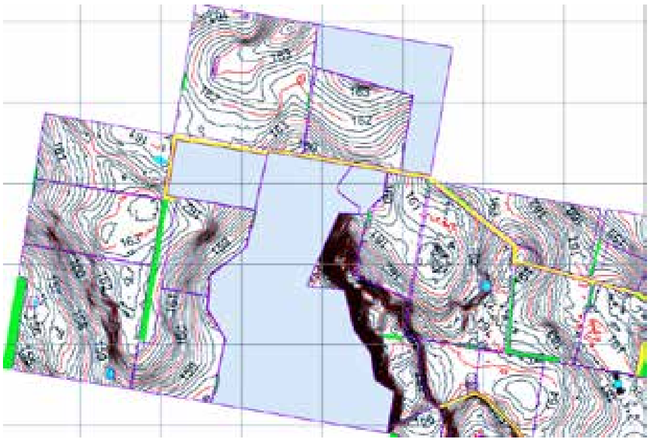


Table 1. Land capability considerations, potential limitations and reasons for assessment

Land capability consideration	Potential land capability limitation for dairy developments	Reasons for the assessment of potential land capability limitation
Location	Geographic setting Site boundaries	• To define region, local council and other regulatory authorities who may be potential stakeholders • To define key local receptors who require consideration • To define setbacks for effluent irrigation, or spreading of effluent, sludge and manure from neighbouring land • To define activity boundaries within development sites • To support assessment of odour in determining physical separation distances from receptors
	Proximity to sensitive receptors	• To define distances from sensitive receptors (e.g. Neighbouring or local dwellings, townships or other intensive land uses
	Odour separation distances	• To define if potential odour may impact neighbouring residences
	Flooding or flood overlays	• To define if proposed developments may potentially be impacted by flooding
Planning – Zoning, overlays, areas of significance (common examples only)	Land subject to inundation	• To define if the proposed development requires special measures to manage periodic or seasonal inundation (eg. Banks around effluent pond walls, elevation of earthen pads and roads for access)
	Areas of aboriginal cultural heritage sensitivity	• To define if proposed development lies within an Aboriginal Heritage Overlay (AHO), where liaison with local Registered Aboriginal Parties (RAP) may be required, or a cultural heritage management plan (CHMP)
	Special controls	• To define if any special controls are placed on the land impacting use
	Environmental significance	• To define if the site has any areas of environmental significance that require consideration
Climate	Rainfall: Annual, monthly and event-based (various storm intensity)	• To support calculating irrigation water balances for crops and pastures, providing sustainable reuse of nutrients from effluent, sludge and manure (see hydrology) • To support calculating winter storage periods when rainfall exceeds evapotranspiration (Et) (southern regions), or storage months in northern regions where daily Et allows for management of effluent storage (see hydrology) • To define stormwater runoff volumes based on varying event-based rainfall scenarios, influencing the sizing of sumps, pumps and decisions around contingency measures • To support stormwater management within and around development areas, not connected to effluent and how these are managed separate to effluent systems (e.g. upslope catchment drainage around or through activity areas, non-contaminated stormwater collection from within the activity area, rooftop rainfall collection) • To support selection of rainfall erosivity factors and calculating vegetative filter strip design for mitigating nutrient-laden runoff from non-containment areas, including tracks and laneways
	Temperature and relative humidity	• To understand how temperature and relative humidity influence daily and monthly Et, irrigation water budgets and opportunities for effluent irrigation outside and within storage months • To understand how temperature and relative humidity may enhance or impact facility type and design (size, ventilation, orientation)
	Wind	• To understand prevailing and common wind directions, speeds and times of day in which they commonly occur • To determine if neighbouring or local receptors may be impacted from potential odour

<table>
<tr><th>Land capability consideration</th><th>Potential land capability limitation for dairy developments</th><th>Reasons for the assessment of potential land capability limitation</th></tr>
<tr><td>Landform</td><td>Topography</td><td>• To understand how landform and topography will influence:
– Site layout
– Integration of components, particularly effluent system design
– Management of effluent irrigation sites and area for spreading of sludge and manure
• To support assessment of odour in determining terrain factors</td></tr>
<tr><td></td><td>Aspect (facing direction)</td><td>• To support siting and layout considerations for managing climate related decisions (specialist consultants, external to LCA), including:
– Ventilation and air flow
– Management of heat stress and cold weather
– Shading and moisture management, particularly within compost bedded pack or loose housing facilities
• To support development of new effluent irrigation areas for maximising photosynthetic activity and minimising shading in mornings or afternoons</td></tr>
<tr><td></td><td>Slope and surface drainage</td><td>• To support understanding of site drainage, develop drainage plans and understand how slope and drainage will impact site and system management (e.g. cuts and fills, need for engineered fill pads)
• To confirm upslope drainage run-on impacting proposed development sites and required drainage diversion around activity areas
• To define or engineer slopes for yard floodwashing and gravity conveyance of effluent systems, minimising pumping, maintenance, energy and contingency plans
• To confirm slopes across existing and proposed effluent irrigation areas, sludge and manure spreading areas
• To support assessment of odour in determining valley drainage zones and potential for katabatic drift
• To support selection of slope factors in calculating vegetative filter strip design
• To determine if discharge points and rates of flow may be altered</td></tr>
<tr><td>Geology</td><td>Depth to rock, rock outcrops, rock type and perviousness</td><td>• To confirm if the site has adequate rootzone depth, yield potential and capacity for effluent absorption (water-holding) and nutrient adsorption (nutrient retention) to function sustainably
• To confirm if rock is pervious and if deep drainage below the rootzone is likely where shallow soils exist over rock (e.g. limestone cost of south-eastern South Australia)</td></tr>
<tr><td></td><td>Exposed surface rock</td><td>• To confirm if rock may limit agricultural operations, including the capacity to produce high-yielding crops and pastures with high nutrient requirements</td></tr>
<tr><td>Surface waters</td><td>Watercourses and waterbodies (natural or engineered)</td><td>• To define the location and setback requirements for protection of naturally occurring or engineered surface waterbodies or watercourses, including (but not limited to) rivers, creeks, swamps, wetlands, channels, drains and water authority infrastructure
• To define required protection measures from cow containment areas and effluent management zones for preventing nutrient movement into on-farm drains, potentially discharging into watercourses and passing across farm boundaries</td></tr>
<tr><td>Groundwater</td><td>Bores</td><td>• To define the proximity of existing bores to dairy development sites and effluent irrigation areas
• To define setback requirements for effluent irrigation, sludge and manure spreading
• To determine protection measures required for existing and proposed bores</td></tr>
<tr><td></td><td>Depth</td><td>• To define the presence, depth and quality of groundwater, particularly permanent or seasonally shallow groundwaters
• To determine if groundwater or capillary rise may impact the integrity of agricultural structures and long-term operation
• To determine if nutrient from effluent, sludge or manure may potentially leach to groundwater and cause contamination across fields proposed for application
• To understand whether shallow groundwater (permanent or seasonal) may interact with the floor and walls of effluent ponds
• To confirm if shallow groundwater will impact crop or pasture rootzone depth, yield potential and crop nutrient removal</td></tr>
<tr><td></td><td>Quality (chemical and physical characteristics)</td><td>• To confirm the chemical and physical characteristics of groundwater
• To confirm if the site lies within an area of high-quality groundwater or where groundwater requires special protection measures</td></tr>
</table>

Land capability consideration	Potential land capability limitation for dairy developments	Reasons for the assessment of potential land capability limitation
Soils	General soil types	• To confirm existing soil literature, soil types, suitability for high-production fodder and nutrient reuse • To support selection of soil erodibility factors in calculating vegetative filter strip design for mitigating nutrient-laden runoff from non-containment areas, including tracks and laneways
	Geotechnical suitability for impermeable lining	• To define the presence and potential volumes of suitable clay to construct impervious lined effluent ponds and earthen pads for feedpads, manure management and commodities storage or if other impermeable synthetic liners are likely for adoption
	Acid sulphate soils	• To confirm the presence and depth of potential acid sulphate soils (PASS) or actual acid sulphate soils (AASS) • To define if an Acid Sulfate Soil Management Plan is required prior to further site planning or disturbance • To define the development constraints on AASS
	Saline soils	• To define the presence and depth of saline soils • To define potential impacts of salinity on foundations and earthen structures (e.g. Flocculation of impervious effluent pond lining) • To confirm if salinity may impact yield potential or sustainability across existing and proposed irrigation areas
	Sodic and dispersive soils	• To define the presence and depth of sodic and dispersive soils • To develop protection measures for managing sodic and dispersive soils during site development and earthworks • To define the presence of sodic and dispersive soils and amelioration measures for preventing soil structural decline across agricultural areas, including those proposed for effluent irrigation, sludge and manure spreading
	Waterlogging and poor drainage	• To define if waterlogging and poor drainage will impact effluent irrigation, sludge or manure spreading areas, their yield potential and trafficability • To confirm engineered drainage requirements for agricultural areas to prevent waterlogging
	Soil physical properties, including erodibility	• To confirm soil physical properties, including soil texture, structure and profile drainage • To confirm effective rootzone depth for irrigated crops and pastures • To confirm the presence of shallow soils and potential losses of irrigation, effluent and nutrient below the rootzone • To confirm the suitability of soils for effluent irrigation, sludge and manure spreading, the risks associated with use and the management measures required for sustainable use (e.g. sandy soils with low water-holding capacity and high potential for leaching to groundwater) • To confirm aggregate stability in water and erodibility for earthworks planning and staging
	Soil chemical properties, including nutrient management	• To confirm soil chemical status, including imbalances, excesses or deficiencies • To define amelioration requirements (eg. lime, gypsum, dolomite) • To provide a baseline for crop and/or pasture nutrient budgeting and sustainable nutrient management • To identify if a nutrient balance can be achieved and the required land area • To identify if phosphorus sorption may be required where land limitations constrain the adoption of a nutrient balance
	Soil characteristics for septic systems to support dairy shed domestic wastewater	• To confirm soil conditions for separate land capability for onsite domestic wastewater management (separate LCA required by councils for domestic wastewater along with independent wastewater management system requirements)

Land capability consideration	Potential land capability limitation for dairy developments	Reasons for the assessment of potential land capability limitation
Biodiversity, vegetation and bushfire risk	Biodiversity (general)	• To confirm the presence, condition, significance and ecological function of native flora and fauna and their habitats across development sites • To identify threatened species of flora and fauna and determine mitigation measures for protection
	Vegetation, including remnant stands	• To confirm vegetation status within and around development sites and support preparation of site plans, marking vegetation • To confirm the presence and condition of remnant vegetation, potential impacts and whether alternate site layout should be considered to minimise or eliminate impact • To support assessment of odour, specifically vegetation factors and surface roughness • To support assessment of bushfire risk and management • To support selection of groundcover factors in calculating vegetative filter strip design for mitigating nutrient-laden runoff from non-containment areas, including tracks and laneways
Hydrology	Water balance for confirming effluent irrigation period	• To calculate irrigation water balances for crops and pastures, providing sustainable reuse of nutrients from effluent, sludge and manure
	Water balance for determining effluent storage period	• To confirm winter storage periods when rainfall exceeds evapotranspiration (Et) (southern regions), or storage months in northern regions where daily Et allows for management of effluent storage
Air quality and odour	Odour emissions passing over boundaries	• To calculate recommended separation distances for potential odour from neighbouring receptors based on the development type and method of operation • To calculate cumulative odour impacts, where other odour generating facilities exist

- **Define:** Specific location or exact measurement
- **Determine:** To develop based on several factors or inputs
- **Confirm:** To identify or clarify based on site conditions
- **Calculate:** To identify or calculate a specific outcome or unit of measurement
- **Support:** Element used to assist with defining, determining, or calculating other considerations or limitations

2 Field investigations

2.1 Site verification and investigations

Following preliminary desktop review, the following fieldwork is required to complete a detailed LCA:

1. Site verification by the LCA assessor, confirming the accuracy of land capability considerations and limitations which are adequately detailed from desktop review.
2. Commencement of investigations by consultants in specialist areas of expertise.

Key areas of specialisation commonly relied upon for dairy developments include, but are not limited to the following:

- **Land surveyor:** To collect a detailed account of existing surface levels and features and prepare a survey plan. The survey will be used to support facility and earthworks design by external consultants, including dairy design consultants.
- **Geotechnical engineer:** To understand material type, suitability, constraints and recommendations for use in constructing impermeable effluent ponds and water storages (detailed in Chapter 5).
- **Soil scientist and/or suitably trained agronomists:** To sample and describe soils and provide an assessment to support high-yielding crops and pastures for sustainable nutrient reuse. The consultant must set limits for sustainable nutrient removal and application (details in Section 2.2 and 2.3).
- **Hydrogeologist, environmental or soil scientist:** To sample bores, understand groundwater depth and chemistry and interactions between soil, surface water and groundwater.
- **Ecologist or environmental scientists,** to address all elements of native vegetation management, flora and fauna and potentially threatened species and their management.

Figure 3. Developing a property image using drone technology with a phoenix Lidar sensor

2.2 Soil physical assessment

For dairy development sites subject to application of effluent, sludge and manure, knowledge on soil properties is required for sustainable, long-term nutrient management. Site and profile drainage along with baseline a review of soil physical and chemical properties must be verified across application, ensuring the development size is sustainable.

Soil investigations require an assessment of land broadly consistent with the process and methods described in the *Australian Soil and Land Survey Field Handbook,* Fourth Edition, by the National Committee of Soil and Terrain, published by CSIRO (NCST, 2024). The handbook is abbreviated as the 'ASLSHF'. Soil Science Australia encourages developers to use Certified Professional Soil Scientists (CPSS) to carry out specialist soil science investigations to professional standards and use the ASLSHF to guide fieldwork.

Chapters 2–7 of the ASLSHF provide support for consultants carrying out LCA's or areas of specialist consulting around site concept planning, general land survey and details on the assessment of site location, landform, vegetation and land surfaces. Chapters 8 and 9 provide details of typical assessment requirements for soil profiles and substrate materials.

Soil assessments should be carried out on a grid that reflects the landscapes variability, sensitivity and intensity of use. Where landscapes are variable, where environmental sensitivity is high or where double-cropping will be practised, grids should be tightened to ensure high-level data and site variability is captured. Tools used to further support decision making around landscape variability and survey intensity include:

- EM38 horizontal and vertical dipole (electromagnetic mapping of apparent conductivity), measuring the ability for a soil to conduct an electric current, reflecting areas of increased clay, salt, moisture or rock.
- NDVI (Normalised Difference Vegetation Index), showing measures of historic paddock greenness at various stages of crop growth.
- Elevation and contour data, collected by either field survey or from government database information, which may include LiDAR (Light Detection and Ranging). For flat irrigation lands, field survey is required at a minimum.
- Historic yield mapping, showing end yield which is often correlated to soil condition.

Typical profile assessment parameters: Soil profile assessment, either by soil pit or core should define the soils physical attributes which should include, but are not limited to the following parameter, measurement, observation or calculation in Table 2.

Existing nutrient reuse sites: An assessment of soil profiles across existing nutrient reuse areas is a minimum standard to determine baseline physical properties, chemistry, nutrient and salinity conditions. State guidelines for effluent or recycled water management should be used to set baseline and threshold soil test levels, under consent of a soil scientist or suitably trained agronomist.

Greenfield sites: For greenfield sites, new irrigation development guidelines must be adopted for each state or region, with the support of a soil scientist or suitably trained agronomist to understand baseline physical properties, chemistry, nutrient and salinity conditions and their potential impact on sustainable nutrient reuse. In Victoria, new irrigation development guidelines are required for adoption in accordance with Standard Water-Use Conditions, a ministerial determination made under sections 64P, 64Y(1) and 64AI of the *Water Act 1989*. Other states and regional guidelines for new irrigation development must be adhered to for compliance.

Table 2. Soil profile parameter, measurement, observation, calculation and reference methods

Soil profile parameter, measurement, observation (horizons) or calculation	Reference – methods
Horizon notation	NCST, 2024; Northcote, 1979.
Horizon depth (cm)	NCST, 2024; Visual measurement by surveyor
Texture	NCST, 2024; Northcote, 1979
Soil colour (Munsell)	Munsell Colour Charts, 2015
Soil structure	NCST, 2024; Northcote, 1979.
Consistence (% brittleness)	NCST, 2024; Butler, 1955
Plasticity	NCST, 2024
Field pH (water)	CSIRO pH kit
Carbonate reaction to 1 molar HCl	NCST, 2024; McKenzie et al, 2008.
Segregations (eg. carbonate, gypsum, mangans)	NCST, 2024
Coarse fragments	NCST, 2024
Cutans	NCST, 2024
Mottling	NCST, 2024
Root abundance (score) and organic matter	NCST, 2024; Visual measurement by surveyor
Classification of carbonate layers	Weatherby & Oades, 1975; Isbell & NCST, 2021
Pans	NCST, 2024
Depth to impeding layers (physical and chemical)	Visual measurement by surveyor
Drainage status (per horizon)	Estimate by surveyor
Effective rootzone depth (cm)	Visual measurement and estimate by surveyor
Groundwater presence	Visual, measurement by surveyor
Readily available water (RAW) for irrigation (calc)	Allen et al, 1998; NSW DPI, 2014.

2.3. Soil, groundwater and effluent: Chemical assessment, nutrient management and testing

Sustainable nutrient management is critical for dairy developments, particularly where intensive grazing and fodder production occur or are proposed, requiring high-level nutrient application either all or in part by effluent, sludge and manure. Sustainable reuse must be demonstrated by sound LCA planning, which must extend beyond a basic nutrient removal and balance to determine sustainability.

Determining the sustainability for proposed application requires engagement by a business's agronomist, in conjunction with a soil, agricultural or environmental scientist to look at all factors which minimise risk of loss to the environment. Consultants must ensure the production system considers current and seasonal groundwater levels, profile and surface drainage, potential accessions to groundwater, surface and groundwater interactions, losses via field runoff, runoff collection and nutrient recycling.

To support a detailed LCA, the following is required for assessment:

1 A review of **historic soil test data, groundwater levels and groundwater chemistry,** to define patterns and trends and understand if sites are subject to nutrient loss below the rootzone, or determine if sites have traditionally been overloaded.

2 A review of **current soil test data, groundwater levels and groundwater chemistry**, confirming whether soil parametres are exceeding thresholds or below critical levels and forming a baseline:
   - The assessment should include all land subject to past and proposed effluent, sludge and manure application.
   - Both topsoils and subsoils should be tested, to a minimum depth of 60cm for measuring available soil nutrient, particularly ammonium, nitrate nitrogen and sulphur. Recommended testing increments are 0-10cm for topsoils, 10-30cm for upper subsoils and 30-60cm for mid-deep subsoils.
   - For sites subject to intensive nutrient application and production, annual soil testing is recommended as a minimum requirement.

3 Calculations for **proposed nutrient removal,** based on:
   - One crop or pasture per season, with nutrient removal dictating preliminary application rates, or
   - 'Double-crop' application rates, where three crop or pasture sequences are grown over a 2-year period, with the total nutrient requirements calculated and averaged per year, dictating preliminary application rate

4 **Results of effluent testing**, sourced from an effluent management plan (EfMP) by a suitably trained dairy effluent systems designer:
   - Volumes of effluent, sludge and manure generated at peak operation.
   - Concentrations of nutrients including N, P and K within effluent, sludge and manure, after losses to volatilisation and adsorption by sludge, organic matter or earthen pond lining are considered.

5 **A preliminary calculation of a nutrient balance**, setting the maximum potential nutrient removal and application per year, base volumes of nutrient generated vs volumes required.
   - Nutrient levels in irrigation waters should also be considered.
   - Maximum thresholds for limiting soil nutrients should dictate the maximum application rates of effluent, sludge and manure. In most instances, phosphorus often sets the upper limit for application.
   - This approach may potentially be tempered under land limiting conditions if phosphorus sorption can be relied upon (subject to testing and suitable conditions).

6 **An evaluation of the sites LCA considerations and limitations and adjustments to a nutrient balance**, with application rates tempered to suit site conditions, under direction of agronomist, soil, agricultural or environmental scientist advice. Some examples include:
   - If groundwater is seasonally high, irrigation of effluent must be restricted during periods when groundwater is within 1.5 metres of the natural surface, reducing the period (months) when application is sustainable without losses to leaching or runoff.
   - If soils are sandy or permeable, including soils throughout the limestone coast regions, nutrient loadings must be adjusted to meet crop nutrient requirements at any one time, preventing losses to leaching or runoff.

Both soil and groundwater test results should be reviewed simultaneously by expert consultants covering both fields of expertise. Where groundwater chemistry is above background levels, or patterns and trends show increases, nutrient application should cease and detailed assessment of groundwater, soil and effluent application be commissioned to understand sources of contamination.

Double-cropping: Some intensive dairy operations aim to 'double-crop', with the aim of growing two crops per season. In practice, most businesses that double crop more commonly grow three crops over a 2-year period, as difficulty is experienced with back-to-back cropping every season due to rain or operational constraints impacting planting and harvest dates. Rarely are two crops able to be grown back-to-back every season and if so, these are typically cut for fodder and the total nutrient requirement (removal) may reduce significantly under shorter growing periods. Double cropping should be based on 3 crops grown in a 2-year period for the purpose of nutrient budgeting, with annual soil testing.

Phosphorus sorption: Phosphorus budgets typically dictate overall effluent application rates under a balanced nutrient budget. This process is often not practical or achievable based on land area requirements for application. Under suitable soil conditions, phosphorus sorption, or storage may be relied on to store phosphorus applied at above removal rates without environmental impact, allowing additional nitrogen and potassium to be applied to match a nutrient balance. Phosphorus sorption is possible particularly within clay soils with high adsorption capacity. This practice is typically not suitable sandy soils, other permeable soils (eg. limestone soils) or sites with shallow or beneficial use groundwater.

An evidence-based approach is required to adopt phosphorus sorption. Soils must have high phosphorus sorption capacity and generally low or acceptable baseline levels, with physical incorporation (tillage) typically used for sludge or manure application to minimise risk of runoff.

Accurate soil classification, description, sampling, testing, interpretation and advice is required to determine how much phosphorus a soil can sorb per unit of area and confirm the sustainable lifespan of the practice. Annual monitoring is required on any site where phosphorus sorption is practised.

Salinity and salt budgets: Where salinity is of a concern, salt budgets should be prepared to describe the fate of salts applied. Leaching of salts below the rootzone, particularly chloride, is well-recognised as a requirement for long-term, sustainable irrigation of elevated salinity waters, groundwaters and effluent. Salts from irrigation water must also be considered and included within a nutrient balance.

Effluent, sludge and manure testing: Annual testing of the effluent stream, sludge samples and screened manure should be carried out to understand typical nutrient concentrations and parameter levels. This should form part of an EfMP for dairy developments. Results vary depending on the cow numbers, time and volume of effluent collected, water use for dairy shed, yard and feedpad cleaning and rainfall collected from catchments contributing to the effluent stream. Volumes of effluent applied and/or hydraulic loading of nutrient can be tempered based on site-specific characteristics.

Testing parameters: Typical soil, effluent, groundwater, surface waters, sludge and manure testing parametres are listed in Tables 3-5. Soils should be tested using methods consistent with those within 'Soil Chemical Test Methods – Australasia' by Rayment and Lyons (2011), published by CSIRO, unless alternate methods and references are listed. Groundwaters should be monitored for standing water levels.

Table 3. Typical soil testing parameters, units of measurement and reference methods

Laboratory test and units of measurement	Unit of measurement	Test method – Rayment & Lyons, 2011
pH (1:5 water)	Units	4A1
pH (CaCl2)	Units	3A1
Electrical Conductivity (1:5 water)	dS/m	4B4
Chloride	mg/kg	5A2b
Organic Carbon (Walkley & Black)	%	6A1
Total Carbon	%	6B1, 6B2b
Organic Matter	%	Calculation from OC x 1.72
Total Nitrogen	%	7A5
Ammonium Nitrogen	mg/kg	7C2b
Nitrate Nitrogen	mg/kg	7C2b
Sulphur (KCl 40°C)	mg/kg	10D1
Phosphorus (Colwell)	mg/kg	9B2
Phosphorus Buffer Index (PBI)	Unitless	9I2b
Phosphorus (Olsen)	mg/kg	9C2B
Phosphorus (Melich 3)	mg/kg	18F2
Phosphorus (Total)	mg/kg	9G1
Phosphorus Sorption Capacity	mg/kg	7-day sorption capacity trial (Ryden & Pratt, 1980) – EAL laboratory
Potassium (Colwell)	mg/kg	18A1
Exchangeable Calcium, Magnesium, Potassium, Sodium (Ammonium Acetate)	mg/kg, cmol/kg	15D3
Exchangeable Aluminium (KCl)	mg/kg, cmol/kg	15G1
Exchangeable Sodium Percentage (ESP)	Base saturation percentage	Calculation from exchangeable cation data
Cation Exchange Capacity	cmol/kg	Calculation from exchangeable cation data
Trace elements: Copper, Iron, Manganese, Zinc (DTPA extraction)	mg/kg	12A1
Boron (Hot CaCl2)	mg/kg	12C2
Dispersion and slaking	Units	Loveday & Pyle, 1973; ASWAT test by McKenzie, Koppi & Field (1997)
Emerson aggregate test (slaking and dispersion)	Units	Emerson (1967); AS 1289 (2017), 3.8.1. AS 1289 (2020), 3.6.3.
Particle Size Analysis (% fine sand, % coarse sand, % silt, % clay (hydrometer) and texture	%	AS 1289 (2020), 3.6.1.

Table 4. Typical testing parameters and units of measurement for effluent, groundwaters and surface waters

Laboratory test and units of measurement	Unit of measurement
Standing water level (groundwater only) – field measurement when sampling	mbgl (metres below ground level)
Biochemical Oxygen Demand (BOD5) – measured over 5 days	mg O_2/L
Total coliforms	CFU/100 mL
E. Coli	CFU/100 mL
Electrical Conductivity - 1:5 water	dS/m
Total Dissolved Salts (TDS)	mg/L, ppm
Chloride	mg/L
pH (1:5 water)	Units
Carbonate	mg CaCO3/L
Bicarbonate	mg CaCO3/L
Total Alkalinity	mg CaCO3/L
Water Hardness	mg CaCO3/L
Residual Sodium Carbonate	meq/L
Sodium - total and dissolved (acid digestion)	mg/L, meq/L
Calcium - total and dissolved (acid digestion)	mg/L, meq/L
Magnesium - total and dissolved (acid digestion)	mg/L, meq/L
Potassium - total and dissolved (acid digestion)	mg/L, meq/L
Sodium Adsorption Ratio	Unitless
Ammonium Nitrogen	mg/L
Nitrate Nitrogen	mg/L
Total Kjeldahl Nitrogen (TKN)	mg/L
Phosphorus - total and dissolved (acid digestion)	mg/L
Sulphur - total and dissolved (acid digestion)	mg/L
Zinc - total and dissolved (acid digestion)	ug/L or mg/L
Copper - total and dissolved (acid digestion)	ug/L or mg/L
Manganese - total and dissolved (acid digestion)	ug/L or mg/L
Iron - total and dissolved (acid digestion)	ug/L or mg/L
Boron - total and dissolved (acid digestion)	ug/L or mg/L
Aluminium - total and dissolved (acid digestion)	mg/L
Molybdenum - total and dissolved (acid digestion)	ug/L or mg/L
Cobalt - total and dissolved (acid digestion)	ug/L or mg/L

Table 5. Typical sludge and manure test parameters, typical testing methods and units of measurement

Laboratory test and units of measurement	Typical testing methods	Unit of measurement
Dry matter	% at 70 degrees	%
Moisture	% at 70 degrees	%
Total Carbon	Dry combustion method	mg/kg, %
Total Nitrogen	Dry combustion method	mg/kg, %
Carbon-Nitrogen Ratio (C/N)	Calculation	Ratio
pH	1:5 water	Units
Electrical Conductivity	1:5 water	dS/m
Chloride	Water soluble: 1:5 water	mg/kg
Ammonium Nitrogen	Water soluble: 1:5 water	mg/kg
Nitrate Nitrogen	Water soluble: 1:5 water	mg/kg
Boron (Water soluble, total)	Water soluble: 1:5 water, Total: ICP-OES	mg/kg
Calcium (Water soluble, total)	Water soluble: 1:5 water, Total: ICP-OES	mg/kg
Copper (Water soluble, total)	Water soluble: 1:5 water, Total: ICP-OES	mg/kg
Iron (Water soluble, total)	Water soluble: 1:5 water, Total: ICP-OES	mg/kg
Magnesium (Water soluble, total)	Water soluble: 1:5 water, Total: ICP-OES	mg/kg
Manganese (Water soluble, total)	Water soluble: 1:5 water, Total: ICP-OES	mg/kg
Phosphorus (Water soluble, total)	Water soluble: 1:5 water, Total: ICP-OES	mg/kg
Molybdenum (Water soluble, total)	Water soluble: 1:5 water, Total: ICP-OES	mg/kg
Potassium (Water soluble, total)	Water soluble: 1:5 water, Total: ICP-OES	mg/kg
Sodium (Water soluble, total)	Water soluble: 1:5 water, Total: ICP-OES	mg/kg
Sulphur (Water soluble, total)	Water soluble: 1:5 water, Total: ICP-OES	mg/kg
Zinc (Water soluble, total)	Water soluble: 1:5 water, Total: ICP-OES	mg/kg

3 LCA summary and reporting.

LCA reporting should address all environmental factors concerning dairy development and confirm whether the land and method of operation can be sustainably supported. Results must be presented in a way which regulatory authorities can assess and complete their own detailed environmental assessments, confirming information accuracy. An LCA must be of high integrity and defendable, should elements be questioned or objected to by local councils, referral authorities, state planning tribunals or the public. An LCA will inform an EMP or EIS in demonstrating how environmental constraints from site development will be avoided, managed and monitored.

5.3 Site investigation

Site investigations must consider both the construction site and the site for borrowing earth.

Underground services locators

Where there is any known occurrence of underground services, an underground service locator is required to peg the alignment of these features and provide guidance on the safe working distance from these features. Clearance for any works should not proceed until all known services are located.

Site survey and site plan

A qualified and experienced land surveyor should carry out a feature survey with levels. A site survey is critical to confirm slopes, drainage flow paths, speed of drainage and likelihood of inundation as well as supporting the design stage that must detail options for manure management. A site survey sets the basis for development of a site plan required by authorities to assess planning applications and for earthworks and construction contractors for quoting works.

Engineers will base their designs on the topographic data collected by the site surveyor. The site survey data will be provided to the engineers and other professional service providers in digital format for computer aided design and drafting (CADD).

Following the approval of the site development proposal, the surveyor will again be required for the set-out and confirmation of the positioning of features. Plans are required to ensure authorities assessing applications and contractors providing quotations understand:

- Site boundaries
- Existing buildings
- Location of neighbouring residences and neighbouring land use
- Waterways, watercourses, depressions, low areas and natural drainage lines
- Native vegetation
- Markers indicating the presence of underground services
- Easements, including council, water authority or other
- Cross sections, including earthworks volumes and schedules, allowing borrow material volume from sumps or ponds to be matched with requirements for pad or embankment construction
- Stormwater drainage away from the site under high rainfall design intensity scenarios (e.g. 1 in 100-year rainfall).

Site drainage

Poor drainage and uncontrolled soil moisture ingress can impact on earthen structures and facilities causing excessive ground movement and failures in structures and concrete. This is important in fine-textured, clay-dominant soils or where high-water tables and capillary rise of groundwater impact foundations. All areas of poor drainage should be avoided or engineered to prevent drainage impacts.

Location of effluent ponds and borrow pits

Sites for effluent ponds and borrow pits should be defined early in the planning process by targeting preferred soil types, or by identifying the logical location of the storage site from the facility. In most cases, the most common location for accessing suitable borrow material for construction of earthen pads is by excavating soil from proposed effluent pond sites.

Additional borrow material may need to be sourced for flat sites, poorly drained sites, sites impacted by inundation, flooding, high water tables or sites requiring elevation above natural surface level.

5.4 Geotechnical investigation and materials suitability

Depth of geotechnical investigation and equipment

Geotechnical investigations are well supported with use of Electromagnetic Mapping (EM) which measures apparent conductivity of a soil to variable depths, reflecting changes in texture, moisture, salts and rock. EM31 should be used for deep investigation to 3.0–4.0 metres. EM38 vertical dipole can be used for shallow investigations to 1.0 metre.

Depth of investigation should extend to at least 1.0 metre below the proposed base of an effluent pond or foundation depth, allowing for characterisation of deeper materials. For example, if an effluent pond or sump has a proposed depth of 3.0 metres, investigations should extend to at least 4.0 metres.

Geotechnical investigations should be carried out with the aid of equipment including an excavator, backhoe or drilling rig. Excavators and backhoes provide greater accuracy and clarity to determine soil horizons and accuracy in sampling, particularly where in-situ lining and horizon thickness is critical to determine. Further reasoning includes:

- A reduction in smearing and mixing of soil during investigation
- Ability to collect clean, uncontaminated samples from set depths by hand in shallow pits or by machine retrieval from deep pits
- Measurements of shallow or perched groundwater which are timely and accurate
- Ease in collection of large samples for geotechnical testing
- Exposure of soil layers for in-situ permeability testing.

Figure 4. Layers of soil extracted from investigation sites using an excavator

Figure 5. Layers of soil extracted from investigation using a drill rig

Soil classification and suitability

Materials should be classified using the Unified Soil Classification in accordance with AS 1726:2017 Geotechnical Site Investigation. Different soil types are needed for different purposes and types of construction activities.

Constructing earthen feedpads, manure stockpiles or composting areas: construction may occur using coarse or fine-grained soils. Materials should be compacted to 98–100% of standard Maximum Dry Density for coarse grained soils and 95–98% for fine textured soils. All material types should have provisions for external and internal drainage to control moisture ingress and prevent fluctuations in moisture content. Fine grained soils may suffer ground movement with changes in moisture content from seasonal variation, perimeter plant growth, groundwater and capillary rise. Moisture content may also change if pads develop cracks allowing moisture to enter or if there are failures in plumbing.

Use of highly organic soils of any type are not recommended for use in pads. The organic fraction is subject to decay causing soil consolidation and pad movement. Furthermore, organic materials may promote excessive moisture ingress and retention which must be prevented.

Lining effluent ponds: fine-grained soils including clays and some silts are preferred for impervious soil lining. The suitability of materials generally increases with an increasing clay percentage. Materials suitability is summarised as follows:

- Preferred – fine grained soils:
  - CH, CI and CL: Clays of high, moderate or low plasticity.
- Marginal – silts, low plasticity clays with high sand percentages and some clayey sands.

Materials may require soil treatment or amendment by importation and mixing clay, bentonite or sodium tripolyphosphate.

  - MH: Silt of high plasticity.
  - CL: Clay, low plasticity with high sand percentages.
  - SC: Sand, clay.
- Not suitable – coarse grained soils including sands and gravels, or silts with excessive rates of permeability:
  - ML: Silt of low plasticity.
  - GW, GP, GM and GC: Gravels of all types.
  - SW, SP, SM and SC: Sands of all types.

Marginal soil materials and options for reducing permeability to achieve minimum permeability standards:

1 Clay spreading and mixing, including dispersive clay which may seal from dispersion when in contact with fresh water.

Note

- Care is required in use of dispersive clays around pipes and structures through banks. Soils around pipes and structures should be stabilised with hydrated lime.
- Dispersive clays may not disperse under elevated electrical conductivity (EC) levels from flocculation.

2 Bentonite, spread and mixed into surface layers of lining, rates of 7–10kg per m^2 are used as a guide on marginal soils.

3 Sodium tripolyphosphate (STPP), spread and mixed into surface layers of lining. Rates of 0.5kg per m^2 are used as a guide on marginal soils. STPP can also be incorporated into water supplies at 0.5g per litre to reduce permeability.

Gypsum (Calcium Sulphate) should not be used for sealing embankments. Gypsum is a salt which flocculates clay, reduces or eliminates soil dispersion and enhances the structure and permeability of clay. Gypsum is suitable for reducing or eliminating dispersion and rill erosion on the finished surface of embankments, enhancing prospects for achieving pasture cover.

Laboratory assessment

Geotechnical testing of soil materials should be carried out by a NATA accredited laboratory. Laboratory testing should be in accordance with procedures outlined in AS 1289 (2000) *'Methods of testing soils for engineering purposes'*. Minimum testing requirements for understanding material characteristics and suitability include:

- Moisture Density Relationship (MDR):
  - Optimum Moisture Content (OMC)
  - Maximum Dry Density (MDD).
- Particle Size Distribution:
  - Sieve analysis – all coarse fractions to 75 microns
  - Hydrometer analysis – percentage sand, silt and clay.
- Atterberg Limits, including:
  - Liquid Limit (LL)
  - Linear Shrinkage (LS)
  - Plastic Limit (PL)
  - Plastic Index (PI).
- Moisture Content (MC).
- Permeability (Constant Head) carried out using a saline brine reflective of the electrical conductivity (EC) of effluent.

Agricultural soil testing to compliment geotechnical testing: parameters which are beneficial include:

- EC 1:5 (salinity): measure of salts in the soil
- pH (water): measure of soil acidity
- Slaking Class: measure of aggregate stability and breakdown upon wetting
- Exchangeable cations, including calcium, magnesium, potassium, sodium and aluminium: Measure of the cation balance of a soil and likely stability. Required for calculating Exchangeable Sodium Percentage (ESP)
- Exchangeable Sodium Percentage (ESP) (calculated). Measure of the likely soil dispersion that may occur.

Groundwater assessment and measurement: the presence of groundwater should be recorded along with the depth. Where possible, groundwater should be sampled and tested for EC (salinity) and pH. Evidence of groundwater should also be recorded. Pit or borehole smearing by equipment is expected. Groundwater is best checked several hours or the following day after digging pits or drilling boreholes, allowing standing water levels to stabilise.

5.5 Construction requirements for earthen feedpads, embankments and liners

Topsoil removal and management

Topsoil including all soil material with organic matter and tree roots should be removed from all areas for construction of feedpads, contained housing facilities and effluent ponds and infrastructure supporting where earthen pads, banks and lining is required. Topsoil should be stockpiled for embankment shrouding, paddock renovation or construction of aesthetic banks.

Borrow areas

Guidelines for extracting borrow soil as potential sites for effluent ponds or freshwater storages are:

- **Batter slopes:** should permit machinery access and maintenance, with grades of 3:1 horizontal to vertical (H:V).
- **Soil stripping:** materials should be stripped in layers of uniformity, reflecting horizons. Each layer should be individually or composite tested for laboratory assay.
- **Depth of borrow:** depth based on geotechnical investigation results. In clay-dominant soils, ideally a minimum of 600mm of impervious clay should be retained for lining.
- **Inspection:** all borrow areas should be inspected on completion of excavation, confirming materials are suitable for impervious lining.

Embankment construction for effluent ponds and small fresh water storages

- **Embankments:** zoned, ensuring a core section which provides security of water impoundment and intercept of any horizontal water flow or preferential pathway for water transmission.
- **Core construction:** common core construction methods are shown in Figure 6 and Figure 7. Configuration and thickness are listed as follows:
  - Extend from the base of the key trench or borrow pit to the crest
  - Minimum thickness of 0.6 metre.
- **Batter slopes:** minimum of 3:1 horizontal to vertical (H:V) grade or flatter for safety, access for maintenance and minimal erosion. Steeper grades can be applied however trafficability is limited, safety risks for machinery increase and erosion of banks is more likely. Where less than 5:1, erosion control measures will be required.
- Freeboard:
  - Refer to relevant state or territory guidelines or code.
- Crest:
  - Width: minimum of 3.0 metres, allowing a 5:1 phreatic line to be maintained from full supply level on the inner batter without reaching the outer toe.
  - Slope: 1 in 25 to 1 in 40 H:V grade sloping towards the dam.

Figure 6. Common embankment core construction method – central clay core

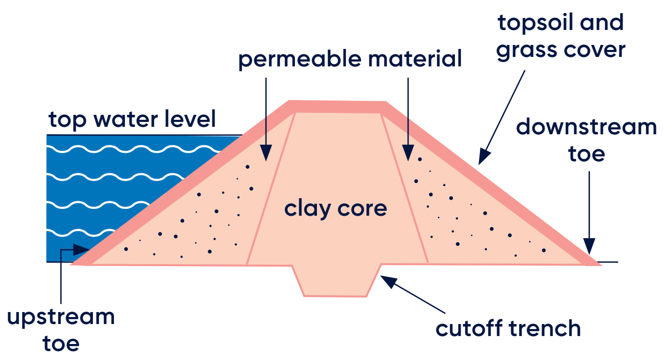
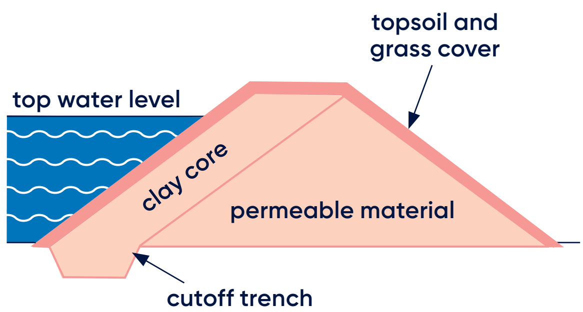


Figure 7. Common embankment core construction method – typical upstream clay core



- **Core section**: 98% of the standard maximum laboratory dry density determined in accordance with Method 5.4.1 of AS 1289, at the optimum moisture content (OMC).
- **Non-core section/non-liner material compaction:** 95–98% of the standard maximum laboratory dry density determined in accordance with Method 5.4.1 of AS 1289, at the OMC.
- **Construction technique:** lifts of approximately 150mm, wetted to the OMC and compacted to the MDD for specific material type.
- **Protective shroud (topsoiling) over liners and embankment:** minimum of 100mm of topsoil or any available material to protect embankments and liners from drying and desiccation.
- **Pipes through embankments:** minimum of two cut off collars installed, extending at least 0.6m in all directions around the pipe, affixed and sealed to the pipe.
- **Stabilisation of soil around pipes and cut off collars:** incorporate hydrated lime mixed through the soil at 1% w/v, wetted and compacted to the specifications for soil core construction.
- Track walk the banks to reduce rill erosion, enhance stability and promote the lodgement of seed for establishment.
- Gypsum treatment of finished embankments after topsoiling is recommended at 1% w/v to control dispersion.
- Seeding of embankments is recommended using grass species such as Kikuyu. Trees should not be planted on embankments.
- **Overflow systems:**
  - Effluent ponds should be contained with no overflow. Alarm systems should be installed for monitoring pond levels.
  - Fresh water storages should have overflow systems installed at full supply level to prevent overtopping. Overflow discharge areas should be rock armoured or stabilised by grass cover or geosynthetic options.

Construction of internal farm roads and laneways

Construction of earthen pads should follow guidelines and procedures for earthen lining, outlined in the previous section on embankment construction for effluent ponds and small fresh water storages above. This includes topsoil stripping and compaction of selected materials.

For internal farm roads and laneways, coarse-grained materials including gravels and sands are preferred as sub-grade or sub-base material. These materials have low shrinkage values and less propensity for soil movement. In accordance with AS1726:2017, these materials are classified as gravels (GW, GP, GM, GC) and sands (SW, SP, SM). Clays and silts (CH, CI, CL, MH and ML) can be used if well-drained with minimal risk of moisture ingress. Imported materials may need to be imported to achieve elevated tracks, laneways and roads that are well-drained with minimal ground movement.

Safe bearing pressures should be based on engineer specification, set based on axle loads, frequency of use and material type.

5.6 Earthworks quality assurance assessment

Quality assurance (QA) assessments should be carried out on all earthworks supporting dairy feedpads and contained housing facilities. Earthworks should be supervised or be periodically checked at various stages by qualified or experienced personnel.

Supervision during earthworks is essential to ensure:

- Topsoil are adequately stripped from all borrow areas, from under embankments, earthen pad sites and any other area including tracks and laneways prior to construction.
- Placement of clay on pads or embankment areas occurs in a 'like-on-like' fashion, ensuring compacted clay is placed on the same material and adequately bonded. Topsoil, manure and other foreign material must not be mixed into any earthen pad or liner.
- Clays excavated from borrow areas are uniform in condition. Where variable, compaction specifications will need to be adjusted for differing material types.
- Sand and other unfavourable material is not uncovered in any borrow area or used for construction of embankments or pads. Where uncovered, in-situ liners are not suitable, and an engineered clay liner is required for construction to an impervious standard.

For large projects, QA checks covering site plans and specifications should occur constantly throughout the project. AS 3798 (2007) provides guidelines around earthworks testing for commercial development sites.

Embankments, liners and pads must be checked for compaction as layers of material are placed. Testing should occur in accordance with differing material types and the contractors requirements, ensuring they achieve the recommended specifications for moisture and density. Samples that fail will require ripping, rewetting to the OMC and compaction.

Permeability testing is required on all in-situ liners to ensure a minimum coefficient of permeability of 1×10^{-9} metres per second is achieved, reflecting an impermeable condition.

Borrow areas should be inspected upon completion for pervious materials. EM38 mapping may be beneficial across the borrow area to define any pattern of subsurface conductivity that defines sand lenses.

Erosion control measures should be constructed within and around construction sites to ensure rainfall does not cause excessive erosion.

Clay-dominant soils, particularly those that are dispersive should be covered with topsoil or have a layer of gypsum spread on the surface to reduce dispersion and turbidity of stormwater emanating from construction sites. Sites should be left in a condition that allows for drainage without site ponding.

5.7 Engineered lining options for ponds and sumps

Several dairying areas of Australia contain soils and geology not suitable for impervious lining. Regions with pervious limestone rock such as the south-east of South Australia, widespread sandy soils in Western Australia or dairying regions on alluvial soils in old river valleys of Victoria, Tasmania and New South Wales often reveal no clay for use in lining ponds. Under these conditions, geosynthetic lining, concrete lining or other engineered lining options are required to achieve impervious conditions.

Two of the most common geosynthetic lining options include Geosynthetic Clay Lining (GSL) and High-Density Polyethylene (HDPE) (Figure 5). Liners of this type should be constructed to the following criteria and considerations:

- Suitable for effluent or use as an impervious barrier for effluent or leachate.
- Installed to manufacturers requirements, including site preparation.
- Adequate ultra-violet (UV) rating for the proposed lifespan of the material.
- Drainage and seepage detection beneath the liner.

Where small structures or sumps are required, concrete is the most common option for providing an impervious barrier which is not subject to movement. Concrete can also withstand trafficking and cleaning with machinery. Sulphate resisting concrete should be used where concrete will be subject to liquid with an elevated salt loading, where soils are saline or where groundwater impacting foundations is saline.

Above-ground tanks are used in landscapes where pond construction is difficult based on landscape characteristics.

Figure 8. HDPE lining installed for impervious ponds in northern Victoria

5.8 Finalise plans and supporting documentation

Final plans

All site plans must be finalised prior to submitting development applications to council for approval.

Earthworks plans, schedules and machine control

Earthworks plans and schedules quantities should be prepared for any site subject to earthworks of a reasonable scale. Earthworks plans and quantities allow for:

- Developers to gain a real appreciation of the size and scale of works to be undertaken along with anticipated costs of earthworks and maintain works to set budgets.
- Authorities to have quantified the exact amounts of earth to be shifted during each stage.
- Contractors to provide accurate quotations for works.

An equal earthworks balance should be calculated, ensuring that the required volume of earth (compacted) for all earthen structures including embankments, liners and pads equals the amount available and designated for excavation. A compaction factor of 10–15% should always be allowed for in calculations for earth.

Where possible, machine files should be created for contractors carrying out works. Machine files allow all finished levels to be matched to plans without continual need for supervision. Regular checks of levels against benchmarks should occur.

Figure 9. Construction of an earthen feedpad and ponds – long view

Figure 10. Construction of an earthen feedpad and ponds

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Accredited effluent system designers:

agriculture.vic.gov.au/livestock-and-animals/dairy/managing-effluent/effluent-system-designers

Queensland pond lining **daf.qld.gov.au/business-priorities/agriculture/animals/pigs/managing-environmental-impacts/constructing-effluent-ponds**

Soil management, erosion and sediment control information, available at **nt.gov.au/environment/soil-land-vegetation/soil-management-erosion-sediment-control**

06

Water supply

Introduction

The purpose of any water supply system is to support production and ensure appropriate standards of animal health, welfare and hygiene are maintained by:

- providing sufficient volumes of good quality water.
- designing the system to manage periods of increased demand.
- designing and locating water troughs that are easily accessible, easily cleaned and positioned to minimise contamination by feed.

It is also important to ensure water requirements to operate a dairy farm are readily available by:

- understanding potential water consumption and frequency of use.
- identifying opportunities to capture and utilise rainwater sustainably.

6.1 Stock water quantity and quality requirements

When planning temporary containment or longer-term contained housing facilities where cattle are concentrated to a designated area, it is essential to determine stock water requirements, both from a quantity and quality perspective, while providing adequate access for all stock.

Dairy cows need access to clean, fresh water supplies, with the potential to consume 30–50 per cent of their daily water intake within one hour following milking. It has been reported that lactating cows can consume water at rates of up to 20 litres per minute.

The amount of water a cow drinks depends on several variables such as: size and milk yield, quantity of dry matter consumed, temperature and relative humidity of the environment, water temperature, quality and volume of water on offer, and amount of moisture in the feed ration (Table 6).

Table 6. Estimations of dairy cow water requirements

Dairy cow	Daily water requirement
Non-pregnant cows in cool environment (less than 15°C)	Estimated 3.5 litres of water per kg of dry matter consumed
Pregnant cows in warm environment (around 21-25°C)	Up to 7.1 litres of water per kg of dry matter consumed
Lactating cows	5 litres of water per kg of dry matter consumed plus • additional allowance of 1 litre of water per litre of milk produced • additional requirement during hot weather

On average throughout the year, dairy cows typically drink somewhere in the range of 120–150 litres of water per day when producing about 20 litres of milk. Approximately 25–35 per cent is obtained from the various feed rations consumed and the rest from drinking.

Water is an important source of nutrients during periods of heat stress. Dairy cows drinking intake can increase by as much as 80 per cent on days over 35°C. Therefore, on hot days, allow 200–250 litres per cow each day.

Signs that indicate the water delivery system is inadequate are cows queuing up to drink, regularly empty troughs or cattle damaging float valves.

Optimal drinking water temperature is between 15–20°C. However, water temperature only has a slight effect on drinking behaviour and animal performance, therefore responses to chilling water under most circumstances would not warrant the costs of cooling the water.

It is good practice to routinely test the water supply to ensure water quality parameters are within an acceptable range to maintain animal performance. Testing should include levels of total dissolved salts (TDS), pH, hardness, specific minerals/compounds, heavy metals, other toxic compounds, and microbes.

If results of water analysis indicate water quality problems, seek an alternate water source, or water treatment system that can improve the specific parameters.

Excess concentrations of minerals above recommended stock tolerance will not only limit the amount of water consumed, due to palatability issues, but also affect the animal's digestive and physiological functions.

Table 7 shows the upper limits for stock water quality and the likely effects on animal health if these limits are reached or exceeded.

Table 7. Stock water quality – upper limits of mineral/metal levels for livestock

Element	Upper limit milligrams per litre (mg/L)	Effect
Calcium	> 1000 mg/L	Phosphorous deficiency
Magnesium	> 1000 mg/L	Scouring and diarrhoea
Nitrate	> 1500 mg/L nitrate, > 30 mg/L	Vomiting, convulsions, death
Sulphate	> 1000–2000 mg/L	Diarrhoea
Aluminium	5 mg/L	Phosphorous deficiency
Arsenic	0.5 mg/L	Diarrhoea, anaemia, poor coordination
Copper	0.5 mg/L	Liver damage and jaundice, copper accumulation in the liver
Fluoride	> 2 mg/L	Tooth damage and bone lesions
Iron	Low toxicity	
Lead	0.1 mg/L	Respiratory diseases, anorexia, poor co-ordination
Molybdenum (related to copper)	0.15 mg/L	Scouring and loss of condition. Infertility, skeletal disorders, testicular damage.
pH	> 9 < 5	Highly alkaline water (> 9) may cause digestive upsets and diarrhoea, lower feed conversion efficiency and reduce intake of water an feed. Highly acidic water (< 5.5) may cause acidosis and reduce feed intake.
Total dissolved solids	Variable generally > 5000 mg/L	Poor production, diarrhoea, higher mortality rates

6.2 Water trough types and design requirements

Dairy cattle water troughs can be constructed from a range of materials including concrete, heavy duty plastic, polyethylene, stainless steel, galvanised steel, and fibreglass, all with lifespans over 10 years.

- Over time, the inside surface of concrete troughs may become more difficult to clean.
- Surfaces deteriorate due to hardness of the water, cattle saliva, enzymes in feed stuffs and general cleaning processes.
- Concrete surfaces can be protected by a fibreglass or polyethylene insert.
- An epoxy resin can also be used to coat the interior of the tank preferably when the trough is new, like the way concrete feed alleys are coated to eliminate deterioration.

Water trough volume and receival flow rates:

- At least 200 litre trough volume for receival flow rates of up to 10 litres per minute.
- At least 100 litre trough volume for receival flow rates of up to 20 litres per minute or greater.

Water trough spacing:

- At least 80–100mm of linear water trough space should be provided per cow in systems where cattle are contained for 24 hours per day.
- The upper edge of the trough should be located 610–810mm above the cow standing surface for mature Holstein cows and 530–740mm for Jerseys.
- Ensure a water depth of 150–200mm to maintain a cool water temperature and reduce debris accumulation.

Figure 11. Well-designed tippable trough with reinforced protection around the float and ball valves

At least two troughs should be present per group of 15-20 cows to prevent dominant cows from monopolising a single water trough and allowing for 10-15 per cent of a herd drinking at the same time.

Troughs with closed external vertical walls to protect piping and fittings and that eliminate spilt feed and manure building up under the trough are recommended. These types of troughs enable any manure and spilt feed to be removed regularly and this reduces odour production and habitat for flies. Sturdy reinforced protection around the float and ball values is essential to prevent cows from damaging troughs if the inflow of water is slow (Figure 12).

Troughs should have drainage bungs or be tippable to enable complete and easy cleaning. Drained water should be directed towards the manure management system by dumping into the flushed alleys.

A further recommendation for troughs on non-concreted surfaces is installing a 3 metre concrete apron along or around the trough due to the heavy trafficking and regular damage caused by cows accessing water.

6.3 Water trough location

Locating and positioning water troughs throughout the dairy complex is just as important as an ample supply of quality water and requires careful consideration to minimise:

- Unnecessary congestion of cows around the feed alley and water troughs
- Restrictions and bottle necks in cow flow entering and leaving feeding areas
- Pugging and surface water pooling if located in low lying areas
- Contamination from overhanging trees and dust from nearby tracks.

Water troughs should be surrounded by plenty of passage space for cows to move freely, preferably on the outside of the traffic curve and be easily accessible for cleaning. Various studies indicate that during the summer months, 10 per cent of the herds total daily consumption is consumed at the dairy.

Preferred location on earthen and concreted feedpads:

- Place water troughs within about 15m of the feeding table, but not next to the feeding table to minimise feed spillage from cow mouths directly into water troughs.
- For earthen feedpads: on the downslope side of an earthen pad, so that water can drain directly into the site drainage.
- For concrete feedpads: to enable water from the trough to be drained or piped directly into the manure management system.

Preferred location in a freestall:

- At the crossovers to prevent feed contaminating the water and to reduce the incidence of cattle blocking each other in the alleys.

Preferred location at the dairy:

- On the exit side of the dairy shed. Locate in a wide passage, preferably on the outside of cow traffic curve.

Figure 12. Well positioned and guarded water trough – can be tipped into the cow alley

Water troughs can be readily contaminated with cud, manure, bird faeces, rodents, pesticides, dust, feed, bedding material, and microbes entering through water systems. These contaminants can provide a nutrient rich substrate for bacterial growth and survival at the bottom of a trough. Troughs management should include regular inspection and cleaning (at least weekly but more frequently if possible).

6.4 Determining water requirements to operate the facility

Dry seasonal conditions invariably put stress on farm water supplies. Properties that have access to reliable groundwater are fortunate, whereas those using dams reliant on runoff will require more planning to ensure their water supplies are ample to meet demand.

A key step before constructing a dairy complex, is understanding the volumes of water beyond typical stock drinking water, that are required to operate the facility. Water is required for:

- The flushing and removal of effluent from cow alleys.
- Supplying cooling systems such as sprinklers.
- Servicing any automatic milking systems housed within the facility.
- Cleaning manure build up around facility entry and exits points.
- Cleaning manure from around troughs in raised crossover sections.
- Pressure spraying mechanical stationary screens used in the solid separation process.

The amount of water required to operate cooling systems, remove manure, bedding material and flush cow alleys can be significant for various facilities depending on herd capacity and occupation times and should not be under-estimated.

These volumes are in addition to any water requirements to milking areas where they are separate from the housing system.

For example, concrete feedpads using flush systems have recorded consumption rates of more than 61,000 litres of water per cleaning cycle for a 500-cow herd.

In contained housing facilities, water volumes to flush cow alleys several times throughout the day has been recorded at more than 400,000 litres per day. Some facilities catering for much larger herds, (i.e. more than 3,000 cows) budget on a total water use of 780,000 litres per day.

From a site planning perspective there are critical decisions to be made. These include:

- Where will this water be sourced from and is it a reliable all year-round?
- How will this water be stored and delivered to the facility to match volume and peak demand?
- How will the quality of the water be monitored and maintained?
- How many times throughout the day should cow alleys be flushed?
- How will this water be captured and collected at the end of the facility?
- How will it be stored, reused or irrigated to fodder crops and pastures?
- What options are available to utilise recycled effluent from the effluent storage pond?

There are several factors, from a design perspective, which influence the overall water consumption required to operate these facilities and the frequency in which cleaning processes are used.

It is critical in the planning phase of the development to estimate expected water consumption.

Typically, water requirements for cow alleys will depend on the width and length of area being cleaned, the roughness co-efficient of the concrete and slope, with a recommended minimum depth of wave height of 50mm and a recommended velocity of 1 metre per second to adequately remove deposited manure or 1.5 metres per second for sand bedding deposited in the cow alley.

For example, a concrete alley of 5m width and length of 160m would require an estimated 24,400 litres per flush for cleaning at a 1% slope, compared to 14,300 litres per flush, should the slope be set at 2%.

Dry scraping prior to flushing can reduce the volume of water required for wash down.

A key starting point in understanding potential water consumption is commencing with the existing dairy complex and conducting a full water audit to determine if overall water use is compatible with industry water use data for a similar herd size and dairy type. Agriculture Victoria has collected and analysed this information, following over 1,500 dairy facilities water use audits throughout Australia, with clear strategies for water saving measures. Once the dairy complex consumption has been determined, available tools such as effluent design calculators can be used to estimate potential water use. Combining this information will not only assist with reviewing the manure system requirements, but also assist in identify options for recycling effluent to reduce freshwater consumption.

It is also important to consider evaporation rates from farm dams, particularly if used to supply the facility with freshwater, as volumes and supplies may be compromised during the summer months.

6.5 Recycled effluent

Recycling effluent from appropriately designed pond systems is a long-established practice within the Australian dairy industry and has successfully been applied in many situations to reduce freshwater usage when cleaning manure from dairy holding yards and alleys from within contained housing facilities.

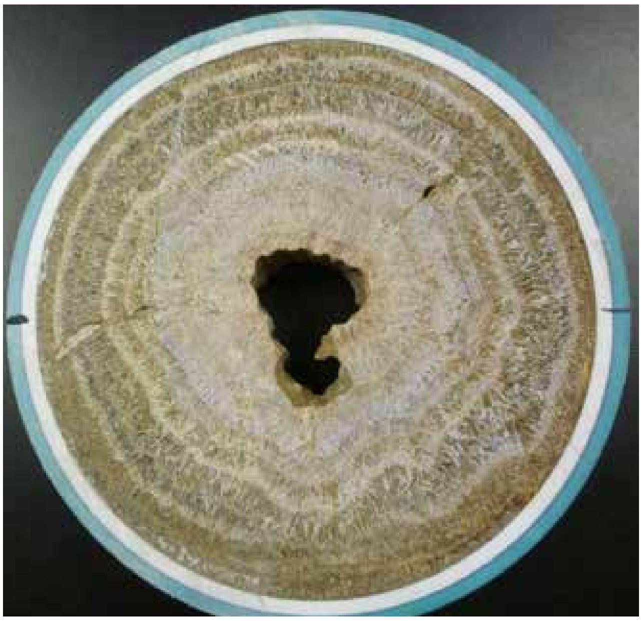
Recycled effluent is typically extracted from the final pond in multiple pond systems (or as a lesser option, larger single storage ponds) because at this stage effluent has undergone settling and some treatment, providing a better option for recycling for flushing or irrigation to land.

Even though recycling effluent has many benefits, it is important to monitor the effluent ponds to ensure quality doesn't deteriorate and impact the facilities. Irrigated farms may mix freshwater with recycled effluent during the summer months to improve the quality, prior to irrigating pastures or crops. Dairy farms will need to monitor the pond performance and quality of recycled effluent prior to reuse.

Farm indicators that recycled effluent has deteriorated in quality may include:

- Heavy crusting.
- Slime deposits and growth on surfaces around the facilities impacting cow traction.
- Increased odour emissions.
- Struvite (salt crystallisation) build up in pumps and piping.

Figure 13. A pipe clogged by struvite (salt crystallisation) build up



Struvite management

The continuous use of recycled effluent without freshwater dilution can lead to the build-up of struvite; a crystalline build-up of magnesium ammonium phosphate resulting in blockages in piping and poor pump performance. Struvite accumulates where there is turbulence in the water flow particularly around valves, joins, bends, and in the pump (Figure 13).

Key management practices to reduce issues could include:

- Dilute the effluent to reduce the chances of salt accumulation.
- Ensure ponds are emptied each year.
- Check salt levels in the pond and try not to exceed 3,000–5,000 uS/cm. This can be difficult to achieve when groundwater is used for washing around the dairy complex.
- Have an irrigation technician check the system hydraulics to reduce turbulence ensuring pumps and pipes are compatible.
- Minimise suction lift by locating pumps near water level. Make sure suction pipes are large enough to prevent cavitation. Have gentle bends rather than sharp turns in pipes.
- Replace pipes and fittings. This may be easier than trying to dislodge the built-up crystals which need a hammer and chisel to break them off fittings.
- Dissolve crystals with acid cleaning solutions. A recirculating system is best, but care is needed if metal components are involved because the acid is corrosive.

Make sure any pump is well grounded to earth to ensure no stray voltage or electrostatic charges can contribute to crystal build-up.

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07

Manure management

> **Introduction**
>
> The Effluent and Manure Management Database for the Australian Dairy Industry is a repository of reliable and scientifically validated technical information on dairy manure management. It provides design and engineering criteria adaptable to all dairying regions in Australia.
>
> Understanding how dairy manure can be contained, handled and managed then enables value to be extracted from reusing it on farm as a fertiliser or for renewable energy generation.

7.1 What is manure?

Manure is the faecal and urinary excretion of livestock. It may be mixed with bedding, spilled feed, water, soil and sediment, fibrous material as well as other components not associated with excreta such as dairy plant wash water, detergents, milk residue and hair.

Liquid manure is typically referred to as effluent. Effluent is produced by cleaning the dairy shed and holding yards with water. Effluent may also include stormwater, residual milk and chemicals from cleaning dairy plant and equipment. Effluent may be recycled (i.e. recycled effluent) and used for washing manure from areas such as holding yards, alleys and housing facilities, or applied to land.

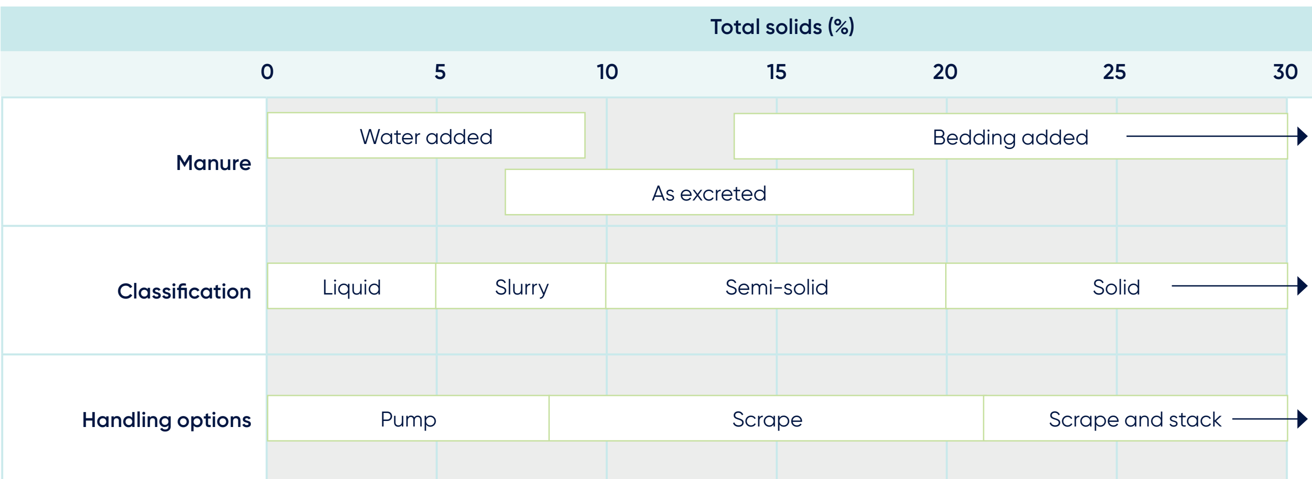
The manure stream can be classified in different ways depending on its solid and moisture content, which ultimately influences handling, storage, and application methods on farm (Figure 14). Manure guidelines often use a common terminology of Total Solids (TS) to classify manure such as:

- Liquid effluent (less than 5% TS)
- Slurry manure (5–10% TS)
- Semi-solid manure (10–20% TS)
- Solid manure (greater than 20% TS).

To simplify terminology throughout this chapter the generic term "manure" will be used as a representation of all forms covering liquid, slurry and solid materials. However, understanding the composition of the manure stream and the volumes generated will be important to ensure the most suitable manure system design, appropriate components and farm management is implemented to ensure manure is managed productively.

This is particularly important for any contained housing facilities such as freestalls or loose housing which utilise a range of bedding material such as sand or organic materials, as the extraction and recovery of this material from the manure stream requires specialised consideration. The overall volumes of manure generated from these facilities where cows spend a significant proportion of their time is considerably higher than for a grazing operation typically collecting manure just from the dairy shed, therefore requiring a greater focus on design and management.

Figure 14. Moisture content, manure classification and manure handling



Source: ***www.nrcs.usda.gov***

7.2 Industry guidelines and standards

Every state within Australia has established dairy guidelines or codes of practice, which clearly outline the expectations for the management of manure, closely aligned to the state Environment Protection Acts and any subsequent regulations.

Irrespective of the size of the dairy farm, the number of cows or type of feeding infrastructure used, the objectives for manure management at a farm are similar. In that:

- All manure generated from the dairy complex, underpasses and contained housing (point sources) must be contained, managed, and reused sustainably to aid production and mitigate risks.
- Manure must not enter surface waters such as streams, rivers, lakes, wetlands, reservoirs, and creeks, with each state having a clear definition of waterways.
- Manure must not enter groundwaters either directly or through infiltration from poorly constructed ponds via seepage.
- Manure must not contaminate land by the continuous discharge onto the same area of land causing a nutrient overload and higher risks of leaching and runoff to groundwater and surface waters.
- Odours must be minimised and managed in line with regulations such as the state's General Environmental Duty.

State based environmental legislation, which covers all sectors including residential, commercial, industrial, and agricultural, often classifies manure as a by-product or waste stream generated from livestock production.

Australian livestock industries will continue to focus on manure as a valuable nutrient resource, that if managed correctly not only mitigates environmental risks, but provides significant productivity benefits to farms through its agronomic application to fodder crops and pastures.

7.3 Manure management systems and components

The Australian dairy industry has been proactive over a long period in designing and developing manure management systems to manage both liquid and solid streams generated from farm point sources where cows congregate for longer periods, particularly the dairy shed, feedpad and contained housing facilities.

State based legislation does not provide prescriptive and technical information on how to design and construct manure management systems. It sets clear standards on expected outcomes for the protection of the environment and amenity. These expectations focus the dairy farm's attention to contain, manage and recycle manure into the farm's production.

It is the responsibility of the dairy farm owner, lessee and operators to identify the most appropriate manure management system and the relevant components of that system best suited to the farm's circumstances, locality, and overall management. Decision makers are strongly encouraged to source information from experienced system designers.

Removing and cleaning manure from feeding areas

Broadly there are three fundamental approaches to removing deposited manure from dairy sheds, feedpads and contained housing facilities:

1. Dry scraping is the most practical method when dealing with manure as a semi-solid or solid. It is commonly used on earthen feedpads utilising compacted earth, rubber matting, a geohex modular foundation or concreted aprons around feed troughs and modular hay rings. Occasionally farms with concrete feedpads during periods of lower use, will opt for a temporary dry scrape approach to conserve flushing water. It is important that scrapers use a "sacrificial edge" such as rubber that contacts with the surface to reduce damage and not compromise the feedpad foundations.

Scraping works well during the drier months of the year, when manure has an opportunity to air-dry, but is more problematic during the wetter months when manure tends to become a slurry, hence the requirement to consider slope and adequate drainage.

Typical equipment used for dry scraping includes rubber tyres (cut in half), front-end loader buckets, skid steer loaders, quad-bike mounted scrapers (Figure 16), tractor mounted blades or automated cow alley scrapers (more common in contained housing).

2. Vacuum tankers provide a more effective approach for slurry and semi-solid manure particularly for larger concrete feedpads as the manure can be collected and transported directly from the feedpad and applied to land, without the need for stockpiling and double handling.

Note that avoidance of double handling is only an option during those periods when the paddock is not too wet.

3. Flushing with fresh water or recycled effluent of concrete surfaces. Tanks may be located at the higher end of feedpads either mounted on the ground or raised on platforms to generate sufficient head. Alternatively, it is common for a buried pipe main and riser or hydrant systems to flush the manure down the alley using clean water or recycled effluent pumped directly from storage ponds (Figure 16).

The most effective volume and desired flow rate is dependent on several key factors such as: slope, width and length of area being cleaned, surface texture, amount of manure deposited and type of bedding material present. Freshly deposited manure will require more energy to break up and entrain the material in the slurry manure compared to hay and straw bedding. Removing sand requires more energy than any other bedding option. Any attempt to scrape, break up manure or pre-wet prior to cleaning will reduce the amount of energy and water required.

It is important to keep in mind that this approach has the potential to use significant volumes of water, with a 500 cow feedpad having the potential to use 70,000 litres per day or 480,000 litres per day for a 1000 cow freestall, typically flushed a minimum of three times each day.

Feedpads are often cleaned during milking or while the herd is grazing, while contained housing, due to the higher occupation of herds, are sometimes cleaned with cattle present.

Figure 15. ATV mounted manure scraper

Figure 16. Buried main and riser

Liquid – solid separation components

There is a trend towards larger herds spending more hours contained for milking, feeding or loafing. This makes it increasingly important to focus on separating and removing larger particles and organic material.

The advantage being to:

- Reduce the rate of sludge accumulation and volatile solids loading on primary ponds, which reduces the pond footprint or the frequency of desludging.
- Remove spilt feed and fibrous material to prevent blocking of conveyance pipes and pumps.
- Collect and establish sufficient composted material to reuse as bedding material or as organic fertilisers easily applied around the farm.
- Allow more conventional irrigation equipment to distribute recycled effluent from adequately sized single ponds.

Solid separation systems are broadly associated with two categories:

1. Gravity-separation components such as: trafficable solids traps (Figure 17), concrete basins, shallow sedimentation ditches and sand recovery lanes. During the cleaning process manure from feedpads, holding yards or contained housing facilities is conveyed to an appropriately sized structure that utilises weeping walls, weirs, sieves or other settling methods to allow solids to settle out of the manure stream.

These systems can consistently remove more solids and nutrients from liquid manure than mechanical methods when the total solids (TS) content is low. It remains the preferred approach for many farms utilising feedpads washed on a regular basis. Earthen sedimentation basins – designed for ease of desludging, are a suitable option where the catchment area around a feedpad generates a significant volume of runoff during a rainfall event.

2. Mechanical separation devices such as: inclined or elevated stationary screens (Figure 19), vibrating or rotating screens, centrifugal decanters, roller press, belt press or screw press. Manure directed from cow alleys and holding areas is collected in large sumps and agitated to keep solids in suspension before being pumped to the mechanical device. Separated liquid is directed to the ponds, while the separated solids are deposited on a bunded stockpile area.

These systems are suited to larger contained housing facilities, which have more significant manure volumes to manage and rely on the need to capture and recover adequate bedding material for reuse.

Separation technologies can be supplemented by chemical treatment to improve separation efficiency. While chemical separation is rarely used on dairy farms in Australia, it is based on coagulants and flocculants used to treat municipal and industrial wastewater. The chemicals (including alum, ferric sulphate and ferric chloride, and polymers such as various polyacrylamides) cause sedimentation of particulate matter, resulting in the precipitation, usually of soluble P, and the flocculation and aggregation of suspended material. The result is liquid fractions with lower turbidity and greater clarity, and solids with a higher nutrient content. This technology is usually applied to wastewater with low TS.

Figure 17. Trafficable solids trap with offset sump

Figure 18. Mechanical stationary screen – screw press combination

Manure management systems and risk mitigation

Producers have two broad options when choosing an appropriate manure management system.

1. Direct application with buffer storage – manure is pumped directly from the collection point to pasture or crop, and a small sump or pond provides buffer storage.

This system is mainly used for small herds that operate low water use dairy sheds and minimal use of stock containment or feedpads. Direct application is generally less likely to suit feedpads or contained housing due to the larger volumes of manure being generated. Direct application systems do not cope with large catchment areas or large and regular rainfall events. For example, an earthen catchment area of 500m^2 would be large enough to overwhelm a pump with a capacity of 10 litres per second during a 15mm, 10 minute storm event.

Contingency or buffer storage would need to be included in any direct application system to contain storm runoff, allow the dairy farm to avoid application during extremely wet conditions and allow time for equipment to be fixed or replace as a result of a breakdown.

This option is regarded as potentially high risk and would require stringent management and monitoring. Significant separation distances are likely to be required for this application method.

2. Deferred application - manure is stored in one or more ponds or tanks for a period before it is reused on pasture or crops.

- This option suits feedpads and contained housing as larger volumes of manure being generated make direct application hard to manage. It is important that deferred application systems have sufficient storage and are sized to manage the risk during the wettest year in ten.
- Retention of effluent in ponds or tanks results in reduced organic, nutrient and pathogen loads, thus producing a product more suitable for reuse than raw effluent. Ponds enable storage during the wetter months and allows for strategic use and application of nutrients.

Pond systems

Ponds have been successfully used in the Australian dairy industry for many decades to:

- Provide storage for effluent during the typical wetter periods of the year.
- Reduce the nutrient and pathogen loadings.
- Provide recycled effluent for cleaning cow alleys and holding yards.
- Minimise blockages in conventional pumping and irrigation components.
- Recover and recycle accumulating solids.
- Provide an opportunity for biogas production.

Understanding the fundamental difference between the type of ponds is important due to the different design functions, potential configurations, and positioning within the overall manure management system as well as the expected management requirements. Australian dairy farms commonly use a range of ponds depending on the intention for solid deposition and/or storage. Single ponds are usually constructed for smaller herds seeking a storage option given the pond can become too large for effective solids management with larger herds. Dual or multiple ponds separate the functions of solid deposition and liquid storage and support more effective management of the system. Effluent quality from dual pond systems is substantially better than for single pond systems and so reuse can occur via a broader range of irrigation systems.

Ponds can be constructed either above or below ground depending on the site chosen and integrated management equipment. Pond dimensions are subject to specific farm variables including storage requirement, depth to groundwater and soil type.

Primary or solids ponds: designed to allow solids to drop out of suspension and be managed separately to the liquid fraction. Primary ponds operate with a fixed water level (via a transfer pipe fitted with a 'T' inlet for excluding floating solids) which allows for the higher quality liquid fraction to pass through to the effluent storage pond. Surface crusting is common.

Desludging must occur at regular intervals whereby settled solids are removed and land applied or alternatively, stockpiled and/or composted. If the system and equipment requirements allow, desludging on an annual basis supports more effective nutrient recovery.

Desludging must be completed well before the primary pond is full of sludge. That is, an absolute minimum of 600mm (preferably 1000mm or more) of liquid above the sludge level is required for solids deposition processes to occur. If the sludge layer reaches the level of the transfer pipe, significant transfer of solids into the effluent storage pond will have occur and effluent quality will deteriorate.

Anaerobic ponds are also designed as the primary pond in multiple pond systems, retaining the manure for processing, allowing the liquid component of the manure to transfer into a storage pond ready for land application or recycling to cow alley flush systems.

Effluent storage ponds: provide storage of effluent during those periods when land application would potentially result in runoff and loss of nutrients. The required volume is calculated on dairy complex water use, 90th percentile rainfall contributions (yard, roof, and pond surfaces) over those periods when land application is not possible based on local climatic data. All ponds should maintain a minimum 600mm freeboard to accommodate wave actions and provide bank stability. These ponds are commonly used when effluent storage over the wetter months of the year is the preference to allow a strategic application of nutrients to paddocks during the irrigation season or when pastures are actively growing. Typically, the final storage pond, if managed correctly, also provides the opportunity for recycling to cow alley flush systems.

The design and construction of ponds require professional knowledge, not only in the type of ponds, best suited to the situation and required capacity, but just as importantly the siting and construction phase which requires appropriate investigations.

The importance of pond management

Ponds are not designed to be managed with a "construct and forget" mentality. Pond maintenance and monitoring programs are critical to optimise performance, reduce failures and minimise unnecessary environmental risks.

Primary ponds are designed with a specified desludging frequency, which is the trigger point at which sludge or solids need to be removed. Failing to do so will compromise available capacity, performance and where applicable consent conditions. Monitoring sludge accumulation is vital to ensure pond performance is not compromised.

For effluent storage ponds to work effectively, they need to have sufficient storage capacity at the onset of the wetter months (retaining 0.3m to prevent liners and pond surfaces from cracking) so that all effluent generated from the various cow facilities can be contained.

In the event of extended wet periods and increased effluent and stormwater entering the pond, dairy system managers should seek to draw down the pond volume, to eliminate the risk of overtopping, by strategic application of low rates of effluent to areas of the farms that are less likely to cause environmental or amenity impacts.

Emergency disposal of milk

Even though suitably sized ponds can handle several milk dumps (in the event milk cannot be collected from farm), the practice is generally discouraged due to the potential to compromise microbial activity within the pond resulting in poor functioning, performance, and risks of odour.

Alternative approaches such as diluting milk with water (7-parts water to 1-part milk) and irrigated onto pasture with a 10–12mm application. Under no circumstances can milk enter waterways.

Strategic reuse of manure

The land application of manure and effluent should be strategically linked to the dairy farm's soil fertility targets, ongoing fertiliser applications and ability to specifically target less productive areas of the farm (Figure 19).

Figure 19. The final stage of the effluent system returning nutrients to enhance pasture and crop production

7.4 Intensifying – impact on current manure and farm management

It is common for existing ponds and manure management systems servicing the milking parlour and holding yard to be significantly compromised when connecting additional manure streams from new feedpads or contained housing developments. Depending on the current system and opportunity for expansion or modification, it is usual to have to construct either a new or separate manure management system.

Planning a new or upgraded manure management system needs to consider collection, conveyance, solids separation, storage, application, monitoring and management.

Before undertaking any significant development on farm, it is important to understand the current capacity and performance of existing sumps, traps and ponds, along with the current volume of manure being generated from the dairy. The expected increase in manure volume due to farm developments can be estimated using industry data and will guide an upgrade of the system.

The amount of manure deposited in any location is often proportional to the time the cows spend on the area, with traditionally 10-15 per cent of the daily manure output occurring at the milking parlour and holding yard. The inclusion of a feedpad or contained housing facility may increase the time cows spend contained to 8-12 hours per day, which significantly increases the volume of manure that needs to be managed.

Any increase in herd number should also be factored into each of these calculations.

Farm changes influencing manure management system design

The following dairy farm variables are significant considerations when it comes to designing manure management systems, hence the need to be mindful when incorporating feedpads and contained housing.

- **Rainfall contributions:** Large hard catchment areas such as roofing, cattle handling yards, concrete feedpads, manure drying pads and cow access laneways all have the potential to contribute stormwater into the manure stream. This rainfall input needs to be calculated as it will influence the required size of the storage pond.
- **Total water used at the facilities**: The water used to clean yards, concrete feedpads, cow alleys, dairy platforms, milking plant and equipment produces a large volume of manure that needs managing. This volume influences the size of the storage pond, hence the need to be water conscious and use recycled effluent where possible on yards and alleys. Water used in cow cooling systems generally does not coincide with winter storage periods and therefore are not typically included in the design criteria.
- **Cow occupation times on concrete:** The more time cows spend on concrete surfaces, the more manure being collected. Understanding the amount of manure being deposited is an important consideration which directly influences solid separation components and the primary pond in dual or multiple pond systems.
- **Cow production:** Production is a good indicator of the amount of manure generated with a direct link between dietary intake and manure production. Higher producing cows have larger dry matter intake and consequently excrete more manure than lower producing cows.
- **Cow flow and facility design:** This is often underestimated but plays an important part in the manure management system, with restricted flow and congestion of the herd causing stress which results in increased manure deposition at the facility.
- **Recycling effluent:** Recycling from the storage pond for yard and alley cleaning will reduce the overall water consumption, and capacity of the effluent storage ponds. Recycled effluent needs to be from sufficiently sized ponds (preferably in a dual or multiple pond system) to ensure an adequate quality.
- **Solid separation before ponds:** Solid separation components (traps, screens, screw presses, ditches) reduces the required footprint of the primary pond.

On average a cow will produce about 11 per cent of her body weight in manure. So, for a 600kg cow that is 66kg of manure every day.

7.5 Odour mitigation

While it is unrealistic to expect no odour from a dairy farm, it is the combination of appropriate siting, design and on-going management that reduces odour problems.

Odour emissions are generated during the incomplete anaerobic decomposition of organic matter in manure. Likely sources of odour around the dairy complex include ponds, solids separation systems, manure stockpiles, silage, commodity and feed preparation areas, feedpads, contained housing and loafing areas. Odours can build up over 4–5 days particularly after rainfall events.

The following siting recommendations and management practices will reduce the frequency and intensity of odour production within containment areas, feedpads and contained housing facilities.

- Appropriate siting to provide a suitable separation distance to sensitive uses. Most complaints derive from poorly sited infrastructure and cows in pugged paddocks close to roadways.
- If the manure stockpile is large or emitting odours, it may need to be windrowed and turned regularly until it dries enough to maintain aerobic conditions required for composting. However, such turning is likely to release significant odours and must be timed to avoid worsening the situation.
- Manure solids and sludge extracted from trap cleaning and pond desludging processes should be stored in appropriate locations to promote the drying and composting process if they cannot be spread immediately. Stockpiling and double handling may increase the risk of odour production. Once drying is complete, solids should be strategically applied to pasture and crops based on manure analysis results and known soil fertility.
- Placing a cover over the disturbed face of the silage bunker may be necessary where neighbours experience effects.
- Spoiled grain and silage can be a source of offensive odour, and spills should be removed promptly. Any feed accumulating behind feed bunks or around feedpads must be removed, as it can also discourage cows from accessing the area.
- Feed storage areas should be constructed so that feed is kept dry. Purchased feedstuff should be stored for a short time before use. Ideally, these feedstuffs should be stored on an impervious surface, in a covered area or shed.
- Attention to minor details such as cleaning under fences and around troughs to maintain drainage and removing accumulated manure or spilt feed.

For larger scale dairy farms maintaining an activity logbook is recommended to record critical management events such as:

- Pond desludging
- Manure and compost spreading
- Effluent irrigation
- Removal of stockpiled manure
- Dry scraping loafing areas or removal of bedding from contained facilities.

These activities should consider weather forecasts (i.e. rainfall, prevailing winds, humidity) to minimise neighbour complaints. A complaints log should be available to record any complaints and to action investigation and mitigation.

7.6 Manure stockpiling and composting

Stockpiling and composting are not the same thing; a common misconception is that piling manure into a mound and letting it decompose is composting.

Composting requires a carefully managed process to control temperature (40-60 degrees), moisture (50-60 per cent), effective carbon:nitrogen ratio and aeration over an extended period. It involves adding straw, sawdust, or hay to manure to balance the carbon requirement and regular turning of the pile. Manure stockpiling should be short-term or temporary storage of manure, waiting for the right opportunity to spread on land.

The advantages of composting include:

- More biologically stable and does not generate noxious odours during land application and can be stored without being a nuisance or forming a water repellent crust.
- Does not provide a medium for the breeding of flies.
- Destruction of pathogens and common weed seeds during the process.
- More concentrated plant nutrients with removal of biodegradable carbon compounds reducing the manure volume.
- A more viable option for bedding material readily extracted from the manure stream, as opposed to alternatives such as sand, wood chips and straw.

Key considerations for siting and management of stockpiled manure and composted rows include:

- Machinery access, manure volume, access to carbon source, distance to neighbours and waterways and other sensitive uses.
- Locating on an area of impermeable ground such as a compacted earthen or concrete pad that will provide all weather trafficability for machinery.
- Diverting stormwater away from the area and transferring runoff from within the composting area to the manure management system.
- Ensuring the compost is analysed and regularly utilised for production purposes.

7.7 Warning signs and contingency planning

The first indication that something has gone wrong with the manure management system should not be notification from a regulatory authority. Dairy producers should understand the warning signs that can flag an urgent need to address potential risks.

These may include:

- Reduced pond freeboard indicating risk of ponds overtopping.
- Heavy crusting and silting of primary pond indicating urgent need to de-sludge before blockage in piping or compromising the function of the secondary pond(s).
- Recycled effluent creating odour or slime deposits at the dairy indicating quality has deteriorated and requires freshwater injection and mixing of the pond.
- Soil analysis results from recently conducted soil testing indicating imbalances in nutrients.
- Structural integrity of ponds being compromised with erosion, cracking, wall breaches or damage following machinery use on or near the ponds.
- Regular pump failures leading to effluent conveyance issues and manure build-ups in solid separation components.
- Conveyance pipe blockages indicating damage, solid build-up, and presence of struvite (crystalised salts) restricting or preventing effluent conveyance to ponds or irrigation equipment.
- Effluent pond liner floats to surface indicating liner integrity compromised.
- Continuous cleaning of solid separation components and primary ponds indicating the effluent system may need upgrading following significant farm changes such as increased cows, longer time on concrete.
- Increased incidences of mastitis, higher bulk milk cell counts, milk fever, salmonella or grass tetany indicating the need to test paddocks and discuss with local vet.
- Increased presence of birds indicating large quantities of spilt and unmanaged feed.

Irrespective of the feeding infrastructure utilised on farm or manure management system in place, a regular maintenance program and contingency planning is critical as these two aspects of the farm have the potential to create impacts if left unchecked and not monitored regularly.

A contingency plan should enable procedures to be put in place immediately once issues arise, before the actual failure, to minimise impact to farm operations, community amenity and the environment. All farm staff members should be familiar with contingency plans and procedures.

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08

Feeding infrastructure to support grazing and intensive dairy production

Overview

The Australian dairy industry is historically recognised as predominantly grazing-based production systems.

Producers have successfully adopted an extensive range of innovative feeding and containment solutions from temporary and basic feed-out areas to more complex integrated housing facilities. The fundamental aim being to feed, shelter and sustain production during periods of adverse weather, seasonal variability and emergency events. This minimised production losses, animal health issues and protected paddocks from pugging and damage to laneways.

In most recent years, the dairy industry has seen an increase in cattle shelters. These shelters have been used for extended loafing to combat months of the year which routinely impact production i.e. wet winters or hot summers. Some producers are deciding to change their farming system away from grazing to more intensive, zero grazing contained housing systems such as freestalls, loose housing and dairy dry lots. These contained housing facilities provide improved management flexibility for livestock and improve opportunities to explore technologies and significantly mitigate farming risks.

A fundamental step when contemplating farm developments, particularly with contained housing and feeding infrastructure, is determining if the changes to the farm will alter land use, with each state having different planning requirements depending on whether the infrastructure supports grazing animal production or changes to intensive animal production.

Grazing animal production applies to farms where grazing is a key component of the farming system.

Grazing Animal Production is land used for animal production where the animals' food is obtained by directly grazing, browsing or foraging plants growing on the land. It includes:

- emergency, seasonal and supplementary feeding
- the incidental penning, feeding and housing of animals for weaning or other husbandry purposes.

In this definition:

- **emergency feeding** means providing feed to animals when an emergency event such as a flood, bushfire or biosecurity event restricts or prevents the animals from grazing, browsing or foraging plants growing on the land;
- **seasonal feeding** means providing feed to animals when seasonal conditions, including drought, restrict or prevent the animals from grazing, browsing or foraging plants growing on the land;
- **supplementary feeding** means providing feed to animals to supplement the food the animals obtain by directly grazing, browsing or foraging plants growing on the land.

Dairy farming enterprise (pasture-based) means a dairy that is conducted on a commercial basis where the only restriction facilities present are milking sheds and holding yards and where cattle are constrained for no more than 10 hours in any 24-hour period (excluding during any period of drought or similar emergency relief).

If there is little intention for the animals to meaningfully obtain food by directly grazing/browsing/foraging (e.g. eating grass growing in the paddock), then the use would likely be Intensive Animal Production.

Dairy farming enterprise (restricted) means a dairy that is conducted on a commercial basis where restriction facilities (in addition to milking sheds and holding yards) are present and where cattle have access to grazing for less than 10 hours in any 24-hour period (excluding during any period of drought or similar emergency relief). It may comprise the whole or part of a restriction facility.

Intensive Animal Production is land used for animal production where the animals' food is imported from outside the immediate building, enclosure, paddock or pen. The provision or availability of nominal, incidental or minimal grazing is not sufficient for a farm to be considered grazing animal production.

Throughout Australia the development of contained housing facilities (i.e. dairy dry lot, loose housing or freestalls) should be considered intensive animal production as these facilities are designed to house animals 24 hours per day supported by a total mixed ration diet (i.e. zero grazing).

Understanding the difference between grazing production and intensive production is critical from a statutory planning perspective as restrictions and consent will apply with changes in land use and the documentation required to support the proposal will be different.

8.1 Feed delivery infrastructure

A diverse range of alternative feed delivery methods and feeding and housing infrastructure are used on Australian dairy farms. Determining the most appropriate feed delivery infrastructure depending on whether the farm is seeking a temporary short-term solution, or a more permanent frequently used solution requires careful planning and longer-term thinking. This is a personal choice that producers should not need to justify or defend to others, as the decision will be influenced by many factors including:

- Farm's natural resources: land area, topography, soil type and climate
- Stocking rate and calving patterns
- Type and range of supplements being fed
- Frequency of use for the infrastructure throughout the day and over the year
- Milk supply company and pricing system
- Labour constraints and employment preferences
- Life stage and/or business cycle stage
- Longer term vision for the property and stages of development.

Fundamentally in the Australian Dairy Industry, there are five main types of feed delivery infrastructure. Infrastructure 1 to 4 are typically used for partial mixed ration feeding to support farms focused on grazing and infrastructure 5 (contained housing) are typically used in intensive operations supported by total mixed ration feeding and zero grazing.

1 Temporary feed-out area
2 Basic feed-out area
3 Formed earthen feedpad
4 Concrete feedpad (may have shelter i.e. roofed feedpad or cattle shelter)
5 Contained housing facility (freestall, loose housing or dairy dry lot).

The rationale for these five types of feed delivery infrastructure follows:

- A classification system should be based on a facility's design and its pattern of use. It is de-coupled from the type of ration fed.
- A classification system is best limited to five main types of feed delivery infrastructure as more would be difficult for producers and advisers to grasp.

A detailed description of each type of delivery infrastructure is presented in Table 8.

Table 8. Five main types of feed delivery infrastructure

Type	Description	Concerns	Typical patterns of use
1. Temporary feed-out area	• Area located in a pastured paddock, sacrifice paddock or along a laneway • No prepared surface • Feed on ground, in hay rings or tractor tyres • Can be readily relocated to other sites on the farm • Very basic feed storage facilities and machinery • Use front-end loader (FEL) or silage cart • Capital cost for feed-out facility: Very low cost per cow	• Risk of herd health problems (mastitis, lameness) if wet conditions and poor drainage • Risk of heat stress if shade not available • Difficulty accessing area with tractor if wet conditions and poor drainage • Pugging • Very high feed wastage • Manure build-up if over-used • Nutrient runoff • Odour, flies	• Feed out hay/silage before/after milkings to sustain cows' daily feed intakes during periods when is limited standing pasture • Hold, feed, and water cows between am and pm milkings on very hot days if tree shade is plentiful • Hold, feed, and water cows during emergency event such as bushfire or flood • *If use for 3-4 hours/day: require >3.5 m²/cow* • *If use for 8-12 hours/day: require >6 m²/cow* • *If use for 24 hours/day: require >10 m²/cow*
2. Basic feed-out area	• Contains an area with a compacted surface shared by cows and vehicles which may be able to be scraped • Can be relocated to another site on the farm (with effort) if necessary • Low-cost modular concrete troughs or conveyor belting under cable or hot wire +/- loafing areas • Very basic feed storage +/- mixing facilities and machinery, effluent system • Use silage cart or mixer wagon • Capital cost for feed-out facility: Low cost per cow	• Risk of herd health problems (mastitis, lameness) if wet conditions and poor drainage • Risk of heat stress if shade not available • Pugging of loafing area • Moderate-high feed wastage • Manure build-up/stockpiles contaminated with rubble, making it difficult to spread on paddocks • Nutrient runoff • Odour, flies	• Feed out hay/silage before/after milkings to sustain cows' daily feed intakes during periods when is limited standing pasture • Hold, feed, and water cows between am and pm milkings on very hot days if tree shade is plentiful • Hold, feed, and water cows during emergency event such as bushfire or flood • *If use for 3-4 hours/day: require >3.5 m²/cow* • *If use for 8-12 hours/day: require >6 m²/cow* • *If use for 24 hours/day: require >10 m²/cow*
3. Formed earthen feedpad	• Formed earthen pad with a compacted surface shared by cows and vehicles and regularly scraped. Fixed structures including purpose-built concrete troughs or nib wall under cable or hot wire +/- narrow cement strip for cows to stand on while eating +/- loafing areas, shade structures • Basic to more developed feed storage and mixing facilities and machinery, effluent system • Use mixer wagon • Capital cost for feed-out facility: Moderate cost per cow	• Risk of herd health problems (mastitis, lameness) if wet conditions and poor drainage • Risk of heat stress if shade not available • Pugging of loafing area • Moderate feed wastage • Manure build-up/stockpiles contaminated with rubble, making it difficult to spread on paddocks	• Feed out hay/silage before/after milkings to sustain cows' daily feed intakes during periods when is limited standing pasture • Practice 'on-off grazing' of day paddock to protect pastures from pugging damage during prolonged wet weather • Hold, feed, and water cows between am and pm milkings on very hot days • Cool cows on hot days if feedpad is fitted with shade structures and/or sprinklers over feeding table fitted with concrete apron • *If use for 3-4 hours/day: require >3.5 m²/cow* • *If use for 8-12 hours/day: require >6 m²/cow* • *If use for 24 hours/day: require >10 m²/cow*

Type	Description	Concerns	Typical patterns of use
4. Concrete feedpad, Roofed feedpad and Cattle shelters	• Concrete areas for cows and feed (usually separated) which can be scraped, or flood washed • +/- loafing areas, shade structures, sprinklers and fans for cow cooling • Well-developed feed storage and mixing facilities and machinery, effluent system • Usually use mixer wagon • Capital cost for feed-out facility: High cost per cow • When combined with shade structures over large loafing areas, may use facility to hold, feed and water cows for extended periods when there is no standing pasture e.g. summer	• Risk of herd health problems (mastitis, lameness) if wet conditions and poor drainage • Risk of heat stress if shade +/- evaporative cooling not available • Pugging of loafing area • Low feed wastage • Manure build-up/stockpiles contaminated with rubble, making it difficult to spread on paddocks	• Feed out hay/silage before/after milkings to sustain cows' daily feed intakes during periods when is limited standing pasture • Practice 'on-off grazing' of day paddock to protect pastures from pugging damage during prolonged wet weather • Hold, feed, and water cows between am and pm milkings on very hot days • Cool cows on hot days if feedpad is fitted with shade structures and/or sprinklers over feeding table fitted with concrete apron • *If use for 3-4 hours/day: require >3.5 m^2/cow* • *If use for 8-12 hours/day: require >6 m^2/cow* • *If use for 24 hours/day: require >10 m^2/cow*

5. Contained Housing
Dairy dry lot
Loose housing
Freestall
	• Many fixed structures including shade structures
	• Well-developed feed storage and mixing facilities and machinery, effluent system +/- sprinklers and fans for cow cooling
	• Use mixer wagon
	• Capital cost for feed-out facility:
	  - Freestall: Very high cost per cow
	  - Loose housing facility: Very high cost per cow
	  - Dairy dry lot: Moderate cost per cow
		Dairy dry lot:
		• Cow comfort
		• Risk of heat stress if shade or cooling systems are not adequate
		• Weather variability and wet conditions
		Loose housing
		• Cow comfort
		• Risk of heat stress if ventilation and cooling systems not adequate
		• Ability of cows to move around facility and access feed and water
		Freestall:
		• Cow comfort
		• Risk of heat stress if ventilation and cooling systems not adequate
		• Ability of cows to move around facility and access feed and water
			Freestall or Loose housing or Dairy dry lots:
			• Hold, feed, and water cows permanently with zero grazing

8.2 The five types of feed delivery infrastructure

1. Temporary feed-out area

Description

Area located in a pastured or bare cropping paddock, a designated sacrifice paddock or along a laneway without a prepared surface where feed is delivered to cows either on the ground, in hay rings or in tractor tyres. Can be readily relocated to other sites on the farm.

Generic types

Grazing or cropping paddock, sacrifice paddock, laneway.

Suitable for use with

Low bail feeding system	Moderate-high bail feeding system	PMR feeding system	Hybrid feeding system (if large loafing areas)	TMR feeding system

Purposes

- Fill seasonal pasture gaps
- Increase herd feed intake and milk production without increasing farm size
- Better manage pasture residual mass on each rotation (prevent over-grazing).

Characteristics

Frequency of use	Before/after milkings to sustain cows' daily feed intakes during periods which pasture is limited or during an emergency event (i.e. fire/flood)
Typical hours per day	3-4 hours per day
Surface	Pasture, bare earth, or roadway
Feeding table	On the ground, in hay rings or tractor tyres
Loafing areas	Nil
Shade/cooling	Nearby trees if available
Effluent management	Dry scraping manure and stockpiling
Feed prep. and delivery	Front-end loader, side winder round bale feeder, silage cart or mixer wagon
Feed storage	Silage pits/bunkers and hay sheds +/- commodity bunkers if using mixer wagon to prepare PMR

	Very low	Low	Moderate	High	Very high
Time and effort to set up	✓				
Weather durability		✓			
Permanency		✓			
Capital cost	✓				
Feed wastage					✓
Potential production benefits	✓				
Improved farm efficiencies		✓			

Costs

Capital cost: Very low/cow (not including silage cart, mixer wagon and feed storage and mixing facilities).

Operating costs: Very low.

Lifespan

Depends on how firm the area's surface is and how quickly it deteriorates with use by cow and vehicles in dry and particularly wet conditions.

Examples of temporary feed-out areas

Hay/silage fed out under wire along a laneway and along an irrigation check bank

Hay fed out in rings in sacrifice paddock. Note high level of wastage

Wastage at this hay ring was measured at 27%

Old tractor tyres cut in half and used as feeders on a sacrifice paddock

Hay fed out in a line on a grazing paddock

Skill level/training required to operate

- Low if feeding out forage mixes with a silage cart
- Need to ensure silage or hay is placed correctly on the feed-out area and not wasted
- Moderate if preparing and feeding out a mixed ration.

Wastage after feeding out lucerne and cereal hay on this grazing paddock was measured at 18%

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • +/- less walking • +/- reduced heat stress	• Temporary feed-out area may be used to deliver hay, silage or a mixed ration to cows. • It may increase milk production by increasing total daily feed intake. • If the area is located near the dairy and is large enough to be used to feed cows and enable them to rest between milking instead of a day or night paddock, it may help to reduce energy spent walking. • If cows are fed a high level of concentrates in the bail at milking, using the feed-out area immediately before or after milking it may help to maintain a more stable rumen. • If herd is highly susceptible to heat stress due to farm location, breed, the herd's age profile and level of milk production, and the feed-out area provides plentiful tree shade, then its use may help to reduce heat stress on cows in hot weather, resulting in more milk.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage • reduced pugging damage	• A sacrifice paddock may be used to some extent to reduce pugging damage in grazing paddocks in wet conditions. However, feed wastage will be high, and the area may become unusable in a short period of time, requiring another site on the farm to be set up as a temporary feed-out area.

Limitations/concerns

Limitation	Comment
Maintenance	• Very difficult to maintain feed-out area as it does not have a prepared, well drained surface and effluent cannot be captured. It will therefore need relocating regularly to maintain an adequate level of hygiene for cows.
Feed wastage	• Feed wastage is high (5–25% on a grazing paddock under dry conditions, 5–35% in a sacrifice paddock, fed on bare ground, in ring feeders, or under a fence line). • Feed refusals cannot be collected and fed to other cattle. They are wasted. • Feed wastage can be very high in wet conditions.
Cow health risks	• Environmental mastitis and lameness if feed-out area deteriorates. • Increased spread of disease if cows spend time in a contained area.
Environment issues	• Runoff of effluent must be managed to ensure no nutrients are reaching waterways. • Odour can be an issue particularly when there is non-agricultural land use close by. • Dust can be an issue to workers and neighbours and poses a respiratory or allergy risk. • Noise can potentially cause nuisance to neighbours with regular use of trucks, tractors, and machinery.
Safety	• A feed-out area in which cows and vehicles share the same area is never ideal. • In wet weather, the area may become slippery for cows and vehicles.

2. Basic feed-out area

Description

Contains an area with a permanent compacted earthen feeding infrastructure shared by cows and vehicles which may be able to be dry scraped. Can be relocated to another site on the farm (with effort) if necessary.

Generic types

Compacted earthen feed-out area +/- loafing areas.

Suitable for use with

Low bail feeding system	**Moderate-high bail feeding system**	**PMR feeding system**	**Hybrid feeding system** (if large loafing areas)	TMR feeding system

Purposes

- Fill seasonal pasture gaps
- Increase herd feed intake and milk production without increasing farm size
- Better manage climate and market volatility
- Better manage pasture residual mass on each rotation (prevent over-grazing)
- Help protect pastures from pugging in wet weather.

Characteristics

Frequency of use	Before/after milkings to sustain cows' daily feed intakes during periods which pasture is limited or during an emergency event (i.e. fire/flood)
Typical hours per day	3-4 hours per day
Surface	Compacted earth, sand/clay mix, crushed/decomposed rock, or natural gravel, with or without geosynthetic sheets
Feeding table	Low-cost, modular concrete troughs or conveyor belting under cable or hot wire
Loafing areas	Size will depend on time intend to keep cows off pasture
Shade/cooling	Nearby trees if available
Effluent management	Dry scraping off feedpad regularly, may require site drainage to control nutrient runoff
Feed prep. and delivery	Front-end loader, side winder round bale feeder, silage cart or mixer wagon
Feed storage	Silage pits/bunkers and hay sheds +/- commodity bunkers if using mixer wagon to prepare PMR

	Very low	Low	Moderate	High	Very high
Time and effort to set up		✓			
Weather durability			✓		
Permanency			✓		
Capital cost		✓			
Feed wastage				✓	
Potential production benefits		✓			
Improved farm efficiencies		✓			

Examples of basic feed-out areas

Large square hay bales fed out with front-end loader into low-cost troughs with steel frame and conveyor belting

Silage fed out with silage cart into low-cost troughs ('Waste-Not Fair Go Dairy Feedpad' panels)

PMR fed out with mixer wagon into very low-cost troughs made of conveyor belting with/without timber sides

PMR fed out with mixer wagon into 2 types of modular concrete troughs (3-sided profile and 'J' profile). On trough with J profile, note strip of timber added to low side

Costs

Capital cost: Low/cow (not including silage cart, mixer wagon and feed storage and mixing facilities).

Operating costs: Low (may be increased if manure needs to be stockpiled and spread).

Lifespan

Depends on how well the area's compacted surface (rock or clay) stands up to use. Surfaces of suitable rock base material or clay compacted with a heavy roller and water may last up to 20 years. Poorly prepared areas may only last a few years before requiring re-surfacing. Lifespan depends on:

- How well the area was formed with drainage and the surface compacted when first set up, and
- How intensely the area is used by cows (number x time) and vehicles in dry and particularly wet conditions.

Skill level/training required to operate

- Low if feeding out forage mixes with a silage cart
- Need to ensure silage or hay is placed correctly on the feed-out area and not wasted
- Moderate if preparing and feeding out a mixed ration.

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • +/- less walking • +/- reduced heat stress	• Basic feed-out area may be used to deliver hay, silage, or a mixed ration to cows. • It may increase milk production by increasing total daily feed intake. • If the area is located near the dairy and is large enough to be used to feed cows and enable them to rest between milkings instead of a day or night paddock, it may help to reduce energy spent walking. • If cows are fed a high level of concentrates in the bail at milking, using the feed-out area immediately before or after milking it may help to maintain a more stable rumen. • If herd is highly susceptible to heat stress due to farm location, breed, the herd's age profile and level of milk production, and the feed-out area provides plentiful tree shade, then its use may help to reduce heat stress on cows in hot weather, resulting in more milk.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage • reduced pugging damage	• Feed wastage at feed-out may be reduced by up to 15% when conserved forages and mixed rations are fed out on a basic feed-out area rather than in a sacrifice paddock, on bare ground, in hay rings or under a fence line. This effectively reduces the cost per tonne of feeds fed out by up to 15%. • A basic feed-out area may be used to some extent to reduce pugging damage in grazing paddocks in wet conditions if it provides sufficient space to enable 'on-off' grazing management to be used.

Limitations/concerns

Limitation	Comment
Maintenance	• Repairs may be required if surface or feeding table is damaged by cows or vehicles. • Feed-out area's surface may be difficult to regularly dry scrape. • Feed troughs are generally difficult to clean. Spoiled feed may accumulate in bottom of trough, causing odour, reduced feed palatability. Troughs may hold water during rain events.
Feed wastage	• Feed wastage is moderate to high (5–20% under dry conditions). • Feed refusals cannot be collected and fed to other cattle. They are wasted. • Feed wastage can be very high in wet conditions. • Wastage will be increased if troughs used and their height and width are not compatible with front end loader, feed cart or mixer wagon used.
Cow health risks	• Environmental mastitis and lameness if feed-out area deteriorates because it is not well prepared and/or regularly scraped. • Increased spread of disease as cows spend time in a contained area. • Cows may fall into troughs and injure themselves. • Poor trough hygiene may increase mycotoxin risk.
Environment issues	• If gravel is scraped up with manure, it is unsuitable for spreading on pastures, leading to manure build-up/stockpiles. • Runoff of effluent must be managed to ensure no nutrients are reaching waterways. • Odour can be an issue particularly when there is non-agricultural land use close by. • Dust can be an issue to workers and neighbours and poses a respiratory or allergy risk. • Noise can potentially cause nuisance to neighbours with regular use of trucks, tractors, and machinery.
Safety	• A feedpad in which cows and vehicles share the same area is never ideal. • In wet weather, feedpad surface may become slippery for cows and vehicles.

3. Formed earthen feedpad

Description

Formed earthen pad with a compacted surface shared by cows and vehicles and regularly scraped. Fixed structures including purpose-built concrete troughs or nib wall under cable or hot wire +/- narrow cement strip for cows to stand on while eating +/- loafing areas, shade structures.

Generic types

Compacted earthen feedpad +/- loafing areas +/- shade structures.

Suitable for use with

Low bail feeding system	**Moderate-high bail feeding system**	**PMR feeding system**	**Hybrid feeding system** (if large loafing areas)	TMR feeding system

Purposes

- Fill seasonal pasture gaps
- Increase herd feed intake and milk production without increasing farm size
- Better manage climate and market volatility
- Better manage pasture residual mass on each rotation (prevent over-grazing)
- Help protect pastures from pugging in wet weather.

Characteristics

Frequency of use	Feed out hay/silage before/after milkings to sustain cows' daily feed intakes during periods which pasture is limited. Practice 'on-off grazing' of day paddocks to protect pastures from pugging damage during prolonged wet weather. Cool cows on hot days if feedpad fitted with shade structures and/or sprinklers
Typical hours per day	3-4 hours per day
Surface	Compacted earth, sand/clay mix, crushed/decomposed rock, or natural gravel, with or without geosynthetic sheets
Feeding table	Purpose-built concrete troughs or nib wall. Feed barrier usually hot wire or cables, but may be post and rail +/- narrow cement strip for cows to stand on while eating
Loafing areas	Size will depend on time intend to keep cows off pasture
Shade/cooling	Shade cloth or solid roofed structures possible over feeding table and/or loafing areas
Effluent management	Dry scraping off feedpad regularly. Basic to well-developed effluent system
Feed prep. and delivery	Usually a mixer wagon, but may be a side winder round bale feeder or silage cart
Feed storage	Basic to well-developed storage and mixing facilities including silage pits/bunkers, hay sheds +/- commodity bunkers if using mixer wagon to prepare PMR

	Very low	Low	Moderate	High	Very high
Time and effort to set up			✓		
Weather durability			✓		
Permanency				✓	
Capital cost			✓		
Feed wastage			✓		
Potential production benefits			✓		
Improved farm efficiencies			✓		

Costs

Capital cost: Moderate/cow (not including silage cart, mixer wagon and feed storage and mixing facilities).

Operating costs: Low-moderate (may be increased if manure needs to be stockpiled and spread).

Lifespan

Depends on how well the feedpad's compacted surface (rock or clay) and fixed structures stand up to use. Surfaces of suitable rock base material or clay compacted with a heavy roller and water may last up to 20 years. Poorly prepared areas may only last a few years before requiring re-surfacing. Lifespan depends on:

- How well the area was formed with drainage and the surface compacted when first set up, and
- How intensely the area is used by cows (number x time) and vehicles in dry and particularly wet conditions.

Examples of formed earthen feedpad

PMR fed out in two reversed J troughs on an earthen feedpad

Narrow square-profiled trough being overfilled by mixer wagon, resulting in excess

Wider square-profiled trough on earthen pad under solid roof

PMR fed out in one trough on earthen pad. Note vertical bars defining each cow space and frame for shade cloth yet to be installed above feeding table

Skill level/training required to operate

- Moderate if preparing and feeding out a mixed ration
- Low if feeding out forage mixes
- Need to ensure PMR, silage or hay is placed correctly on the feedpad and not wasted.

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • +/- less walking • +/- reduced heat stress	• Permanent feedpad may be used to deliver hay, silage, or a mixed ration to cows. • It may increase milk production by increasing total daily feed intake. • If the area is located near the dairy and is large enough to be used to feed cows and enable them to rest between milkings instead of a day or night paddock, it may help to reduce energy spent walking. • If cows are fed a high level of concentrates in the bail at milking, using the feedpad immediately before or after milking it may help to maintain a more stable rumen. • If herd is highly susceptible to heat stress due to farm location, breed, the herd's age profile and level of milk production, installation of solid-roofed or shade cloth shade structures over feeding table and/or loafing areas may result in a saving of 2+ litres milk/day in hot weather.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage • reduced pugging damage	• Feed wastage at feed-out should be reduced to 2-10% when conserved forages and mixed rations are fed out. This compares to wastage of 5-25% on a grazing paddock under dry conditions, 5-35% in a sacrifice paddock, fed on bare ground, in ring feeders, or under a fence line. This effectively reduces the cost per tonne of feeds fed out by up to about 30%. • A feedpad may be used to reduce pugging damage in grazing paddocks in wet conditions if it provides sufficient space to enable 'on-off' grazing management to be used.

Limitations/concerns

Limitation	Comment
Maintenance	• Feedpad surface needs to be regularly dry scraped. • Feed troughs may be difficult to clean. If so, spoiled feed may accumulate in bottom of trough, causing odour, reduced feed palatability. Troughs may hold water during rain events.
Feed wastage	• Feed wastage is moderate (2–10% under dry conditions. Higher under wet conditions). • Feed refusals should be able to be collected and fed to other cattle. • Wastage will be increased if trough height and width is not compatible with FEL, feed cart or mixer wagon used. Other factors related to feedpad design and construction, feed ingredients/rations offered and feeding management may influence % feed wasted.
Cow health risks	• Environmental mastitis and lameness if feedpad is not well designed, constructed and regularly scraped. • Increased spread of disease as cows spend time in a contained area. • Cows may fall into troughs and injure themselves. • Poor trough hygiene may increase mycotoxin risk.
Environment issues	• If gravel is scraped up with manure, it is unsuitable for spreading on pastures. • Runoff of effluent must be managed to ensure no nutrients are reaching waterways. • Odour can be an issue particularly when there is non-agricultural land use close by. • Dust can be an issue to workers and neighbours and poses a respiratory or allergy risk. • Noise can potentially cause nuisance to neighbours with regular use of trucks, tractors, and machinery.
Safety	• A feedpad in which cows and vehicles share the same area is never ideal. • In wet weather, feedpad surface may become slippery for cows and vehicles.

4. Concrete feedpad

Description

Concrete areas for cows and feed (usually separated) which can be scraped, or flood washed +/- earthen surfaced loafing areas, shade structures, sprinklers, and fans for cow cooling.

Generic types

Concrete feedpad +/- earthen surfaced loafing areas +/- shade structures.

Suitable for use with

Low bail feeding system	**Moderate-high bail feeding system**	**PMR feeding system**	**Hybrid feeding system** (if large loafing areas)	TMR feeding system

Purposes

- Fill seasonal pasture gaps
- Increase herd feed intake and milk production without increasing farm size
- Better manage climate and market volatility
- Better manage pasture residual mass on each rotation (prevent over-grazing)
- Help protect pastures from pugging in wet weather.

Characteristics

Frequency of use	Feed out hay/silage before/after milkings to sustain cows' daily feed intakes during periods which pasture is limited. Practice 'on-off grazing' of day paddocks to protect pastures from pugging damage during prolonged wet weather. Cool cows on hot days if feedpad fitted with shade structures and/or sprinklers
Typical hours per day	3-4 hours per day
Surface	Concrete for cows and vehicles. Compacted earth, sand/clay mix, crushed/decomposed rock, or natural gravel for loafing areas
Feeding table	Purpose-built concrete troughs or nib wall. Feed barrier may be cables, post and rail or headlocks
Loafing areas	Size will depend on time intend to keep cows off pasture
Shade/cooling	Shade cloth or solid roofed structures possible over feeding table and/or loafing areas +/- sprinklers and fans
Effluent management	Dry scraping off feedpad regularly, may require site drainage to control nutrient runoff
Feed prep. and delivery	Usually a mixer wagon
Feed storage	Well-developed storage and mixing facilities including silage pits/bunkers, hay sheds and commodity bunkers if using mixer wagon to prepare PMR

	Very low	Low	Moderate	High	Very high
Time and effort to set up				✓	
Weather durability				✓	
Permanency				✓	
Capital cost				✓	
Feed wastage		✓			
Potential production benefits				✓	
Improved farm efficiencies				✓	

Costs

Capital cost: High/cow (not including silage cart, mixer wagon and feed storage and mixing facilities).

Operating costs: Moderate (may be increased if manure needs to be stockpiled and spread).

Lifespan

If fully concreted, more than 30 years. Depends on how well the facility was designed and constructed.

Skill level/training required to operate

- Moderate if preparing and feeding out a mixed ration
- Need to ensure PMR, silage or hay is placed correctly on the feedpad and not wasted
- Need to push feed up regularly if nib wall.

Examples of concrete feedpad

PMR fed out on fully concreted feedpad with nib wall, central feed alley

Cows beginning to push PMR out of reach

Concrete bunkers for storing by-products

Alternative feed barriers: Cables, post and rail, headlocks

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • +/- less walking • +/- reduced heat stress	• Permanent feedpad may be used to deliver hay, silage, or a mixed ration to cows. • It may increase milk production by increasing total daily feed intake. • If the area is located near the dairy and is large enough to be used to feed cows and enable them to rest between milkings instead of a day or night paddock, it may help to reduce energy spent walking. • If cows are fed a high level of concentrates in the bail at milking, using the feedpad immediately before or after milking it may help to maintain a more stable rumen. • If herd is highly susceptible to heat stress due to farm location, breed, the herd's age profile and level of milk production, installation of solid-roofed or shade cloth shade structures over feeding table and/or loafing areas may result in a saving of 2+ L milk/day in hot weather.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage • reduced pugging damage	• Feed wastage at feed-out should be reduced to 0-5% when conserved forages and mixed rations are fed out. This compares to wastage of 5-25% on a grazing paddock under dry conditions, 5-35% in a sacrifice paddock, fed on bare ground, in ring feeders, or under a fence line. This effectively reduces the cost per tonne of feeds fed out by up to about 30%. • A feedpad may be used to reduce pugging damage in grazing paddocks in wet conditions if it provides sufficient space to enable 'on-off' grazing management to be used.

Limitations/concerns

Limitation	Comment
Maintenance	• Feedpad surface needs to be regularly dry scraped or flood washed. • Some feed troughs may be difficult to clean. If so, spoiled feed may accumulate in bottom of trough, causing odour, reduced feed palatability. Troughs may hold water during rain events.
Feed wastage	• Feed wastage is low (0-5% under dry conditions. Higher under wet conditions). • Feed refusals should be able to be collected and fed to other cattle. • Wastage will be increased if a trough with height and width is not compatible with mixer wagon used. Other factors related to feedpad design and construction, feed ingredients/rations offered and feeding management may influence % feed wasted.
Cow health risks	• Environmental mastitis and lameness if feedpad is not well designed, constructed and regularly scraped or flood washed. • Increased spread of disease as cows spend time in a contained area. • Cows may fall into troughs and injure themselves. • Poor trough hygiene may increase mycotoxin risk.
Environment issues	• Runoff of effluent must be managed to ensure no nutrients are reaching waterways. • Odour can be an issue particularly when there is non-agricultural land use close by. • Dust can be an issue to workers and neighbours and poses a respiratory or allergy risk. • Noise can potentially cause nuisance to neighbours with regular use of trucks, tractors, and machinery.
Safety	• A feedpad in which cows and vehicles share the same area is never ideal. • In wet weather, feedpad surface may become slippery for cows and vehicles.

4. Roofed feedpad

Description

Concrete areas for cows and feed (usually separated) which can be scraped or flood washed, with solid-roofed or shade sail structures over feeding table and/or loafing areas +/- sprinklers and fans for cow cooling.

Generic types

Fully concreted feedpad with a solid, corrugated iron roof. Typically a widespan structure comprising a pitched roof with a central, open ridge vent in the roof apex to let heat and humidity escape. Alternatively, a flat, angled roof.

Fully concreted feedpad with a series of steel poles holding large shade sails under tension.

Suitable for use with

Low bail feeding system	**Moderate-high bail feeding system**	**PMR feeding system**	**Hybrid feeding system** (if large loafing areas)	TMR feeding system

Purposes

- Fill seasonal pasture gaps
- Increase herd feed intake and milk production without increasing farm size
- Better manage climate and market volatility
- Better manage pasture residual mass on each rotation (prevent over-grazing)
- Minimise heat stress
- Help protect pastures from pugging in wet weather.

Characteristics

Frequency of use	Feed out hay/silage before/after milkings to sustain cows' daily feed intakes during periods which pasture is limited. Practice 'on-off grazing' of day paddocks to protect pastures from pugging damage during prolonged wet weather. Cool cows on hot days
Typical hours per day	3-4 hours per day. Longer on hot days if earthen surfaced loafing areas provided nearby
Surface	Concrete for cows and vehicles. Compacted earth, sand/clay mix, crushed/decomposed rock, or natural gravel for loafing areas
Feeding table	Purpose-built concrete troughs or nib wall. Feed barrier may be cables, post and rail or headlocks
Loafing areas	Size will depend on time intend to keep cows off pasture
Shade/cooling	Solid-roofed or shade sail structures over feeding table and/or loafing areas +/- sprinklers and fans
Effluent management	Dry scraping off feedpad regularly, may require site drainage to control nutrient runoff
Feed prep. and delivery	Usually a mixer wagon
Feed storage	Well-developed storage and mixing facilities including silage pits/bunkers, hay sheds and commodity bunkers if using mixer wagon to prepare PMR

	Very low	Low	Moderate	High	Very high
Time and effort to set up				✓	
Weather durability				✓	
Permanency				✓	
Capital cost				✓	
Feed wastage		✓			
Potential production benefits				✓	
Improved farm efficiencies				✓	

Costs

Capital cost: High/cow (not including silage cart, mixer wagon and feed storage and mixing facilities).

Operating costs: Moderate (may be increased if manure needs to be stockpiled and spread).

Lifespan

Fully concreted feedpad: more than 30 years.

Solid-roofed shade structure: more than 25 years. Shade cloth shade structure, more than 10 years. Depends on how well the facility was designed and constructed.

Examples of roofed feedpads

Concrete roofed feedpad with multiple rows of feed troughs

Concreted overlapping roofed feedpad

Fully concreted feedpad with nib wall, central feed alley, solid roof and flood wash system

Concrete roofed feedpad with extended eaves for cattle loafing

Concrete roofed feedpad with dry scrape feed alleys

Skill level/training required to operate

- Moderate if preparing and feeding out a mixed ration
- Need to ensure PMR, silage or hay is placed correctly on the feedpad and not wasted
- Need to push feed up regularly if nib wall.

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • +/- less walking • +/- reduced heat stress	• Permanent feedpad may be used to deliver hay, silage, or a mixed ration to cows. • It may increase milk production by increasing total daily feed intake. • If the roofed feedpad is located near the dairy and is large enough to be used to feed cows and enable them to rest between milkings instead of a day or night paddock, it may help to reduce energy spent walking and minimize heat stress. • If cows are fed a high level of concentrates in the bail at milking, using the feedpad immediately before or after milking may help to maintain a more stable rumen. • If herd is highly susceptible to heat stress due to farm location, breed, the herd's age profile and level of milk production, installation of solid-roofed or shade cloth shade structures over feeding table and/or loafing areas may result in a saving of 2+ L milk/day in hot weather. • If solid-roofed shade structure is installed, key considerations for maximum effectiveness and useful life are: roofing material (aluminium or white galvanised steel increase solar reflection), roof height and pitch, ridge opening, eave overhang, guttering and downpipe design, and orientation (east-west works best for concrete floors). • If shade cloth shade structure is installed, key considerations for maximum effectiveness and useful life are: fabric material (green or black coloured material of minimum 300 grams per square metre is preferred), height, orientation, support posts and foundations, fastening of fabric to posts.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage • reduced pugging damage	• Feed wastage at feed-out should be reduced to 0-5% when conserved forages and mixed rations are fed out. This compares to wastage of 5-25% on a grazing paddock under dry conditions, 5-35% in a sacrifice paddock, fed on bare ground, in ring feeders, or under a fence line. This effectively reduces the cost per tonne of feeds fed out by up to about 30%. • A feedpad may be used to reduce pugging damage in grazing paddocks in wet conditions if it provides sufficient space to enable 'on-off' grazing management to be used.
Public acceptance	• If designed and managed well, roofed feedpads will improve cow comfort and may be viewed positively as an addition to grazing-based dairy farm systems.

Limitations/concerns

Limitation	Comment
Maintenance	• Feedpad surface needs to be regularly dry scraped or flood washed. • Some feed troughs may be difficult to clean. If so, spoiled feed may accumulate in bottom of trough, causing odour, reduced feed palatability. • Shade cloth shade structure.
Feed wastage	• Feed wastage is low (0-5% under dry conditions. Higher under wet conditions). • Feed refusals should be able to be collected and fed to other cattle. • Wastage will be increased if a trough with height and width is not compatible with mixer wagon used. Other factors related to feedpad design and construction, feed ingredients/rations offered and feeding management may influence % feed wasted.
Cow health issues	• Environmental mastitis and lameness if feedpad is not well designed, constructed and regularly scraped or flood washed. • Increased spread of disease as cows spend time in a contained area. • Cows may fall into troughs and injure themselves. • Poor trough hygiene may increase mycotoxin risk.
Environmental issues	• Runoff of effluent must be managed to ensure no nutrients are reaching waterways. • Odour can be an issue particularly when there is non-agricultural land use close by. • Dust can be an issue to workers and neighbours and poses a respiratory or allergy risk. • Noise can potentially cause nuisance to neighbours with regular use of trucks, tractors, and machinery.
Safety	• A feedpad in which cows and vehicles share the same area is never ideal. • In wet weather, feedpad surface may become slippery for cows and vehicles.

4. Cattle shelter

Description

A permanent, engineered roofed structure, with or without walls, under which some or all cows in a milking herd, or dry cows or young stock can loaf and rest comfortably on loose bedding material. The shelter's roof may be solid, corrugated iron, a white or clear, plastic film, or a set of shade sails. Feed and water may be offered to animals inside the shelter, either in troughs, along nib walls either side of a drive-through central feed alley, or in troughs along the perimeters of the shelter. Alternatively, feed and water may be offered to animals on a new or existing feedpad located adjacent to the shelter. Cows are not confined in the shelter – they are free to move outside to access the feedpad (if present) or to return to paddocks. The shelters are suited to grazing farms in regions where wet, cold, windy winter conditions may stress cows and lead to mastitis and damage to paddocks and laneways, and where summer heat impacts milk production and cow welfare. On hot days, the shelter with its feeding and watering infrastructure may only be used by cows in the hours between am and pm milkings. However, in harsh winter weather it may be used 24 hours per day for up to 2-3 weeks.

Generic types

Engineered steel-framed structure comprising interconnecting, multiple spans, clad with a tensioned clear or white fabric (polypropylene, polyethylene or polyvinylchloride of varying thickness). May be referred to as an 'eco-shelter'.

Engineered steel-framed structure with a corrugated iron roof. Typically a widespan structure comprising a pitched roof with a central, open ridge vent in the roof apex to let heat and humidity escape. Alternatively, a flat, angled roof.

Engineered structure comprising a series of steel poles holding large shade sails under tension.

Suitable for use with

Low bail feeding system	**Moderate-high bail feeding system**	**PMR feeding system**	**Hybrid feeding system** (if large loafing areas)	TMR feeding system

Purposes

- Provide cow comfort and reduce heat stress and cold stress
- Support supplementary feeding with a PMR or TMR
- Increase herd feed intake and milk production without increasing farm size
- Better manage pasture residual mass on each rotation (prevent over-grazing)
- Help protect pastures from pugging in wet weather.

Characteristics

Frequency of use	Practice 'on-off grazing' of day paddocks to protect pastures and laneways from damage during prolonged wet weather. Cool cows on hot days if feedpad fitted with shade structures and/or sprinklers. Loaf and feed cows for extended periods (e.g. 1-2 weeks) during wet, cold winter conditions or during hot periods when little/no pasture available
Typical hours per day	System dependent, multiple hours up to 24 hours per day at times of the year
Surface	Deep litter (e.g. woodchips) on a compacted clay base
Feeding table	Purpose-built concrete troughs or nib walls installed along centre or perimeter of shelter or located in area adjacent to it. Feed barrier may be cables, post and rail or headlocks
Loafing areas	Size will depend on time intend to keep cows off pasture
Shade/cooling	Cattle shelters may be fitted with manually or automatically controlled overhead shade screens, roof vents, fans, misters and roll-up wall blinds as optional extras Steel-framed structures with solid roof may be fitted with fans and misters
Effluent management	Removal of bedding material at regular intervals (may be spread on pastures, reducing fertiliser costs) Dry scraping or flood washing of feed alley (if fitted) at regular intervals
Feed prep. and delivery	Mixer wagon
Feed storage	Silage pits/bunkers, hay sheds, commodity bunkers, tanks for liquids

	Very low	Low	Moderate	High	Very high
Time and effort to set up			✓	✓	
Weather durability			✓	✓	
Permanency			✓	✓	
Capital cost			✓	✓	
Feed wastage		✓			
Potential production benefits				✓	
Improved farm efficiencies				✓	

Costs

Capital cost: Moderate-high/cow (not including feeding and watering infrastructure inside or adjacent to shelter, silage cart, mixer wagon and feed storage and mixing facilities).

Operating costs: Moderate (may be increased if manure needs to be stockpiled and spread).

Lifespan

Ecoshelter: steel frame, more than 25 years, clear or white fabric cladding, more than 10 years. Solid-roofed structure: more than 25 years. Shade sail structure: more than 10 years. Depends on how well the facility was designed and constructed and prevailing weather conditions.

Examples of cattle shelters

Woodchips and manure bedding with external troughs for feeding

Stand alone cattle shelter with spouting and downpipes to remove rainfall

Woodchips and manure bedding in an eco-shelter

Straw bedding to accommodate the herd during wet winters to minimise pugging

Skill level/training required to operate

- Moderate if preparing and feeding out a mixed ration
- Need to ensure PMR, silage or hay is placed correctly on the feedpad and not wasted
- Need to push feed up regularly if nib wall
- Need to manage bedding and top up/replace regularly.

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • +/- less walking • +/- reduced heat stress	• Cows in shelter expend minimal energy walking. • If herd is highly susceptible to heat stress due to farm location, breed, the herd's age profile and level of milk production, installation of solid-roofed or shade cloth shade structures over feeding table and/or loafing areas may result in a saving of 2+ L milk/day in hot weather.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage • reduced pugging damage	• Feed wastage at feed-out should be reduced to 0-5% when conserved forages and mixed rations are fed out in purpose-built troughs. This compares to wastage of 5-25% on a grazing paddock under dry conditions, 5-35% in a sacrifice paddock, fed on bare ground, in ring feeders, or under a fence line. This effectively reduces the cost per tonne of feeds fed out by up to about 30%. • Shelters may be used to manage paddock rotations • Shelters may be used in wet conditions to reduce pugging damage by cows in grazing paddocks, thereby improving pasture growth rates and annual pasture utilisation, and reducing pasture renovation costs.
Improved cow comfort and welfare	If well designed and managed, a cattle shelter provides cows with: • unlimited access to feed and drinking water. • freedom to lie down and rest, eat and move around and socialise each day. • close monitoring and assessment for production and health. • shade +/- evaporative cooling, so they are protected from heat stress. • protection from adverse weather events, muddy walking tracks and paddocks etc. • a comfortable environment during the transition period.
Public acceptance	Dairy shelters are relatively new to the Australian dairy landscape – if designed and managed well they will improve cow comfort and may be viewed positively as an addition to grazing-based dairy farm systems.

Limitations/concerns

Limitation	Comment
Climatic	• Careful choice of location and orientation of shelter on each farm is required (including rainfall, wind and heat considerations). • A solid roof may be more suitable for shelters on farms in regions with very high solar radiation loads than a clear fabric roof with optional overhead shade screens and roof vents.
Increased operating costs	When being operated, requires more specialised skills in staff management, animal management, ration balancing and environmental management: • PMR/TMR needs to be delivered to cows at each feed bunk at least once per day and pushed up regularly to maximise intake and reduce wastage. • Pack needs to be tillered at least once per day even when not in use and have unrestricted air flow over it. • Bedding material needs to be regularly topped up.
Availability of bedding material and pack maintenance to control mastitis	• Bedding material may be costly or in limited supply in local area. • If the pack is not managed well, the higher risk of exposure to environmental mastitis pathogens can add to costs. Temperatures reached in the compost bedded pack may not be high enough to eliminate mastitis-causing bacteria, especially if the shelter is not being used 24 hours per day.
Planning process	• Dairy shelters are classed as an integrated facility for feeding and housing cows system and hence trigger a change in land use requiring a planning permit. Obtaining necessary approvals and permits across a range of government departments can be very slow and involved.
Higher skill/training level and standard of management required	• Attention to detail and management skill are required to ensure the pack surface in the shelter remains dry, and to detect and mitigate issues early • If management of feed purchasing, storage, mixing and delivery to shelter, and of cow comfort are sub-optimal, milk production and milk income less feed costs will be sub-optimal.

5. Contained housing: Dairy dry lot

Description

These systems typically have centralised roofed shelters over non-composting bedding packs, composting bedding packs, or packs that only actively compost occasionally, located in earthen pens that are adequately sloped for drainage to a centralised manure collection system. The dairy herd is grouped depending on production and stage of lactation and various management groups. Typically, feed troughs and water supply are located away from the shelters to improve cattle movement and reduce congestion. Alternatively, a centralised concreted feedpad (either sloped and flushed or flat and dry scraped) provides effective infrastructure for feeding. Manure from the pens is regularly dry scraped and stockpiled in a designated area for composting and reused as bedding or re-applied to land supporting fodder production. These systems are most suited in hot, arid climates with suitable soils that facilitate drainage.

Generic types

Concrete feedpad +/- earthen surfaced loafing areas +/- shade structures.

Suitable for use with

Low bail feeding system	Moderate-high bail feeding system	PMR feeding system	Hybrid feeding system (if large loafing areas)	**TMR feeding system**

Purposes

- Compacted and sloped earthen pens and cattle loafing areas support supplementary feeding with a PMR or TMR
- Increase feed intakes, feed conversion efficiency and milk yields/cow
- Provide cow comfort and minimize heat stress
- Control nutrient run-off.

Characteristics

Frequency of use	Hold, feed and water cows permanently
Typical hours per day	System dependent, multiple hours up to 24 hours per day at times of the year
Surface	Earthen sloped pad
Feeding table	Concrete nib wall. Cow barrier either post and rail or head locks. If sprinklers are fitted at feeding table, it is important that the concrete cow feeding platform be constructed with a nib wall against the dry lot to prevent the runoff from the sprinklers reaching the earthen surface of the pen
Loafing areas	Large earthen sloped loafing areas to facilitate drainage
Shade structures	Shade structures constructed with a north-south orientation parallel to the feeding infrastructure. This allows the shade to move throughout the day, resulting in cows resting on different sections of the dry lot surface. Shade shelters are fitted with gutters removing rainfall away from the pen to allow the dry lot earthen surface to dry faster during wet weather and eliminating pugging around the shelters
Effluent management	Dry scraping or flood washing of cow alleys at regular intervals throughout the day Manure from the pens regularly dry scraped and stockpiled for composting and applied to land to support fodder production
Feed prep. and delivery	Mixer wagon
Feed storage	Silage pits/bunkers, hay sheds, commodity bunkers, tanks for liquids

	Very low	Low	Moderate	High	Very high
Time and effort to set up				✓	
Weather durability			✓		
Permanency				✓	
Capital cost			✓		
Feed wastage	✓				
Potential production benefits					✓
Improved farm efficiencies					✓

Costs

Capital cost: Moderate/cow (not including mixer wagon, feed storage and mixing facilities or milking facilities). The advantage of dairy dry lot facilities lies in the lower capital investment per cow compared to CBP sheds or freestalls.

Operating costs: Higher than a permanent feedpad due to extra labour, machinery, and material costs to till bedding material under skillion shelters and dry scrape manure from earthen pens for composting, handling, transport and application.

Lifespan

More than 5–10 years. Depends on how well the facility was designed and constructed and maintained with regional climate. Extended wet periods can cause pugging so developing systems with adequate slope to accommodate drainage, so water drains off pens is critical. The slope of pens will have a dramatic impact on how fast the earthen surface will dry.

Examples of dairy dry lots

Shade shelters at a dairy dry lot with a north-south orientation

Cows resting comfortably on compost bedded pack aerated daily

Cows feeding at concrete central feedpad

Concrete cow feeding alley ways constructed with a nib wall against the dry lot to prevent the runoff reaching the earthen surface of the pen

Cows resting on sloped earthen pen of dairy dry lot

Flood washing of concrete cow feeding alleyways

Water trough with concrete drinking apron to prevent runoff onto earthen pen and pugging damage around the trough

Skill level/training required to operate

High

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • Less walking • Reduced heat stress	• TMR enables cows' daily feed inputs to be more closely controlled. • Feeding cows a TMR 2+ times per day is optimal in terms of rumen stability and function. • Presenting the milker diet as a TMR has been shown to optimise daily feed intake. • Cows on dairy dry lots expend minimal energy walking. • Under hot weather conditions, a dairy dry lot with effective cooling systems such as sprinklers placed at cow feeding alleyways and adequate shade may result in a saving of up to 5L milk/day.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage	• Studies indicate that feed wastage at feed-out may be reduced to 1–2% when presented as a TMR and fed out at a feed bunk. • Annual average feed conversion efficiency of 1.5L/kg DM (ECM) is achievable in a dairy dry lot (Don Stewart, Pers. comm)
Improved cow comfort and welfare	If well designed and managed, a dairy dry lot provides cows with: • unlimited access to feed and drinking water • freedom to lie down and rest, eat and move around and socialise each day • close monitoring and assessment for production and health • opportunity to calve in a special maternity facility under supervision • no need to walk long distances or wait in a dairy holding yard to be milked in the hot sun • shade and evaporative cooling, so they are well protected from heat stress.
Public acceptance	• Dairy dry lots are relatively new to the Australian dairy landscape – if designed and managed well they will improve cow comfort and may be viewed as an alternative to freestall or loose housing facilities
Specialisation of labour and management	• If enterprise is large enough, can train and manage specialised operational teams for earthen pen management (scraping and tilling of bedding), fodder growing and harvesting, feed mixing and delivery to cow, herd management, milk harvesting, young stock management and improved monitoring during joining
Improved feed utilisation	• Shifting feedbase to forages which are mechanically harvested eases pugging and compaction which may occur during grazing in miserable weather

Limitations/concerns

Limitation	Comment
Climatic	• Careful choice of location is required (including rainfall and heat considerations) and design for satisfactory year-round dairy health. A dairy dry lot may work in a semi-arid environment. While earthen pens are sloped extensive rainfall events can challenge dairy dry lots – particularly if they are overstocked. • During severe windy, wet conditions skillion shelters provide little protection from wind-chill.
High operating costs	Requires more specialised skills in staff management, animal management, ration balancing and environmental management: • TMR needs to be delivered to cows at each feed bunk at least once per day. • TMR needs to be pushed up regularly to maximise intake and reduce wastage. • Pack needs to be tillered at least twice per day and bedding regularly topped up.
Availability of bedding material and pack maintenance to control mastitis	• If the pack under the skillion shelters is not managed well, there is a higher risk of exposure to environmental mastitis pathogens which can add to costs. • Temperatures reached in the compost bedded pack may not be high enough to eliminate mastitis-causing bacteria.
Planning process	• Dairy dry lots are classed as an integrated facility for feeding and housing cows system and hence trigger a change in land use requiring a planning permit. Obtaining necessary approvals and permits across a range of government departments can be very slow and involved.
Economies of scale with herd size	• The two major costs of contained housing facilities (besides the cost of capital) are feed costs and labour costs. While major savings in labour and other overhead costs can be achieved with increased herd size, feed costs tend to be similar across herd size. Maximising utilisation of dairy parlour requires a larger herd size.
High skill/training level and standard of management required	• Attention to detail and management skill can be critical in the management of a dairy dry lot system to detect and mitigate issues early. Different management skills are required as labour units are increased – including delegating responsibility, providing access to training etc. Regular and open communication is essential. Workplace health and safety needs to be addressed.
More complex labour requirements	• As the size of the enterprise increases, several labour units – with specialised skills and different areas of expertise and responsibility – tend to be required in a large dairy dry lot.
Environmental pressures	• Under dry lot conditions – especially close to urban and non-farming areas – infrastructure and management needs to be sufficient to prevent odours, dust and increased fly population that are likely to attract negative attention. Nutrient movement needs to be controlled, captured, and re-applied within the farm boundary.

5. Contained housing: Loose housing

Description

A large, permanent, engineered roofed structure in which cows are fed and housed 24 hours per day. Loose housing facilities comprise of a large open resting area, bedded with a range of different bedding materials to create a comfortable lying surface that encourages cows to lie down. Loose housing facilities do not include stalls and partitions and the cows' resting and exercise areas are combined. Ventilation is natural or mechanically assisted.

Generic types

These facilities are typically categorised by their management of the bedded area:

- **Deep litter pack** where absorbent organic bedding is added regularly to the bedded area, but there is no mechanical tilling, or
- **Compost bedded pack** that is mechanically tilled at least twice daily.

All bedding is usually removed at intervals of 6-12 months, then new absorbent organic bedding added back into the facility.

Suitable for use with

Low bail feeding system	Moderate-high bail feeding system	PMR feeding system	Hybrid feeding system (if large loafing areas)	**TMR feeding system**

Purposes

- Have maximum control over feeding, with minimal wastage
- Achieve optimal feed intakes, feed conversion efficiency and milk yields/cow
- Have maximum control over climatic variability and extreme weather events
- Provide maximum cow comfort and minimize heat stress and cold stress
- Control nutrient run-off.

Characteristics

Frequency of use	Hold, feed and water cows permanently – zero grazing
Typical hours per day	24 hours per day
Surface	Organic materials, such as sawdust, straw, woodchips, wood shavings, shredded paper, dried manure, bark, seed hulls (e.g. rice, almond etc) can be used effectively for deep bedding.
Feeding table	Concrete nib wall. Cow barrier either post and rail or head locks
Loafing areas	Large resting area without partitions with composted bedding surface
Shade structures	Solid roof over entire facility
Effluent management	Dry scraping or flood washing of feed alleyways at regular intervals Removal of composted bedding material at regular intervals
Feed prep. and delivery	Mixer wagon
Feed storage	Silage pits/bunkers, hay sheds, commodity bunkers, tanks for liquids

	Very low	Low	Moderate	High	Very high
Time and effort to set up				✓	
Weather durability					✓
Permanency					✓
Capital cost					✓
Feed wastage	✓				
Potential production benefits					✓
Improved farm efficiencies					✓

Costs

Capital cost: Very high/cow (not including mixer wagon, feed storage and mixing facilities or milking facilities). Per cow construction costs are generally lower than for a freestall, despite more area being required per cow, as less concrete is used and there is no investment in freestall partitions and bases.

Operating costs: Higher than a freestall due to extra labour, machinery, and material costs to till bedding material and top up regularly.

Lifespan

More than 30 years. Depends on how well the facility was designed and constructed.

Examples of loose housing facilities

Deep litter pack – low bed retaining curb, water troughs, access from feed alley only

Cows resting comfortably on compost bedded pack

Cows in feed alley and on compost bedded pack

Tilling a compost bedded pack with harrows to help aeration and to break up clumps while the cows are off the pack being milked

Skill level/training required to operate

High

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • Less walking • Reduced heat stress	• TMR enables cows' daily feed inputs to be more closely controlled. • Feeding cows a TMR 2+ times per day is optimal in terms of rumen stability and function. • Presenting the milker diet as a TMR has been shown to optimise daily feed intake. • Cows in loose housing facilities expend minimal energy walking. • Under hot weather conditions, a well ventilated loose housing facility with effective cooling systems may result in a saving of up to 5 L milk/day.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage	• Studies indicate that feed wastage at feed-out may be reduced to 1-2% when presented as a TMR and fed out at a feed bunk. • Annual average feed conversion efficiency of 1.6 L /kg DM (ECM) is achievable in a loose housing facility.
Improved cow comfort and welfare	If well designed and managed, a loose housing facility provides cows with: • unlimited access to feed and drinking water • freedom to lie down and rest, eat and move around and socialise each day • close monitoring and assessment for production and health • opportunity to calve in a special maternity facility under supervision • no need to walk long distances or wait in a dairy holding yard to be milked in the hot sun • shade and evaporative cooling, so they are well protected from heat stress • protection from adverse weather events, muddy walking tracks and paddocks etc.
Public acceptance	• Loose housing facilities are generally viewed by the public as better in terms of cow welfare than a freestall, and are likely to have less odours and flies if well managed
Specialisation of labour and management	• If enterprise is large enough, can train and manage specialised operational teams for fodder growing and harvesting, feed mixing and delivery to cow, herd management, milk harvesting, and young stock management.

Limitations/concerns

Limitation	Comment
High capital cost	• Engineered structures with steel and concrete fixtures. • Addition costs are required for facility ventilation and cooling systems, and effluent system
High operating costs	• TMR needs to be delivered to cows at each feed bunk at least once per day. • TMR needs to be pushed up regularly to maximise intake and reduce wastage. • Pack needs to be tillered at least twice per day and bedding regularly topped up.
Availability of bedding material and pack maintenance to control mastitis	• Bedding material may be costly or in limited supply in local area. • If the pack is not managed well, the higher risk of exposure to environmental mastitis pathogens can add to costs. Temperatures reached in the compost bedded pack may not be high enough to eliminate mastitis-causing bacteria
Planning process	• A planning permit for intensive animal husbandry is required, under the state and local planning policy frameworks. There are several additional state legislations and policies that may impose additional requirements on the development and operation of a loose housing facility. Objections to a planning permit application may be received from neighbours and other members of the local community (noise, odour etc.)
Economies of scale with herd size	• The two major costs of contained housing facilities (besides the cost of capital) are feed costs and labour costs. While major savings in labour and other overhead costs can be achieved with increased herd size, feed costs tend to be similar across herd size. Maximising utilisation of dairy parlour requires a larger herd size.
High skill/training level and standard of management required	• If management of feed purchasing, storage, mixing and delivery to facilities, herd numbers and composition (age, stage of lactation, milk yield), and cow comfort are sub-optimal, milk production and milk income less feed costs will be sub-optimal.

5. Contained housing: Freestall

Description

A large, permanent, engineered structure in which cows are fed and housed 24 hours per day. They may be open or partially or fully enclosed. The term 'freestall' refers to the bedding area (or cubicles) where cows lie down and rest. Additional loafing areas may also be provided. Cows are kept in pen groups and access a TMR at a feed bunk via alleyways. Cows leave the facility 2-3 times each day to be milked in an adjacent milking parlour. Alternatively, if it is a robotic freestall, milking stations are located within the facility. Ventilation in the facility may be natural, crossflow or tunnel.

Generic types

Freestall with alternative layouts: 3-row, 4-row (head-to-head or tail-to-tail), 6-row, 6-row with perimeter feeding, 8-row wide-body, low profile, cross-ventilated facility (head-to-head or tail-to-tail).

Suitable for use with

Low bail feeding system	Moderate-high bail feeding system	PMR feeding system	Hybrid feeding system (if large loafing areas)	**TMR feeding system**

Purposes

- Have maximum control over feeding, with minimal wastage
- Achieve optimal feed intakes, feed conversion efficiency and milk yields/cow
- Have maximum control over climatic variability and extreme weather events
- Provide maximum cow comfort and minimize heat stress and cold stress
- Control nutrient run-off.

Characteristics

Frequency of use	Hold, feed and water cows permanently – zero grazing
Typical hours per day	24 hours per day
Surface	Concrete or rubber
Feeding table	Concrete nib wall. Cow barrier either post and rail or head locks
Loafing areas	Cubicles with bedding +/- additional loafing areas adjacent to contained housing facility
Shade/cooling	Solid roof over entire contained housing facility
Effluent management	Dry scraping or flood washing of alleyways at regular intervals to remove manure to a professionally designed effluent system
Feed prep. and delivery	Mixer wagon
Feed storage	Silage pits/bunkers, hay sheds, commodity bunkers, tanks for liquids

	Very low	Low	Moderate	High	Very high
Time and effort to set up					✓
Weather durability					✓
Permanency					✓
Capital cost					✓
Feed wastage	✓				
Potential production benefits					✓
Improved farm efficiencies					✓

Costs

Capital cost: Very high/cow (not including mixer wagon, feed storage and mixing facilities or milking facilities).

Operating costs: Moderate-high depending on whether bedding in cubicles is sand or mattresses.

Lifespan

More than 30 years. Depends on how well the facility was designed and constructed.

Examples of freestalls

Sand bedded cubicles. Flood-washed cow alley

Feed push-up using tractor

Sand replenishment

Alternative cubicle bedding: Sand, mattresses top-dressed with wood shavings or bentonite

Skill level/training required to operate

High

Possible benefits

Benefit	Comment
More milk/cow/day through: • Improved rumen stability • Higher feed intake • Less walking • Reduced heat stress	• TMR enables cows' daily feed inputs to be more closely controlled. • Feeding cows a TMR 2+ times per day is optimal in terms of rumen stability and function. • Presenting the milker diet as a TMR has been shown to optimise daily feed intake. • Cows in freestalls expend minimal energy walking. • Under hot weather conditions, a well ventilated freestall with effective cooling systems may result in a saving of up to 5 L milk/day.
Higher feed efficiency and reduced feed costs through: • reduced feed wastage	• Studies indicate that feed wastage at feed-out may be reduced to 1-2% when presented as a TMR and fed out at a feed bunk. • Annual average feed conversion efficiency of 1.6 L/kg DM (ECM) is achievable in a freestall.
Improved cow comfort and welfare	If well designed and managed, a freestall provides cows with: • unlimited access to feed and drinking water • freedom to lie down and rest, eat and move around and socialise each day • close monitoring and assessment for production and health • opportunity to calve in a special maternity facility under supervision • no need to walk long distances or wait in a dairy holding yard to be milked in the hot sun • shade and evaporative cooling, so they are well protected from heat stress • protection from adverse weather events, muddy walking tracks and paddocks etc.
Specialisation of labour and management	• If enterprise is large enough, can train and manage specialised operational teams for fodder growing and harvesting, feed mixing and delivery to cow, herd management, milk harvesting, and young stock management.

Limitations/concerns

Limitation	Comment
High capital cost	• Engineered structures with steel and concrete fixtures. • Addition costs are required for facility ventilation and cooling systems, and effluent system
High operating costs	• TMR needs to be delivered to cows at each feed bunk at least once per day. • TMR needs to be pushed up regularly to maximise intake and reduce wastage. • Cubicles need to be regularly groomed and bedding topped up • Effluent management • Sand (if used) needs to be recovered from effluent system
Planning process	• A planning permit for intensive animal husbandry is required, under the state and local planning policy frameworks. There are several additional state legislations and policies that may impose additional requirements on the development and operation of a freestall. Objections to a planning permit application may be received from neighbours and other members of the local community (noise, odour etc.)
Economies of scale with herd size	• The two major costs of contained housing facilities (besides the cost of capital) are feed costs and labour costs. While major savings in labour and other overhead costs can be achieved with increased herd size, feed costs tend to be similar across herd size. Maximising utilisation of dairy parlour requires a larger herd size.
High skill/training level and standard of management required	• If management of feed purchasing, storage, mixing and delivery to facilities, herd numbers and composition (age, stage of lactation, milk yield), and cow comfort are sub-optimal, milk production and milk income less feed costs will be sub-optimal.

8.3 Moving from one type of feed delivery infrastructure to the next

It is common for a farm to set up a basic feed-out area or formed earthen feedpad, and then, over many years, develop it into a fully concreted permanent feedpad (or possibly even into an integrated facility for feeding and housing cows). This is only feasible if the factors in Table 6 are well considered at the outset. Otherwise, down the track, a new permanent feedpad may need to be constructed at another site on the farm (with many costs being incurred again) and another use found for the old feedpad (e.g. as a calving pad).

Feed delivery infrastructure for basic feed-out areas, formed earthen feedpads, concrete feedpads and integrated facilities for feeding and housing cows all enable mixed ration feeding systems to be used. These have advantages and disadvantages (Table 4).

Table 9. Factors to consider when moving from one type of feed delivery infrastructure to the next

Factor	
Area	Will the feedpad be large enough to cater for increased cow numbers and how long you intend cows to stay on the feedpad per day?
Site on farm	Consider weather and wind, proximity to the dairy, feed storage and mixing facilities, water points, drains, effluent ponds. Think about vehicle access, distance from boundaries and easements etc.
Orientation	Is it possible that the feedpad may evolve into a permanent, concrete-surfaced feedpad with a roof? If so, consider an east-west orientation.
Topography, soil type and slope	Consider the natural slope and drainage of the proposed site. What will happen to storm water? Will you need to undertake earthworks? Soil investigations and permeability tests establish load tolerance and likelihood of pad surface cracks, nutrient leaching, and seepage into effluent storage.
Impact on ground and surface water	Consider how siting and effluent runoff management will impact ground and surface water. Remember, runoff containing effluent must not leave the boundary of your property.
Odour, dust, noise	Cow numbers, climate, type of feed and feedpad management all affect feedpad odour. What buffer distance is planned? Fine particle dust can be managed by good laneway design and regular management. Buffer zones help reduce noise too – very important if you have neighbours close by.
Vehicle access to feedpad	Vehicles require a minimum of 3.7m for easy access – 4m for all weather access. Have you allocated enough room for the distribution of feed as well as access for cleaning? Large trucks need high clearance.
Cow access to dairy, loafing pad, feed areas	Routes for laneways should permit easy cow flow and allow for herd expansion.
Stock water	Stock need access to water close to where they will be feeding. You may need water for cleaning the feedpad. How will water be delivered to the site? If collecting off roofs, how will rainwater be diverted and stored?
Drainage	Effective drainage is important for all weather access. Can your proposed feedpad handle a flood or one-in-20-year-24-hour storm event? You may need diversion banks and catch drains to carry storm runoff and effluent.
Power	Will you need access to power at the feedpad site – now and in the future?

How one farm's feedpad evolved through 3 stages of development over 15 years

Table 10. Mixed ration feeding systems – advantages and disadvantages

Advantages	• More resilient in the face of drier, hotter weather conditions and extreme weather events, greater fluctuations in home-grown forage availability and quality due to greater climate variability, and greater volatility in milk, water, grain and fodder markets • Can further intensify their operation to increase productivity and remain profitable (increasing stocking rate and feeding more supplementary feeds per cow) • Increase flexibility, to access cost-effective by-products and cope with increased climate and market volatility • Can feed cows higher levels of grain/concentrates with less ruminal acidosis and better feed efficiency than possible using bail feeding in the milking shed • Can better control diets and reduce feed wastage associated with feeding out hay, silage and other supplements • Can better control monthly milk flows to suit their processor's requirements and payment scheme (particularly if supplying the domestic liquid milk market)
Disadvantages	• Increase complexity – diets, pasture and feeding management • More time pressures on staff and cows • Increase business overheads - finance and capital costs for new facilities and equipment • An increase in the cost structure of the farm business which necessitates achievement of higher levels of feed efficiency to remain viable • Fixed structures which cannot be moved or sold • Increased risk of cow health problems such as lameness and mastitis if not managed well • A need to manage manure and effluent well and avoid image and odour problems • Changes required in thinking re. feeding cows and in daily work routines

Before committing to a specific type of feed delivery infrastructure, consider these farm management questions:

- How will pasture management be adjusted to maximise efficiency?
- How will a feedpad impact the farm's profitability?
- What will the feedpad be used for?
- How will animal health and welfare on the feedpad be managed?
- How will the proposed system be operated long term, for example feed management?
- Will a change in system align with goals for the farm?
- Will the farm change to a higher input feeding system?
- Does the farm have sufficient staff to run a supplementary feed system?
- How will the increased effluent and stormwater generated from the pad be managed?

A feeding facility which enables mixed rations to be fed and perhaps also enables cows to be sheltered or housed for varying periods of time (from a few hours a day to a few days at a time to permanently) invariably involves:

- Increased capital
- A changed operating environment with increased operating costs
- Increased complexity, with impacts on labour and time management, and skills required, and
- A change in risk profile for the farm business.

Future designs of permanent infrastructure for feeding and housing cows

The main factors shaping future designs for feeding and housing cows are:

- Animal welfare issues, especially less lameness and fewer hock lesions, and more natural behaviour
- Less emissions of ammonia and greenhouse gases
- Reuse of waste products
- Climate control
- Aesthetics of the building in the landscape
- Increased capital efficiency, and
- Increased manure quality.

Additional factors shaping future design to consider include:

- Farm production, larger higher production animals – US freestall designs and cubicle spacing is increasing
- Increased technologies (e.g. cattle monitoring, manure systems with advanced solid separation and anaerobic digestion), and
- Incorporation of robotic milking systems into housed complexes.

(Scott McDonald, Pers. Comm.)

8.4 Benefits of feed delivery infrastructure

Through use of feed delivery infrastructure, it is possible to achieve:

- More milk/cow/day from:
  - a) increased rumen stability and daily feed intake
  - b) reduced walking distance per day, and
  - c) Reduced heat stress
- Higher feed efficiency and reduced feed costs from:
  - a) reduced feed wastage, and
  - b) reduced pugging damage to soil in wet weather

More milk/cow/day from:

a) Increased rumen stability and feed intake

Milk yield increases seen from progressing from a system where grain and concentrates are fed in the bail and conserved forage in the paddock to a PMR system where all the forage and concentrates are included in the one ration and delivered on a feedpad are at least 3.5kg/day. Milk yield increases by progressing from a feedpad to a TMR contained housing system with no access to pasture may be in excess of an additional 6.0kg/day. These increases are achieved due to improved rumen stability, higher daily feed intakes and improved feed conversion efficiency.

Kolver and Muller (1998) were one of the first to quantify the difference in production of dairy cows fed either only high-quality pasture or a nutritionally balanced TMR. The increase in milk yield from 29.6–44.1kg/day was due largely to the increase in DMI from 19.0–23.4kg/day.

Bargo *et al.* (2002) demonstrated that feeding a TMR maximised DMI and milk production. They found that the dry matter intake of cows receiving pasture and up to 10kg/day concentrate in the bail consumed 21.6kg/day comprising 12.9kg DM pasture and 8.7kg DM concentrate, while TMR cows consumed 26.7kg DM/day. Cows on an intermediate treatment of grazing during the day, and then housed and fed a mixed ration overnight consumed a total of 25.2kg/day comprising 2.2kg DM concentrate, 7.5kg DM pasture and 15.5kg DM/day of the mixed ration. The respective milk yields were 28.5kg/day for pasture plus concentrate in the bail, 38.1kg/day for the TMR cows and 32.0kg/day for the intermediate system.

The research group at Ellinbank confirmed greater dry matter intakes were associated with a mixed ration being offered to dairy cows, in addition to grazing on pasture. At the higher daily supplement intakes of about 15.0kg DM total supplement, cows that were provided with their nutrients in a mixed ration form produced about 2.0kg ECM/day (Energy Corrected Milk) more than cows feed the same concentrate in the bail and silage in the paddock (Auldist *et al.*, 2013). In addition, the replacement of part of the wheat with canola meal in the mixed ration improved pasture intake and consequently, ECM milk yield by up to 5kg/day.

The results of a case study of dairy producers progressing from a system that involved grazed pasture, conserved forage fed with a mixer wagon under a hot wire and grain mix in the dairy, to grazed pasture and forage and grain mix from the mixer wagon fed to cows on a feedpad, have been described by Dairy Australia (2020). In this case study, milk yield increased by 3.5kg/day, which is similar to that observed by Bargo *et al.* (2002).

b) Reduced walking distance per day

Feed delivery infrastructure may also increase milk yield by reducing the amount of energy expended in activity if it enables cows' walking distances to be reduced. On relatively flat terrain as in the Murray region, each kilometre walked requires a conservative 2 MJ metabolisable energy (ME). Given that each litre of milk produced requires about 5.0 MJ ME, the milk yield loss for every km walked is approximately 0.4 litres.

Janna Heard used the equations from the Standing Committee on Agriculture (1991) to calculate the energy cost of walking from the paddock to the dairy (Heard *et al.*, 2004). Using the Standing Committee on Agriculture equations, Heard and co-workers calculated that the energy used in walking 1 km along the horizontal was 2.6 MJ/kg bodyweight, which is about 1.6 MJ for a 600kg cow. Assuming the efficiency of converting energy from feed into milk is 75% another 2.1 MJ ME is required for every km walked. Assuming 5.0 MJ ME required per litre of milk (Moe & Tyrell, 1975), this equates to 0.42kg milk/km walked on predominantly flat terrain.

Moran (2005) estimated that on flat terrain an additional 1 MJ ME will be required to provide the energy to walk to and from the dairy for every km covered. In hilly country this energy requirement increases up to 5 MJ ME/km. Assuming about 4.5 MJ ME are required to produce a litre of milk (Moran, 2005), the estimated loss in milk yield/km walked would be about 0.22kg/km on relatively flat terrain, but over 1kg/km travelled in hilly terrain. Later, Islam *et al.* (2015) provided an intermediate value when they estimated that milk yield decreased by 0.61kg for every 1 km increase in total walking distance between the dairy and paddock.

c) Reduced heat stress

> Modifications to the infrastructure involved in housing cows, even for relatively short periods of time during summer, can have a marked effect on cow comfort and productivity. Physical modification has been the primary way of reducing these adverse effects of hot weather conditions. The use of shade and various forms of cooling that may include sprinklers, fans and ventilated buildings can been used to reduce heat stress exposure.

When cows are suffering heat stress, their maintenance energy requirement increases 20–30% due to efforts to defend their core body temperature to ensure it stays within the optimal range through panting. In addition, during hot weather, dry matter intake decreases. NRC (1981) estimated that dry matter intake can drop by about 8% as temperature increases from the thermoneutral level of about 20-35°C. Thus, the energy status of the cow receives a double hit, greater energy costs trying to maintain a stable internal body temperature as well as the lower energy intake. It is not surprising that milk production decreases. Again, NRC (1981) estimated that milk yield drops by over 30% when the temperature increases from 20–35°C. At these higher temperatures, dairy cows may also be more prone to ruminal acidosis and less able to digest and absorb nutrients.

The susceptibility of cows to heat stress is dependent on farm location, breed, the herd's age profile and level of milk production.

The best single descriptor of heat stress is the Temperature Humidity Index (THI), because this combines temperature and relative humidity into a single comfort index. The higher the index, the greater the discomfort, and this occurs at lower temperatures for higher humidity's. Many of the experiments that have examined the effect of heat stress have used maximum daily THI as the key measure of heat stress.

Although feed management may help in controlling the adverse effects of heat stress on intake and milk yield, physical modification of the environment has been the primary way of reducing these adverse effects of hot weather conditions. Shade and various forms of cooling that may include sprinklers, fans and ventilated buildings can be used to reduce heat stress exposure. Use of sprinklers and fans helps cows offload heat through evaporative cooling. These measures will decrease respiration rate and subsequently increase dry matter intake and milk yield. Provision of shade can lessen the intensity of the heat load of cows each day.

There has been little quantitative information on the impact of heat stress on dairy herd milk production in Australia. In their study of effectiveness of adaptations to heat stress to maintain dairy productivity in the Murray region Nidumolu *et al.* (2010) calculated estimates using conversion factors based on literature and expert knowledge for cows with different susceptibility to heat stress. They examined low susceptibility cows (i.e. a Brown Swiss Jersey producing less than 5,500 litres or milk per year), moderately susceptible cows (i.e. other European breeds or cross breeds producing 5,500–8,000 litres of milk per year) and highly susceptible cows (i.e. Large Holstein-Friesian producing more than 8,000 litres of milk per year) (Little & Campbell, 2008). In all three cases milk production losses were assumed to occur when daily THI values exceeded 75. When THI exceeded this threshold the amount of milk lost in litres per cow per day was calculated by subtracting 75 from the daily THI value and multiplying this difference by a scaling factor.

For the cows with low susceptibility to heat stress a scaling factor of 0.6 was used. For moderately susceptible cows a scaling factor of 0.8 was used and for highly susceptible cows a scaling factor of 1 was used. Maps of the Murray region were generated to show the impact of THI on milk production (litres/cow/year) using climate data for 1971–2000 as base years (Figure 21). Additional impacts of THI on milk production over and above those for the base years due to climate change by 2025 and 2050 were also projected using a climate model with 3 alternative emission scenarios. Figures 21a and 21b show impacts based on the most pessimistic emission scenario 'A1F1', which is how actual emissions are tracking.

Figure 20. Impact of THI on milk production for 'low susceptibility', 'moderate susceptibility' and 'high susceptibility herds in Murray region, based on climate data for 1971–2000

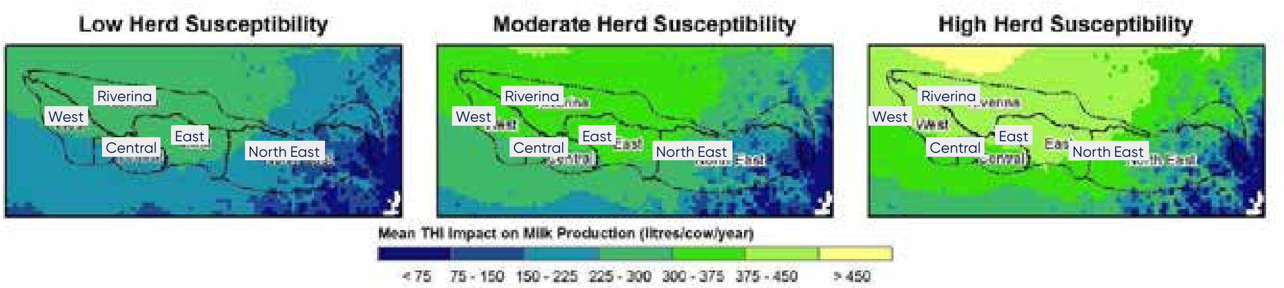


Figure 20a. Further changes in milk production for 'low susceptibility', 'moderate susceptibility' and 'high susceptibility herds for 2025 (based on A1FI emission scenario)

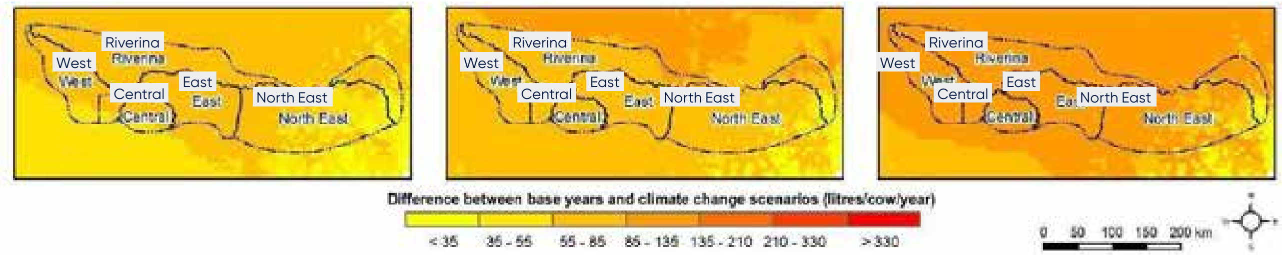
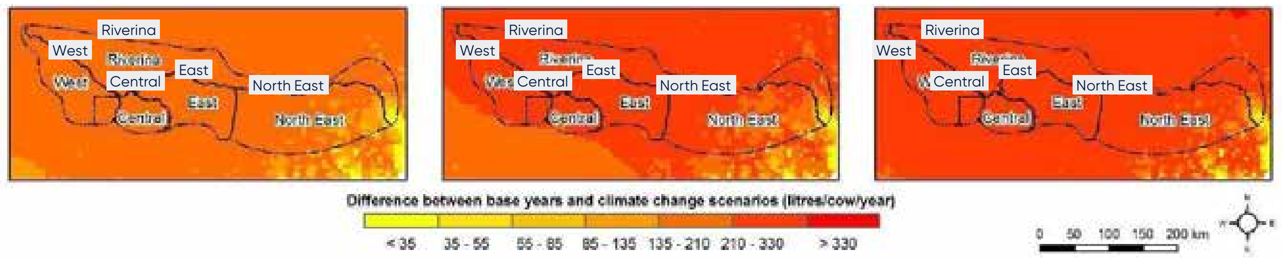


Figure 20b. Further changes in milk production for 'low susceptibility', 'moderate susceptibility' and 'high susceptibility herds for 2050 (based on A1FI emission scenario)



Providing shade and cooling to dairy cows limits their accumulation of heat load during long periods of hot days and warm nights and during heat wave events, thereby avoiding dramatic falls in daily feed intake, milk yield, protein test and cow health problems. There has also been little quantitative information on what are the benefits of providing shade and cooling to dairy cows that has been published in Australia. A few studies conducted in Australia confirm the beneficial effects of shade and cooling.

For example:

- The results of trials in Queensland have shown that 30 minutes of wetting cows with sprinklers at the dairy can produce an extra 1 litre of milk/cow/day, while 60 minutes has produced an extra 1.5 litres of milk/cow/day in hot weather (QDAF, 2013).
- Shade can reduce a cow's heat load from the environment by up to 50% (QDAF, 2013).
- Wildridge *et al.* (2017) found that providing shade in the yard for the short period before milking during summer in a pasture-based system can alleviate heat stress by decreasing respiration rate and improving milk yield by 0.5kg/day. Obviously providing shade for longer times in the more intensively housed dairy systems will have an even more beneficial effect on cow comfort and productivity.

Cost:benefit estimations provided towards the end of this section, assume that the provision of cooling infrastructure in paddocks and laneways, and on dairy holding yards and feedpads, will reduce losses in milk production per year due to heat stress by differing percentages, as proposed in Table 11 (Pers. comm. S Little). Note that the percent reduction in milk production losses per year due to heat stress in Table 11 are additive. For example, if a herd's annual milk yield drops by 350kg/cow due to heat stress, the addition of sprinklers and fans used with a shade structure over a feedpad to ensure good evaporative cooling, even on days with little/no wind, will reduce this annual milk yield loss by 50% to only 175kg/cow, or an improvement of 175kg milk/cow.

Table 11. Estimated reductions in milk production losses per year due to cooling infrastructure

Cooling infrastructure item	Estimated per cent reduction in milk production losses per year due to heat stress
Trees provide every cow with $4m^2$ shade at midday in paddocks on all warm/hot days.	45%
Additional water troughs enable cows to access cool drinking water in all paddocks and main laneways.	5%
Sprinklers in dairy holding yard used effectively on all cows before morning and afternoon milkings on all warm/hot days.	15%
Structure over dairy holding yard provides cows shade while waiting to be milked.	10%
Structure over dairy holding yard provides cows shade for longer periods before afternoon milking on warm/hot days.	15-20%
Fans used with sprinklers in holding yard to ensure good evaporative cooling, even on days with little/no wind.	5%
Trees in a sacrifice paddock provide cows $4m^2$ shade each at midday on all warm/hot days	30%
Structure over feedpad (shade cloth or solid roof) provides cows $4m^2$ shade each at midday on all warm/hot days.	35-45%
Sprinklers and fans used with shade structure over feedpad to ensure good evaporative cooling, even on days with little/no wind.	10–15%
Additional water troughs enable cows to access cool drinking water within 15m of feed while on feedpad.	5%

There have been many studies in the US that have studied the effects of environmental mitigation strategies on the physiology and productivity of dairy cows. For example, results of these types of studies have provided good quantitative information on the effects of sprinkler attributes such as flow rate, frequency of spray application and amount of water delivered on productivity and cow comfort.

In addition, there have been several extensive reviews on environmental strategies for alleviating heat stress of dairy cows. For example, Fournel *et al.* (2017) recently reviewed the effects of cooling in humid climates through shade, fans, and sprinklers on thermal stress and consequently on cow health and productivity.

Much of this information is transferable to Australian dairy farms, and good practical information and tools for managing heat stress in dairy cows have been provided by Dairy Australia (2019b) in their Cool Cows publication and website.

Higher feed efficiency and reduced feed costs from:

a) Reduced feed wastage

Feed wastage during feed-out can be significant and will vary depending upon the type of feed delivery infrastructure that is in place. Based upon feed wastage values measured on commercial dairy farms, reliable values for feed wastage are ascribed for each of the five feed delivery infrastructure systems that may be used on Australian dairy farms.

Feed wastage is reduced as one progresses to more developed feed delivery infrastructure. Although feed wastage can be significant and in some cases approach well over 20%, the amount of feed losses during feed-out has not been well documented. The amount of feed wastage was measured in a range of different feed-out methods on Australian dairy farms from feeding on pastures in the paddock through to a TMR type system (Dairy Australia, 2009). Six feed-out methods were assessed, and the average estimated feed wastage ranged from 8.8% (range 0.9–22.3%) for a temporary feed-out area to 1.8% (range 0–5.6%) in a permanent and well developed feedpad (Dairy Australia, 2009).

Based upon these observed feed wastage values measured in commercial dairy farms, the following values for feed wastage may be reliably used when comparing different feed delivery systems (Table 12). Applying these feed wastage values effectively reduces the cost per tonne of feeds fed out.

Table 12. Feed wastage rates for different feed delivery systems (dry conditions)

Feed delivery infrastructure	Feed wastage
Temporary feed-out area	Range: 5-35% Typical: 25%
Basic feed-out area	Range: 5-20% Typical: 10%
Formed earthen feedpad	Range: 2-10% Typical: 5%
Concrete feedpad	Range: 0-5% Typical: 3%
Integrated facility for feeding and housing cows	Range: 0-5% Typical: 3%

A key finding of the feed wastage study (Dairy Australia, 2009) was that there was substantial variation in the amount of feed refusal and wastage between and within feed-out methods on Australian dairy farms. With all feed-out methods, some producers achieved very low wastage. These variations may reflect variations in farm management with a particular feed-out method e.g. feed-out procedure, feed bunk management, forage quality, operator skill etc. There was no significant association between the amount of feed offered per cow and amount of feed wastage per cow across all feed-out methods.

Unlike temporary and basic feed-out infrastructure, formed earthen feedpads, concrete feedpads and integrated facilities for feeding and housing cows enable feed not consumed by cows after a certain period following feed-out (termed 'refusals') to be collected before it is contaminated and spoiled. It can then be fed to other cattle on the farm such as dry cows.

Three critical factors help to minimise waste during feed-out on feedpads and therefore help to optimise the return on investment in the feedpad. These include:

a. feedpad design and construction

b. feed ingredients/rations offered, and

c. feeding management.

These are discussed later in this review, in the section 'Keys to Success'.

There are emerging discussions from farms transitioning to permanent feeding infrastructure that supplementary feed wastage is significantly declining. However, pasture utilisation may decrease in herds returning to paddocks if cows are already full of feed.

b) Reduced pugging damage

Poorly drained soils are prone to treading or "pugging" damage and may occur on grazed pastures during the wetter months of the year. The results of research studies conducted in Australia and New Zealand have shown that if pugging in winter is significant, pasture yield in the following spring and pasture utilisation may be reduced by about 40%. One simple method of reducing pugging is removing the cows from pasture and housing them for various lengths of time on a feedpad. A feedpad with a large loafing area enables 'on-off' grazing management to be used, which reduces pasture wastage by cows and enhances re-growth. Under extremely wet conditions, a feedpad with an adequate area and surface may enable cows to be held on it continuously for several consecutive days.

Pugging is a form of compaction and is the term used for when cows damage both the soil structure and the pasture. Pugging seals the soil surface and exacerbates waterlogging of the topsoil by impeding infiltration and providing surface indentations for water storage, thereby reducing the efficiency of surface drainage from the paddock to many soil types in wet weather.

As pasture is the cheapest source of feed for most producers it is important to minimise the damage that cows can do to pastures through pugging up the paddocks. A grazing trial conducted in south-western Victoria found that medium to heavy pugging in winter reduced pasture yield in the following spring by 40–42%, pasture utilisation by 34–40% and perennial ryegrass tiller density by 39–54% (Nie *et al.*, 2000). DairyNZ research has shown similar results in that pasture seriously pugged in Spring will likely produce about 40% less DM than undamaged pasture through the following season, although pasture yield reductions of up to 80% have been recorded (DairyNZ, 2020a).

Cost:benefit calculations provided towards the end of this section, assume that pugging causes a 30% reduction in pasture utilisation rate. One simple method of reducing pugging is removing the cows from pasture and housing them for various lengths of time on a feedpad. A feedpad with a large loafing area enables 'on-off' grazing management to be used, which reduces pasture wastage by cows and enhances re-growth.

Cost:benefit estimations (typical examples)

More milk/cow/day from:

a) Increased rumen stability and feed intake

If use of a feedpad enabled an increase in feed intake of 3kg DM/day at a cost of $350/t DM, and this resulted in an increase in milk yield of 3.5kg/day at a milk price of $0.40/kg, this would give a milk income minus feed cost (MOFC) of $0.35/cow/day. For a herd of 300 cows, this equates to $105 extra MOFC per day or nearly $40,000 extra MOFC per year.

b) Reduced walking distance

If a typical 300 cow farm in the Murray region was to reduce the walking distance of each cow by 4 kilometres per day using a permanent feedpad near the dairy which meant that cows only had to walk to/from a paddock to graze once a day (instead of twice), this would equate to 1,200 km saved per day for the herd. Assuming, on an energy basis, 0.5 litres milk per km walked on flat terrain, this would equate to 600 litres extra milk per day.

At a milk price of $0.40/litre, this would equate to extra income per day of $240. If this pattern of use continued for 60 days over summer, when pasture was limited, this would equate to extra income of $14,400 during this period.

c) Reduced heat stress

The inherent level of susceptibility to heat stress of a herd of 300 moderate sized Holstein-Friesian cows on a farm at Tatura in the Murray region producing 6,500kg milk/year is moderate. Nidumolu *et al.* (2010) estimated that this herd would incur an average annual milk production loss due to heat stress of 355kg/cow based on expected climatic conditions. At an average milk price of $0.40/kg, this would equate to a cost of approx. $142/cow/year or $42,600 for the herd per year.

If an investment of $70,000 was made in a shade cloth structure over an existing feedpad and installation of sprinklers, and this feeding and cooling facility was used effectively, this would reduce this annual milk production loss by 45% (35% for shade cloth structure plus 10% for sprinklers, as per Table 8) i.e. 160kg/cow, to 195kg/cow.

At an average milk price of $0.40/kg, this would equate to an annual benefit of approx. $19,200 per year due to a reduction in lost milk production. The represents a return on investment of 27% per annum, and a payback period of less than four years.

Note

- Losses in milk income due to effect of heat stress on milk yield can often be doubled when you also account for losses from low milk protein and fat tests, reduced in-calf rates, more clinical mastitis cases and other cow health problems.
- Payback period assumes no debt funding. If debt funding is required, payback period will be longer.

Higher feed efficiency and reduced feed costs from:

a) Reduced feed wastage

If a typical 300 cow farm was feeding out 1,500kg DM of hay/silage per cow per year valued at $300/t DM in hay rings and wasting 20% using this method, this equates to a loss of $90/cow/year or $27,000 for the herd per year. If use of a well designed and constructed permanent feedpad enabled feed wastage to be reduced by 15% to 5%, this would represent a saving of $68/cow/year or $20,250 for the herd per year.

b) Reduced pugging damage to soils

If a paddock from which 9 t DM/ha/year would have been utilised was subjected to very wet weather, and a 30% reduction in utilisation rate was prevented through practising 'on-off grazing' using a feedpad, this would equate to a saving of 2,700kg DM/ha. Assuming a pasture growing cost of $0.15/kg DM, this would equate to a saving of $405/ha/year.

Additional benefits captured by industry:

The benefits outlined earlier focus on cow production, feed, and pastures. As farms transition to TMR feeding and housed systems producers are experiencing additional productivity gains. While the gains may be small in isolation, the cumulative effect may be greater than the sum of the parts. These include:

- Increased labour efficiencies
- Potentially greater ability to retain labour as some staff favour indoor environment compared to working outdoors in variable weather
- Optimal milking plant performance
- Improved conception and animal health detection with closer monitoring
- TMR/PMR systems help create an environment for high genetic cows the reach their genetic potential
- Improved farm WUE on higher yielding fodder crops under cut and carry as opposed to pasture-based systems
- Reduced laneway maintenance costs, particularly with a winter stand-off
- Decreased costs to renovate and recover pastures, pugging and compaction
- Reduced fertiliser costs associated with improved effluent and manure distribution
- Improved machinery efficiencies
- Opportunity to attract premium milk pricing
- New income opportunity to sell solids, bedding compost and energy anaerobic digestion, and
- Improved fodder production with less compaction.

The dairy transition economic and risk project was conducted by Agriculture Victoria, DPI NSW and Dairy Australia. It will attempt to identify and where possible estimate, the productivity gains producers are experiencing from their change to a TMR feeding system. While the gains may be small in isolation, the cumulative effect may be greater than the sum of the parts.

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09

Facility design and management

Introduction

The design and construction of feedpads and contained housing facilities should:

- Achieve appropriate standards of animal health, welfare and hygiene by providing good access to feed and water, sufficient space and clean lying surfaces, solid surfaces for standing free from mud plus access to shade and shelter
- Minimise the risk of adverse amenity and environmental impacts and allow for regular manure removal
- Support the operational efficiency of the farm – easy cow movements around the system, easy access to the alleys for vehicles
- Provide a safe working environment for farm staff.

In addition, all housing designs should:

- Allow for multiple routes between bedding and feeding/watering areas to minimise 'boss' cows restricting the movement of less dominant cows
- Incorporate adequate cow access and egress to suit the milking system that is used on the farm – herringbone, swing-over, double up, rotary or robotic/automatic milking system (AMS) dairy.

9.1 Feedpad overview

As noted in chapter 8, feedpads are typically used for partial mix ration feeding to support farm production focused on grazing. The surface of feedpads is either formed, laid with a durable material or stocked at a rate that precludes vegetation.

Examples of feedpad facilities include:

Temporary feed-out area: Located in a pastured or bare cropping paddock, a designated sacrifice paddock or along a laneway without a prepared surface where feed is delivered to cows whether on the ground, in hay rings or in tractor tyres. Can be readily relocated to other sites on the farm.

Temporary feed-out area using an electric fence along a laneway

Basic feed-out area: Contains an area with a permanent compacted earthen feeding infrastructure shared by cows and vehicles which may be dry scraped. Can be relocated to another site on the farm (with effort) if necessary.

Basic feed-out area with portable feed troughs

Formed earthen feedpad: Will have a compacted surface shared by cows and vehicles and regularly scraped. Fixed structures including purpose-built concrete troughs or nib wall or cable or hot wire with or without narrow concrete strip for cows to stand on while eating with or without loafing areas, shade structures.

Formed earthen feedpad with concrete troughs

Concrete feedpad: Will either have separate drive and feed alleys or a combined drive and feed alley. The advantage of individual drive alleys is that there is no direct interaction between machinery and cattle, which is obviously preferred. This allows feed to be delivered or feed to be pushed-up at any time during the day (cattle will push feed away from the feeding table as they eat which requires pushing back to the feeding table). It also can reduce spoilage and waste as mud and manure are kept separate.

Concrete feedpad with separate drive and feed alleys

Roofed feedpad: A common expansion phase for farms with concreted feedpads where herds spend considerable time supplementary feeding and standing off paddocks is the inclusion of some type of shade structures over the feeding table and loafing area to mitigate adverse weather, particularly during the cooler and wetter seasons and the hotter days throughout the summer period.

A range of shade structures typically used in the dairy industry include widespan corrugated iron roof, comprising a pitched roof with a central, open ridge vent in the roof apex to allow heat and humidity to escape, flat angled roofs, overlapping roofs, heavy duty membranes and fabric covered structures.

Keeping cows cool and comfortable is critical to maintaining high feed intakes and high milk production. Feedpad design and the selection of appropriate roofing can have a major influence on cow performance.

Concrete roofed feedpad with dry scrape feed alley

Cattle shelters: Dairy cattle shelters and calving sheds are becoming increasingly popular within the dairy industry to provide management flexibility with the herd and to mitigate seasonal climatic events, which can dramatically impact production. Typically, these shelters are primarily cow loafing facilities used to compliment grazing farms in regions where summer heat impacts production and animal welfare, whilst providing a much cooler environment for loafing and resting between milking and feeding. Cows are generally not confined to these shelters, having freedom to move outdoors for feeding and watering, or return to paddocks for grazing.

Woodchips and manure bedding with external troughs for feeding

Woodchips and manure bedding in a fabric covered shelter

9.2 Contained housing overview

Contained housing is an integrated facility for feeding and housing cattle and are typically used in intensive operations supported by total mixed ration feeding and involve zero grazing.

The main contained housing facility types are:

Dairy dry lot

An open, well-drained area with an earthen surface and a shade structure over part of the area to protect animals from the sun and rain. A bedded area may be provided under the shade structure. These systems are most applicable in hot, arid climates with suitable soils that facilitate drainage. Manure accumulates on the floor of the area and is regularly mechanically tilled, then all manure removed at intervals of 1-6 months.

Loose housing

The key difference to a freestall is that the stalls and stall alleys are replaced with a bedded area of absorbent organic bedding including straw, wood chips, composted manure or sand bedding. These facilities are typically categorised by their management of the bedded area as a:

- Deep litter pack where absorbent organic bedding is added regularly to the bedded area, but there is no mechanical tilling; or
- Compost bedded pack that is mechanically tilled at least twice daily.

All bedding is usually removed at intervals of 6-12 months, then new absorbent organic bedding added back into the facility.

The lower section of bedding is removed only when the maximum height is reached. Typically the top 300mm of bedding is kept.

Sand bedding sheds are mechanically cleaned once a day. Sand is added every 6 months to the shed.

Loose housing facility with a deep litter pack

Loose housing facility with a compost bedded pack

Freestall

These can be open-air, partially or fully enclosed structures in which dairy cattle are housed. They can be used to house dairy cattle long term and include a bedding area for cattle to lie down, and possibly a loafing area for cattle to stand. The term 'freestall' refers to the bedding area where cattle are allocated specific cubicles (stalls), which they enter to lie down. Feed and cow alleys, and bedding areas are cleaned regularly (usually daily) to maintain cow comfort and health. Freestalls can be classified by the number of 'stall' rows they contain.

Freestall with sand bedding

Loose housing – sand pack

Dairy sand loafing sheds are a new contained housing facility for the Australian dairy industry providing improved comfort, hygiene, and support for cows. This bedding choice is linked to better cow health, including lower rates of hock lesions, reduced bacteria, lower odour, less flies and improved cow cleanliness. However, sand bedding requires specialised manure management systems to separate the sand for reuse, as its abrasiveness can damage conventional equipment.

The loose housing sand bedded pack shed will be novel to Australia, although dairy cow housing is becoming more common, the bedding is usually composting material, which can be problematic in some regions due to weather and climatic conditions.

Sand commonly used for freestall facilities requires manual raking and continual replacement, resulting in ongoing maintenance costs. The sand bedded pack allows cows to have free range, allowing the specialist bedding equipment to be operated without any restrictions to collect manure and clean the sand.

The sand system separates urine and manure in situ through a network of drains and conveys it to a storage tank as a ready supply of liquid nitrogen for use as fertiliser on pasture or pumped to the effluent system. Specialised sand bed cleaning equipment will allow the solid manure to be collected from the shed and placed in the effluent stream. Sand losses from the shed are minimised with a passive recapture system, minimal sand loss is achieved by creating a concrete lane with a low gradient washing sand with the flood wash system to collect sand. Once the sand is washed and dried it can be returned to the shed. Resulting in an efficient and sustainable system, which requires minimal input.

Design and construction considerations

Base and drainage

The base structure should be impervious with a liner to prevent water and urine from entering the base material. A slotted drainage pipe system above the liner collects any urine and moisture which is stored in a suitably sized tank.

Bedding depth

A significant amount of bedding is necessary, with a guideline being about 7-10 cubic metres per animal. The bedding pack is designed to be around 500-600mm deep.

Airflow and ventilation

Proper design with a vented ridge and ventilation gaps in the walls is important for air circulation, similar to other shed designs.

Machinery used for cleaning sand sheds

Roof design

Features like eave overhangs can provide extra weather protection.

In the context of dairy farming, a 'Loose housing sand bedded pack' refers to a type of covered area where dairy cows can rest, or 'loaf', on a deep layer of sand bedding. This housing style is considered the gold standard for dairy cow comfort and health.

- **Site selection and layout:** The shed's location and orientation are chosen to maximise natural airflow and manage stormwater runoff. An east-west orientation can take advantage of prevailing winds for cross-ventilation. Proper spacing is required for cows to move in and out freely.
- **Bedding containment:** Retaining walls are often used to separate the deep sand bed from the feed alley, preventing the sand from drifting and contaminating the feed.
- **Sand management:** Since sand does not flow like liquid manure, specialised systems are needed to handle sand-laden manure. Sand separation and recycling systems, which can recover up to 98% of the sand, are used to reduce the amount of new sand needed.

Sand quality and sourcing

The quality of sand used is crucial for maximising benefits and managing the system effectively.

Sand quality and maintenance: Not all sand is suitable for this type of pack. Fine sands are not suitable for the draining systems and larger sands are unsuitable for cows' hooves. The best sand to use is well graded and between 250mm and 500mm deep.

Sand should be replaced once the depth is reduced by 250mm. Past experience tells us that sand replacement will be approximately every 6 months. Before replacement, remove the existing top layer to ensure that no contaminated sand layer is formed.

Sand to avoid: Avoid using 'free' sand dug from fields. It often contains excessive fine particles, clay and organic matter, which can pack hard, retain moisture and increase bacterial growth.

9.3 Bedding overview

The bedding system and type of bedding materials used in contained housing facilities impacts the design and management and therefore should be considered in the early planning stages.

When choosing a bedding system and type of bedding material it is important to consider the local climate, availability and price of bedding material, how the bedding will be managed on a daily basis, what interaction it will have with the effluent management system and how the waste bedding will be handled once removed from the housing. Bedding options are compared in Table 8 for freestalls and 9 for loose housing.

Table 13. Comparison of bedding options for freestalls

	Mattress	Waterbed	Sand	Dry manure solids	Sawdust	Other organic
Advantages	Minimal bedding No extra water to pump	Minimal bedding No extra water to pump Some cushion effect	Conforms to cow's body Standing/ Lying cushion Increased resting time Milk quality	Availability Easier to handle down stream of housing area	Availability Easier to handle down stream of housing area	Availability Easier to handle down stream of housing area
Concerns	Leg and hock injury Milk quality Udder contact with wet surface	Leg and hock injury Milk quality Udder contact with wet surface	Manure handling challenges Poor sand quality	Stall compaction if not groomed Rewetting from urine, humidity, water Airflow velocity vs dust	Lack of bedding depth Airflow velocity vs particle movement Moisture absorbed by bedding Udder contact with wet surface	Lack of bedding depth Airflow velocity vs particle movement Moisture absorbed by bedding Udder contact with wet surface
Manure handling	Solid Separation + Liquids	Solid Separation + Liquids	Sand Separation + Solid Separation + Liquids	Solid Separation + Liquids	Solid Separation + Liquids	Solid Separation + Liquids
Cow welfare	Leg and hock injury Perching in stalls due hard surface	Leg and hock injury Perching in stalls due hard surface	Leg and hock injury Perching in stalls due to hard surface	Resting time if stalls become hard Air borne particulate matter when fans operating	Leg and hock injury Perching in stalls due hard surface	Leg and hock injury Perching in stalls due hard surface
Daily volume	Manure production + feed line soaker water	Manure production + feed line soaker water	Manure production + sand bedding + feed line soaker water	Manure production + manure bedding + feed line soaker water	Manure production + organic bedding + feed line soaker water	Manure production + organic bedding + feed line soaker water
Flush velocity and minimum alley slope	≥ 1.2m per minute 0.75%	≥ 1.2m per minute 0.75%	≥ 1.8m per minute 2.0%	≥ 1.2m per minute 1.0%	≥ 1.2m per minute 1.0%	≥ 1.2m per minute 1.0%
Water total solids if flushing	Generally if using solid separation, there is enough water generated from cleaning the dairy, milk deck and holding pen that no extra water is required for flushing	Generally if using solid separation, there is enough water generated from cleaning the dairy, milk deck and holding pen that no extra water is required for flushing	Generally additional water has to be added to the system if the sand is reclaimed. The total solids in flush or cleaning water should be <= 3 %. The volume of extra water required is dependent on performance of solid separation equipment	Generally if using solid separation, there is enough water generated from cleaning the dairy, milk deck and holding pen that no extra water is required for flushing	Generally if using solid separation, there is enough water generated from cleaning the dairy, milk deck and holding pen that no extra water is required for flushing	Generally if using solid separation, there is enough water generated from cleaning the dairy, milk deck and holding pen that no extra water is required for flushing

Source: Adapted by James Green (Greencon) from table originally developed by Joe Harner (Professor, Kansas State University), Jake Martin (Consultant, JGMiii Dairy Design) and Dennis Armstrong (Professor Emeritus, University of Arizona), 2017

Table 14. Comparison of bedding options for loose housing

	Sand	Sawdust/Shavings	Woodchips
Advantages	Availability Conforms to cow's body Standing/Lying cushion Increased resting time Milk quality	Availability Easier to handle down stream of housing area	Availability Easier to handle down stream of housing area
Concerns	Manure handling challenges Poor sand quality and type	Airflow velocity vs particle movement Udder contact with wet surface	Airflow velocity vs particle movement Moisture absorbed by bedding Udder contact with wet surface
Manure handling	Sand Separation + Solid Separation + Liquids	Solid Separation + Liquids	Solid Separation + Liquids
Cow welfare	N/A	N/A	N/A
Daily volume	N/A	N/A	N/A
Flush velocity and minimum alley slope	≥ 1.8m per minute 2.0%	≥ 1.2m per minute 1.0%	≥ 1.2m per minute 1.0%
Water total solids if flushing	Generally additional water has to be added to the system if the sand is reclaimed. The total solids in flush or cleaning water should be <= 3 %. The volume of extra water required is dependent on performance of solid separation equipment	Generally if using solid separation, there is enough water generated from cleaning the dairy, milk deck and holding pen that no extra water is required for flushing	Generally if using solid separation, there is enough water generated from cleaning the dairy, milk deck and holding pen that no extra water is required for flushing

Source: Adapted by James Green (Greencon) from table originally developed by Joe Harner (Professor, Kansas State University), Jake Martin (Consultant, JGMiii Dairy Design) and Dennis Armstrong (Professor Emeritus, University of Arizona), 2017

9.4 Feedpad design and management

A feedpad can be installed for a wide range of different uses and a range of different types have been described earlier in Section 9.1 of this chapter. The final option chosen will depend on each individual site, the proposed feeding system and farm management.

Feedpad design should:

- allow for easy cow movements around the facility (i.e. resting, eating, drinking, exercising and milking)
- allow for regular manure removal
- provide adequate feeding table space
- provide easy access to the drive and feed alleys for vehicles.

The following section provides guidance on the design and management of feedpad facilities.

Temporary feed-out area

A temporary feed-out area can be set up in several ways:

- Running an electric wire along a laneway
- Placing hay rings or old tractor tyres in a designated sacrifice paddock
- Simply running hay/silage mixed ration along the ground in a grazing paddock or a bare cropping paddock.

Site selection and set-up

The following factors are important for ensuring that cows are comfortable while using the temporary feed-out area:

- If setting up a sacrifice paddock, select a paddock which needs to be renovated anyway, has good drainage and provides trees for shade.
- Avoid a paddock near a roadway or waterway.
- If using a grazed paddock, select one that has good pasture cover and is not wet.
- Provide ready access to water troughs.
- Feed-out area per cow (general guidelines):
  - If cows are only on the feed-out area for a few hours a day (i.e. < 4 hours), an area of 3.5m^2/cow is adequate
  - If the patten of use of the feed-out area involves cow resting on it for up to 12 hours (i.e. the entire period between consecutive milkings), then at least 6m^2/cow is required.
  - If cows are to remain on the feed-out area constantly for several consecutive days (e.g. when paddocks are very wet or during hot weather), an area of 10-12m^2/cow is required.
- Avoid using the temporary feed-out area for too long, especially in wet conditions.
- Relocate to another site on the farm as soon as necessary.
- Feed can be placed directly on the ground, on rubber matting or in modular steel or concrete troughs.
- If feeding on bare ground, in ring feeders, old tractor tyres or under a fence line, it is recommended that:
  - Feed-out in dry conditions
  - Feeders used are large and deep enough to easily hold quantity of feed to be fed without spillage
  - Feeders are not being over-filled
  - Feeders have minimal residual feed in them after each feeding event
  - Feed space of cow width + extra 10-30% is provided to each cow
  - If using hay rings, adequate rings are provided so that no more than 20 cows share each ring.

Basic feed-out area and formed earthen feedpad

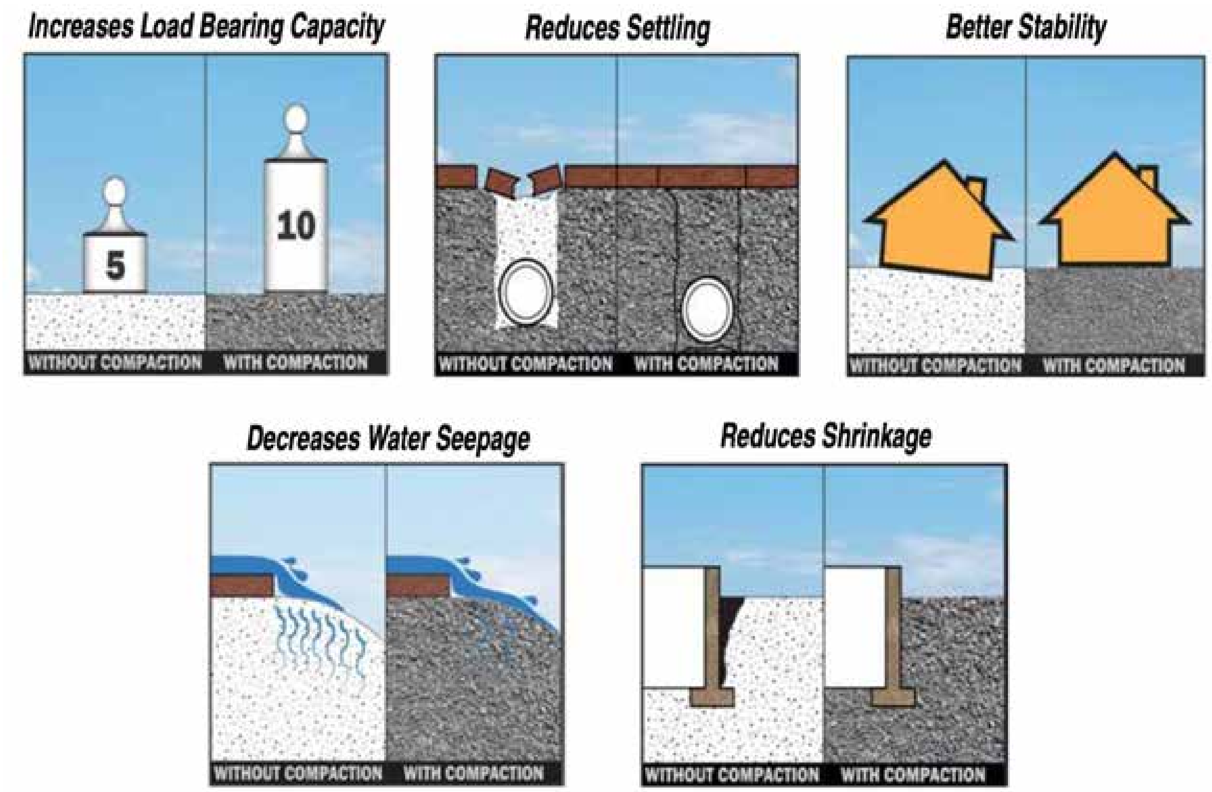
The lifespan of a basic feed-out area and formed earthen feedpad can be extended from just a few years to 20+ years if the following critical design factors are considered.

Surface material selected

The surface material for an earthen feedpad must be selected very carefully. It should be a uniformly blended mixture of coarse and fine aggregate (i.e. an evenly graded material) that is free from sharp stones, cobbles, stumps, roots, sticks etc. While gravel surfaces are more durable and can withstand higher loading, they are not as hoof friendly.

If the material on-site has low load-bearing strength because of an excess of clay, silt, or fine sand, adding a stabiliser such as hydrated lime or gypsum, or buying in a good quality material from a quarry, should be considered. Geosynthetics, which are thin, flexible, and permeable sheets of synthetic material used to stabilise soil, should also be considered. They are resistant to moisture and bacteria, their filtration restricts movement of fine soil particles but allows some water to permeate.

Figure 21. Effects of compaction



Compaction of material

Compaction of the material is necessary to increase its dry density and therefore its load-bearing capacity, durability, and water permeability. This is achieved with a vibrating or compression roller (as used in road construction).

Figure 21 illustrates the importance of a well compacted surface in terms of loadbearing capacity, settling, stability, water seepage and shrinkage.

Each material has an optimal moisture content for maximising dry density with compaction (Figure 22). Materials that are dry are wetted down using a water truck during construction.

Figure 22. Optimal moisture content for dry density of a material

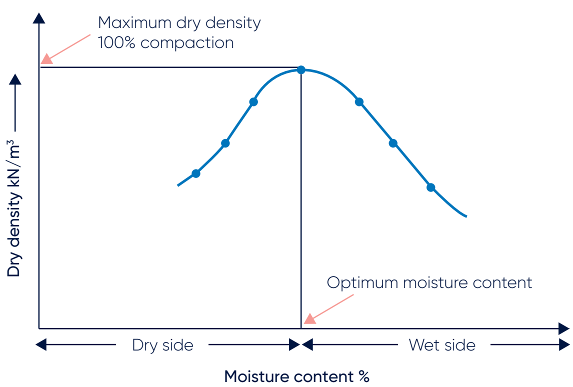
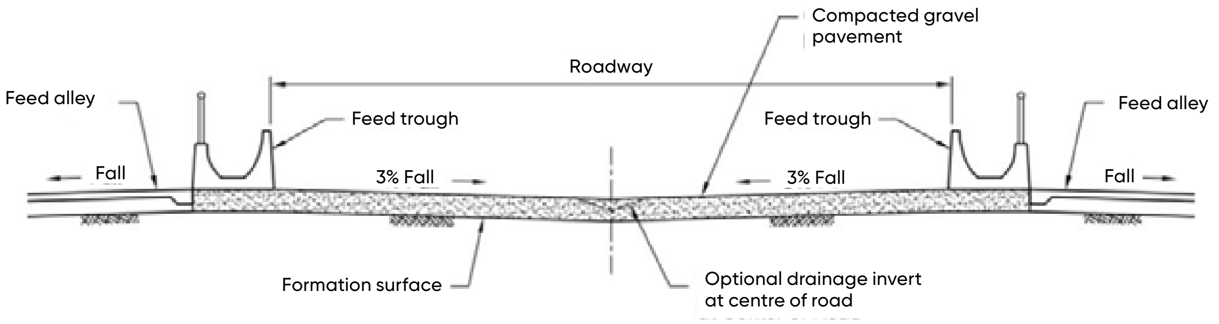


Figure 23. Feedpad with contours for a central drive alley and pen aprons on either side



Thickness

Ensure that the surface layers of the feed pen and roadway are thick enough to spread the load of cow and vehicle traffic so that the underlying subgrade is not stressed. These thicknesses will depend on the load-bearing strength of the material used, the strength of the foundations, drainage and expected load of both cows and vehicles. A thickness of between 150–360mm may be required for feed pens and between 200–670mm for roadways (MLA, 2016).

Contours

The pad needs to be contoured with sufficiently angled slopes (3–5%) to carry manure and run-off away from the feeding table (Figure 23).

Gradient

A formed earthen surface needs a gradient of at least 1:500 (0.2 per cent). However, operating experience shows it is better to aim for slopes in the 2 to 4 per cent range.

Concrete and roofed feedpad

The main design principles used for a concrete feedpad can be applied to contained housing facilities (i.e. freestalls and loose housing) and are therefore incorporated in *Sections 9.8 and 9.9* of these guidelines.

A concrete feedpad usually consists of a concrete pad located adjacent to the dairy of the main farm laneway. The pad generally consists of a concrete feed alley that is used by vehicles for delivering feed (drive alley) and a separate alley that cattle stand on whilst feeding (feed alley).

The surface of the actual feedpad should be designed to provide sufficient slope to contribute to effective drainage and to prevent surface wastewater reaching the subsoil. The pad should be elevated to facilitate fall with a recommended longitudinal slope of 0.5-3 per cent (i.e. along the entire pad length). The pad should be sloped away from feed and drink facilities. Pad slope and surface must facilitate safe purchase of cow hooves.

Dairy producers are required to manage manure and recycled effluent to avoid adverse impacts from odour and dust, prevent the pollution of ground and surface waters and land, and to provide a safe working environment for staff and contractors. Accumulated manure can either be scraped or vacuumed from the alleys; or flood washed into a containment sump or pond.

A poorly designed and/or managed feedpad may result in potential issues such as:

- runoff from the site, which can lead to surface or subsurface water contamination
- muddy surfaces, especially in wet conditions, which can lead to increased incidence of mastitis
- dust, especially in dry conditions
- excessive odour and or noise
- spilt feed can result in increased bird numbers and unwanted defecation by the birds on nearby residences
- increased animal health issues such as pinkeye.

Key construction, cleaning and maintenance guidelines:

- Regularly monitor stock for animal health concerns, such as pinkeye and mastitis.
- Ensure safe and easy access for animals, vehicles and farm workers around the pad to meet with occupational health and safety needs.
- Provide adequate spacing for loafing, recommended 9m^2/cow short term durations or 15m^2 long term.
- When constructing, use appropriate surface and subsurface materials which will increase the longevity of the pad and allow for effective drainage.
- Effective drainage is important to deal with wet conditions plus allow all weather access. Dairy feedpad surfaces should provide sufficient slope for effective drainage. A concrete surface can drain at a slope of 1:500 (0.2 per cent) or even shallower if smooth and for water only. However, operating experience shows it is better to aim for slopes in the 2 to 4 per cent range, for effluent drainage.

- Good collection and harvesting of manure and spilt feed is important and should be scraped or removed from the pad, stockpiled and stored on an impervious surface and well bunded structure (e.g. concrete or a compacted earthen pad with drainage to the effluent system). It can then be applied appropriately to paddocks as a source of fertiliser.
- Use harvested manure and effluent on crops and pastures.
- The right design and proper maintenance will help to protect ground water from contamination from leaching down the soil profile, and from runoff of effluent.

Plan with the future in mind

When designing and building a feedpad, there are a number of important considerations to ensure it can be further developed in the future. If this is not done, a farm may find itself a few years down the track having to construct a new feedpad from scratch at another site on the farm to meet its needs (with many costs being incurred again). Planning with future expansion in mind will allow an effectively sited feedpad to be retrofitted into a contained housing facility using a process of a staged development.

Site the feedpad so that it can be expanded in the future. Select a site which provides:

- Scope to expand the feedpad's area and further develop the effluent system
- Easy vehicle access
- Easy cow access to the dairy and main laneways
- Easy access to feed storing and mixing facilities
- Good access to stock water and power
- Good drainage, and minimal risk of generating excessive odour, dust and noise.

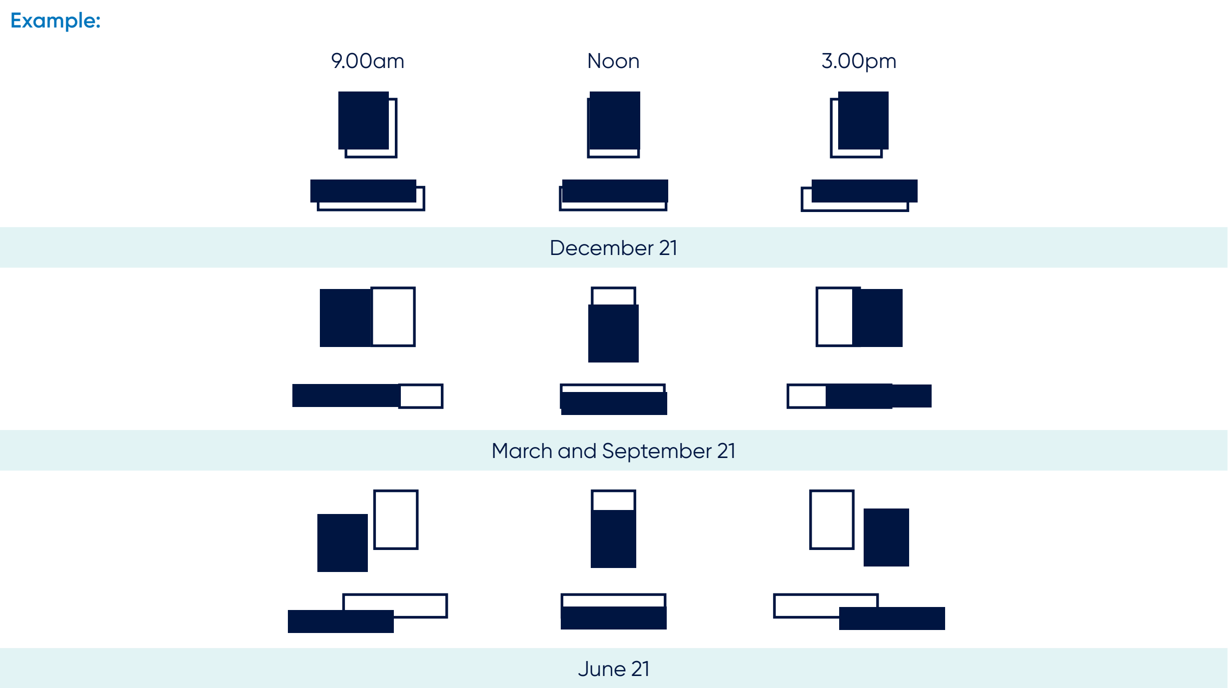
Consider feedpad orientation

Careful consideration should be paid to the orientation of a feedpad. Formed earthen feedpads with roof structures are well suited to a north-south orientation because the sun strikes every part of the floor area under and on either side of the roof at some time during the day. This helps keep the floored area dry and restricts pathogen build up.

However, with a concrete feedpad with a roof over it, an east-west orientation is ideal from a heat stress management, viewpoint, because provided the roof is wide enough, it will ensure that the feed table and water troughs are shaded at all times (Figure 24).

Given the effort and cost to re-orient a feedpad, whether a roof will be placed over the feedpad initially or at some later stage should be carefully considered when deciding in which direction to orient the feedpad.

Figure 24. Shed profiles at 9am, noon and 3pm at four different times of the year



9.5 Cattle shelter design and management

Farms with flatter low-lying topography, often have herd management issues over the wetter winter months maintaining milk quality and minimising damage to pastures and laneways. Moving away from the traditional earthen stock containment areas or sacrifice paddocks, these shelters provide a more sustainable environment to contain the herd temporarily until conditions improve enabling the herd to return to paddocks.

Similar to the contained housing options the type of bedding material used and the overall management is critical for cow comfort as well as consideration for rainfall collection off roofing to minimise water pooling and pugging of the areas around the facility.

Cattle shelters are often standalone facilities with just bedding material, allowing the herd to seek shelter and provide loafing and resting space, while feeding and watering infrastructure are sited a short distance away to encourage cows to disperse and prevent congregation around the shelter.

The other common approach is incorporating troughs and a concrete apron along the outer perimeter of the shedding to accommodate loafing on the inside and more convenient feeding with feed equipment not having to enter the facility. A more openly spaced bedding area allows easier management, without having to navigate posts and concrete alleys.

The type of cattle shelter can range from shade sails, plastic membranes (Figure 25) or corrugated roofing depending on the region's climatic conditions and the farm's requirements.

Figure 25. Cattle shelter with a steel frame and flexible clear roof membrane.

9.6 Dairy dry lot design and management

Dairy dry lots are generally more successful in hot, dry climates on sites with well draining soils. Constructed with the correct slope for drainage to a centralised manure system, a well-managed dairy dry lot provides cows with a comfortable, low stress environment. Feeding areas may be fitted with cooling infrastructure such as misters to make sure cows stay cool on hot days. Cows have freedom to lie down and rest and move around and socialise. Compared to other contained housing systems (i.e. loose housing, freestalls), dairy dry lots have a lower capital cost and tend to have lower disease prevalence (e.g. lameness and mastitis) and better reproductive outcomes.

Factors which impact on cows' lying time and general level of comfort are:

- Access to shade
- Bedding and management
- Dairy dry lot layout

Access to shade

Shade is important to protect cows from direct exposure to radiant heat and rain. Ideally, shade structures should be constructed parallel to the feed table and cow alleys in the centre of pens so that cattle can follow the shaded area as it moves across the pen during the day. The orientation of a shade structure should be north-south with the eastern side of the structure elevated to provide a 10–15° pitch (Figure 26). This allows better pen floor drying during the morning, provides more shade area during the afternoon and increases air flow under the shade structure.

Shade roofs should be steel clad with a minimum height of 3.6m from the ground. The installation of gutters is recommended on shades structures to remove water from the pens to allow the earthen surface to dry quicker after inclement weather. The total area of shade recommended is 4.6m^2 per cow. Cooling measures such as fans and water misters may be used beneath the shade.

Figure 26. Centralised shade shelters at a dairy dry lot with a north-south orientation

Bedding and management

The bedding in dairy dry lot shelters can be non-composting bedding packs, composting bedding packs, or packs that only actively compost occasionally. The pack needs to be managed to provide cows with a comfortable, dry bedding surface (Figure 27). The pack relies on an aerobic process to decompose cow waste (manure and urine) in the bedding. Tilling at least twice a day is generally recommended and can be timed when the cows are being milked. If possible, cows should be kept off the pack for at least an hour after tilling to enable the top layer to dry, especially during winter.

Regular mechanical tilling fluffs up the bedding and encourages the composting process drying the pack and killing some pathogens, viruses and fly larvae. A loose fluffy pack is a good indicator of a well-managed pack, especially if it feels warm below the surface, as it is aerated and the microbes are active and generating heat. Conversely, a compacted, cool pack results in chunky bedding indicating the pack is not well composted (Figure 28).

Figure 27. A well-managed compost bedding pack provides cows with a comfortable, dry bedding surface

Figure 28. A compost bedding pack that is not well managed – over-crowding results in a wet, chunky, cold bedding surface

Dry lot layout

Sound design ensures optimum animal performance, good animal welfare and high standards of environmental performance (Figures 29 and 30).

Key considerations of well-designed pen layouts:

- Pens are constructed with 2-4% side slope and 0.5-1% down slope. Pens with a double slope are ideal with the shade located at the high point of the pen. Pen slopes less than 2% do not drain well and can emit odour at 50 to 100 times the rate of dry pen surfaces. Wet patches also lead to discomfort of cows.
- Proper site drainage design. Construction of dairy dry lot so water drains outside of the pens in ideal. The slope of the pen will have a dramatic impact on how fast the earthen surface will dry (Smith *et al.* 2006).
- There should be 45 to 50m^2 of net space per cow in the dry lot if feed lane manure is scraped or flushed out of the system. If feed lane manure is scraped into the lot, then net space per cow should be increased to 60m^2 or higher (Jake Martin, Pers. Comm.).
- Feed table and feed alley design is similar to a freestall or compost shed feed alley design. The feed alley is parallel to the shade structures. If sprinklers are used at the feed table, it is important that a nib wall is installed, and the alley is sloped towards to the feed table to prevent runoff from the sprinklers reaching the earthen surface of the pen.
- Wind breaks can improve cow comfort where the potential for severe weather exists.
- Water troughs design and specification is as for a freestall. Water troughs should allow dairy cows access to an adequate supply of good quality water for their survival, welfare and performance without causing environmental impacts on the feedlot. The water trough system should:
  - Provide clean, cool, fresh water at an adequate volume of water to livestock
  - Provide sufficient access area to enable all cattle to drink regularly
  - Allow for easy and regular cleaning inside the trough
  - Not cause wet areas or drainage problems in pens or lead to pen maintenance issues.

Figure 29. Aerial image of a well-designed dairy dry lot with north-south shade structures and central feeding table

Figure 30. A leaking trough will cause drainage problems on the earthen dry lot pen

9.7 Loose housing design and management

Deep litter pack

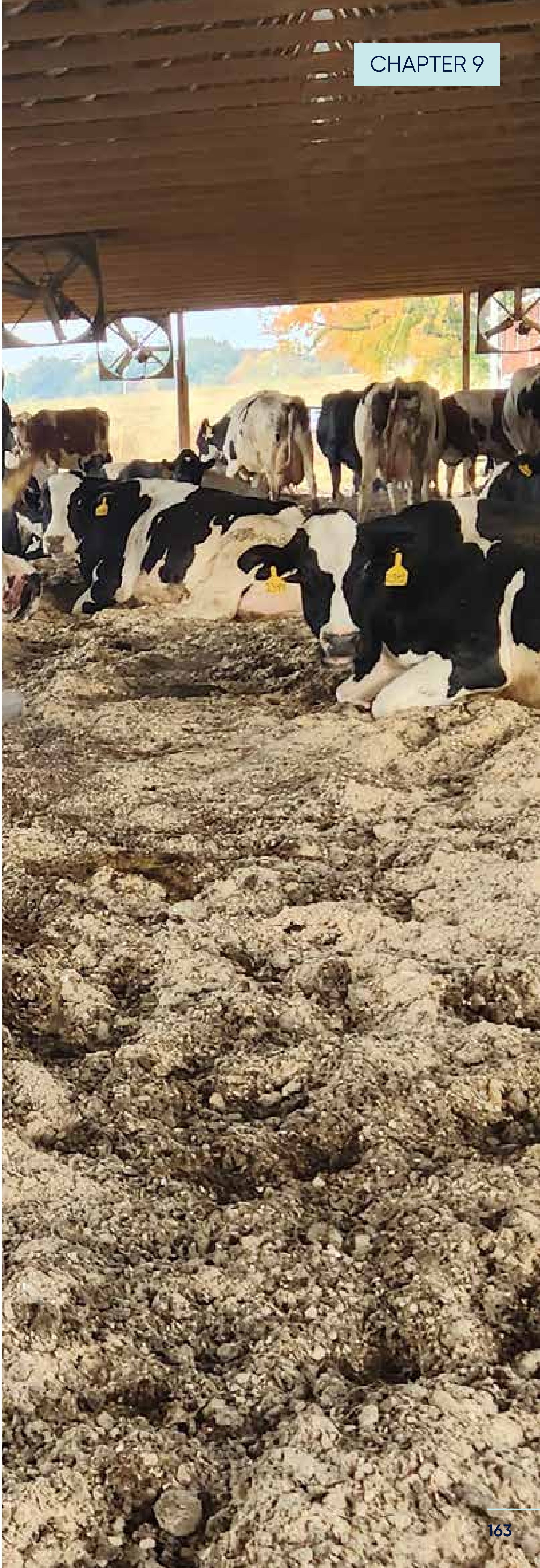
This type of loose housing facility requires less specialised operational knowledge or pack maintenance, when compared with a compost bedded pack loose housing facility. A deep litter pack, if managed well, generally achieves better cow comfort, in comparison to a freestall, with very high lying times. They can accommodate different sized animals, have higher oestrous detection rates, and have lower levels of lameness (with the exception of white line separation and heal ulcers in heifers reported in some studies) and have a lower capital cost.

The reduced capital cost to build a deep litter pack loose housing facility compared with a freestall can make this an attractive housing option. However, the quantity and cost of bedding material and the cost of managing the bedding material on a daily basis also need to be considered.

Design and layout

Loose housing facilities with a deep litter pack are generally covered yards with bedding added daily to absorb urine and faeces. Sufficient bedding must be added to keep animals clean and dry. Fresh dry straw is added daily to a bed and this remains unturned. The straw accumulates in layers over a period before removal and replacement. The layers compact, become moist and decompose, removing oxygen from the bed, leading to an anaerobic fermentation.

Loose housing facilities with a deep litter pack can be built with or without feed bunks and concrete alleyways, depending on their use and other facilities that are available. These systems become difficult to manage on a large scale (> 70 cows) and many converted sheds with low roofs may result in bedding becoming too deep inhibiting removal of soiled bedding with machinery. Poor ventilation can also be an issue in some facilities as well as mastitis, lameness and respiratory disease.



The preferred design for anaerobic packs is to allow drainage of moisture away from the surface. Concrete can be used, sloped to facilitate drainage to the feed alley to prevent liquid collecting low corners of the bed. A drainage pipe covered with single size aggregate gravel is an expensive option requiring annual or periodic maintenance, but these systems will use less bedding due to the lower moisture content.

Similar to other contained housing facilities, good ventilation is necessary to ensure cow health, aid in pack drying and reduce odour. For more design and layout details refer to *Section 9.7*.

Bedded area management

A deep litter pack requires constant monitoring and management to ensure the bedding material remains effective. An upper layer moisture content of <15 per cent is required in the pack to maintain cow cleanliness, low cell counts, cow health and to maximise cow comfort. To maintain this environment, with anaerobic fermentation, straw or similar organic bedding is added to the bedded area daily at a rate of approximately 12kg bedding per cow per day (Figure 31). Bedding use may be reduced through removal of manure from the pack area and feed alleys and water areas. After a period of 4-6 weeks all bedding is removed, and the process repeated.

Figure 31. Organic bedding added to a loose housing facility with a deep litter pack

Space per cow

Providing adequate space per cow is essential. Cows constantly add manure and urine to the deep litter pack (this is exasperated with higher yielding, larger cows). Greater cow density also increases pack compaction. More space per cow reduces the use and costs of bedding. A minimum of $12m^2$ of pack space per cow is recommended for lactating Holstein cows to achieve better cow comfort, with very high lying times.

Figure 32. Deep litter pack – low bed retaining curb, water troughs, access from feed alley only

Compost bedded pack

This type of loose housing facility consists of a large, open resting area, usually bedded with sawdust or dry, fine wood shavings and manure composted into place and mechanically stirred on a regular basis to aerate the pack. This design however does require a larger overall footprint, expert pack management as well as more bedding requirements compared to loose housing facilities with a deep litter pack or a freestall.

The difference between a compost bedded pack and a deep litter pack is that the composting process is an actively managed process adding oxygen to bedding materials by stirring 2-3 times daily using various types of cultivators or roto tillers. Composting creates heat that dries the bedding material, which provides the cows a clean, dry place to lie down. This keeps cows clean, with no increase in clinical mastitis levels (Figure 33).

Figure 33. Properly managed compost bedded packs providing a dry resting surface is important for herd health

Cows housed in loose housing facilities with a compost bedded pack benefit from increased area to rest and exercise compared to a freestall (Figure 33). When working effectively, these facilities have the potential to improve cows' comfort, hoof health and milk yields. Heat detection is also easier. Other benefits claimed by operators include increased cow longevity, less odour, fewer flies, less concern with cow size, ease of manure handling and improved manure value (Figure 34). Compost bedded packs also minimise the time cows stand on concrete.

Figure 34. Cows have more freedom of movement on a composted bedded pack, being able to lie down and get up without restrictions

Facility design, ventilation, timely addition of fresh, dry bedding, frequent and deep stirring, and avoidance of overcrowding are the keys to a good working compost bedded pack.

Loose housing facilities with a compost bedded pack are not for everyone. The risk for mismanagement is higher for a compost bedded pack than for a freestall. Ignoring the basic principles of compost management may lead to very undesirable compost bed conditions, dirty cows, elevated somatic cell counts, increased clinical mastitis incidence, and increased digital dermatitis.

Figure 35. Compared to freestall facilities, compost bedded packs allow animals choice when resting

Design and layout

Some newly constructed loose housing facilities with a compost bedded pack are built by modifying existing designs for two-, three-, or six-row freestalls. This allows flexibility for converting to a freestall later by adding concrete alleys, freestall platforms, dividers, and waterers. These modifications allow flexibility in case the producers find the facility does not meet their needs or a changing market in bedding supply makes modifications necessary.

While a number of different facility designs exist, a suggested layout is illustrated in Figure 36. This single structure includes the open compost bedded area with a concrete feed alley for access to the feedbunk and waterers. The bedded pack is surrounded on all sides by bedding retainer walls, including a wall to separate the bedded pack from the feed alley. The layout has two access points to the bedded pack, a feed alley and a drive alley. Waterers are against the concrete wall, separating the bedded pack from the feed alley. They are accessed from the feed alley only.

- **Bedded area** should be rectangular, with the longest side adjacent to the feed alley, and divided lengthwise to create a 4-5m wide concrete apron next to the feeding table, and a bedding area typically no more than 9 to 20m wide. With flexibility in mind, the width of the bedded area should be designed to equal the width of two rows of freestalls and a stall alley, so it can be converted later if desired.
- **Bedding retaining walls** 0.6 to 0.75m surround the perimeter of the bedded pack to keep bedding material in the facility bedded area. These walls are usually precast or cast-in-place concrete, designed and specified to withstand the considerable forces that the compost pack puts on them as it builds up. The bedding must be contained so it does not drift into the feed alley by the use of a bedding retainer (Figures 35 and 36). The size and shape of this depends on the type of bedded area being constructed. To prevent cows from walking over the wall adjacent to the feed alley when bedding has built up over time, steel post and rail fence is recommended along the top of the wall (Figure 39).

Figure 36. Typical loose housing compost bedded pack facility layout (not drawn to scale)

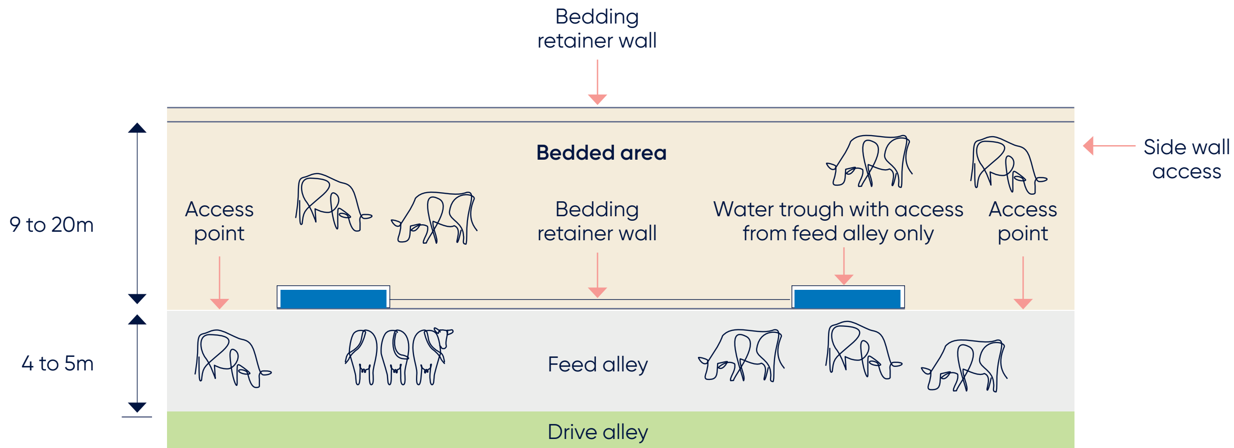


Figure 37. Concrete retaining walls provide separation between the feed alley and the bedded pack area which is helpful in managing pack moisture

Figure 38. A retaining wall separating the bedding pack and feed alley reduces bedding drift. Monitor the bedding pack height

Figure 39. Compost bedded pack – high retaining walls, barriers stop cows climbing over wall if bed is full

- **Access points** to the bedded pack should be located every 15 metres and at each end. Cows will generally use the resting space provided more efficiently when they have multiple entry access points along the long side of the rectangular bedded area. Limiting access points may result in the development of wet areas because of increased cow traffic. The effective resting area will be reduced because cows avoid this area of the pack when resting.
- It is worth noting that some more recent designs of loose housing facilities in Australia are opting not to have any form of barrier separating the bedded pack from the feed alley except around the back of the water troughs, to minimise high traffic areas that can become wet and contaminated. A bedding retainer (nib wall or plinth) in the form of a concrete kerb, rounded at the edges 200mm wide is recommended. The retainer allows access to the bed along the length of the feed table while reducing bedding drift (Figure 38).
- The **floor** beneath the bedded area should be an impermeable material of at least 600mm in thickness (permeability must be less than 1×10^{-9} metres per second).
- **Feeding table** space, design and feed barrier (post and rail or head locks) as per in a freestall (see *Section 9.9*) (see Figure 40).
- **Sidewall access** to machinery for pack filling, tilling and removal.
- **Wide eaves** to minimise rain reaching the pack and roof gutters to prevent water running off roof and blowing into the loose housing facility onto pack. A 900 to 2,500mm eave overhang is recommended (Figure 41).
- **Water troughs** (see *Section 9.9*).
- **Feed and drive alleys** (see *Section 9.9*).

Figure 40. Feeding table, feed barrier (post and rail) in a loose housing facility with a compost bedded pack

Figure 41. Eave overhangs can help minimise the amount of wind, precipitation, and sunlight entering the housed facility

- **Ventilation** is essential to remove heat and moisture created by cows and the composting process. Proper ventilation generally includes natural air movement through the facility, but mechanical ventilation (fans), can also be used to prevent stagnant areas (Figure 42). Fans must be hung high enough to avoid equipment operating in the bedding area. As a guide, use 3.6m plus the expected bedding height for clearance. High open sidewalls maximise cross ventilation. A minimum 5m opening should remain between the top of the retaining wall and the bottom of the housed facility eave. Refer to *Section 9.9* for additional ventilation and cooling requirements.
- **Facility orientation** has a significant impact on the natural light patterns.

A facility with a compost bedded pack should be oriented east-west as it allows the least sunlight penetration into areas where the cows rest or eat.

Figure 42. Mechanical ventilation (fans) – fans hung high enough to avoid equipment operating in bedding area

- With an east-west orientation, the sun moves over the top of the housed facility through the day. With a north-south orientation, the sun moves over the broader sides of the facility, which creates more light intensity in areas where the cows rest or eat. During heat stress conditions, cows will move away from areas with more light and move toward darker parts of the facility resulting in cow bunching behaviour. In extreme situations, cows may only use 10 to 20% of provided space.
- East-west facility orientation also takes advantage of prevailing southerly, summer winds. Prevailing winds can be regional or site specific due to the local terrain and facility position within the landscape. Under these situations, the facility should ideally be oriented so the prevailing summer wind is perpendicular to the longitudinal sidewall to allow for adequate ventilation. Under these circumstances an extension of the roof eave may be required to reduce afternoon sunlight from entering the facility.
- **Resting space per cow:** A guide for determining a size for a compost bedding pack shed is in Table 15. Additional space increases cows' lying time per day.

Typical mature Holstein cows require 12-15m^2 of bedded space per cow while Jerseys require 10-12m^2. Climatic conditions are an important consideration when determining bedding space per cow.

Greater pack space per cow is needed for higher producing cows as they produce more urine and manure due to higher daily food and water intakes. In facilities for special needs cows including maternity areas, producers should provide at least 14m^2 of resting space.

Table 15. Calculating loose housing, compost bedded pack dimensions – an example

Step	Calculation		Formula	Example inputs*		Example answer
1	Required Pack Area	=	RC x NC	12 x 100	=	1,200 sq m
2	Facility Length	=	(MC x NC)/100	(60 x 100)/100	=	60m
3	Pack Width	=	RPA/FL	1,200/60	=	20m
4	Total Facility Width	=	PW + FAW + EW	20 + 5 + 0.3	=	25.3m
5	Total Facility Area	=	TFW X FL	25.3 x 60	=	1,518 sq m

KEY:

FL = facility length	EW = exterior walls	FAW = feed alley width
MC = manger space/cow	NC = no. of cows	PW = pack width
RC = resting space/cow	RPA = required pack area	TFW = total facility width

**Recommendations: RC = 12 sq m/cow, MC = 60cm/row, FAW = 5m, EW = 0.3m.*

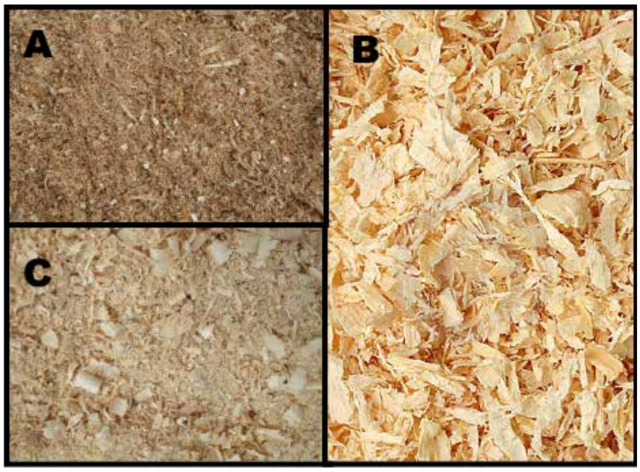
The most common cause of compost bedded pack failure is overstocking.

Providing less than 12m^2 of resting space per cow can lead to serious problems as the amount of moisture deposited through urine and manure is too much to overcome increasing the pack's moisture content and slowing the composting process. Increased pack moisture content causes the bedding to become more compacted, reducing airflow in the pack. The incidence of environmental mastitis may also increase because of the amount of faecal contamination.

Bedding material: Several bedding materials have been used in compost bedded packs. However, dry, fine wood shavings or sawdust are considered the gold standards for compost bedded pack shed bedding (Figure 43). Even when mixed with shavings, sawdust has enough structure to be able to be easily stirred and remain fluffy enough to ensure oxygen transfer within the bedding material. Sawdust provides a large surface area to volume ratio, is easier to till and absorbs liquids well.

Kiln-dried sawdust performs well as long as the dry matter is 88% or more. Green sawdust is generally wet and may harbour Klebsiella bacteria and more bedding is required to maintain the composting process.

Figure 43. Sawdust from (A) sawn wood, (B) planed wood, (C) mixture



Woodchips are less desirable than sawdust and wood shavings as they hold less water due to their lower surface area/volume ratio. If they have sharp edges, they may also injure cows.

Bedding material is only added when the pack moisture increases, to where the pack is not dry and fluffy.

Keys to management

As with any facility, the success of a compost bedded pack facility hinges largely on how well it is managed. Maintaining proper aeration and stocking density are fundamental. When the pack is stirred frequently and uniformly, the manure and urine from the surface are stirred into the pack while oxygen and moisture are incorporated. The result is better heating and aerobic decomposition of organic material.

The composting process: A composted bedded pack is managed very differently from a deep litter pack, requiring significant attention to bed management. When the compost pack is working well, the pack surface will appear dry and fluffy (Figure 44). However, when the pack is not working well, the surface appears wet and chunky (Figure 45).

Reasons to compost vs deep litter

- Use less bedding/cost savings
- Less frequent cleanout
- Reduction in volume of material to remove
- More nutrient dense material for application to cropping areas
- Retains more nitrogen
- Odour reduction
- Fly reduction

Composting relies on aerobic microorganisms to break down organic matter and produce carbon dioxide, water, and heat. In a compost bedded pack facility, the manure and urine released by cattle and the added bedding provide the essential nutrients (carbon, nitrogen, moisture, and microorganisms) needed for the composting process.

Composting is an aerobic process. The continuous introduction of oxygen (air), carbon and nitrogen (through manure) and moisture control (new bedding) is required for success. In a compost bedded pack facility, the oxygen comes from stirring (aerating) the bedding and from the air that diffuses into the bedding surface, which should be fluffy to encourage the air infiltration. How well the compost bedded pack works depends on maintaining the appropriate balance of carbon, nitrogen, oxygen, moisture, temperature, and microbial activity populations. When the proportions of bedding, cow stocking density, oxygen, and moisture are optimally balanced, the microorganism population will thrive and produce sufficient heat to dry the pack and maintain active aerobic bacteria to continue the composting process. This may result in reduction of pathogens, fly larvae, and weed seeds.

Figure 44. A well-managed compost bedded pack looks dry and fluffy

Figure 45. When the compost process is not working the pack surface will appear wet and chunky

The temperature of the pack provides a good indication of the level of microbial activity. Temperatures near the surface of the pack are closer to the air temperature because moisture, evaporation, and air movement dissipate heat. The bedding surface-temperature under a resting cow will rise, however. The ideal pack temperature goal, measured at approximately 15 to 30cm below the surface, is between 43 and 60°C (Figure 46). When temperatures exceed 66°C, surface temperatures may increase to the point where cows do not want to lie down on the pack. A temperature in that range indicates that organic materials are breaking down rapidly. When the temperature is lower, the composting process is too slow, often from inadequate oxygen, too high moisture, or high heat loss during the winter. When it is above this range, the beneficial aerobic bacteria are killed.

Figure 46. Frequent measurement of temperature with a long probe is important for monitoring compost success and understanding

A: Example of compost heating well with high temperature and dry material – forms loose ball

B: Example of compost that is too wet with insufficient temperature – forms firm ball with water drops

C: Example of compost that is too dry with insufficient temperature – will not form ball

Temperatures can be measured with a long cooking thermometer. If a thermometer is not available, you can feel the material (at 30cm beneath the surface) with your bare hands. If the pack is hot almost to the point that you do not want to touch it, the temperature is likely high enough (> 43°C). Above 55°C you will not be able hold it at all. Particularly in the morning, compost that is heating properly may even produce steam. This is not always a good indicator – it just means that the temperature of the bed is warmer than ambient.

Manure, urine, and microbial activity produce a pack's source of moisture, which ideally should be between 45 to 55% but an operating range that can still have significant activity for success is 40 and 60%. When the moisture level is too low, the microbes will not have enough water, and the compost will be too cool, resulting in a compost rate that is too slow. If the moisture level is too high, the pack becomes anaerobic (lacking oxygen); the rate of microbial decomposition will slow; and again, composting and heat generation will be too slow.

As a simple moisture check, grab a handful of bedding and squeeze it. If you can squeeze water out or if water droplets drip from or appear on the surface of squeezed bedding, the pack is too wet. This is a sign that new dry bedding should be added to the pack. If you cannot form a loose ball that easily falls apart, the pack is too dry. This condition may actually occur when bedding is added too frequently. When the pack is working well, the bedding material will appear loose and fluffy, not compacted and chunky.

Generally, temperatures are higher when the pack is fluffy because air promotes microbial activity. When the pack is compacted and has excessive moisture, you will see reduced temperatures. Moreover, when moisture is excessive, the bedding and manure then will more readily stick to the cow's hide and udder then you will see temperatures falling out of the ideal temperature range.

Excessively high temperatures in the compost bed (more than 65°C) occur when there is high microbial activity due to the presence of easily digestible organic matter and moisture is near the low end of the optimal range. Under these conditions, the pack does not have enough water for evaporative cooling. Lack of water may occur when cow density is low, when air movement dries the pack more quickly, or in warm, dry weather.

Ideally, the Carbon:Nitrogen (C:N) ratio for a peak composting rate needs to be between 25:1 and 30:1. New bedding material, besides absorbing water, will also aid in achieving this ratio. If you can smell ammonia in the housed facility, the C:N ratio is likely below 25:1.

Compost bed start-up in a new facility or after facility cleanout requires 300 to 500mm of dry bedding to be applied to the facility floor. Depending upon facility size, cow numbers, and pack area, several semi-loads of sawdust may be required to start the pack. Make sure to add enough sawdust so that the mixing equipment does not encounter the facility floor. Starting a new bed should occur when 4 to 6 weeks of weather with highs generally above 10°C are expected. Ideally, the new compost should be started so that heat generation rate reaches a peak before the arrival of cooler temperatures. Not achieving an actively composting bed going into winter may result in low heat production that does not overcome the heat losses and poor bed performance results throughout the winter.

Compost cleanout: The pack depth may reach 1m before cleaning depending on sawdust used and composting intensity. Most producers return the top 15 to 30cm of old material to help start microbial activity in their new pack. The top layer of the old compost bed is the most active, and will help start up the composting process in the new bedding.

It is possible to allow the composting process to continue and be completed by stockpiling material after the pack is cleaned out. This dry composted material can then be mixed with new sawdust to stretch the sawdust supply for new bedding.

Bedding stirring/aeration: Uniform stirring and mixing provide a clean, soft, dry surface upon which the cows lie. The compost bedded pack should be aerated to at least 30cm at least twice daily during milking while the cows are out of the facility. This reduces the risk of respiratory disease from the dust created. Workers should also wear personal protective equipment (PPE). Some producers plow the pack twice during each stirring event, both lengthwise and crosswise, to further increase aeration. Periodic deep stirring, up to 45cm, with a chisel plow reduces the amount of bedding you will need and increase pack temperatures.

If possible, cows should be kept off the pack for at least an hour after stirring to allow the top layer of bedding to dry (especially during the winter). Running fans after stirring helps dry the surface throughout the year, not just during warmer conditions. Packs should be stirred as soon as new bedding is added.

Equipment: A variety of methods is used to stir compost bedding. Most producers use a cultivator or tines attached to a skid steer or small tractor (Figures 47–48). The depth of tilling varies, depending on the operator and the equipment used, but 18-30cm is typical. Fixed tine tillers generally have a deeper penetration (25-30cm). However, best results are observed with specialized roto-tillers that reach at least 30-45cm deep (Figure 49). These types of equipment provide deep tillage but also break apart clumps of material, where there is no internal moisture, very well.

Figure 47. Most compost bedded packs are tilled twice daily with a field cultivator. Many different types of tillage implements have been used successfully

Figure 48. Sweeps or shovels may be added to tillage implement tines to provide more effective stirring. This is a cheap and effective addition to existing implements

Figure 49. Roto-tillers may be used and are helpful to break up clumps of bedding material and maximize oxygen/air infiltration into the pack providing a uniform mix of material

It is important to breakup tractor tracks by positioning mixing tools to follow the tires. If heavy equipment is used, wheel tracks will not be broken up; also, if the pack is too wet, the pack may become compacted, limiting oxygen and causing lower temperatures (Figure 50). Compaction prevents air infiltration into the pack, which is needed by composting bacteria. Compaction also leads to higher bed moisture and thus inadequate aeration.

Figure 50. Compaction of material may occur when heavy tractors are used to stir the pack or when implements are pushed rather than pulled

Addition of bedding material: To check pack moisture grab a handful of bedding and squeeze it. If you can form a tight ball, squeeze water out or if water droplets drip from or appear on the surface of squeezed bedding, the pack is too wet. New bedding (10 to 20 cm) is added to the pack before the moisture increases to the point where the tight ball is formed. Response of the bedding addition will be a higher temperature and lower moisture content within 24 to 48 hours, depending on how high the moisture content is above 60%. Waiting until bedding starts to stick may be too late.

The frequency of adding bedding depends on how much evaporation occurs, how much manure and urine are introduced, season, ambient temperature, and ambient humidity. Generally, the new bedding is added every one to six weeks (more frequently when humid and wet in winter). Some producers add smaller amounts of bedding more frequently. More bedding may be used during humid or wet weather or if the facility is overcrowded. When using green sawdust, more bedding will be used since it will not absorb as much moisture as kiln-dried sawdust.

Moisture control of bedding in the 40-60% range and twice-daily bed stirring are critical for success. The compost bed can get out of balance if management does not recognise poor moisture conditions before temperatures start falling, cow hygiene deteriorates, and the risk of environmental mastitis rises. Moisture control depends on recognising the moisture range by the hand squeeze test and responding with added bedding, lower cow numbers, and increasing stirring effort for improved drying and aeration.

Winter management of compost bedded packs is the most challenging and requires the most bedding. When pack moisture levels exceed acceptable levels in the winter resulting in dirty cows (Figure 51), many dairy producers alter their management toward more frequent addition of thin layers of fresh bedding to keep cows dry and clean. Bedding usage during winter is generally 2 to 3 times more than during summer. Because sawdust is generally more available in summer but needed in winter, building a roofed facility for stockpiling bedding material can be helpful for sawdust supply management (Figure 52).

Figure 51. When conditions increase pack moisture, the wet resting surface creates conditions conducive for an increased incidence of dirty cows, mastitis, digital dermatitis, and elevated somatic cell counts

Figure 52. Dedicating a storage area for bedding supplies helps keep bedding supplies dry and allows for stockpiling of bedding material for times of high demand or low supply

Mastitis pathogens: Surface bedding bacteria levels are high in compost bedded pack in loose housing facilities. Contrary to popular belief, composting heat doesn't reach a high enough temperature to kill mastitis causing bacteria. Producers must use recommended milking procedures and mastitis preventative practices to maintain low somatic cell count in herds in compost bedded pack loose housing facilities. Extra attention should be paid to cleaning teat ends during the milking process. Vaccination of cows with *E. coli* and *Klebsiella* vaccines have been beneficial in many cases.

9.8 Freestall design and management

The term freestall refers to a resting cubicle or 'bed' which dairy cows are free to enter and leave, as opposed to being contained in pens. Freestall housing carries the chief advantage that it reduces the volume and cost of required bedding material, while allowing cows freedom of movement. The typical features of a freestall are shown in Figure 56.

Design and layout

Freestall facilities with an east-west orientation will provide greater protection from direct sunlight than north-south orientation. When freestall facilities are oriented north-south rather than the preferred east-west, there will be greater solar exposure along the west side of the facility during the afternoon hours, creating bunching issues and reducing the usage of the outside row of stalls.

Stall layouts and milking cow group sizes

Freestalls are built with feeding tables either located centrally or along one or both sides most commonly with between two and four rows of freestalls. Rows of stalls may be in:

- A single row or double row, oriented head-to-head (cows facing each other on a single double stall platform.
- Tail to tail (two single stall platforms with one row of cows facing the feeding table and the other row facing the opposite direction).
- Head to tail (two single stall platforms with cows each facing away from the feed bunk).

The number of rows of stalls significantly influences the space allowance per cow at the feed alley. A freestall 'pen' refers to self-contained groups of cows that are housed and managed together and milked as one group in the dairy parlour.

Figure 53. A three-row pen with a single row of stalls along the side wall

Note the double head-to-head row of stalls adjacent to the feed alley.

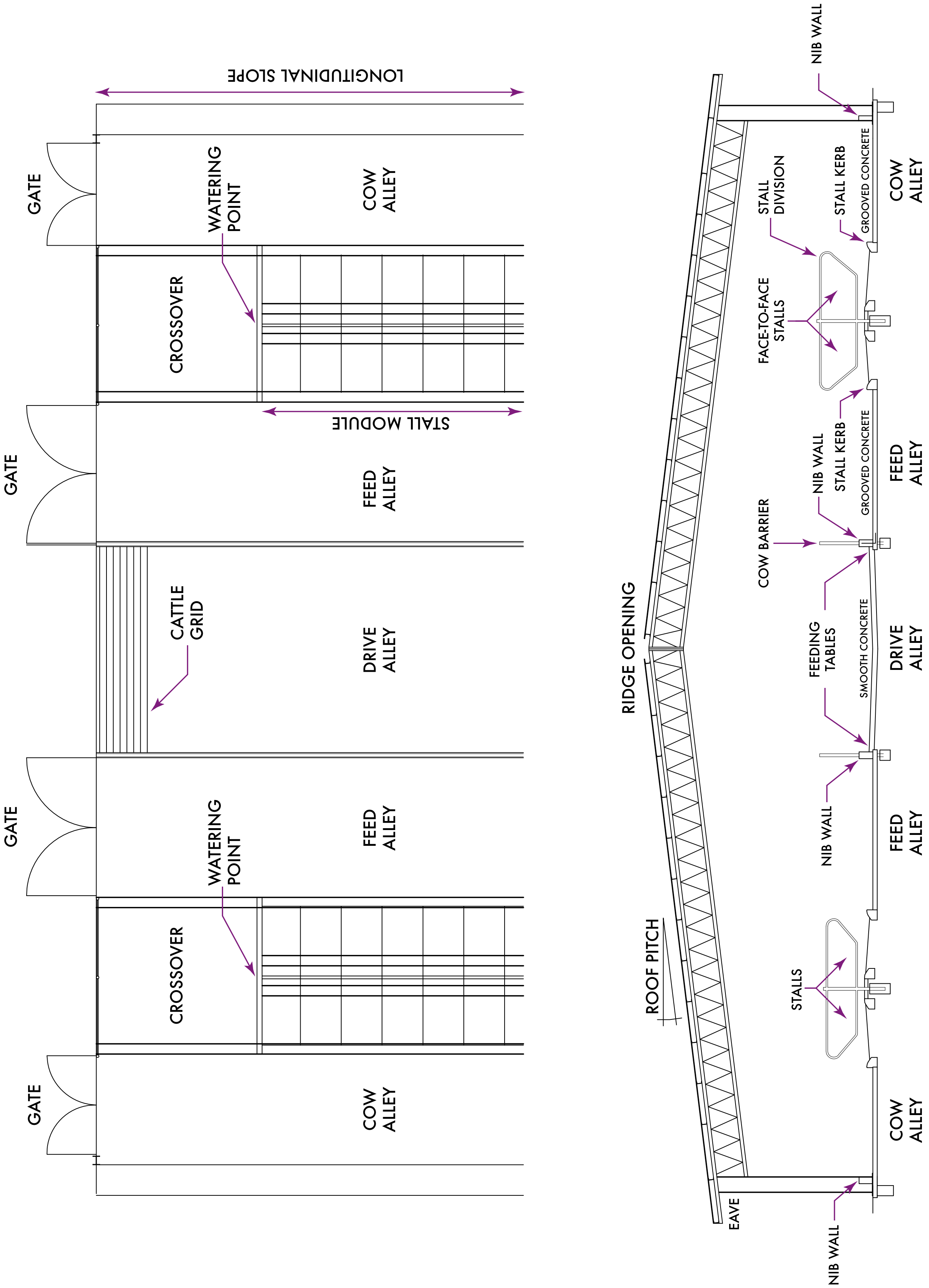
Figure 54. A two-row pen with double row of head-to-head stalls

Figure 55. Two-row tail to tail freestall pen

The total group size in the pen depends on the capacity of the dairy and the milking facility and its throughput. The aim is to minimise the time out of the pen away from food, water and a place to rest. Current recommendations are to limit pen size so as not to exceed 3 to 3.5 hours per day total time out of the pen milking per day, and not to exceed one cow per stall stocking density, to maximize the opportunity for rest and minimise the risk for health problems such as lameness.

For example, a dairy with 20 milking places that milks at a rate of 4.5 rows (sides of the dairy) per hour would milk 4.5 x 20 = 90 cows per hour, which would be the target pen size.

Figure 56. Plan and cross section view of a typical 4-row freestall with central feeding tables



Stall terminology and dimensions

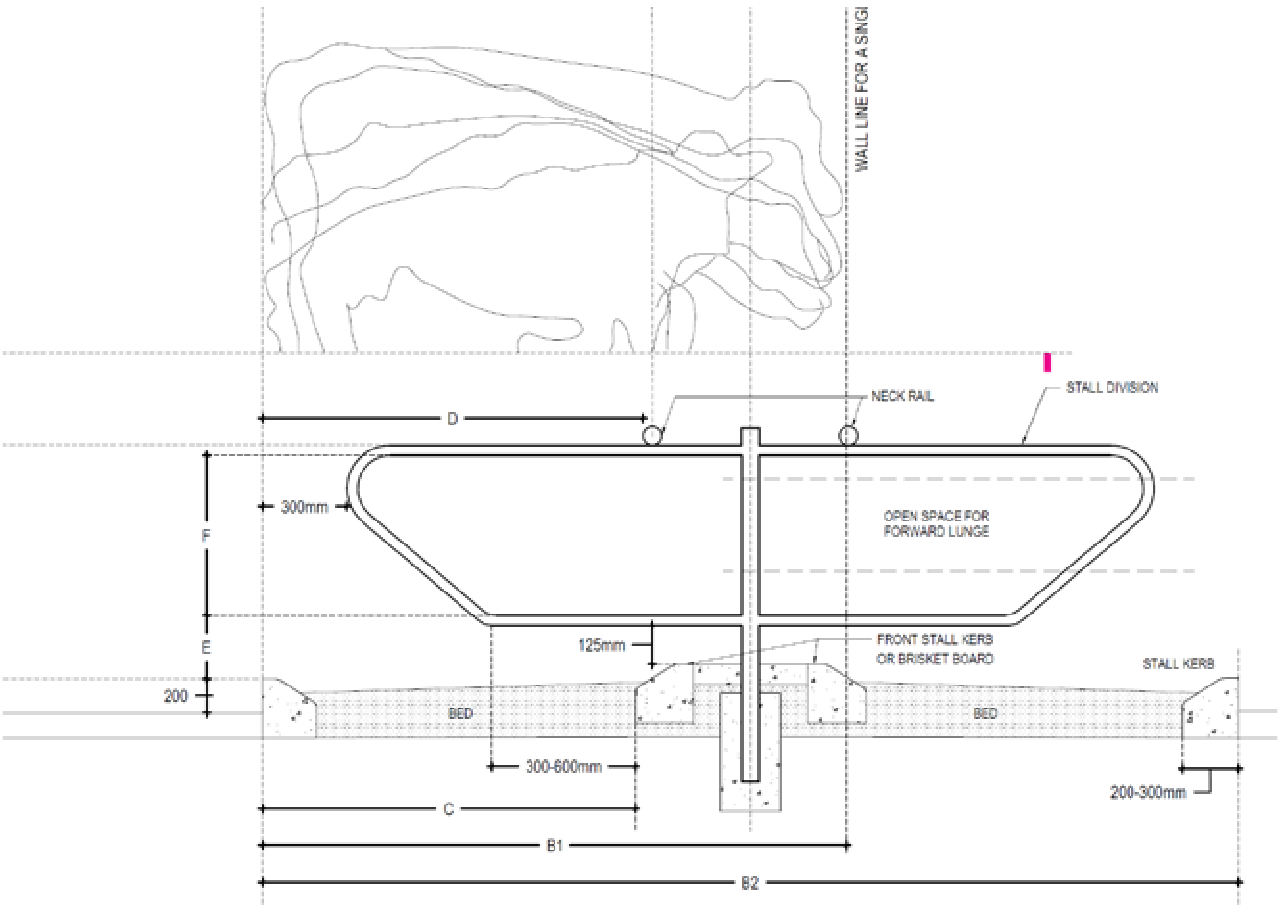
Freestalls consist of elements which serve to provide a bedded structure within which a cow may rest. Key elements to this structure include:

- **Stall kerb:** The barrier at the back of a freestall used to prevent slurry manure from the alley contaminating the bedding.
- **Brisket locator:** A device at the front of the stall that prevents cows from lying too far forward in the stall.
- **Neck rail:** A rail to assist the position of cows when they are standing in the stall so that they have enough forward lunging space when they lie down in a stall. They are also referred to as a 'training rail'.
- **Divider loop:** A metal loop that delineates the lateral borders of the stall resting area and assists in positioning the cow when lying down. There are many divider loop manufacturers available.

The stalls should be sized to accommodate the resting frame of the cattle using them and allow for easy lying and rising movements, including forward lunge space – *see Figure 58*. Recommendations are provided based upon an estimate of body weight in Table 16.

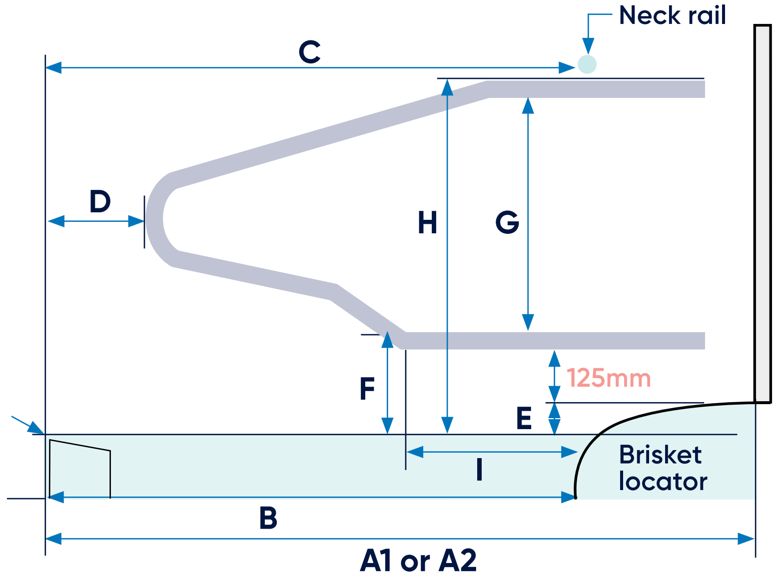
The resting space in front of the cow may be defined by a brisket locator, the purpose of which is to assist in the alignment of the cow when lying in the stall. When located too far from the rear edge of the stall kerb, cows will lie too far forward and soil the rear of the bed. If used, brisket locators must be no higher than 100mm above the stall surface so the cow can get her leg over the top of the locator as she rises. Some deep bedded stalls are designed without a brisket locator, where the bedding is used to form a mound in front to assist with cow placement. However when these mounds are large, they compromise the height of the divider rails and neck rail.

Figure 57. Side view of a typical stall (head to head)



Source: O'Keefe et al, 2010

Figure 58 Stall diagram – parts labelled



Key: A = stall length, B = distance from rear point of kerb to brisket locator, C = distance of neck rail from rear point of kerb, D = distance from the rear edge of the divider loop to a point vertically above the rear kerb, E = distance between bottom rail and top of brisket board, E = height of the brisket locator, F = height of lower divider rail, G = interior diameter of loop, H = height to the top of loop/underside of neck rail, I = distance of the angle of the loop from the brisket locator. Distance from top of brisket locator to lower divider rail should be 125mm to avoid leg entrapment.

Table 16. Typical target freestall dimensions (mm) based upon an estimate of a cow's body weight (kg)

	Body weight estimate							
Stall dimension (mm)	**270kg**	**360kg**	**450kg**	**550kg**	**650kg**	**750kg**	**820kg**	**900kg**
Centre-to-centre stall divider loop placement (stall width)	860	960	1,070	1,140	1,220	1,270	1,370	1,450
Total stall length facing a wall (A1)	2,030	2,240	2,440	2,740	2,740	3,050	3,050	3,200
Outside stall kerb to outside stall kerb distance for head-to-head platform (A2)	3,960	4,270	4,570	4,880	4,880	5,180	5,180	5,490
Distance from rear stall kerb to brisket locator (B)	None		1,630	1,680	1,730	1,780	1,830	1,910
Horizontal distance between rear edge of neck rail and rear edge of stall kerb for mattress stalls (C)	1,170	1400	1,630	1,680	1,730	1,780	1,830	1,910
Horizontal distance between rear edge of neck rail and rear edge of stall kerb for deep bedded stalls (E)	1,020	1250	1,470	1,520	1,570	1,630	1,680	1,750
Height of upper edge of bottom stall divider loop rail above top of stall kerb (loose bedded stall or mat/mattress surface) (F)	200	200	250	250	310	310	330	360
Interior diameter of the stall divider loop (G)	610	710	760	840	840	910	910	910

Note: letters in brackets refer to Figure 58.

Stall divider loop design and placement

The freestall divider has a number of functions, including:

- Defining the lateral limits of the resting space
- Facilitating lying direction of the cow – straight rather than diagonal is preferred for cleanliness
- Permitting or preventing side lunge
- Determining the height of the neck rail

The most important part of the divider is the lower rail.

- The rail's purpose is to guide the cow where to lie down and it must allow her to rise without obstruction or risk of injury.
- The height of the lower rail must allow for at least a 125mm gap between the lower edge of the bar and the top of any brisket locator that is used. This will prevent front leg entrapment below the rail.
- Divider rails that are located too low allow cows to rise with their front legs over the lower rail – leading to entrapment, while divider rails that are too high do not prevent side lunge into the adjacent stall.
- The preferred height of the lower rail above the level stall surface (or rear point of the stall kerb in a deep loose bedded stall) is 250 to 330mm for most cows.
- The rear limit of the divider loop should be 230 to 300mm inside the rear stall kerb – close enough to the kerb to prevent cows from walking along the back of the stalls, but not so close that the loop may get damaged by machinery used for alley scraping.
- The open diameter of the loop determines the height of the neck rail. A distance of 840 to 910mm from the upper edge of the lower rail to the lower edge of the upper rail should locate the neck rail at the target height of 1,170 to 1,320mm – depending on the size of the cow.

Whatever design of loop is chosen, it should meet the criteria above to place the cow correctly in the stall and avoid injury (Figure 59).

The neck rail provides lateral stability to the stall dividers, while helping position the cow in the stall while she is standing. Proper standing position limits the amount of manure on the rear of the stall. For deep loose bedded stalls with a raised rear kerb, with the neck rail 1,170 to 1,270mm above the stall surface, locate the neck rail about 150mm closer to the rear stall kerb than a correctly located brisket locator. This will force cows to take a step back and perch in the stall when rising.

Figure 59. Well-designed freestalls – choice in resting position, optimises resting behaviour, keeps cows clean

Stall surface and bedding

A variety of freestall base surfaces and bedding materials have been employed. Cows bedded on mats and mattresses have been repeatedly shown to be at greater risk for hock injuries and lameness compared to deep sand bedding. For this reason, deep-loose bedding is recommended to provide a comfortable resting surface to optimise resting behaviour. Sand is often considered to be the 'gold-standard' for deep-loose bedding but other options such as recycled manure fibre have also been used successfully with good management (Figure 60).

Deep loose bedding is a challenge to maintain and requires the frequent removal of wet contaminated material each milking and the addition of fresh bedding at least once weekly. In addition, bedding material needs to be levelled flat with the rear stall kerb typically at least twice a week.

Figure 60. A comfortable freestall bedded with a deep layer of sand

9.9 Additional contained housing design and management considerations

Water troughs

Water troughs should only be accessible from the feed alley with a wall built around to limit access from the bedded pack side and to prevent splash from entering the bedded area. When cows can access waterers, the areas around the waterer are generally wet and bacteria-laden. The increased moisture from waterers and cow congregation impair compost success. Alley-only access minimises excess moisture in the pack and keeps water cleaner. It also eliminates the need to alter water trough height as the pack depth changes (Figure 61).

Figure 61. Adequate water access is critical without allowing access from the pack

Figure 62. Water troughs located in the middle of alley

Building eave heights

High eaves are necessary to facilitate natural ventilation in sheds. Sheds may need a 4.5m side eave in cool climates and 5-5.5m side eaves in hot climates.

Circulation fans spaced over the bedded area facilitate air movement, but they must be hung high enough to avoid machinery operating in the bedded area.

- As a minimum, allow 3,000–3,600mm from the bottom of the fan to the floor – factor in bedding height.
- A 900 to 2,500mm eave overhang is recommended to minimise the chance of roof runoff and rain being blown onto the stalls.

The eave heights of tunnel and cross ventilated sheds need to be designed to suit the design and the structure and the location of access doors to the feeding table and cow pens and as low as possible to accommodate equipment heights.

Keys to management

Freestall management is key to achieving optimum cow health and cow comfort. Following the best management practices will help producers maintain clean, dry bedding, comfortable freestalls and happy, healthy, high milk-producing cows.

Bedding management: A key to stall management is to keep the bedding clean and dry. Clean and dry bedding reduces the ability of mastitis pathogens and bacteria to survive. It also keeps the cows cleaner and drier by absorbing moisture from the cows' bodies.

Clean, dry stalls are more comfortable and encourages cows to have longer bouts of lying time which results in more milk production.

If bedding is being recycled, starting with clean, dry bedding is key. For sand bedding, sand separation systems can be used to remove the sand from the manure stream and wash away a majority of the organic matter in the recycled separated sand. For manure fibre bedding, manure separation systems and dryers can be used to remove the liquid from the manure fibres and dry to a moisture content suitable for bedding.

Bedding depth: Bedding depth influences lying time. Freestall maintenance research found that lying time decreased by 11 minutes per 24 hours for every 1cm decrease in sand depth.

Freestall bedding needs to be deep enough to cushion the cow but not deep enough to retain moisture that can allow bacteria to grow. Sand bedding should be 15 to 20cm deep and should cover the cows' feet as she enters the stall.

As cows naturally prefer to rest facing slightly uphill, bedding should be higher at the front of the stall and slope back towards the kerb. The height of the sand in the back of the stall should be higher than the kerb to maximise lying time.

Bedding frequency: Fresh bedding material needs to be added frequently to replace bedding kicked out of the stall and to maintain bedding depth.

Sand bedding requires replacement at least once a week while manure solids should be replaced more frequently (at least twice a week and sometimes daily). Regardless of bedding material, any soiled bedding should be removed from the stall prior to the addition of new bedding material.

Freestall grooming: Freestalls require regular grooming to improve cow comfort. Bedding can become compacted under the weight of the cows' as they lie down. Stall grooming equipment make it easy to rake and aerate the stalls between the addition of bedding material. Stall groomers attach to a skid-steer and fit neatly under the neck rails to access an entire row of stalls in once pass. Stall groomers help keep the stall bedding loose and comfortable to allow for better drainage, drier bedding and drier cows (Figure 63).

Figure 63. Machinery is used to add fresh bedding to stalls

Alleys and cross overs

In freestalls, there are three types of alleys:

1. **Feed alley** – the alleys occupied by cattle when they are accessing feed. These alleys are located parallel to the feeding table.
2. **Cow alley** – these alleys provide a walkway for cattle to access the stalls.

Alley width recommendations vary with their purpose and are shown below for conventional and robotic freestall pens. The recommendations in Table 11 should be viewed as minimum requirements given the cost of concrete. The wider recommendations for robotic facilities reflect the importance of cow flow around the pen to and from the milking robot, and the need to reduce congestion in the alleys.

Table 17. Freestall alley width recommendations by alley type

	Recommended minimum alley width (mm)	
Alley type	**Standard facility**	**Robotic facility**
Cow alley	3,500	3,700
Feed alley	4,000	4,600

The width of the alley depends on its purpose.

- For the feed alley in a tail to tail pen layout, 3,700mm is recommended so that a cow can stand at the feeding table eating, with sufficient space for two cows to pass behind the cow side by side.
- For a feed alley in a head to head or head to tail pen layout, where cows must also access a stall from the opposite side of the alley, the width recommendation is increased to 4,000mm.

Figure 64. Drive alley in loose housing – compost bedding pack

Cross overs between the feed and stall alleys should be located at the ends of each pen to avoid dead ends which inhibit cow flow.

- Water troughs are usually positioned at these locations and it is preferable to place them along the outside concrete wall rather than up against the stalls to facilitate cow movement and to keep water from entering the stalls.
- If free movement of cows is to be maintained while cows drink at these locations, then the alley must provide a minimum of 3,700mm of available space for a cow to drink and two cows to pass behind.
- Taking account of space required for the water trough and typical stall dimensions, the total cross over alley width should be 4,800mm with a single water trough. In cross overs with two water troughs on both sides, the recommendation would be 6,000mm (Figure 65).
- Cross overs without water troughs may be 2,400 to 3,000mm wide.

Figure 65. A wide cross over with a water trough and cow brush

When cow brushes are used, they are commonly added to cross overs to facilitate grooming and enhance cattle welfare.

- When present, the cross over should be increased in width by a further 1,200 to 1,500mm and the water trough should be located on the opposite side.
- One brush per 60 cows is the current standard.

Cross overs in front of robotic milkers must be a minimum of 6,000mm to allow for cows waiting to be milked and adequate cow flow around this important area.

Each cross over is elevated above feed and stall alleys and should not be excessively crowned as these areas can become very slippery.

- A 50 to 100mm rise to the centre encourages quick drainage.
- Cross overs should be raised 100 to 150mm above the feed and stall alleys to prevent the spillage of manure into the area while scraping or flushing.

Cross overs between feed and stall alleys must be located frequently enough to maintain good cow flow and provide for sufficient access to water. The distance should be less in pen layouts with no direct stall access from the feed alley (i.e. tail-to-tail layouts).

- It is recommended that a cross over be provided every 20–25 stalls for tail to tail and 6-row stall arrangements and 25–32 stalls for other stall layouts.
- In transition cow pens, more frequent crossovers every 15–20 stalls are recommended to improve availability.

Water troughs are usually located in cross overs, and water access must be taken into account when determining the optimum number of cross overs. Often, the number of cross overs is governed by the number of water troughs and brushes required, especially in a 6-row freestall.

Figure 66. A double cross over with the trough located in the middle

Feeding table

All contained housing facilities require the incorporation of a feeding table along which cattle may eat their ration. Feeding tables are most commonly designed with a single post and rail system with headlocks (head gates, stanchions etc) or with a double rail system. In youngstock facilities slant bar feeders are also common.

While post and rail feeding tables allow greater freedom of movement, there is more wasted feed and there are more aggressive displacements between dominant over subordinate cows at the table compared with headlocks. Headlocks have the advantage of facilitating animal handling in critical groups such as transition cows (within 21 days before and after calving), and the sick cow or hospital groups. However, headlocks are more costly and when used, they should not be introduced for the first time to inexperienced animals during the transition period as this may significantly impact dry matter intakes at this crucial stage.

The feeding table surface should be 900–1,000mm wide and smooth to encourage feeding activity. Suitable epoxy paint, ceramic tile or high-strength concrete performs well with silages and split feeds which tend to etch concrete over time.

Headlocks can be mounted on a 400 to 500mm high feed kerb for Holsteins (400mm for Jerseys). The height of the upper edge of the lower headlock rail should be approximately 50 to 100mm above the kerb. Some producers will angle the headlock toward the feed in an effort to increase the cow's reach. However, if headlocks are properly installed and the feeding table is properly managed this is not necessary. Note that different manufacturers of head stall sections have differing heights and length requirements.

- Headlocks are generally available in 3,000mm lengths providing 600 to 750mm wide spacing options. The latter is recommended for transition and sick cows.
- At peak utilisation of the feed alley with 600mm wide headlocks, it is typical for only 80% to be filled.
- When planning facilities, it is important to realise that one headlock does not necessarily equal one feed space.

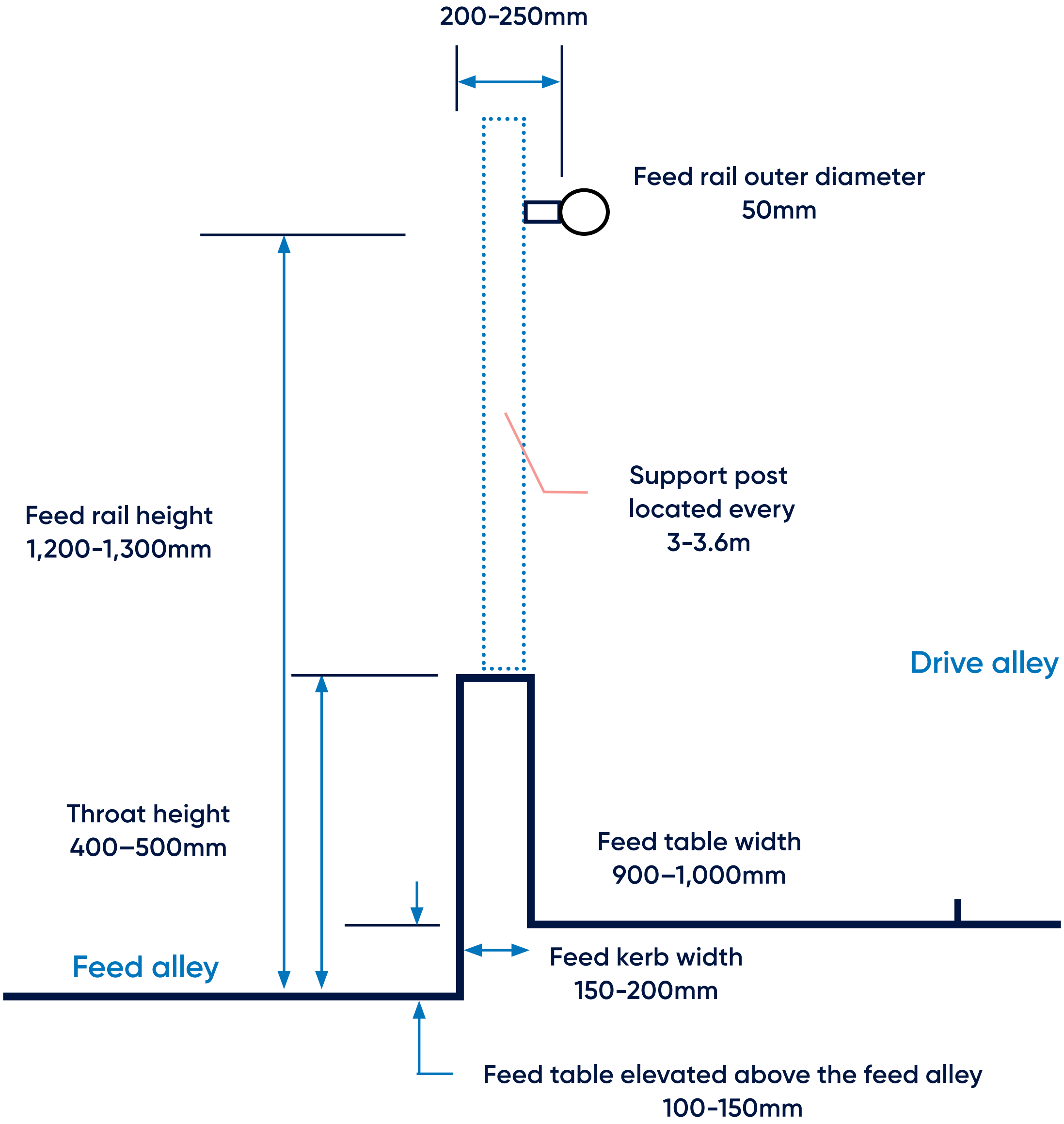
For post and rail type barriers, the feed alley kerb height is equivalent to the height of the upper edge of the lower horizontal rail of the headlock (Figure 67). The drive alley side should be elevated 100mm above the feed alley. The kerb should be 170–200mm wide.

Feed rails are typically 50mm Nominal Bore med gal pipe and should be mounted 1,200 to 1,300mm above the cow-side feed alley depending on the size of the cow (Figure 66). The rear edge of the bar should be 200 to 250mm forward of the cow-side of the kerb, with the greater distance used for the wider kerb. The rail needs to be supported every 3,000–3,600mm with a post. Posts are typically 80mm Nominal Bore med gal pipe.

Personnel access points are typically located at intervals of 30m along the drive alley and are made 600mm wide, to allow one feeding space when not in use.

Figure 67. A feeding table along which cows may eat their ration with a single post and rail system

Figure 68. Diagram of feeding table dimensions for Holstein cows – metric



Feed troughs

Precast concrete troughs and modular steel troughs are commonly used as they provide a robust, sturdy feeding table that can be relocated if required but careful selection is required to minimise feed wastage.

- Due to the large module size of some troughs or feeders, cattle may not be able to reach the feed at the base, therefore spoilt feed will need to be removed periodically.
- Troughs should be cleaned at least weekly.
- Cleaning may require the modules to be partly dismantled or moved to allow access for a front-end or skid-steer loader to clean the area.
- Raised troughs facilitate the cows reaching the feed when appropriately sized and they can also reduce the ability of cattle to flick/toss feed out of the troughs.
- A cow barrier such as a metal rail may need to be installed above the centre line of the troughs to prevent cattle from standing in the troughs.

Precast concrete troughs

Precast concrete troughs volume is relatively small; therefore feed is delivered at least daily.

- The internal profile of a concrete trough can be an oval, semi-circle or square shape.
- A square internal profile may allow feed to accumulate in the front and back corners of the trough, but it also allows for easier cleaning with a skid steer or tractor fitted with a scraper attachment.

Modular steel troughs

Modular steel troughs sit on the ground or on concrete.

- Some modules provide a large volume to store feed.
- Large round or square hay bales to be placed directly into them.

Cow transfer lanes

Correctly designed and sized cow transfer lanes facilitate cow movement to and from the milking facility and movement of cattle between pens. In larger farms with high throughput rotary dairies, dual cow transfer lanes facilitate the simultaneous flow of cattle to and from the milking facility.

Recommendations for cow transfer lane widths based on group size are shown in Table 12.

Table 18. Cow transfer lane widths based on pen size

Pen size (cows)	Cow transfer lane width (mm)
Up to 150	4,500
151-250	5,000
251-400	6,000
Greater than 400	7,500

Return lanes from the milking facility would only have to be 2,500 to 3,500mm wide, since cattle will be returning in smaller groups. This transfer lane should be wide enough to accommodate manure scraping machinery or the aforementioned widths if machinery access not required.

Flooring types

Flood washed cow and feed alleys and high traffic areas are constructed of concrete, with a variety of finishes. Strategic use of rubber flooring is also important in the design of a contained housing facility.

Special attention must be paid to concrete floor surfaces since they do not provide enough friction to allow natural locomotion behaviour. As a consequence, it is common to see cattle slip and injure themselves on concrete floors. Enhancing this friction will often involve a combination of surface finish and concrete grooving to avoid problems.

Grooving concrete floors is as much art as it is science, and experienced finishers are required to provide a proper finish to provide confident footing for cows. There are numerous grooving patterns, but the final product must strike a balance between providing enough grip to prevent slipping, while not being so rough that it promotes excessive wear of the sole of the hoof. The aim of any grooving pattern is for the cow's foot to make contact with the floor over a groove wherever the foot lands. This will force the manure from the floor into the groove and facilitate contact between the claw sole and the concrete surface. As the claw meets the sharp vertical edge of the groove, it slides to a stop, providing traction.

When the walking surface is completely flat, with appropriate grooves going in the direction of the main traffic (i.e. in the direction of the alley) the best mobility in cows is observed (Figure 69). The "Deep Groove" pattern has provided the best overall results for adult cows: grooves are spaced 80 to 100mm on centre, 19mm wide and 13mm deep. This is the most used floor pattern worldwide with less animal slips reported and an increase in stride length (Figure 70). Deep grooves that are cut with diamond blades have a sharp 90 degree edge, which provides best traction. Grooves made with a bull float at the time of placing new concrete will never provide as sharp an edge in comparison and in the long term will result in more slips and an increase in lameness (Figure 71). V-shaped grooves should also be avoided as they allow the claw to slip which may cause trauma to the hoof wall. In Figure 70 it is obvious that the v-shaped grooves are not creating a 90 degree edge, in the long term this pattern will result in more slips and an increase in lameness.

Figure 69. Concrete grooves on flooring

Note: Grooves cut into the concrete in the direction of the alley.

Figure 70. A deep groove pattern provides the best traction for cows

Figure 71. Grooves made by a bull float will never provide as sharp of an edge

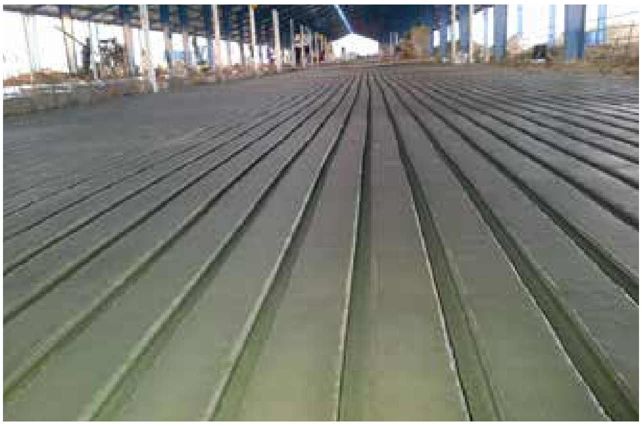


Figure 72. V-shaped groove patterns should be avoided as they result in more slips and an increase in lameness

A good quality finished floor is essential for the long term success of the facility and experienced dairy construction personnel should be employed to deliver it. The flooring surface must be flat rather than convex between the grooves, and the edges must be smooth, with little or no aggregate exposure. Floating and stamping are time sensitive and must be done when the concrete is not too wet (grooves tend to fill in, concrete sticks to stamp), or too dry (poor penetration and shallow grooves with aggregate exposure and bulging between grooves). Before the cows are exposed to the concrete, it may be necessary to grind the floor to smooth off the finished surface, removing all sharp and broken edges. While groove floating wet concrete is cheaper, some producers choose to cut grooves in formed dry concrete. This would be desirable when experienced concrete finishers are not available.

Figure 73. A typical float used to groove wet concrete

The compressibility of the floor, independent of roughness, reduces the risk for slippage. Animals walking on rubber have been shown to slip less, take longer fewer strides and increase the speed of walking, compared to walking on concrete. For this reason, it has been commonplace for grooved or textured rubber flooring to be used to facilitate the movement of cows between pens and the milking facility.

Grooved or textured rubber floor surfaces could be provided in the following locations:

- Cow transfer lanes – especially where cows are walking significant distances to the milking facility.
- Holding areas – where cows are forced to stand for an hour or more.
- Dairy exit or return lanes – where excessive slopes >2% may enhance wear.
- Dairy platforms and exit areas from rotary dairies – where cows make sharp turns.
- Cow and stall alleys – to provide the cow a comfortable surface for standing while eating and to facilitate cow flow from large pens or crossovers.

Sick cows

It is advantageous to provide a separate **'hospital or sick cow pen'** where cows can be hospitalised for treatment and recovery, ensuring that milk with antibiotic residues is diverted from the milk vat.

Where sick cows are kept separate from fresh cows, the hospital pen should be sized to accommodate 1.5 to 2% of the herd size. The pen could be a loose housed deep litter pack or a freestall with a two-row design fitted with 750mm wide headlocks and:

1. Have a separate water trough used only by the sick cow group to reduce the risk of spreading faecal/oral pathogens, and must be cleaned out daily.
2. Be located on the end of the alley manure removal system to avoid moving sick cow manure through healthy cow pens.
3. Be adjacent to a storage area for easy access to medicines, and a handling chute for the easy administration of treatment.

It is becoming increasingly clear that herds need a separate management plan for lame cows and a lame cow recovery pen is recommended, in addition to the traditional hospital pen. The **lame cow pen** should have a deep litter pack where treated cows can be housed in a low stress environment in which they can recover – milked no more than twice a day. Ideally, this pen should be located immediately adjacent to the dairy to minimise the distance walked at milking time and sized to match the expected population of lame cows in the herd.

Transition cow and maternity area management

Successful housing and management of the cow during the transition period defined as the time from 21 days before to 21 days after calving is critical to the overall success of the dairy herd. The transition cow facility impacts the lactations of all of the cows in the herd, thus its design and layout warrant particular emphasis in overall facility planning.

The transition area should be designed around five basic design principles:

1. 750mm of feeding table space per cow for the period 21 days before and after calving to ensure that all cows can eat at the same time.
2. Deep litter packs sized to accommodate the size of the cows using them or a comfortable, dry bedded area to ensure that non-lame and lame cows have a comfortable place to rest and rise without hindrance.
3. At least one stall per cow (or at least 10m^2 of bedded area per cow) to ensure that transition cows do not have to compete for a place to rest.
4. Minimise regrouping stress within the critical period 2–7 days before calving to avoid any risk for a precipitous drop in dry matter intake during the crucial stage of gestation.
5. A quiet place to calve, with limited disturbance from humans and other cows, to ensure as natural a birth as possible with a lowered risk for difficult labour and stillbirth.

Cows should be provided with a dedicated area to calve – referred to as the calving or maternity pen. As cows managed outdoors enter the first stage of labour, they tend to seek isolation from the rest of the group, presumably as a defence against predators and to promote bonding between the dam and offspring, and this same type of behaviour has been observed in housed cattle. Efforts should be made to design calving accommodation to allow cows to express these natural behaviours.

Locate the maternity area in a quiet area of the farm, free from busy animal and human traffic, close to the dry cow housing or pasture area, and provide cows the ability to isolate themselves from their herd mates at the point of calving.

- Calving pens may be designed as individual pens or group pens, with the provision of sufficient bedded space (14m^2 per cow).
- Cows show a preference for straw bedding in the calving area.
- Isolation may be achieved by providing a solid wall within the pen to allow cows to rest against, or individual areas with solid partitions.

Depending on the herd size, there are a variety of approaches to managing the dry cow and maternity area.

Where herd size is less than 250 cows and where 24-hour monitoring of the maternity area cannot be assured, group maternity pen management is preferred.

- A duration of stay of around 7 days or more – avoid the stress of regrouping within the critical period 2–7 days before calving.
- Prior to being moved to the maternity pen in this system, cows may be managed in one or two groups of dry cows.
- These dry cow groups are often referred to as the close-up group within 21–30 days of calving and far-off groups for cows between dry off and 21–30 days before calving.

The maternity pen should be sized to accommodate at least 1.4 times the average daily calving rate of cattle for the calving period, to ensure sufficient space is provided at peak calving rates. The area is designed as for all loose housing, with the addition of a handling area to manage cows requiring assistance.

The system described for smaller herds maybe used as herd size increases, but the bedded area tends to become too large and time consuming to manage effectively, and other options for management become available as the possibility of 24-hour monitoring of calving cows presents.

One approach is a switch to 'just-in-time' calving in larger herds; where cows are moved at the point of calving to an individual maternity pen to deliver the calf, and the duration of stay in the pen is reduced to a few hours.

- Each individual maternity pen typically measures at least 3,700 x 3,700mm, and the pens are designed for ease of cleaning, with folding gates.
- The required number of calving pens is 1.5 times the average daily rate of calving for the calving period.
- In order to reduce the risk for dystocia (a slow or difficult labour or birth), it is essential that the move to the maternity pen be short and stress free, for the cow and for the handler.

Cows should be moved when the calf is in the pelvis and the feet are showing at the vulva. Moving cows too early will result in a delay in parturition. This approach requires sufficient staffing for round the clock supervision of the calving area, which may not be possible when there are staff shortages and wage rates are high.

Prior to being moved into the maternity pen for calving, dry cows in larger herds are typically managed in two main groups: a close-up group and a far dry cow group.

In these larger herds, these groups are typically managed in dairy dry lots, loose-housing or freestalls and fed separate dedicated rations. Close-up pens maybe sub-divided by parity – housing the heifers separate from the older cows. Since the close-up pen is susceptible to overstocking during periods of intense calving, it is recommended that it be sized to 1.4 times the average daily calving rate of cattle for the calving period, while the far dry group is sized at 1.2 times the average daily calving rate of cattle for the calving period.

When freestall housing is used for the housing of close-up cows, 2-row pens are preferred to optimise feed accessibility, with the head to tail layout having the advantage that the cows can be checked for signs of calving from just the feed alley side of the pen, rather than having to walk around the entire pen. The maternity pens should be located immediately adjacent to the close-up pen to facilitate ease of movement between the pens.

One alternative approach to transition housing and management is the 'all-in, all-out' approach, which utilises a series of loose housing pens, sized to accommodate one week of calvings (Figure 74).

Figure 74. An all-in all-out facility for close up dry cow – three separate pens sized to fit one week of calvings

- Cows typically enter the pen 21–30 days before calving from the far dry group and remain in a socially stable group for the entire close-up period.
- Each week, a new group is formed in a separate pen. Eventually, the cows calve out and the pen is emptied and cleaned out ready for the next group of cows to enter.

Cows are moved from far off to close up pens once per week, to reduce the periods of regrouping stress. A drovers' lane facilitates movement between pens in transition cow facilities, with gates located in pens to facilitate single person movement.

Handling areas

Ease of handling cattle is an essential component of any contained dairy operation. Specific handling areas required include a dedicated treatment area, area for hoof-trimming and a truck loading area. Other routine tasks such as vaccination and routine veterinary checks may be performed at the feeding table if headlocks are used, or in a palpation rail.

Wherever cattle need to enter a narrow lane or chute system, a redirection pen or 'Bud Box' is ideal (Figure 75). This concept works on the basis that cows like to return from the direction that they came from, and this eases movement. The box is typically 3,700–4,300mm wide and 6,000mm long for around 5 cows to be handled at a time. Cows enter the box through a gate which is then closed, and the chute access lane is opened. A correctly positioned handler then turns the cows around and they willingly enter the lane.

Footbaths

The footbath is an essential component of infectious hoof disease control in herds at risk from digital dermatitis and foot rot (Figure 75).

Footbaths should be located:

- For use when cows exit the dairy or milking robot
- So cows can be diverted around it when it is not required.

Commonly, the bath is in the dairy exit lanes or on one side of a cow transfer lane. It is essential that the bath be in a long straight lane so that cows can follow each other through the bath.

Design footbaths so that each cow walks through the bath and that each limb is immersed at least twice – this ensures good contact with the chemical. Footbaths that are 3–4m long meet this recommendation, whatever the width chosen.

- To reduce bath volume to around 200 litres, one method would be to limit the width of the bath to 500–600mm at the base and the side walls slope outward to 1m wide to accommodate the girth of the cow at 1m height.
- The step-in kerb should be 250mm to retain solution and short stride the cow as she enters, and the bath should be filled to 100mm depth.

In larger farms with faster dairy throughputs, multiple long narrow baths can be built in parallel, or alternatively, a single wider footbath that can accommodate many cattle at a faster rate can be used (Figure 76).

Figure 75. Cow handling area with a footbath

Note: Footbath on the right, and a chute area adjacent to a redirection pen or 'Bud Box' on the left. Cows enter from the far end and the gate is closed behind them. The gate to the race is then opened and the cows are redirected.

Figure 76. Two long, narrow footbaths with high side walls in use on a large dairy herd

For easy emptying and mixing, ensure that the footbath has a drain point 75 to 100mm diameter.

> Since footbath chemicals are dangerous to handle, staff must comply with Safety Data Sheets (SDS) when handling, mixing, emptying and disposal of footbath solution.

Ventilation and cooling

Ventilation is the provision of fresh air into a building space to displace heat, moisture, noxious gases and airborne dust and microorganisms. Good ventilation is essential for good respiratory health in cows. In a dairy complex, ventilation may be provided naturally or mechanically using positive or negative pressure fan systems.

In hot climates, dairy cows are impacted by heat stress through several pathophysiological and behavioural pathways, resulting in reduced milk production, infertility and poor health.

- The impact of heat stress becomes apparent at a Temperature Humidity Index of around 68, which under typical relative humidity occurs at an ambient temperature of 21–24°C.
- To combat heat stress, cooling measures are required in addition to ventilation to maintain health and productivity.
- These measures require the use of recirculation fans within the facilities and use of water, either to cool the air reaching the cow, or to soak the cow directly using soakers mounted along the feeding table.

Cows lie down less under conditions of heat stress and engage in bunching activity – where cattle group away from end and side walls of the facility in an effort to avoid direct sunlight. These behavioural changes occur despite the implementation of commonly available heat abatement measures such as feeding table water sprinklers. However, the loss in lying time can be lessened by the provision of fast-moving air, making the addition of fans over the resting areas of the facility a priority in both natural and mechanically ventilated systems.

The final choice for ventilation system will depend upon:

- The climate where the facility is situated
- The size of the facility, the available building space and aesthetics
- Management considerations unique to the farm's situation (i.e. birds, biting flies, dust, etc.)
- Producer comfort with fan maintenance requirements
- Build cost/economics.

It is prudent to consider the costs of installation and operating costs of any given contained housing facility with different systems for different locations under varied climatic conditions.

Figure 77. A naturally ventilated freestall with two-row head-to-head stalls

Note: the high open side walls and fans located over the resting area.

To achieve the minimum cooling air speed required in the resting microenvironment where the cows are lying down:

- Locate fans over the resting surface.
- Position fans to create air moving at 1–2m per second measured at 0.5m above the resting surface (Figure 77).
- Locate panel fans with 900 to 1,400mm diameter at a height of 2.5m, spaced at intervals of 7.5 to 9.1m, angled to direct the air down below the adjacent fan.
- Larger fans may be spaced further apart provided that they achieve the target air speed.

High volume, low speed (HVLS) 'helicopter' fans move large volumes of air, but at lower speeds than desired, and they are generally not suitable for contained housing facilities.

Figure 78. Fans over freestalls and the feeding table

Based upon local climate and a desire for cost-effectiveness, natural ventilation continues to most commonly be adopted for contained housing facilities. Natural ventilation systems require:

- An open ridge or vented ridge
- Side wall openings that can be managed between seasons to optimise air flow into the facility
- An adequate interior roof slope to facilitate the flow of air toward the ridge opening.

Other design specifications are included in Table 19.

Air flows toward the ridge opening as a result of thermal buoyancy as the animals within the facility heat the air, and as a result of the negative pressure created at the ridge opening by the flow of air over the top of the ridge. This 'chimney effect' is sufficient to ventilate the facility in cold and moderate climates. In hot climates however, natural ventilation at higher air exchange rates is dependent upon orienting the facility favourably to prevailing winds, so that the longest axis of the facility captures the wind. There is a limit though as a significant departure from an east-west orientation would expose any west or even south-west facing row to the afternoon sun.

It is also essential that there are no physical obstructions to the wind within 30m or more of the facility.

Close proximity of nearby structures on the prevailing wind side of a natural ventilated facility are a potential problem for the optimisation of natural ventilation as they may cause a wind shadow effect (a phenomenon where airflow is disturbed downwind of an obstruction, such as a build, tree, silo or hill).

Even when these design parameters are met, the high air exchange rates required under hot weather conditions are not met in a naturally ventilated facility when the wind does not blow. Therefore, when the facility site is compromised (i.e. existing obstructions to wind, existing site slopes/elevation changes), and/or under climatic conditions of intense heat and high humidity, this may not be the preferred option and mechanical ventilation may provide a more effective solution.

Mechanically ventilated facilities employ fans to remove heat and humidity from the facility more effectively and reliably than can be done in naturally ventilated facilities. Aim for:

- Air exchange targets of 40 to 60 air changes per hour (ACH)
- At least 2,550m^3 per hour per adult cow.

In hot humid regions this maximum ventilation rate may not be adequate due to the moisture holding capacity of the air. In hot humid regions, the ventilation system design must be adapted based on:

- Cow body weight
- Building type
- Inlet and exhaust area
- Local power availability
- Analysis of local climatic conditions.

Negative pressure mechanical exhaust systems can be configured in two ways:

- Tunnel design – where the air moves in the same direction as the feeding table
- Cross ventilated design – where the air moves perpendicular to the feeding table.

Since air will always follow the path of least resistance and flow over the top and around the cow occupied area, these systems still require the use of fans over the resting area to achieve minimum cooling air speed of 1–2m per second in the resting microenvironment with one exception – fans over the lying area in a cross-ventilation design may be replaced with solid baffle curtains.

Baffles suspended from the ceiling force the air down into the resting space without the use of supplemental fans and are designed with cross-sectional air speeds of 2–3m per second beneath the baffle (Figure 79). The height of the baffle is dependent on the number of baffles used, airflow characteristics in the facility, and target static pressure, but they are usually located 2,400–3,500mm above the stall kerb. These baffle systems have an operating cost advantage since they use fewer fans. In cooler weather, the curtain baffles may be raised, thereby preventing them trapping air within the facility at low airspeeds.

Figure 79. Cross ventilation system with curtain baffles to direct fast-moving air into the resting area

In hot climates, water may be used to provide supplemental cooling. Consider:

- Water may be used to cool the air in low humidity conditions.
- Cross ventilated facilities are well suited to evaporative cooling pads.
- Position cooling pads along the inlet side of the facility.
- If water is hard or contains large concentrations of minerals, if left untreated, then evaporative pad's life is shortened – replace every 3 to 5 years.
- Pads are generally not used in a tunnel contained housing due to pad area along the sidewalls but still an option.
- High pressure fogging systems are an alternative method of cooling the air leaving a fan under conditions up to 60% relative humidity. Once relative humidity exceeds 70% for a significant proportion of the heat stress period, direct application of water to the cow through sprinkler systems above the feeding table is the predominant method used to help cool the cow.

Table 19. Main design characteristics for each of the main ventilation options

	Natural ventilation	Tunnel	Cross – baffle	Cross – fans
Basic description	Open ridge and eave/side walls with fans over the stalls or bedding	Negative pressure with air exhausted at one end of the facility and designed inlets at the opposite end with air movement parallel to the feed alley. Fans located over stalls or bedding	Negative pressure with air exhausted along one side of the facility with inlets along the opposite side with air movement perpendicular to the feed alley. Baffles over the stalls or bedding	Negative pressure with air exhausted along one side of the facility with inlets along the opposite side with air movement perpendicular to the feed alley. Fans located over stalls or bedding
Ridge	Open (target 50mm per 3m of building width)	Closed	Closed (optional cupola fan system for winter)	Closed (optional cupola fan system for winter)
Side wall height	3,000–5,000mm	3,000–4,000mm	4,000–5,000mm	4,000–5,000mm
Roof slope	14–19-degree slope	19-degree slope (may have a flat false ceiling internally)	2–5-degree slope	2–5-degree slope
Cold climate ventilation (less than 5.6°C)	Managed eave opening and open ridge with chimney effect	Fan exhaust set at 4-8 air changes per hour (ACH)	Fan exhaust set at 4-8 ACH	Fan exhaust set at 4-8 ACH
Hot climate ventilation (greater than 20°C)*	Open side walls exposed to wind	Fan exhaust set at around 40-50 ACH and a minimum of 2,500m^3 per cow	Fan exhaust set at ~ 50-60 ACH , minimum 2,500m^3 per cow and air speed below the baffle of 2-3m/s	Fan exhaust set at around 50–60 ACH , minimum 2,500m^3 per cow
Achieving target air speed in the cow resting area	Fans over stalls or bedding	Fans over stalls or bedding	Baffle set at 2,400-3,500mm above stall platform or bedding	Fans over stalls or bedding
Side wall curtains	Yes	No	No	No
Additional cow cooling options	Sprinklers above feeding table or pen sprinklers, high pressure fogging	Sprinklers above feeding table or pen sprinklers, high pressure fogging	Evaporative cooling pads at inlet, sometimes sprinklers above feeding table	Evaporative cooling pads at inlet, sometimes sprinklers above feeding table
Main challenges	Low ventilation rates on still air days and wind shadows from adjacent obstructions to air flow	Air movement and distribution at low ventilation rates.	Air trapped by baffles and unpredictable air movement and distribution at low ventilation rates	Minimal

**Note: In very hot and humid regions, these exhaust specifications may need to be exceeded to ensure optimal ventilation.*

Sprinkler systems

Sprinklers have been installed in holding areas, milking facilities and exit lanes and above the feeding table or stalls because thoroughly wetting the cow improves evaporative heat loss. Controller units can be installed to change soaking times and intervals at different ambient temperatures.

Soaking in the stalls along the feeding table may be problematic. The additional water in the cow alley causes wet manure to be transferred to the freestall bedding, increasing the risk of mastitis. In sand bedded facilities, the extra water leads to sand settling in transfer channels and collecting pits, which leads to pumping problems. Also, water is wasted when cows are not at the feeding table (up to 19 hours per day in some instances).

Feeding table systems fitted with optic sensors can reduce water use with nozzles activated by the presence of a cow beneath them.

Low-pressure sprinklers (15 to 20 psi, 103 to 138 kPa, or 1 to 1.4 bar) may be used along the feeding table. These can be set to deliver 1.1 litres of water per square meter of wetted area per sprinkler per cycle above temperatures of 21 degrees celsius. The wetted area in stalls should be set to cover an area of 1.8 to 2.4m behind the feed line, and the water supply should be sized to provide the necessary flow rate of water.

Wetting cycles with sprinklers on for 0.4 to 0.5 minutes every 12 to 15 minutes are recommended for temperatures between 21 and 24 degrees celsius. During periods of severe heat stress, sprinklers should be on for 0.4 to 0.5 minutes every 6 to 10 minutes.

The nozzles on the water line are typically suspended 15 to 30cm above the top of the headlocks or post and rail type barrier, 1.5 to 1.8m above the cow alley, and 30 to 46cm behind the feeding table. The nozzles used should spray water in a 180-degree arc, and they should be spaced according to their spray diameter, which is usually 1.8 to 2.4m. Avoid the use of nozzles that create fine mists. Droplets need to be large to penetrate the hair coat and wet the skin of the cow. Always check the alignment of the nozzles to make sure that the water is actually landing on the cows' backs, and use nozzles with check valves to prevent the distribution line from draining after each cycle.

Lighting requirements

In contained housing facilities, the number of hours of light and darkness per day can be managed.

Long day lighting aims to deliver a constant, 16 to 18h period of light and 6 to 8h period of darkness (18L:6D) for lactating cows. For three times a day milking herds, milking intervals must allow for a minimum of 6 hours of uninterrupted darkness between two of the milkings.

Target light intensity for long day lighting is 160 to 215 lux of uniform illumination at a level of 0.9m above the resting surface. Lights should be cleaned on a routine basis to have maximum effect.

For low ceiling buildings, LED or fluorescent lighting is preferred while for higher ceilings, LED or metal halide lamps may be a better choice. Lighting design should be discussed with the electrician to ensure that the desired illumination is achieved.

For cow movement and observation during the 'dark' periods of the day, dim red lights (~15W) at 6 to 9m intervals may be used as this will not be perceived by the cow as 'light'.

In contrast to lactating cows, dry cows are responsive to short day lighting. Implementing a photoperiod of 6L:18D in practice has been difficult to achieve on farms.

Building materials and specifications (minimum suggested requirements)

Material suppliers should be able to provide certification of materials being used for a project. The materials should meet the applicable Australian Standards.

Concrete

Companies supplying concrete should comply and guarantee that the concrete product meets the required standards – refer to AS1379 – *Specification and Supply of Concrete.*

The actual concrete strength, type and thickness required will depend on the type and strength of the sub-base and base materials, and the proposed animal and vehicle loadings. Please keep in mind that larger farms use larger equipment for feed delivery, bedding delivery, manure removal, etc., so thicker concrete may be required. In some instances it may be advisable to have a structural engineer provide a design for concrete pavements.

Recommended minimum concrete details	
Concrete strengths	
N = normal class concrete, 20 is the amount of compressive strength measured in megapascal (Mpa).	
Footings	N20 concrete
Pedestrian traffic	N25 concrete
Cow and vehicle traffic	N32 concrete
Concrete thickness for alleys	
Feed and cow alley	100 to 125mm
Drive alley	150mm or greater
Reinforcement	
Footings	As per engineering design
Pedestrian areas	SL72 reinforcing mesh in the top (30mm cover)
Feed and cow alley	SL82 reinforcing mesh in the top (30mm cover)
Vehicle traffic/ Drive alleys	SL82 reinforcing mesh in the top (30mm cover)

Construction joints

Alley design should incorporate construction, expansion and contraction joints. Generally, they should be placed in regular grid intervals approximately matching the widths of the sections but suggest no more than 4,000 to 5,000mm apart.

All construction joint types should be designed in advance of construction.

- Joints to be placed to suit the layout.
- Joints to be designed and placed for movement, shrinkage, expansion and loadings on the concrete.
- Joints to be placed at the end of each pour or for any unplanned breaks in concrete pours.
- Joints are provided to minimise unplanned cracking of the concrete slab.

Many proprietary joint systems are available to form construction joints such as dowel bars, diamond dowels and plate or key joint systems. A structural engineer should provide joint details with the design for concrete pavements.

On concrete areas for cow traffic, care should be taken to seal all joints to prevent manure and recycled effluent from entering the joints and corroding the reinforcing steel. This material is highly corrosive and can quickly cause problems.

Steel

A structural engineer should be contacted for the design for any steel structures, including contained housing facilities and dairy buildings. Note that most councils will require structural certification and plans of all buildings to accompany planning permit applications.

Tube steel products used for structural applications should be fully compliant to AS1163 – *Structural Steel Hollow Sections*. All other structural steel should meet AS/NZS 3679 – *Hot Rolled Bars and Sections.*

It is recommended to install hot-dip galvanised steel wherever possible. Manure and water with high mineral content can cause corrosion issues very quickly. In loose housing facilities, it is advisable to encase steel posts in concrete and PVC sleeves up to a height of 1000 to 1500mm above ground to protect the steel from corrosion due to exposure to urine, manure and gases (Figure 80).

The Australian steel market has non-structural steel sections available for non-structural, general purpose and light duty applications. These products may not meet the above standards for structural construction.

Post, rail and cable minimum suggested specifications

**NB refers to 'nominal bore of the pipe', medium refers to the wall thickness of the pipe.*

Drive alley, stall or gate posts	80 *NB medium galvanised pipe
Intermediate posts	65 NB medium galvanised pipe
Post footings	N20, 300mm diameter x 600mm deep
Top rails	50 NB medium galvanised pipe
Intermediate rails	25 to 32 NB medium galvanised pipe
Cables	12–15mm galvanised cable (either fibre or steel core)

Reinforcement

All reinforcement products should comply with AS/NZS 4671 – *Steel Reinforcing Materials.* Reinforcing Products should be certified by the Australian Certification Authority for Reinforcing Steel.

Figure 80. Posts encased in PVC and concrete protect the steel from corrosion

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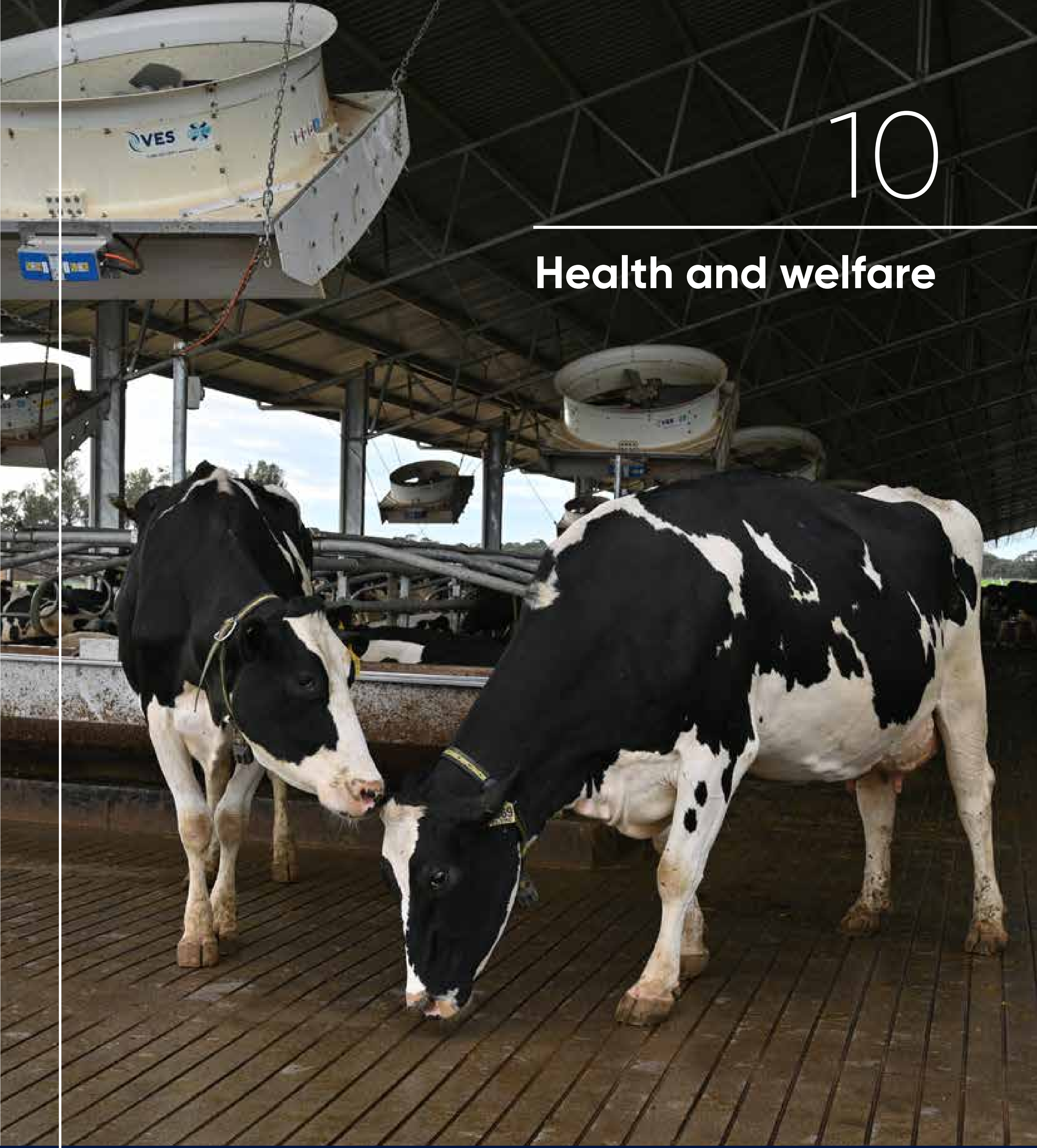

10

Health and welfare

Introduction

When dairy producers transition their animals from a grazing system to contained housing systems, their animals may face a wide variety of health and welfare-related challenges. It is the producers role to design and manage their facility to prevent these challenges. High levels of performance can be achieved while maintaining good standards of welfare in housed dairy cattle systems. Management is the key to success in any system and poor animal welfare is not an inevitable consequence of housing. If poorly managed, any dairy production system can result in significant health and welfare issues.

10.1 Defining cattle welfare

The Australian livestock industry is committed to the 'Five Domains of Animal Welfare'. The Five Domains of Animal Welfare is an internationally recognised standard for optimal animal health and welfare. It provides a means of evaluating the welfare of an animal, or group of animals, with a strong focus on mental wellbeing and positive experiences.

The model reinforces the message that meeting the emotional needs of an animal is just as important as its physical needs, and for animals to be truly looked after, they need to be provided with positive experiences and encouraged to express behaviours that are rewarding.

The Five Domains Model considers both negative and positive aspects of:

- Nutrition
- Physical environment
- Health
- Behavioural interactions
- Mental state.

Experiences within the four functional domains: nutrition, physical environment, health and behavioural interactions, all contribute to an animals mental state. The concept embraces the provision of positive experiences and desirable outcomes to determine the overall welfare state, rather than simply focusing upon limiting animal exposure to negative experiences.

Regulation of dairy cow welfare in Australia

In Australia, state and territory governments are responsible for regulating animal welfare.

Australian Animal Welfare Standards and Guidelines for Cattle (the Standards and Guidelines) (AHA, 2016) are an important initiative intended to guide the development of nationally consistent welfare legislation to enhance animal welfare arrangements across Australia. They were developed at a national level under the Australian Animal Welfare Strategy by the relevant sector, state and federal governments, interest groups, animal welfare experts and researchers and included public consultation.

The Standards and Guidelines have been endorsed by Australian Dairy Farmers (ADF) and all state and territory governments and are being regulated into law by most state and territory governments. However, the degree to which they are implemented in legislation varies (Australian Animal Welfare Standards and Guidelines, 2020). Standards are intended as mandatory requirements, whereas guidelines are intended as voluntary, better practice recommendations.

The standard for facilities and equipment requires that:

S4.1 A person in charge must take reasonable actions in the construction, maintenance and operation of facilities and equipment to ensure the welfare of cattle.

Specific guidelines for housed cattle recommend that:

G4.7 Housed systems should have hospital pens with a comfortable lying surface for sick or injured cattle, and the means to move downer cows to the hospital pen.

G4.8 A normal diurnal pattern of lighting should be provided for indoor cattle.

G4.9 Cattle should have the opportunity for appropriate exercise each day.

G4.10 Air should be of acceptable quality with respect to dust, chemicals and smells. Continuous periods of detectable smoke should be avoided.

G4.11 Concrete flooring in rest areas should be covered by an appropriate depth of bedding material.

G4.12 Fire alarms and adequate firefighting equipment should be fitted and maintained in all indoor housing systems.

Policy direction on animal health and welfare for the Australian dairy sector is set by the Australian Dairy Farmers' Animal Health and Welfare Policy Advisory Group (PAG), which has producer representatives from each state dairy producer organisation. Some recent policies directed by the PAG include:

- Phase-out of calving induction by 2022.
- Provision of pain relief for all calves during disbudding, which must occur under the age of 2 months.
- No euthanasia of calves by blunt force trauma.
- No tail docking.

The Australian Dairy Sustainability Framework, owned by the Australian Dairy Industry Council (producer and processor peak bodies), uses these policies to set targets for the sector, and reports on industry progress against the targets every year. These targets can change over time to reflect evolving practices and attitudes.

In addition, dairy processors often include animal welfare and biosecurity requirements in their quality assurance programs.

10.2 Benefits and challenges of housing systems

Cows do not always prefer to be outside, suggesting that there are elements of housing that are attractive to the cow, and not all aspects of natural living are desirable or 'missed' by the cow when they are housed. When dairy cattle are given a choice between grazing and contained housing facilities, they tend to choose pasture during the night time, and housing during the daytime.

Poor weather and higher levels of milk production lead cows to increase the use of housing and even when the housing facilities are made less desirable by overstocking, cows continue to exhibit the same preference for housing during the day, suggesting that the use of housing at this time is desirable.

Proper nutrition, health, shelter from the weather and protection from predation are important aspects of animal welfare, and these issues can all present as challenges in grazing systems. These challenges may be lessened using containment. Housing provides additional benefits to cows, which include:

- Provision of bedding to keep cattle clean and comfortable (Figure 81).
- Management of separate groups of cattle and manipulation of the nutrients in the feed delivered to those groups.
- Protection from inclement weather, providing shelter from heat as well as from wet, cold, windy conditions.
- Reduced walking distance, and therefore time off feed for cows that are contained close to the dairy, compared to some farms where there may be significant walking times to and from the dairy.

Figure 81. Cow on soft bedding

Specific welfare challenges of housing

Housing can be designed to allow cows to exhibit a broad repertoire of important natural behaviours, and tackle the specific risks faced by cows on feedpads or in containment housing systems.

Multiple features of housing may have the potential for negative impacts on welfare. These include increases in risk for:

- Lameness
- Mastitis
- Metabolic diseases such as ketosis
- Pneumonia
- Injury
- Some infectious agents that spread via faecal-oral contamination, such as salmonellosis Johne's Disease.

Behavioural impacts principally lead to a failure to permit cows to rest when they wish to, for as long as they need. Housing systems may be designed to mitigate the risk of these conditions. Very high standards of health and performance can be achieved, and resting behaviour optimised. Table 20 summarises these approaches which are covered in detail in *Chapter 9*.

Other aspects of welfare potentially impacted by housing are, most notably, the absence of outdoor access and lack of grazing in contained housing facilities such as loose housing and freestalls. The ability to exhibit natural behaviour is an important component of animal welfare and an important societal expectation. Despite evidence that cows find aspects of housing attractive, society may continue to hold a bias against containment housing management.

Housing reduces the space available to the cow compared to a grazing system, creating more barriers to movement as well as ability to rest properly. This may elevate the risk for negative welfare consequences of poor animal handling in these situations, with greater potential for cows to experience fear, and to slip, fall and collide with fittings.

Training the farm team in low stress handling techniques and the provision of purpose-built handing areas for cow treatment is essential for the promotion of good animal welfare.

Table 20. Features of contained housing infrastructure – animal welfare risks

Feature	Risk	Potential consequence	Mitigation of risk
Lack of outside access	May not meet societal expectations for grazing animals	Loss of social licence	Permitting managed periods of outside access in exercise lots
	Low roughage diets may not allow expression of an internal motivation to obtain feed	Thwarted motivation – consequences unknown	Proper ration formulation and adequate provision of fibre coupled with access to feed
Poorly designed resting area	Uncomfortable resting behaviour and inappropriate lying behaviours (e.g. lying in alleyways)	Lameness, mastitis, injury (hocks, knees, neck, back, etc.)	Provision of an appropriately designed resting area with a soft bedded surface
Overstocking and inadequate access to a resting space	Reduction in lying time in subordinate cattle	Lameness (claw horn lesions)	Provision of one usable resting space per cow
Unsuitable flooring	Hoof damage from traumatic or abrasive concrete flooring	Lameness (claw horn lesions)	Proper flooring finishes and targeted use of soft rubber flooring, coupled with low stress animal handling
	Slips and falls on slippery flooring	Injury	
Poor hygiene	Close proximity to manure in alleyways and on resting surfaces	Lameness (infectious causes), mastitis (environmental causes)	Well-designed resting areas, appropriate bedding management and regular manure scraping of alleys
	Exposure to faecal-oral spread pathogens	Salmonella, Johne's disease	
Lack of access to feed	Lowered Dry Matter Intake (DMI) and altered feeding behaviour	Elevated risk for ketosis, sub-acute ruminal acidosis (SARA), retained placenta and metritis. Reduced fertility.	Provision of sufficient bunk space for all of the cows to eat simultaneously and adoption of strategies to optimise feed access such as targeted frequent feed push up
Regrouping (the act of mixing one or more cows together from different groups)	Reduced feeding and lying activity immediately after regrouping, increased social stress and fighting	Elevated risk for metabolic disease and injury	Minimise the frequency of movement of cattle between groups, especially during the transition period
Inadequate ventilation and cooling	Poor air quality and build-up of noxious gases and airborne pathogens	Respiratory disease	Ventilation design to ensure a minimum air exchange rate of 4 air changes per hour in cold weather
	Increase in core body temperature	Heat stress and associated impacts on immune function, gut health and fertility	Provision of shade and drinking water. Ventilation designs to ensure air exchange rates of 40-60 air changes per hour in hot weather coupled with air speeds of 1-2 m/s at resting height, with additional use of water to directly cool the cow or the air around the cow (Chapter 7 Facility Design and Management)
	Abnormal behaviours – increased standing and bunching in groups	Lameness (claw horn lesions)	Provision of adequate air speed and air exchange rates
Potential for increased milking frequency from two times a day to three or more times a day	Increased time spent milking may impact the time available for resting and feeding when prolonged	Lameness (claw horn lesions)	Ensure that time out of the housing facility during milking is no more than 3-3.5 h/d by correctly sizing milking facilities and group sizes
Poor animal handling	Injury and a negative mental state	Injury and gross animal abuse	Proper training of all farm personnel in appropriate handling methods and provision of correctly designed animal handling areas

10.3 Nutrition, environment and behaviour

Nutrition

Provide ready access to fresh water and a diet to maintain full health and vigour to minimise thirst and hunger and enable eating to be a pleasurable experience.

Appropriate nutrient delivery requires the preparation of a balanced ration, suitable for the production level or growth rate of the cattle receiving it, and the provision of sufficient space to consume it. Stale feed and refused feed (refusals) must be frequently removed before fresh feed is added.

At pasture, peak grazing activity occurs around dawn and dusk, but in contained housing systems, group feeding activity is more closely related to milking time, fresh feed delivery and feed push up times. These relatively short, but critical periods of time, place significant pressure on feed space and usage.

High standards of animal welfare dictate that animals be given the opportunity to exhibit natural behaviours.

- Dairy cattle naturally exhibit behavioural synchrony: a tendency when one animal in a group exhibits a behaviour, for the rest of the group to exhibit a similar behaviour.
- Sufficient feed space should be provided to permit the entire group to eat simultaneously during these critical periods of feeding activity – a feed space allowance of 0.6–0.75m per cow, depending on the size of cattle is appropriate.

Greater feed space allowance has been demonstrated to have numerous beneficial behavioural and health related effects including:

- Reduced ration sorting and less variable nutrient intakes across individuals within a group
- Less altered feeding and rumination behaviour in subordinate cattle
- Less risk for elevated non-esterified fatty acids (NEFA) and signs of insulin resistance during the transition period
- Less metritis and ketosis and improved fertility.

Freestall designs with three rows of stalls preclude the ability for all of the cows to eat at the same time, but nonetheless high milk production has been reported from herds in such facilities. Milk production alone cannot be used as a justification for this practice as it is a poor measure of animal welfare, but performance does indicate that perhaps for some groups of cattle, management approaches such as well-timed feed delivery and regular feed push-up can help to offset some of the disadvantages of a lack of bunk space.

However, these approaches do not appear to mitigate the risk for poor post-partum health and performance when bunk space is compromised during the critical transition period from 21 days before to 21 days after calving. Provision of 0.75m of feed space throughout the transition period has become the industry standard recommendation in order to optimise health and productivity, and this space requirement necessitates use of freestall pens with two rows of stalls for these 'special needs' cows. Three-row pens are still in common use for other groups of cattle even though they lack sufficient feed space and excellent feed bunk management is required to mitigate the negative impacts of this design, as outlined above.

All cattle of all ages should be provided sufficient daily access to clean potable water to maintain hydration.

Regular water trough cleaning is recommended to remove contamination as it has been shown that cattle avoid water contaminated with relatively little manure.

See Chapters 6 Water Supply for cow water requirements and *9 Facility Design and Management* for recommendations for waterer design and location.

Sufficient space should be provide for cattle to move freely around alleyways to access feed and water (refer to *Chapter 9*).

Physical Environment

Provide shade/shelter or suitable housing, good air quality and comfortable resting areas to minimise discomfort and exposure and promote thermal, physical and other comforts.

In addition to adequate feeding and drinking space, a well-designed freestall or loose housing pen provides a comfortable, clean and dry place to rest, and appropriately sized alleyways to navigate around the pen without risk of injury from trauma and slipping. In addition, ventilation and cooling systems should be in place to limit extremes in facility temperature and humidity and maintain good air quality. Failure to provide these key elements will result in elevated risk of lameness, injury, respiratory disease, mastitis, and compromised resting behaviour.

Resting comfort

Dairy farm owners building a new facility must make choices about lying surface and bedding type. The surface, or base of the bed, may be earthen or concrete and, in freestalls they must choose between a deep loose bedded stall surface or a rubber mat or mattress (typically constructed of rubber crumbs, foam, air or water) surface with minimal bedding to absorb moisture. In deep litter or compost facilities, different bedding materials are accumulated over time to provide a comfortable resting area.

Some typical combinations of surface and bedding are:

- Dirt and dried manure – usually associated with formed earth feedpads or dry lots.
- Compost bedded pack – deep litter wood chips or dirt that is raked at least daily. A true compost bedded pack generates heat and requires a high degree of maintenance.
- Deep litter pack – a formed base constructed for drainage and covered with deep bedding usually with wood chips or dried manure that is topped up at intervals and may be raked but is not composted.
- Freestalls with deep, loose bedding, typically with sand, sawdust or recycled manure solid bedding.
- Freestalls with a concrete base overlaid with a mat or mattress and a shallow layer of sawdust or dried recycled manure solids to absorb moisture.

Deep bedding that 'gives' around the bony prominences of the hock region reduces pressure and friction and provides traction and support when the cow rises and lies down. While deep bedding has been shown to promote longer lying times in some studies, this has not been the case in every study, indicating that other aspects of stall design and bedding management are also important. Most importantly, deep bedding may make it easier for lame cows to rise and lie down and maintain a normal pattern of resting behaviour – avoiding the abnormally short and abnormally long lying times which may inhibit recovery.

The size of the stall, the divider design and the presence and position of neck rails also influence behaviour and health outcomes. Stalls should be appropriately sized to the animal using them, providing sufficient lying area and room to lunge while rising and lying.

In freestalls, deep, loose sand bedding is considered the gold standard for optimal animal welfare.

- Herds utilising mats or mattresses have been repeatedly shown to have a greater risk for hock injury and a higher prevalence of lameness compared to deep loose bedding with sand.
- Herds using sand report better udder health than those with organic bedding types.

When managing a bedded sand stall, it is important to maintain clean dry uncontaminated sand in the beds, so that it supports a lower bacterial population than organic types of bedding. Bedding material over mats and mattresses should ideally be removed and replaced daily to minimise bacterial growth and mastitis risk,

while fresh bedding should typically be added once or preferably twice weekly to deep loose bedded freestalls. Wet, contaminated bedding material is removed each milking and the beds levelled frequently in order to avoid the cows making dug out 'nests' which negatively impact lying times.

Bedding management for compost facilities is complex with fresh bedding added at a frequency that keeps cattle clean and maintains a healthy composting process (*see Chapter 9 Facility Design and Management*).

Thermal comfort

There is general agreement that the upper critical limit of the thermoneutral zone, at which cows begin to exhibit the signs and effects of heat stress, occurs at a Temperature Humidity Index (THI) of around 68. Under typical levels of relative humidity (20–90%) this limit can occur at ambient temperatures of 21–24ºC.

During periods of heat stress, when cattle experience conditions outside their thermoneutral zone.

Cows may stand in a group bunched together at one end of the pen.

Bunching behaviour appears to be an innate shade seeking response.

When contained in housing facilities, this behaviour leads cows to move to darker areas of the facility, away from the bright light entering the end and side walls, even if the darker area is not cooler.

Bunching can be prevented by improving cooling and maintaining an even light intensity across the whole pen. Similar behaviour may also result from fly worry and responds favourably to fly control if there are large stable fly populations.

Heat stress also results in a significant reduction in daily lying time of around 3–4 hours per day and physiological effects on milk production, gut health and immune function.

Providing shade and sufficient access to cool drinking water is imperative for the mitigation of heat stress. In feedpad and contained housing systems this requires the construction of shade structures under which cows may shelter. In contained housing systems, shade is provided by the roof of the facility, but additional cooling measures are required.

While many producers employ feed line water soakers to reduce heat stress, there is no evidence to suggest that soakers impact the reduction in lying time, but they do reduce the negative impacts on dry matter intake and milk production. Current approaches to lessen the behavioural changes observed involve the delivery of fast moving air directly into the resting microenvironment, with air speeds of 1–2m/s at 0.5m above the lying surface, through the use of fans directly over the stalls and having sufficient exhaust of air to remove the heat and humidity that accumulates within the facility.

Predictable exhaust is difficult to achieve in naturally ventilated facilities that rely on wind vectors for air turnover in hot climates. This has led to growing interest in the adoption of mechanically ventilated facilities typically configured in tunnel or wide-body cross ventilated floor-plans with the negative pressure generated by fan exhaust drawing fresh air into the facility through designed inlets. However, these facilities tend to be more enclosed and their perception is a challenge for the industry to overcome.

An even light intensity across the pen can be achieved by considering facility orientation to the sun at the planning stage and by using sidewall curtains, closed to 80% or shade blinds on the sunlit side of the facility – *see Chapter 9 Facility design and management.*

Dairy Australia's manual, *'Cool Cows: Strategies for managing heat stress in dairy cows'* provides practical advice on planning for and managing heat stress (Dairy Australia, 2019).

Walking and standing surface comfort

In contrast to grazing cattle, who stand on a soft earthen surface for most of the day, housed cattle must stand on concrete when they are not resting in a stall, which likely contributes to an increased risk for lameness. Cattle in loose housing facilities have the advantage that they may stand on a deep bedded surface rather than concrete between lying bouts.

Walking surfaces should not be excessively abrasive, slippery or continuously heavily contaminated with mud or manure. Surfaces may be compacted earth, gravel, concrete or artificial compounds (e.g. rubber coated concrete). Feedpad and laneway surfaces should be designed to shed water and not become excessively muddy or have sharp exposed gravel. Wood shavings or sawdust can be used on laneways to provide softer surfaces in frequently trafficked areas.

Non-slip rubber matting may prove useful in reducing hoof wear in frequently trafficked areas, where cattle may jostle for position (e.g. from the dairy yard to the feedpad). Stones on concrete floors may cause bruising and efforts should be made to remove them on a regular basis. New concrete and grooving are often very abrasive and may need to be abraded and cleaned prior to use.

Alleys and concrete yards need to be cleaned regularly so that cows are not continuously walking in slurry manure (urine and faeces) and mud. This predisposes to excessive hoof hydration, heel horn erosion, wear, infection and lameness. Hooves should be to dry out on a daily basis. Cows' hooves that are wet for extended periods of time become soft and more prone to wear and lameness.

Behavioural interactions

Provide sufficient space, proper facilities, congenial company and appropriately varied conditions to minimise threats and unpleasant restrictions on behaviour and promote engagement in rewarding activities.

Since cattle are social creatures operating within a complex social hierarchy, their natural behaviours need to be taken into consideration in developing approaches to housing and management at critical periods in their life and lactation cycle.

Management at the point of calving is one such period. As they enter the first stage of labour, all cows, whether grazing or housed, seek isolation from the rest of the group, presumably as a defence against predators, and to promote bonding between the dam and offspring. Efforts should be made to accommodate these natural behaviours in calving pen design. The calving area should avoid busy animal and human traffic and be close to the dry cow housing area. Individual or group calving pens may be used, and cows should be given the ability to isolate themselves from their herd mates.

Similarly, sick cows tend to lie down more and seek isolation from other cows within a group, so these animals should be provided a separate area with plentiful space to avoid having to compete for feed, water and a place to rest.

Grazing herds are commonly managed in one lactating cow group, but this is rare in housed dairy herds. As herds increase in size, it is common for dairy producers to manage multiple groups, frequently separating breeding or early lactation cows from pregnant or late lactation cows, necessitating a move between these groups once the cow becomes pregnant or passed peak milk production. Moving cows between groups creates a stressor on those that are moved as they must re-establish their social rank within the new group. For approximately 48 hours, elevated frequencies of agonistic interactions between the transferred cow and the other cows in the group are observed, which reduce feeding and lying times, and reduce milk production by around 3-5%. Lactating dairy cows can be managed in a stable pen for the majority of their lactation, but this approach necessitates adaptations to work routines, such as the requirement to breed cows in multiple pens rather than one or a few pens of cows. In housed dairy herds, it is commonplace to see first lactation cows housed in a separate pen from older cows, with the potential for benefits in health and performance as a result.

Regrouping stress, which occurs when cows from different groups are mixed together, may be of particular significance during the transition period. It is essential to optimize dry matter intake in early lactation, to minimise the negative energy balance that drives ketosis and other immune function related conditions such as metritis. A comfortable environment with adequate access to feed is essential. In addition, and especially as herds increase in size and start to group cattle separately, regrouping within the critical period 2-7 days prior to calving should be avoided.

Agonistic interactions between cows are apparent when they desire access to a resource that is limited. Access to a stall for rest is a common example in freestall housed herds. While the synchronisation of resting behaviour is less apparent in housed dairy cattle compared to grazing cattle, multiple studies confirm that stocking rates in excess of one cow per stall negatively impact lying times.

Health

Prevent or rapidly diagnose and treat disease and injury, and foster good muscle tone, posture and cardiorespiratory function to minimise breathlessness, nausea, pain and other aversive experiences and promote the pleasures of robustness, vigour, strength and well co-ordinated physical activity.

Housing systems elevate the risk for certain health conditions that producers must work to mitigate through design decisions and changes to management when transitioning from a grazing system. This section deals with the specific challenges of lameness and mastitis.

Lameness

Lameness is a significant animal welfare concern and the pain affects the ability of the cow to walk, eat, rest, reproduce, and remain in the herd. The majority of lameness in dairy cattle results from lesions of the foot with genetic, nutritional, hormonal, mechanical, infectious, and environmental factors contributing to their causation. Factors that are associated with lower lameness risk in housed systems include:

- Less time standing on concrete
- Provision of a comfortable place to rest
- Stalls with less restrictive neck rail locations and absence of stall lunge obstructions
- Access to pasture or an outside exercise lot

- Use of non-slip, non-traumatic flooring scraped of manure when the cows are outside the pen
- Use of a divided feed barrier and wider feed alleys
- Prompt recognition and treatment of lameness
- Preventive hoof-trimming and frequent foot bathing.

In addition to the resting area and flooring features and management already discussed, it is recommended that hoof trimming be practised to a high standard, with each cow being trimmed at around dry off and again 2–4 months after calving, and that an effective footbath program be implemented to control infectious hoof disease. Locomotion should be routinely evaluated so that lame cows may be separated and effectively treated as soon as possible. This task should be performed at least monthly and whenever cows may be observed moving between pens and the dairy.

Mastitis

The risk of clinical mastitis in housed systems is potentially elevated. The presence of a mastitis infection can create a painful udder which impacts welfare. Good udder health depends on a number of factors, including:

- Udder and teat-end conformation
- Genetics
- Environmental conditions
- Milking machine function
- Hygienic milking practices.

Housing may increase exposure of the teat end to environmental organisms between milkings, and efforts must be made to mitigate this risk.

The Australian Dairy industry best practice mastitis prevention monitoring and treatment approach 'Countdown' program is recommended to prevent new infections and control the spread of existing infections with contagious and environmental organisms. Prevention of infection with environmental pathogens such as coliforms (e.g. *E. coli*) and *Streptococcus uberis* requires the maintenance of excellent standards of hygiene, both in the housing environment, and in the dairy at milking time.

A clean, dry and comfortable place to rest must be always maintained through excellent design and good bedding management. In the dairy, in addition to pre-milking cleaning prior to milking unit attachment, the use of pre-milking teat disinfection may be necessary to reduce the bacterial load at the teat end.

Biosecurity

Farm biosecurity is a set of measures to protect a property from the entry and spread of pests and diseases which can pose an animal welfare risk.

All dairy producers should have an active biosecurity plan to help protect their own farm and the broader dairy industry from the spread of pests and diseases on and between farms. Biosecurity plans need to be tailored to the specific risks faced by the farm enterprise and region.

Contained housing systems have different biosecurity risks to grazed pasture systems, so biosecurity plans need to be updated when a housing/feeding system changes. For example:

- When silage is put through a mixer wagon the risk of botulism increases as cows are unable to avoid eating source material.
- Cows are in closer contact with their manure, increasing the risk of infections such as *Streptococcus uberis* mastitis and digital dermatitis.
- Closer containment of groups of cows may simplify the management of some diseases, such as Johne's disease which is predominantly spread when youngstock are exposed to the faeces of infected older animals.

There are a wide variety of tools available to assist with developing a biosecurity plan, including Dairy Australia and Agriculture Victoria's online dairy biosecurity tool.

Visit **dairyaustralia.com.au** and search for biosecurity.

Mental state

Provide safe, congenial and species-appropriate opportunities to have pleasurable experiences to promote various forms of comfort, pleasure, interest, confidence and a sense of control.

Numerous studies demonstrate that cattle experience pain and also have emotions such as happiness, frustration, fear and distress. As described in the introduction to this chapter, good welfare goes beyond the prevention of negative experiences and emphasises the provision of opportunities for positive experiences.

Positive mental experience

Behavioural enrichment is the practice of providing animals under managed care with environmental stimuli to improve quality of life. Generally, cows need little behavioural enrichment as feeding, ruminating and resting occupy most of their time and other cows in the herd provide social stimulation.

However, cow brushes may be provided to allow cows to groom and scratch themselves (Figure 82). Grooming is a natural behaviour, and it is common to see grazing cattle rub against a substrate, such as the bark of a tree, in order to remove dirt and external parasites. Grooming appears to be something cows enjoy, since otherwise clean and healthy cattle are highly motivated to access a grooming brush, as much as they are motivated to access fresh feed. It may also reduce frustration and stress due to boredom. The installation of grooming brushes in contained housing facilities is recommended and has been embraced by the dairy industry in new constructions with apparent positive behavioural effects.

Cows can be very vigorous in their use of brushes so these need to be robust. Some brushes automatically start to rotate when an approaching cow is detected, which may encourage their use. Cows particularly use brushes to scratch their backs, rather than their heads, so brushes which allow this behaviour are preferred.

Figure 82. Cow brushes allow cows to groom and scratch themselves - a natural behaviour

Negative mental experience

In contained housing facilities most negative mental experiences develop from fear and frustration.

Overstocking leads to competition for important resources; feed, water access and a place to rest as previously discussed, leading to bullying and frustration in subordinate cows, emphasising the need to follow recommendations for design and stocking rates (*see Chapter 9 Facility design and management*).

Poor animal handling and overt animal abuse involving the hitting of animals, and use of electric prodders and force can arise when the training of personnel is inadequate and in facilities lacking well-designed areas for handling and restraint. A specific knowledge and use of the point of balance and flight and pressure zones is required for all employees coming into contact with cattle and is now a requirement of many global animal welfare audits. Use of triangle and redirection pens can ease the stress of handling on the animals and the humans alike and the use of these designs is recommended for a variety of activities, such as loading cattle into a race or loading them for transport.

10.4 Monitoring outcomes

Management is critical to the success of all contained housing facilities, and it is important to monitor the cows' health and well-being to assess the success of management strategies. It is recommended that all farm team members be well trained in observing normal behaviour and recognising and reporting abnormal or unusual behaviour, and other signs that may indicate emerging health and welfare issues.

Visibly comfortable cows will:

- Ruminate well and produce milk
- Be in appropriate body condition for their stage of lactation
- Stand, lie down and walk easily
- Be free of injuries and have a low incidence of disease.

Cows will not normally lie in alleyways, or backwards in freestalls, and they should be able to lie down and stand-up without hindrance or hesitation.

However, more objective evaluations of animal welfare and physical well-being outcomes are now commonly used in animal welfare programs for dairy cattle (Table 21). These outcomes include:

- lameness/mobility
- hygiene
- injury/hair loss
- body condition
- response to staff/handler
- reason for culling.

Injuries can affect the hock, knee and other body regions – such as the neck, back, tail and wounds over the hook bones. The emphasis is on the avoidance of animals with severe scores which represent a failure of prevention coupled with a failure to identify and treat conditions effectively. The aim would be to achieve levels of severe scores less than 1% of the at-risk population using an appropriate sample size that varies based upon the risk group size, the relative frequency of the outcome being scored and statistical confidence.

These scoring systems may also be used to identify cattle with mild to moderate (score 2) lameness and injury requiring attention and treatment. Note that the hygiene score described herein, adapted from Cook and Reinemann (2007), focuses on areas of the body which reflect the cleanliness of the lying surface that the cattle have access to, rather than approaches that are used to assess udder health (Schreiner and Ruegg, 2003).

Proper nutrition may be assessed visually through body condition scoring – a commonly used management tool with details available in the *Dairy Australia Handbook 2013*. Target body condition score varies with stage of lactation, but the emphasis from a welfare perspective is the avoidance of cows that are body condition score 3 or below.

During periods of hot weather, thermal comfort can be monitored by measuring respiratory rates within a group of cattle. Cattle are considered heat stressed when the group mean respiratory rate exceeds 60 breaths per minute.

Table 21. Suggested 3-point scoring systems for locomotion, injuries and for hygiene

Outcome	Score description			Suggested target
	1	2	3	
Locomotion score	Walks without obvious gait asymmetry or weight transfer between limbs and cannot discern which leg is lame after a few strides. Steps may be slightly uneven and may have a flat or subtle arch to the back.	Asymmetric gait with obvious weight transfer and shortening of the stride of the affected limb altering cadence of movement. May also show a head bob, back arch and joint stiffness leading to abduction of the limb.	Able to walk only with extreme difficulty, almost unable to bear weight on the affected limb. Pronounced back arch with rear limb lameness. These animals are frequently in poor body condition and in obvious pain.	Less than 1% score 3 severe lameness and less than 10% score 2 mild to moderate lameness
Lesion score (hock, knee, neck etc)	No or minimal hair loss (≤2.5cm in diameter), no or minimal swelling (less than 1.0cm in diameter), no abrasion.	Hair loss area greater than 2.5cm in length or width or mild swelling (1.1–2.5 cm). May have a small open wound or dried scab.	Swelling greater than 2.5cm in height over the joint regardless of hair loss or skin abrasion.	Less than 1% score 3 severe injury and less than 10% score 2 mild to moderate injury
Hygiene score *(adapted from Cook & Reinemann (2007)*	Clean or manure or mud (may be dried) on flank or upper hind limb less than 25cm diameter.	Manure or mud (may be dried) greater than 25cm diameter in one of the two regions scored; flank or upper hind limb on the same side.	Manure or mud (may be dried) greater than 25cm diameter in both of the two regions scored; flank or upper hind limb on the same side.	Less than 5% score 3 and less than 20% score 2

Source: Nigel Cook

In addition to regular scoring of physical well-being, producers should keep accurate records of all health events and treatments so that rates of disease can be monitored over time. Dairy Australia's transition program review worksheet has targets for a range of fresh cow health problems, including clinical mastitis (Dairy Australia, 2020). All deaths and herd removals (culls) should be recorded along with a description of the reason for culling.

In the future, new technology will provide other metrics to consider for routine monitoring such as daily rumination and lying times. Rumination monitoring is currently being used to assist in the identification of sick cows and may have some merit as a monitor of welfare when available. The use of activity and lying behaviour is also actively being researched. However while short lying times are detrimental to the health and welfare of dairy cattle, very long lying times may also be reflective of sickness and lameness, making use of an absolute target for daily lying time challenging.


Dairy Australia

INCALF

Transition program review

WORKSHEET

How well has the transition program implemented on this farm performed? What changes need to be made?

Enter the result achieved for each of the key parameters below and compare it to the target.

FARM NAME:

Date:

1 Pre-calving transition diet fed

	Aim for	Result	Comment
Average days cows fed diet	21 days		
Average days heifers fed diet	21 days		
Daily DM intake per cow	10–12 kg/day		
Diet specifications:			
Metabolisable energy	Greater than 11 MJ ME/kg DM 100–120 MJ ME/day		
Crude protein	14 to 16% DM		
NDF	Greater than 36%		
Calcium	Less than 0.6% DM		
Phosphorus	Less than 0.4% DM		
Magnesium	Greater than 0.45% DM		
DCAD	Less than 80 mEq/kg DM		

2 Fresh cow health problems

	Aim for	Result	Comment
Milk fever	Less than 1%		
Retained placenta/RFMs	Less than 4%		
Assisted calvings	Less than 2%		
Displaced abomasums (LDAs/RDSs)	Less than 1%		
Ketosis	Less than 1%		
Mastitis	Less than 5 cases / 100 cows in first 30 days		
Grass tetany	0%		
Lameness	Less than 2% with Score 2 or 3		
Ruminal acidosis	Less than 1%		
Endometritis/vaginal discharge after 14 days	Less than 3%		

For more about Transition Cow Management, go to the Transition Cow Management resources at **dairyaustralia.com.au**

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11

Feeding cows for efficiency

11.1 Efficient feed conversion

The key to all dairy production systems is the efficient production of milk from feed. Two measures that provide an indication of this are:

- **Feed conversion efficiency = kg of feed dry matter/ milk solids produced**
- **Income over feed costs = income in $ of milk solids per day – costs of feeds and feeding per day.**

In the case of more intensive dairies, it is critical that feed conversion is efficient. The most basic version of this concept is conversion of feed dry matter to milk solids. Feed conversion efficiency is influenced by factors such as nutrients fed versus nutrients required, quality of feed and how the feed is offered to the cows including mixing, processing, feed surface and frequency of pushing up. Feed wastage is clearly important in reducing income over feed costs. Income over feed costs is a key financial measure that indicates likely success or failure.

It is critical in any dairy production systems to consider the true costs of feed, including loss of feed in storage and handling. This loss is often called 'shrink'. In pasture-based grazing systems shrink could be considered to include trampling and soiling loss of pasture. In silage systems it includes silage loss in effluent, volatiles, storage and removal of silage. In total mixed ration (TMR) systems it may include commodity wastage and feed rejections. When transitioning from a pasture-based system to contained systems there are a lot of factors that need to be considered in terms of feed storage and handling.

11.2 Nutritional requirements

Knowledge of the nutritional requirements of your herd, and what feeds you will supply to meet these requirements, will inform the design of the feed storage facility. Nutritional targets for cows do not vary with production system but do for stage of lactation.

Table 22 provides information on the nutritional targets for diets for cows in the far-off dry period, during the transition period from 21 days to calving and once in lactation.

Cows in the dry period will eat approximately 2% of body weight, around 2.5% in the transition period before calving and high producing herds 3.5 to 4% of body weight in lactation.

A key goal of any dairy production system is to tempt milking cows to eat extra high-quality feeds, as this strategy is most likely to increase efficiency and income over feed costs; provided the ratio of increased feed cost to milk value is profitable.

In intensively managed herds there are more opportunities to allocate different feeds to different groups of lactating cattle in order to utilise by-product feeds that may have limited availability or feed value.

Some nutritional advisors also use several different lactation diets, perhaps one for very early lactation (e.g. days 0 to 28) and sometimes to reduce the energy and protein density and cost of late lactation diets (e.g. from day 240 to dry-off).

Requirements by replacement heifers

Achieving a suitable liveweight at herd entry is an important component of successful management of dairy herds. Heifers should reach 90% of mature adult weight before calving. A number of studies addressing calf rearing have shown that an increased calf weight at weaning is substantially associated with increased future milk production.

Table 22. Nutrient composition targets for far-off, transition and fresh cows

Nutrient	Far-off dry cows	Transition	Fresh cows
Neutral Detergent Fibre (NDF; %)	greater than 36%	greater than 36%	greater than 32%
Physically effective NDF (%)	30%	25–30%	greater than 19%
Crude protein (CP; %)	greater than 12%	14–16%	16–19%
Degradability of CP	80%	65–70%	65–70%
Estimated metabolisable energy (ME; MJ/kg)	10 (9)*	11	11.5–12
Starch (%)	12–14%	16–18%	22–24%
Sugar (%)	6%	6–8%	6–8%
Ether extract (%)	3%	4–5%	4-5%
Calcium (%)	0.4%	0.4 to 0.5%	0.8 to 1%
Phosphorous (%)	0.25%	0.25%	0.4%
Magnesium (%)	0.3%	0.45%	0.3%
Dietary cation anion difference (DCAD; Meq/kg)	less than 150	less than 0	greater than 250

Note – on a dry matter basis, fresh cows – first 40 days, optimal transition period 21 days.

Source: Lean et al., 2020

**Energy content that is desirable will vary with body condition.*

11.3 Feed storage options

To manage feed inventories and minimise feed losses a well-planned feed management system must be in place. Reducing feed losses by improving management practices during handling and storage can have substantial beneficial economic impact. Good storage helps to preserve quality of the feed and to reduce spoilage from soil, manure, wind, rain and attack by vermin. Dedicated feed sheds will minimise losses of expensive feeds such as protein meals.

Silage

The most common silage storage methods include hillside pits, above ground bunkers, in ground pits and stack and bale silage. The system used will depend on cost, area available, topography, equipment available, expertise and personal preference.

Whatever the method used, the main functions are to exclude air during the ensiling process, prevent air from entering the silage during storage and minimise losses and quality problems during feeding out. Modern technologies, such as inoculants, preservatives and oxygen impermeable covers, can greatly reduce surface losses – irrespective of storage method.

Above ground stack (bun)

Silage stacks are for short-term storage. The silage is placed on top of the ground, then compacted and covered (Figure 83). Large dairies will often use a concrete pad as a base. As there are no side walls, the height of the stack is limited and the surface area to volume ratio is higher. The greater surface area increases potential spoilage. Stacks should be located in an area with a slight slope for drainage and away from trees to minimise potential damage from falling limbs and birds. The stack width should fit the size of the plastic cover to be used.

Figure 83. An above ground silage stack with no side walls

Advantages of above ground stack:

- No material construction costs.
- Easily sealed using a grader blade or front-end loader bucket.
- Removing silage from the face minimises loose silage, reducing air penetration into the bun.
- Size of bun can be adjusted to suit rate of feeding.
- Multiple separate buns can promote quality and better inventory control.

Disadvantages of above ground stack:

- High surface area to volume ratio, thus larger area to cover and greater chance of surface spoilage.
- Can be a workplace health and safety issue for tractor operators during stack formation and compaction.
- Stacks are not suitable for long term storage unless the cover is protected from sunlight exposure (UV degradation).

These stacks are better placed on concrete as there is better control of effluent, less wastage, a better base for machinery and reduced generation of odour from mud and silage mixtures (Figure 84).

Figure 84. An above ground large stack on a concrete base

Hillside pits

Hillside pits are usually dug into the sides or tops of hills, or high embankments, with the 'down hill' end open for drainage and pit access (Figure 85). The surrounding earth provides the side walls of the storage. Earth walls should be sloped to prevent caving in and to enable adequate silage packing. Where soil is unstable, the walls may need to be lined with concrete or untreated timber.

Figure 85. Hillside pits excavated into gently sloping site

Advantages of hillside pits:

- Suitable for long- and short-term storage.
- Lower risk of water entry compared to in ground pits.
- Reduced area to cover compared to above ground storage with no walls.
- Can be replicated by sharing a common wall on either side.

Disadvantages of hillside pits:

- Earth walls may become unstable if rocks or loose soil are encountered.
- Location must be planned to avoid problems with surface water run-off.
- Direct contact with soil generates risks of clostridia and mycotoxins.
- During unloading, any rocks picked up will damage feed mixing equipment.

Bunker storage

Bunker storages are permanent structures constructed above ground and are commonly used in flat areas. Above ground walls are constructed using concrete, earth, steel or timber and braced with timber or concrete buttresses. Bunker storages are rectangular in shape and are open at one or both ends. Most have earth floors, but concrete flooring provides all weather access and is strongly recommended (Figure 86).

Bunker storages must have adequate drainage. The height and width of the structure will depend on the daily silage usage, based on the removal of the required amount of silage per day from the silage face.

Figure 86. Large concrete silage bunker storage

Advantages of bunker storage:

- Can be built in areas where the soil type is rocky or has a high-water table.
- Is reasonably inexpensive to construct (with earth floors – not recommended).
- Can be replicated by sharing a common wall on either side.

Disadvantages of bunker storage:

- Concrete floor bunkers are expensive to construct.
- Poor compaction, or an uneven surface, can lead to water pooling where the cover meets the side walls.
- Earth walls must have stable slopes – ideally they are concreted.
- Requires regular maintenance (e.g. cleaning walls, weed control and re-surfacing the base).
- Losses or wastage from silage can be caught on walls.

Bale storage

Bale storage systems are typically temporary and used for making haylage – wilted forage that is stored at higher dry matter (Figure 87).

Figure 87. Silage bale storage

Advantages of bale storage:

- Greatest flexibility with the storage location.
- Low capital requirement.
- Low labour requirement.
- Stronger wrapping achieved, as the bales can be wrapped multiple times.
- Relatively small face is exposed when a bale(s) is retrieved, which reduces aerobic spoilage.

Disadvantages of bale storage:

- Specialised wrapping machine is required.
- Spoilage can be large if care is not taken to adequately seal out oxygen during the wrapping process and during storage.
- Not suitable for long term storage unless the cover is protected from sunlight exposure (UV degradation) and predator and pest damage.
- Disposal of used plastic may present problems.
- Preparation costs are high due to the cost of the plastic required to seal the forage.

Hay

If possible, aim to stack hay in a shed (Figure 88). Sheds should have good gutters and drainage so that water does not gather around the bottom bales when it rains. Aim to have two to three sides on the shed to protect the stack from weather. Good airflow is also important to prevent moisture build up. Whether the hay is being stored in a shed or outside it is important to have a raised storage pad to stack the hay on. This helps water drain away from the bales during rain events which in turn decrease the chance of mould and rot forming in wet hay.

Figure 88. Good hay storage

Disadvantage of hay:

- Hay fires are reasonably common.
- Special care should be taken to ensure air flow and appropriate dryness of hay to reduce the risk of fire.

Dry and wet commodities

Dry and wet feed commodities may include dry grains, processed grains, oilseed meals such as canola and soybean meal and by products from feed or food processing operations such as wheat mill run, brewers' grain and distillers' grains. Another class of feed commodity includes industrial food wastes such as potato waste, bakery waste (e.g. bread) and fruit and vegetable cannery waste.

For storage and handling of these feed commodities, factors that should be considered include volume, shelf life of product and delivery and loading system. Commodities have varying physical characteristics. Therefore, the volume needed for storage should be calculated according to bulk density. Other physical characteristics such as high moisture content, increase the likelihood of feed quality losses and spoilage.

Storage options include silos, covered flat bottom storage bays and uncovered concrete bunkers for wet feed commodities such as brewers' grain and citrus pulp.

Flat bottom storages are usually concrete bottom bays with timber, steel or concrete walls. Without a concrete floor, commodities can be contaminated with dirt and stones. Several bays may be located next to each other to form a commodity shed. The number of bays will depend on the number of different ingredients, or commodities, likely to be used in the ration mixes.

Flat storage commodity sheds are especially useful for by-product ingredients that do not flow, cannot be moved with augers or cannot be stored in conventional silos where gravity flow is required. Front end or articulated loaders are generally used for both loading and unloading feed from the storage bays to the feed truck or mixer and need convenient access.

For single-row, open-front buildings, a concrete apron in front of the bays allows manoeuvring by delivery vehicles and equipment. The bays should be designed and located to allow the delivery vehicle to unload the material directly into the appropriate bay to minimise double handling.

A high roof clearance and ability to back straight into the bay is needed if feed commodities are unloaded from tipping trailers directly into the bay. The base of the bays and any concrete apron should be sloped away from the storage bay to prevent water flowing into the bay. The orientation of the commodity shed should ensure adequate protection against the prevailing wind so that commodities are not exposed to blowing rainfall during storms.

Figure 89. Commodity shed

Figure 90. Design individual bays to cater for typical delivery truck volumes – store feed undercover

Figure 91. Brewers' grain in bunker storage

As seen in Figure 91, wet commodities are often stored without a roof. This can mean that environmental factors such as rain and sun can reduce feed quality. Heavy rainfall can mean that the feed commodity leaches out some of the valuable nutrients such as sugars, starches and protein.

11.4 Planning feed storage

Commodity storage facilities should be designed to:

- Provide enough storage to meet the demands of the herd.
- Provide sufficient storage space for a given volume of each commodity.
- Minimise wastage and spoilage.
- Provide moisture protection for dry commodities.

The physical characteristics of feed commodities vary. Knowing the bulk density (weight per unit of volume) of a feed commodity can be used to determine the volume and area needed for storage (Table 23).

Table 23. Bulk density of common feed commodities

Feed commodity	Bulk density (kg/m^3)
Wet brewers' grain	800
Canola meal	620
Cottonseed meal	593
White whole cottonseed	401
Soymeal	650
Lupins	770
Mill run	350
Wheat grain	730
Dry distillers' grain	480
Almond hulls (whole)	450

Table 24. Dry matter density of common silages

Feed commodity	Dry matter %	Dry matter density (kg/m^3)
Maize silage	33–38	170–250 (average 200)
Ryegrass silage	28–35	160-–180 (average 170)
Lucerne haylage/silage	45–55	200–220 (average 210)
Whole crop cereal silage	40–50	180–220 (average 200)

Storage requirement example for 1,000 cow dairy TMR system

Assuming the following scenarios:

1,000 milking cows with followers and a fully fed in TMR system 365 days with average 24kg dry matter intake (DMI) including dry stock and followers – with the following diet composition:

- 6kg dry matter (DM) Maize Silage
- 6kg DM Ryegrass Silage
- 7kg DM Grain
- 3kg DM Canola Meal
- 1.5kg DM Oaten Hay
- 0.5kg DM Additives

Maize silage storage:

6kg DM x 1,000 cows x 365 days = 2190 t DM + 5% for shrink and wastage = 2,300 t DM

Dry matter density: ***220kg DM per cubic metre***

Area required: 2,300 t DM/220kg DM/m^3= 10,455m^3

Wall height of bunkers are 4 m and removing 6,000kg DM each day (approximately 18,000kg Wet) will allow for bunker width of 30m which means the silage face will be well managed.

Bunker size required: 30m wide x 4m high x 87m long (= 10,440m^3 approximate total volume)

Ryegrass silage storage:

6kg DM x 1,000 cows x 365 days = 2,190 t DM + 5% for shrink and wastage = 2,300 t DM

Dry matter density: ***170 kg DM per cubic metre***

Area required: 2300 t DM/170kg DM/m^3 = 13,529m^3

Wall height of bunkers are 4m and removing 6,000 kg DM each day (approximately 18,000kg Wet) will allow for bunker width of 30m which means the silage face will be well managed.

Bunker size required: 30m wide x 4m high x 112m long (= 13,400m^3 approximate total volume)

Hay storage:

Daily hay usage is 1.5kg DM x 1,000 cows = 1.5 t DM. Ideally a farm should store enough hay for 30 days in a designated hay shed.

Monthly hay storage: 1.5 t DM x 30 days = 45 t DM = 50 t of hay (wet of ~ 90% DM).

Large square bales (2.4 x 1.2 x 0.9m) weigh on average 500kg/bale so there needs to be room for 100 bales.

Shed space required: 2.7m^3/bale x 100 bales = 270m^3 (assuming a new load every month).

11.5 Efficient storage and handling

Storage bunkers and commodity sheds need to be close to the feedpad area to minimise time and labour taken for mixing and delivery.

Most large herd feedpad operations and contained system will be using pit silages such as corn silage, ryegrass silage or cereal silages. To maintain a good silage face and to reduce losses and spoilage, additional equipment such as silage grabs, silage shear grabs and shavers are required. The shear grab allows a block of silage to be removed whilst leaving a clean-cut face. The shaver may reduce dry matter losses over front end loader use by approximately 3% (Figure 92). The shear-grab and the shavers have the advantage of reducing oxidative loss, water penetration and dangers of overhanging silage collapse (Figure 93).

Figure 92. Silage shaver creating a good silage face

Silage grab design can play apart in maintaining silage quality by preventing aeration of the silage face and cleaning up silage that has fallen to the ground. The type of forage ensiled will also impact the cleanness of the silage face and the design of the silage grab that is used. Length of forage ensiled will also determine the efficiency in maintaining a clean silage face i.e. corn silage is easier to achieve a clean face compared to rye grass silage due to the length of cut of the forage.

Figure 93 A clean face on ryegrass silage with use of a shear grab

Other handling equipment required can be hay forks and front-end loader of a suitable size to allow for efficient loading of feed commodities into the mixing and feed out equipment. Many enterprises use a telehandler to good effect for managing commodities.

11.6 Options for feed delivery

An optimal feeding system must meet the following goals:

- Deliver the needed nutrients.
- Provide these nutrients to each cow.
- Support the optimal amount of milk and milk components.
- Provide needed nutrients at the correct time of the lactation and gestation cycle.
- Feeds need to be fresh and palatable.
- Feed should not be contaminated by soil, manure of other contaminants.

Frequency of feed outs should be proportional to the time spent on feedpads or in housed systems.

- Feed must be pushed up regularly to allow for optimal feed intake.
- The mixed feed must be uniformly blended. Samples taken from the beginning, middle and end of loading should show no significant differences in ration composition. Over-mixing can be as detrimental as under-mixing in achieving optimum uniformity.
- Feed out chutes and speed of mixing wagon travel must be calibrated which is particularly important if narrow troughs are used.

Type of mixers

Mixers can be categorised into stationary or mobile mixers, with either horizontal or vertical mixing actions. Selection of the mixer will depend on a wide range of factors:

- Rations with a large percentage of roughage will require larger capacity mixing equipment.
- The mixer size must be selected on budget, ration density, feed intake, herd size and number of feed deliveries per day.

Most mixers have a width of approximately 2.5-3.0m (depending on model and size), so it is important that feed alleys are designed to be wide enough to make sure that the feed it not being run over.

Vertical mixer

The vertical mixer consists of a large tub with one or more vertical screws centred in the tub. The screws elevate the ingredients to the top of the mixer, where they fall by gravity to the bottom to be mixed and re-elevated. The continuous lifting and falling action creates a blended mixture of ingredients. Knife sections may be attached to the screw flighting to cut material, such as hay or straw. Vertical mixers are the most common type found in small trailer mounted mixers but they are now also available in larger sizes for truck mounting.

Figure 94. A tractor drawn vertical mixer

Figure 95. Vertical mixer augers

Horizontal screw

Horizontal screw mixers consist of a series of augers mounted on a horizontal rotor in a hopper. Auger mixers use one to four augers to churn the feed in a hopper. The flighting of the auger(s) moves the feed towards the middle of the mixer where it bubbles to the top, toward the sides and back down to the augers. The mixers have one or two counter rotating auger(s) and/or flighting, moving feed in the opposite direction to the other augers. Feed moves from end to end and from bottom to top. In many mixer designs, notched auger flighting and/or knife sections are attached to the auger flighting to process roughage and improve its incorporation into the ration. Horizontal screw mixers are more efficient than vertical types in mixing ingredients with different particle sizes.

Figure 96. Four auger horizontal screw

Figure 97. Tractor drawn horizontal mixer

Horizontal paddle mixer

The horizontal paddle type mixer combines a set of augers and a paddle in a hopper. The feed is lifted and tumbled by the paddle, moving it upwards to the upper and lower side augers. The augers provide a mixing action and move the feed from end-to-end. The rotor can be configured with three or more paddles (i.e. up to five or six). The tumbling action mixes the lighter roughage and high moisture ingredients without grinding or high-pressure feed movement.

Stationary mixers

These mixers are permanently positioned and so require other equipment for feeding out the mixed ingredients to the feed bunks. The vertical feed mixer is often less efficient than the horizontal mixer because of its smaller size, restricting the level of liquid addition and requiring a longer mixing time.

Mobile feed mixer

The mobile feed mixer can either be trailed behind a tractor or permanently mounted on a truck. These allow the feed to be mixed on the go before the feed is delivered, avoiding the need for double handling and giving faster turnaround times. Tractor drawn feed mixers are the most commonly used in intensive dairy systems. Mobile mixers can be vertical or horizontal types.

Pre-processing of forages

Pre-processing forages with a long forage length can be beneficial for improving the consistency of the mixed feed and to reduce mixing time in the mixing wagon. Various machinery options are available such as having a pre-chopper on a baler, tub grinder or a hay processor prior to forage getting added into the mixer.

11.7 Feeding for health and reproduction

There is a comprehensive review of the nutritional strategies that most influence the risks of disease in the period around calving (Lean *et al.*, 2020). Most of the disease in dairy cows occurs within 20 days of calving and management of the transition period is critical to establishing healthy, productive and successful lactations. These disease conditions include:

- Hypocalcaemia (milk fever)
- Hypomagnesaemia (grass tetany)
- Ketosis or acetonaemia and fatty liver
- Udder oedema
- Abomasal displacement
- Mastitis
- Ruminal acidosis
- Retained foetal membranes/retained placenta and metritis
- Poor fertility and poor milk production.

Table 25 outlines the targets for health performance in early lactation and these can be used to identify whether your herd is performing at an acceptable level. In Table 20 the effects of not meeting or exceeding nutritional targets on health and production indicators are outlined. The targets and measures in these two tables are highly relevant to achieving good health and performance through sound nutritional strategies.

Two related conditions are also of substantial importance to the health and productivity of cattle. Ruminal acidosis and lameness are important disorders of cattle in all production systems.

Ruminal acidosis is not simply one disorder, but rather a continuum of conditions that reflect the degree of generation and safe sequestration of hydrogen in the rumen. The severity of acidosis reflects the substrates available to cattle e.g. sugar and starch that predispose cattle to acidosis and the balance of the diet including fibre that reduces risk. The risk of acidosis is present in all milk production systems, but especially when concentrates are fed.

Studies in Australia have found that 10% of dairy cows less than 100 days in milk had acidosis, as defined by assessment of ruminal volatile fatty acids (VFA), ammonia, lactic acid and pH, when sampled. Studies in the US found that 20.1 and 23% of cows had acidosis. It is likely that many cows will experience some level of acidosis during lactation and, indeed, some may be affected many times.

Table 25. Health performance indicators – target and alarm levels

Indicator	Target performance	Alarm level
Clinical hypocalcaemia (Milk fever)	1% cows older than 8 years – 2%	3%
Pregnancy toxaemia	0%	1 case
Clinical ketosis	less than 1%	2%
Abomasal displacements (left or right)	less than 1%	2%
Mastitis	1.8 cases per 100 cows per 30 days	2.5 cases per 100 cows per 30 days
Lameness [Sprecher, Hostetler *et al.* (1997) scale 1–5]	less than 2% greater than score 2	greater than 4% greater than score 2
Hypomagnesaemia (Grass tetany)	0%	1 case
Retained foetal membranes more than 12 hrs after calving	less than 3%	greater than 6%
Metritis % infected after 21 days	less than 5%	greater than 10%
Calving difficulty	less than 2%	greater than 3%
Clinical ruminal acidosis	0%	1%

Note – expressed as percentage of cases of calving cows within 14 days of calving.

Acidosis is a continuum of conditions of varying severity that reflect the challenge of safely sequestering hydrogen that accumulates from carbohydrate fermentation. Safe pools to 'hide hydrogen' include starch engulfment by protozoa, bacterial glycogen formation, growth of bacteria, methane, and weak organic acids (VFA). Less safe pools include lactic acid. Alternatively, decreasing the hydrogen supply by increasing the more slowly fermenting fibre content of the diet and enhancing rumination can also reduce risk.

Signs of acidosis

Cattle with rumen perturbations consistent with subacute acidosis may present with a range of clinical and subclinical signs that include diarrhoea, poor body condition, a dull and lethargic demeanour, dehydration, a lack of rumen fill, lameness, weak rumen contractions, depression in milk fat, and inappetence.

For acute acidosis: Ruminal distension, diarrhoea (often with grain in the faeces and a sickly, sweet smell), abdominal pain, tachycardia, tachypnoea, staggering, recumbency, coma, a marked decline in milk yield, and death may occur.

Herd diagnosis: acidosis

While access to fermentable feeds is important to the diagnosis of subacute cases, the focus must be on the herd examination, as clinical signs of acidosis can be relatively subtle in the individual animal.

Check the latest herd test results. Milk fat to protein ratios less 1.02 to 1 for cows in the first 100 days in milk provide a weak, but useful, indication of acidosis. It is not true that all cows with a low test are likely to have acidosis, but cows with acidosis are very likely to have low fat test. Unsaturated fatty acids have also been implicated in milk fat depression without relationship to ruminal acidosis. The sensitivity and specificity for using a fat : protein ratio as a predictor of acidosis is 0.54 and 0.81, respectively. The sensitivity indicates that only 54% of acidosis cases were detected by use of a low fat : protein as a test, but the specificity indicates that 81% of acidotic cows had a low fat test. This indicates that there are other causes of a low fat to protein ratio apart from acidosis.

The following examinations of the herd should be made:

Dung check: If a high percentage of cattle are scouring, especially if the dung bubbles and contains grain – the risk of acidosis is high (Figure 98). The dung can contain undigested fibre, particles greater than 1.5cm. Differential diagnoses include very lush grass and parasites.

Lameness check: Only swelling of the coronary band occurs at the same time as ruminal acidosis, but herds that have had acidosis causing other typical foot problems that arise with acidosis often have active acidosis, especially if there has been no effort to control it. Changes observed in hooves such as 'poverty lines' and paint brush haemorrhage indicate acidosis, but the acidosis occurred some-time before examination.

Check the bulk vat: A low fat: protein test on a herd basis is similar to that in a cow. Again, it is only a rough guide, but a low herd fat : protein test is a cause to consider the possibility of acidosis or concerns with excessive intake of dietary unsaturated fatty acids.

History: Have cattle bled from the mouth (or nose) or have liver abscesses been reported for the farm? Both of these indicate that it is very likely the cows have had acidosis in the past. Some acidotic herds have history of increased respiratory disease, but there are many other causes of respiratory disease apart from acidosis.

Ration: An essential step is to check the ration and feeding systems to see whether the following problems are present: Highly fermentable diets e.g. non-structural carbohydrates (NSC) greater than 36% and Neutral Detergent Fibre (NDF) less than 32% of the total diet. These need not be enough alone to provide a problem and acidosis can be present with less NSC and more NDF. Chemical analysis should be performed on individual feed components and residual TMR after feeding to obtain the percentage of dry matter, NDF, acid detergent fibre (ADF), crude protein (CP), starch, sugar, and NSC content - this will allow estimation of the overall chemical composition of diet and for comparison with recommended requirements. This information, combined with the evaluation of the physical characteristics of the feed will indicate possible sub-optimum rumen function and ruminal acidosis. It is often the way that the diet is fed. For example, short chop or sorting in partial mixed ration (PMR) or TMR herds, cows can access extra grain in the milking parlour, and very lush pastures or young grass. Feeding behaviour will be the best indicator of adequacy of dietary fibre and physical form.

Figure 98. Acidotic dung from poorly designed diets with contained housing facility

Feeding behaviour: Feeding behaviour of the herd including the following should be observed: percentage of cows cud-chewing at rest should exceed 50%, sorting behaviour of a TMR, and DMI and whether cows are allowed to go straight to pasture after milking or are held to provide even access. Cows that have a low rumination time, are sorting their feed, have a cyclic feeding pattern, or low DMI may be at risk of ruminal acidosis. Cows that are low in the social order, which are frequently first lactation cows, often eat last and therefore can be exposed to feed with a different effective fibre content or chemical composition resulting from sorting from the previous cows and may increase their risk of ruminal acidosis. The animal's increased risk of ruminal acidosis will be dictated by what they sort for: concentrate (increased risk) or forage (typically decreased risk). All feed sources should be assessed for forage or chop length or particle size if applicable, and quality using relevant characteristics i.e. stage of maturity of pasture, type of pasture or forage.

Table 26. Diet composition targets for early lactation cows – deficiency/excess indicators, production effects

Diet composition (dry matter basis)	Fresh cow targets	Effect of deficiency	Deficiency key indicators*	Effect of excess	Excess – key indicators*
Dry Matter Intake (DMI; kg)	≥ 3.5 to 4% body weight	Weight and Body Condition Score (BCS) loss	Weight loss greater than 75kg and BCS loss greater than 0.75 (calving to nadir), high blood Non-Esterified Fatty Acids (NEFA) and high ketones (urine, blood, milk)	Reduced feed conversion efficiency (FCE); suggests diet is imbalanced. Targets for FCE (Energy corrected milk/DMI) for Day 150 of lactation: TMR greater than 1.3 – ideally greater than 1.4 Pasture and PMR greater than 1.2 – ideally greater than 1.4 Pasture and concentrate greater than 1.2 – ideally greater than 1.3	High residuals: in bunk greater than 2% or pasture greater than 1600kg (ryegrass). Marked increase in body weight or body condition in herds with adequate weight and BCS. Target BCS: 3 to 3.25 peak and 3.25 to 3.5 at calving.
Neutral Detergent Fibre (NDF; %)	28–32	Increased risk of acidosis; reduced feed efficiency	Low NDF in diet. Loose, low fibre content of faeces, fibre greater than 1cm long, undigested feed observed in faeces, low fat test: less than 3.5% (Holstein-Friesian), low rumen fill, decreased rumination: less than 50% chewing cud at rest, lameness prevalence may be high: greater than 25% of cows 2+	Body weight loss, lower milk, production, higher butterfat percentage, lower protein production	High NDF in diet. Low or declining BCS or weight, High fat, low protein test, high rumen fill, large firm faeces, high faecal fibre, high blood NEFA and high ketones (urine, blood, milk)
Physically effective NDF (%)	19–21	Increased risk of acidosis; reduced feed efficiency	Low fibre content of faeces, low fat test, low rumen fill, decreased rumination: less than 50% chewing cud at rest, lameness prevalence may be high (depends on the environment)	Lower production, higher butterfat percentage, lower protein production	Firm faeces, high fibre content of faeces, high rumen fill, unlikely to be excessively high without high NDF%, increased rumination: greater than 50% chewing cud at rest

Table 26. Diet composition targets for early lactation cows – deficiency/excess indicators, production effects cont.

Diet composition (dry matter basis)	Fresh cow targets	Effect of deficiency	Deficiency key indicators*	Effect of excess	Excess – key indicators*
Crude Protein (CP; %)	15.5 – 19	Lower milk production, body protein mobilisation, increased acidosis risk	Pale green faeces, slow passage rates, can have high rumen fill, lower fibre digestion, low Milk Urea Nitrogen (MUN), low milk protein production, low milk protein content	Lower pregnancy rates with high soluble protein intake	Dark green loose faeces, however, colour can be variable, variable passage rates, high MUN, low production, possible weight loss
Degradability of CP (%)	65–70% of CP i.e. 13% rumen degradable protein of diet DM	Lower production depending on the amino acid composition of the rumen undegradable protein fraction of CP	Lower fibre digestion, can have high rumen fill, low blood urea nitrogen (BUN) or MUN, low milk protein production, low milk protein %	Lower production, Lower pregnancy rates with high soluble protein intake, can increase BCS mobilisation	High BUN or MUN
Estimated Metabolisable Protein (g/Day)	11–13, depending on size and production	Lower production depending on the amino acid composition	Poor production with increase in weight gain and BCS over lactation, poor feed efficiency	Loss of income, inefficient use of protein	
Estimated Metabolisable Energy (MJ ME/ kg DM)	11.5–12	Weight and BCS loss	Weight and BCS loss, high blood NEFA and high ketones (urine, blood, milk)	Weight and BCS gain if imbalanced	Low MUN (if high non-structural carbohydrates)
Estimated net energy required for lactation (NEl; MJ/day/ kg milk)	2.9–3.5	Weight and BCS loss	High blood NEFA and high ketones (urine, blood, milk)	Weight and BCS gain if imbalanced	
Starch (%)	20–26, depending on NDF and forage NDF content of diet	Low production (is not an absolute, but often the case)	Low milk protein, can test fecal starch	Increased risk of acidosis and lameness	Loose, bitter sweet smelling faeces (may be low MUN depending on protein in the diet), often contain bubbles of trapped gas, a high prevalence of cattle with pH less than 6.5 on stomach tube or 6.0 on ruminocentesis indicates presence of acidosis
Sugar (%)	6–8	Low production	Low milk protein	Increased risk of acidosis and lameness	Loose, bitter sweet smelling faeces, a high prevalence of cattle with pH less than 6.5 on stomach tube or 6.0 on ruminocentesis indicates presence of acidosis
Ether extract (%)	4–5	Lower efficiency of production		Decreased fibre digestion, lower fat percentage especially rumen degradable	Faeces less well digested and turn white after drying
Dietary Cation-Anion Difference (DCAD; Meq/kg)	25–40	Lower production	Urinary pH in lactation low (less than 7)	Decreases milk production	Urinary pH in lactation high (greater than 8.5), high K & Na and low Cl & S in feed

Source: Lean et al., 2014

11.8 Achieving high performance on total mixed rations and pastures

The following compares the key criteria that are required to achieve high-level performance on total mixed rations and pastures. Subsequently, the core skills and challenges of moving between grazing and total or partial mixed rations are explored.

Keys to achieving high intake on total mixed rations

Increase feeding frequency in early lactation for diets of moderate to high energy density especially when feeding management is not optimal.

- The better the other aspects of feeding management, the less the benefit of increased frequency of feeding.
- Pushing up feeds between feedings is important to ensure that cattle get access to the feed and to stimulate feeding behaviour.
- A reasonable target might be to feed twice a day and push up feed twice in between each feeding.

Ensuring adequate access time to feed:

- Feed bunks should not be empty of feed nor time off pasture excessive - ideally cows should have access to feed for 21–22 hours per day, allowing for milking time.
- Grouping by parity and production level. Primiparous cows and multiparous differ in feed intake and feeding behaviour.

It is important to provide cows with palatable feeds. This means:

- Cleaning the bunks at least once a day to ensure clean feed.
- Avoiding spoiled feeds.

> Providing palatable feeds is important as the impact on individual cattle and the herd in general can be substantial.
>
> Bolsen *et al*. (1999) demonstrated significant decreases in DMI as well as apparent digestibility of dry matter, organic matter and neutral detergent fibre (NDF) in cattle fed silage that consisted of 25% aerobically surface-spoiled silage. In addition, the authors noted that rumen fibre mats in treated cattle were either partially or totally destroyed.

Also important to consider:

- Providing adequate feed bunk space – between 0.6 to 0.7 linear metres per adult cow – *see 9 Facility design and management.*
- Ensuring that cows are comfortable (i.e. relaxed, are not heat stressed, socially adapted). Rapid changes in cow groupings are not advisable, especially during the transition period.
- Feed should not be hot either in the bunk or in the silage stacks or commodity bunks (indicates the deleterious action of yeasts and moulds).
- Monitor moisture in the feed – excessively wet feeds can sour and reduce DMI.
- Cows need adequate time to rest (more than 8 hours per day). Water access and quality need to be high. Cows will drink 40 to 70L of water per day but may require up to 200L of water per day. Cows will go to water from 6 up to even 40 times a day and water sources should be made readily available for cows. Access should be approximately 0.1 to 0.2 linear metres/head and not with a solitary trough or source.
- See *Chapter 6 Water supply.*

Indicators of spoiled silage include:

- Spoilage (mould or blackening, foul smell) in the stack or on the face with slow feeding.
- Dropped, black cud in bunks or near silage.
- Spoiled orts (remainder of food from a meal).
- Changes to faeces – often scant, slow passage, undigested or 'slimy', sometimes liquid diarrhoea.
- Low rumen scores – variable across the group. Rumen scores are a useful tool but need to be assessed with some caution.

Keys for achieving high intake for grazing cattle supported by feeding infrastructure

With grazing cows, availability of feed is influenced by varying the stocking rate, stocking intensity (grazing pressure – which is a function of appetite of cattle and supplementary feeding rates), herbage height or time available for grazing. Changes in digestibility and composition which occur at different stages of the growing cycle must be understood if optimum use of grass is to be made.

Critically, more DMI can be achieved by offering more pasture – feed intake increases in a curvilinear manner, but pasture residuals then also increase.

The residuals that are left influence the rate of grass production in the future and the quality of grass. Simply, leaving too much residual (typically greater than 1,600kg DM/ha for temperate pastures e.g. ryegrass, fescues) can reduce pasture quality for the next grazing; leaving less than 1,300kg/DM/ha for temperate grasses will reduce pasture growth rates. Consequently, ideal residuals for ryegrass are between 1,300 and 1,500kg DM/ha.

In order to achieve high production from pasture and supplement – forage is provided to appetite, the forage is of high digestibility, highly palatable, free of anti-nutritional factors (e.g. toxic endophyte alkaloids, high levels of nitrates) and the ration is balanced by use of supplements (or complementary feeds). Intake of forage is determined by selection, physical form and substitution rates when forage is fed ad libitum.

Keeping production up and rumen function stable on pasture

If pasture residuals are too short, some cattle are not achieving optimal DMI (and grass growth is depressed)

- Grazing short pasture or pasture high in legume may not provide sufficient physically effective fibre for rumen stability.
- If pasture residuals are too long, pasture quality will decline in the future.
- Provide simultaneous access of the herd to the pasture (releasing cattle to pasture as they are milked disadvantages less dominant cattle and heifers).
- Provide ample water access at pasture.
- Meet mineral requirements.

Increase DMI at pasture by:

- Increasing pasture available (stocking rate change, rotation change, fertiliser use).
- Increasing time of access to pasture.
- Improved pasture quality (cultivar selection, fertiliser use).
- Moving hot wires (electric fences) to provide fresh pasture.
- When weather is hot and humid, providing access to pasture in the cooler parts of the day.

Management to achieve high DMI is critical and additional detail can be found in the key reviews listed in the reference list.

Transitioning between systems

As noted above, the nutritional targets for the cow do not differ with production systems. Indeed, the energy density of many good pasture-based diets exceeds that of TMR, but exercise and difficulty achieving high dry matter intakes can reduce milk solids production.

Perhaps the most challenging production system is the partial mixed ration system in which managers and workers need to have high level skills with pasture feeding and mixed rations. The skills required to manage the two systems are often very different, but skilled observation of the cattle is critical to success in both.

Table 27 highlights the critical areas of attention to detail and management observations required in TMR or PMR systems and on pasture.

Achieving consistency of diet and a steady rate of change is vital to the success of changing from one system to another. Ration changes should be made over a period of 2 to 3 weeks.

Options such as provision of green-chop pasture over the first 2 to 3 weeks when changing from pasture to TMR help maintain rumen stability. Similarly, provision of silages and concentrates when adapting from TMR to pasture can be used to manage the change in substrates in feed. In the latter case, consideration of the increased exercise component can be important; feed dense pastures and, by preference, those that do not require considerable walking.

Table 27. Key observations for total, partial mixed ration and pasture-based systems

Key questions for managers	Observation – TMR or PMR	Observation – Grazing
Are cows are being fed to appetite?	A small residue of palatable feed remains in the feed bunk. Feed is pushed up to stimulate appetite. Milk production is high and as expected.	Pasture residuals are optimal. Milk production is high and as expected.
Do cows have enough time to eat?	Access to feed other than when milking.	Access to feed other than when milking.
Do cows have enough time to rest?	Able to rest greater than 8 hours per day.	Able to rest greater than 8 hours per day.
Does exercise and discomfort depress milk production?	No significant mud in 'dairy dry lots'. Bedding in loose housing facilities is dry. Freestall cows are using their stalls well.	Cows get considerably more pasture energy than the exercise required to walk to pasture.
Are cows disrupted moving between diets i) Pasture to TMR	The main dangers are in abrupt changes in diet. Highest risks are with acidosis, if the increase in starch and sugar is too abrupt. Loose faeces. Poor appetite.	Not applicable.
Are cows disrupted moving between diets i) TMR to Pasture		The main dangers are in abrupt changes in diet. However, cows do take a little time to adapt to the increased exercise components and tend to be 'lax in grazing'. Unless the total available dry matter and energy density is similar, cows can markedly drop body condition as they continue to milk and have increased energy loss in exercise, but do not receive sufficient nutrients to support production.

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12

On-farm nutrient management

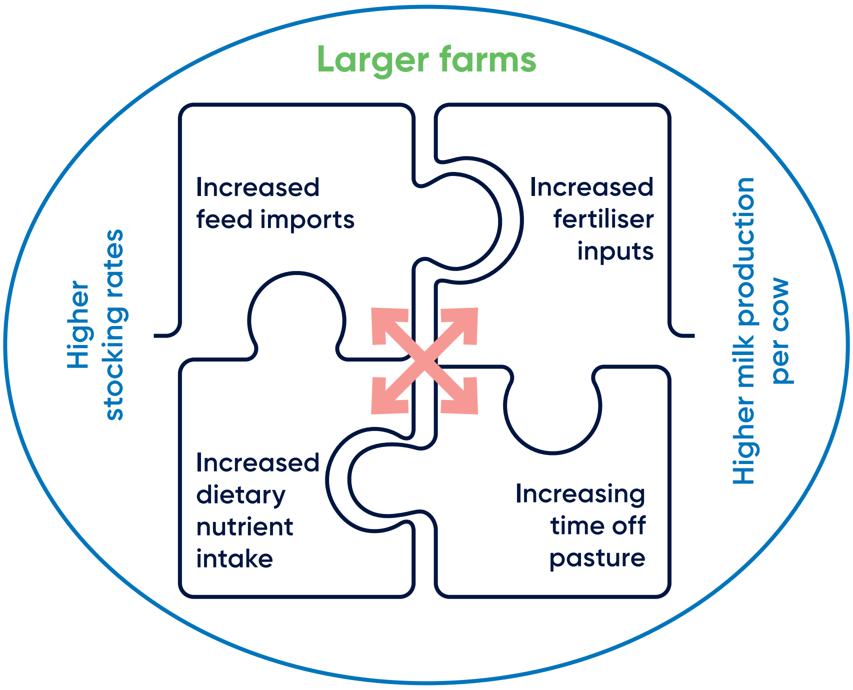
12.1 Nutrient management challenge

As dairy production systems intensify their may be a greater reliance on imported feed (Figure 99). Increased stocking density can also lead to excessive nutrient loads from manure directly deposited in concentrated areas including feedpads and contained housing facilities.

Higher nutrient loads increase the risk of environmental impacts including nutrient, greenhouse gas (GHG) and odour emissions. Consequently, global markets are now expecting evidence of reduced environmental harm, and science-based industry and government policy responses to deal with excess nutrients and a farm-based nutrient management planning approach.

- Manure nutrient management requires greater emphasis when dairy farms import a large proportion of feed and animals are contained.
- Fertiliser nutrient management will require greater emphasis when dairy farms grow most of their own feed.

Figure 99. Implications of intensifying dairy production systems on nutrient load



Source: Cameron Gourley

To achieve the goals of improving nutrient use efficiency and reducing environmental emissions, nutrient management planning needs to be consistent, comparable, complete, accurate and transparent.

12.2 Implications of intensification dairy farm nutrients

Increasing nutrient inputs and load

Increasing land area and milk production per animal often leads to an increase in feed intake, increases in total feed grown, greater inputs of water and nutrients, in particular nitrogen, and increased nutrient inputs.

Dairy farms like this need improved nutrient management practices (monitoring, application rates, timing, placement) and fit for purpose manure management systems. This is because there is a greater potential loss of nutrients to the environment, notably reactive nitrogen and phosphorus, with various transformations and loss pathways caused if not well managed.

- Increased feed and fertiliser inputs will increase overall farm-gate nutrient surplus
- Whole-farm nitrogen budgets are an important tool in managing risks
- Total nutrient inputs and outputs are estimated, and the difference (surplus or deficit) and ratio (nutrient use efficiency) are quantified.
- The whole-farm nutrient budget approach is relatively simple to calculate using generally available farm-scale data.

Increased nutrient intakes and manure nutrient concentrations

Dairy cows inefficiently utilise the nutrients they consume, with only about 20% of nitrogen, 24% of phosphorus and 8% of potassium consumed by lactating dairy cows being secreted in milk.

An average producing Australian dairy herd of about 300 cows per farm and a lactation period of 305 days, would excrete around 35,000kg nitrogen, 5,000kg phosphorus, and 27,000kg potassium in dung and urine.

As total feed intake and milk yield increases per cow, so does the amount of nutrients excreted by cows (Table 28).

Increased nutrient loads and challenges with nutrient distribution

When animals spend more time contained in feedpads and housing facilities there is a greater need for improved capture, storage and sustainable reuse of manure. Ineffective management within any one component can have a cascading negative effect on the others.

A characteristic of dairy intensification is a transition from traditional grazing-based systems to pasture – feedpad hybrid or contained housing facilities such as freestall, loose housing and dry lot. This transition has the potential to increase milk production per cow but also increases the amount of manure that needs to be managed.

For an equivalent herd size, moving from a pasture-based grazing system (with supplements supplied during the milk harvesting process) to contained housing potentially results in a sixteen-fold increase in the volume of manure to be managed (Table 29). The actual mass of fresh manure requiring collection, storage and land application will vary, but can be substantial. For example, it is estimated that 2400 lactating cows in a freestall will produce 187 tonnes of wet manure each day.

In both grazing and contained systems, there can also be other high stocking density parts of the farm where cows are held for feeding, calving, for welfare, or for exercise, but where excessive deposition of manure can be largely uncollected. Even in grazing-based production systems, where most excreted manure is directly deposited onto pasture soils, there will be varied or uneven distribution of manure across the farm landscape. Paddocks regularly receiving solid manure or effluent or where animals were held for long periods typically have had highest soil phosphorus and potassium levels.

Table 28. Minimum, median and maximum annual nutrient excretion

	Cow live weight (kg)	Total Dry Matter Intake (tonne per cow)	Milk yield (litres per cow)	Excreted nutrients (kg per cow)		
				Nitrogen (N)	Phosphorus (P)	Potassium (K)
Minimum	430	3.8	2,628	73	7	51
Median	500	6.5	6,741	157	22	122
Maximum	680	10.4	11,285	289	48	245

Note: for lactating dairy cows with a range of liveweights, dry matter intake and milk production in Australia.

Source: modified from Aarons et al. 2020

Table 29. Increasing herd size – estimated tonnes of wet manure[1] requiring collection

Herd size	150	300	600	1200	2400
% time contained	Manure captured (tonne per day)				
6	0.4	1	2	5	11
12	1	2	4	10	22
25	2	4	9	21	47
50	3	8	18	42	94
75	5	12	28	63	141
100	7	16	37	84	187

1 *Calculations based on 3 litres of wet manure per litre of milk produced (Nennich et al. 2005) and annual milk production increasing from 5,500 to 9,500 litres per cow with increasing herd size.*

12.3 Nutrient concentrations in manure storage systems

Nutrient content of manure sources

Nutrient content of manure sources on dairy farms can vary widely (Table 30), influenced by the feed types and nutrient intakes of dairy cows, dry matter content, methods of manure collection and gravity or mechanical separation processes. Additionally, collection and storage practices can greatly influence nutrient losses and remaining nutrient contents, most notably for nitrogen.

The different types of dairy manure (freshly flushed or scraped manure, first pond sludge, second pond effluent) will contain varying amounts of organic and inorganic nitrogen and phosphorus fractions.

Directly collected and applied dairy manure generally has 50% of nitrogen as ammonia-nitrogen and 50% in organic nitrogen forms. However, these proportions of nitrogen forms vary depending on the dairy cow diet, how much time cows spend on areas draining to the manure management system or frequency of manure collection.

Sludge from the first pond has a high proportion of organic nitrogen forms, which may potentially mineralize over several years after land application. Sludge will also contain a smaller proportion of ammonium nitrogen which is readily available nitrogen to crops or pastures.

Liquid effluent from second and subsequent ponds typically has a low total solids content. Depending on the storage time, liquid effluent will have a higher proportion of ammonia-nitrogen (50% to 90% of total nitrogen) and a comparatively lower proportion as organic nitrogen. Therefore, a high proportion of the total-nitrogen is readily plant available, with added nitrogen supply comparatively short lived.

Semi-solid manure resulting from a screw press (mechanical separation) will have a higher phosphorus to nitrogen ratio, with a higher proportion of nitrogen in an organic form, and so will be more slowly plant available. Composted manure will also have a higher phosphorus to nitrogen ratio, with remaining nitrogen in largely stable forms, resistant to microbial degradation and poorly plant available.

Table 30. Nutrient values for differing manure sources – average and range

Manure Source n=number of farms	Nitrogen (N) (kg/ML or % DM)	Phosphorus (P) (kg/ML or % DM)	Potassium (K) (kg/ML or % DM)	Sulphur (S) (kg/ML or % DM)
Yard wash (directly applied) n=14	419[2] 87-1,334[3]	77 19-237	573 99-1,900	51 9-143
Single pond effluent n=46	323 56-1,800	75 9-622	432 27-3,130	38 7-476
First pond effluent n=50	524 62-2,290	118 22-654	556 150-1,300	87 6-484
Second pond (green water) n=88	211 5-1,080	53 6-250	462 79-1,320	17 2-60
Third/forth pond (green water) n=14	161 7-828	26 6-156	369 70-1,110	16 4-59
Single pond Sludge n=24	0.60 0.26–2.13	0.23 0.05–0.37	0.36 0.12–1.01	0.39 0.07–0.71
Stockpiled Solids n=23	1.2 0.11–3.02	0.32 0.20–0.87	0.62 0.12–3.01	0.26 0.07–2.59

Note: Collected between 2016 and 2019 on commercial dairy farms.[1]

1 Agriculture Victoria Dairy effluent data base (Biosecurity and Agriculture Services, or R Campbell pers comm..
2 Average.
3 Range.

12.4 Manure nutrient losses

Manure is a valuable source of organic matter and nutrients which can enrich soil and enhance pasture and crop production. However, many physical, chemical, and biological processes can alter manure characteristics after excretion and deposition by cows, and during the process of collection and storage. This results in losses in fertiliser value and increasing environmental emissions.

- Rapid transformation of urea nitrogen to ammonium occurs when urine is mixed with faeces on hard surfaces, resulting in immediate and significant ammonia emissions to the atmosphere.
- Ammonia (NH3) gaseous loss is usually rapid, and higher in material with higher nitrogen concentration.

The management and treatment of manure also influences nutrient losses in gas or leaching.

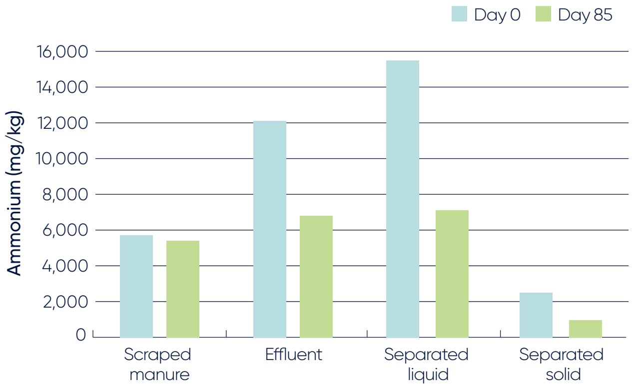
- Nitrogen concentrations continue to decrease during manure storage.
- Ammonia concentrations decrease in stored scraped manure (liquid-solids) after solid-liquid separation.

More soluble elements such as ammonium and potassium will remain in liquid fractions, while phosphorus and organic nitrogen stratify and concentrate in more solid fractions, contributing to variations in nutrient concentrations of manure in different storage systems (Figure 100).

Composting and medium to long term storage of solid manure in stockpiles will further reduce nutrient concentrations and nutrient availability via gaseous and leaching losses, therefore reducing the fertiliser value to crops and pasture (Figure 101).

Manure stockpiles may also produce nutrient rich leachate, with considerably more lost from screen or screw press separated manure solids compared with an equivalent weight of scraped manure (Table 31). Both leachate and atmospheric losses were greater for separated solids manure. Additionally, stored manure can be a significant source of odour (*see Section 7.5 Odour*).

Figure 100. Ammonium concentration in scraped manure, effluent, liquid and solid fractions



Note: Ammonium concentration after solid-liquid separation at the start (Day 0) and end (Day 85) of storage.

Source: Kitching, Shelley, Aarons, Heaven and Gourley – unpublished data

Figure 101. Windrows and composting of manure prior to land application

Windrows and composting will reduce moisture content and overall volume, but also decrease nutrient availability.

Table 31. Degradation of manure

	Scraped yard manure (i.e. total solids 50%)		Screw-press solids (i.e. total solids 50%)	
Loss pathway	**Uncovered**	**Covered**	**Uncovered**	**Covered**
Leachate (% initial weight)	0.2%	0.2%	12%	19%
Atmospheric (% initial weight)	27%	6%	36%	7%
Nitrogen loss to atmospheric (%)	25%	20%	12%	11%
Carbon loss to atmospheric (%)	30%	22%	49%	53%

Note: Scraped from dairy yards or solids separated through a screw press of yard-wash after 318 days

Source: Gourley, Aarons, Shelley, and Heaven; unpublished data

12.5 Developing a dairy farm nutrient management plan

A dairy farm nutrient management plan is a strategy for obtaining the optimal return from on-farm and commercial nutrient resources in a manner that minimise nutrient losses to the environment. In many regions around the world such as Europe, United States of America, Australia and New Zealand, developing and utilising a nutrient management plan is recommended for the operation of a dairy farm.

Nutrient management plans aim to integrate system level information such as milk production, feed, manure and fertiliser management practices, such as described in the Australian dairy industry Fert$mart program to optimize nutrient use efficiency, and better manage nutrient load at the farm- and within-farm scale, to assist nutrient management decisions for improved productivity and environmental outcomes.

A nutrient management plan should be tailored to an individual farm and should efficiently utilise all sources of nutrients to meet pasture/crop needs and minimise nutrient losses to groundwater, surface waters and the atmosphere.

A dairy farm nutrient management plan should rely on readily available and producer accessible information, should be easily understandable, provide clear guidance, and enable benchmarking of nutrient management performance.

Key components of a dairy farm nutrient management plan

The key information sources required to develop a nutrient management plan are provided below. All components of a dairy nutrient management plan are basic farm and nutrient management practices, with required information readily available from a successful dairy farm business.

a) Meeting regulatory requirements.
b) Defined dairy farm system boundaries.
c) Determining whole-farm nutrient balance and nutrient use efficiency.
d) Determining a manure, effluent and nutrient inventory.
e) Identifying nutrient deficiencies and excesses through soil testing.
f) Developing specific management-zone nutrient recommendations.
g) Targeted manure and fertiliser applications
h) Incorporating management strategies to reduce nutrient losses.
i) Opportunities and strategies to export excess nutrients.
j) Planning and record keeping.

a) Meeting regulatory requirements

Advisors and agronomists offering dairy specific nutrient management advice should be aware and understand all the relevant industry guidelines and codes of practice for manure and effluent management.

b) Defined dairy system boundaries

Australian dairy farms generally have land where dairy cows are located during the lactation for grazing and supplementary feeding, and which directly contributes to milk production and nutrient cycling. There are often other land uses within a dairy farm boundary such as native vegetation, wetland and riparian areas, that do not contribute to milk production. Many dairy farms may also have separate land areas (i.e. dairy support areas), where young and dry cows are contained and where additional pasture and forage will be grown and conserved.

- The dairy farm area most relevant to nutrient management planning is the milking platform – this is the principal productivity area.
- The milking platform is the total hectares of land directly contributing to milk production and includes grazed and harvested forage (pasture and crops) and designated feeding and sacrifice areas.
- The greatest nutrient inputs, manure deposition, nutrient cycling, pasture, crop and milk production and potential for nutrient losses occurs on the milking platform.

The milking platform is therefore used as the land area for determining nutrient inputs, outputs and net nutrient balance, reported on a per hectare basis. Whole-farm nutrient use efficiency measures, being a ratio, is not affected by assumptions about the land base.

- An aerial photograph or detailed farm map is useful for determining milking platform. In addition to detailed property and paddock boundaries and dimensions, infrastructure such as buildings, roads and laneways, gates and watering points should be identified.
- The farm map should also categorise bushland, hydrological characteristics such as waterways and gullies, flood plains, soaks and wetlands, and topographic characteristics (i.e. step-rises, sandy ridges.).

Aerial photography, satellite imagery and other coverages such as farm and paddock boundaries are often accessible both online and offline to assist with this task.

c) Determining whole-farm nutrient balance and nutrient use efficiency

A whole-farm nutrient budget considers the quantity of nutrients coming onto the dairy farm milking platform as inputs and the quantity of nutrients leaving in products, usually determined over a 12-month period (Figure 102).

The sum of nutrient inputs and outputs enable the determination of nutrient surpluses and deficits, while the ratio of the sum of nutrient exports to nutrient imports provides an estimate of nutrient use efficiency at the farm scale.

A nutrient budget calculation for nitrogen, phosphorus, potassium and sulphur therefore requires information about the nutrients imported and exported for an individual dairy farm, as determined by their mass and corresponding nutrient concentration.

Key nutrient imports generally include feed (forage and grain-based), fertiliser and nitrogen from biological nitrogen fixation. However, there can also be a wide range of additional nutrient imports such as by-product feeds, bedding, alternative fertiliser products, atmospheric deposition and irrigation of reuse water.

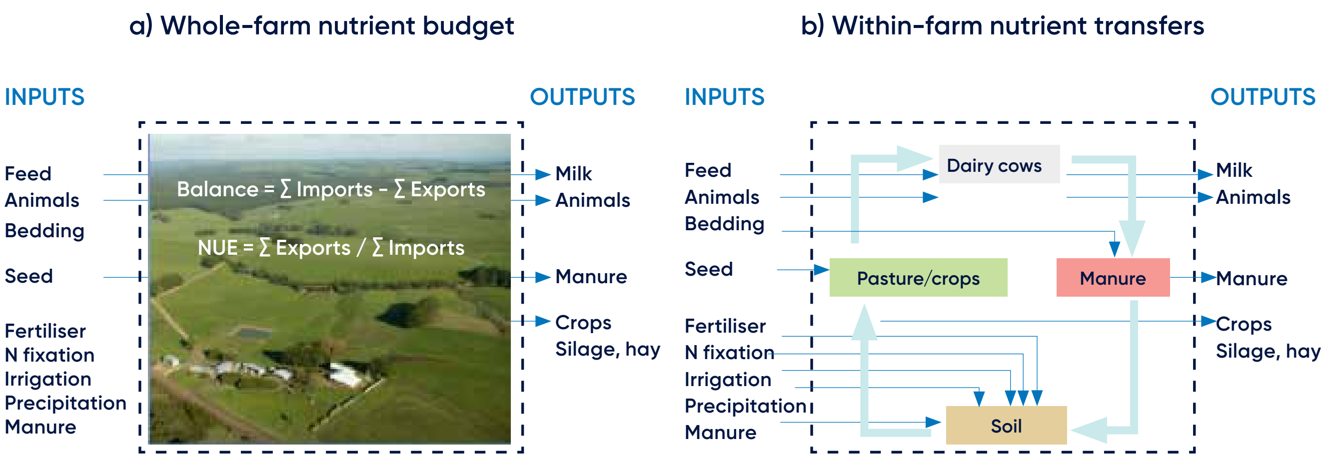
Key exports largely involve milk and animal sales. Additionally, manure may be an important source of nutrient exports on some farms.

While the mass or volume of imported and exported nutrient sources can usually be determined, nutrient budget calculations usually rely on nutrient concentrations sourced from lookup tables provided by commercial suppliers as well as published and scientifically credible industry standards.

Whole-farm nutrient surplus and use efficiency estimates provide a simple and largely standardised way to quantify and differentiate the utilisation of imported nutrients, and when combined with information on key components of nutrient load on dairy farms can greatly assist in targeting improvements in management (Table 32).

- A higher nutrient use efficiency indicates a greater utilisation of nutrients in exported animal products, and/or reduced inputs.
- Note, very high nutrient use efficiency, sometimes greater than 100%, indicates more nutrients are being removed than replaced, mining the soil of nutrients. For farms with excess reserves of soil phosphorus and potassium, this may be appropriate.
- High nitrogen use efficiency may however be decreasing soil nitrogen supply and degrading soil carbon.
- It is unreasonable to expect a farm to be 100% efficient as there are natural losses of nutrients in any ecological system, and agricultural systems are inherently inefficient.
- Whole-farm nutrient budget information is increasingly required by national and international food manufacturers and retailers as part of the demonstration of sustainable nutrient management practices.

Figure 102. Key nutrient load and cycling of nutrients within the farm boundary



Source: Adapted from Fertilizer Australia, 2020

Table 32. Whole-farm nutrient use efficiencies from a range of dairy farms

Nitrogen (N)	Phosphorus (P)	Potassium (K)	Sulphur (S)
Median value: 26%	Median value: 28%	Median value: 20%	Median value: 21%
Range: 14–50%	Range: 6–158%	Range: 9–48%	Range: 6–110%
Target range: 35–45%	Target range: 60–90%	Target range: 30–50%	Target range: 30–50%

Source: Gourley et al. 2012

While whole-farm nutrient balance and nutrient use efficiency are used as broad environmental indicators, the diverse climatic and soil conditions experienced in Australia, makes it difficult to make general predictions about the forms and amounts of nutrient losses from dairy farms. To quantify actual environmental losses, or even to determine relative losses, more detailed measures or predictive modelling is required that includes the partitioning of nutrient losses between various loss pathways.

d) Determining an effluent, manure and nutrient inventory

Nutrients available for land application from manure storage facilities are determined from the dry mass and nutrient concentration of each manure source. Information required include pond or stockpile volume and density, moisture and nutrient content.

Pond volumes are determined using the surface area and depth and adjusting for batter wall angles. However, it is difficult to arrive at an accurate gauge of pond depth and batter wall angles and so the calculated volume needs to be recognised as informed estimates.

Manure stockpile volumes can be determined by collecting length, height and shape data either manually or using software packages that use photogrammetry to capture a detailed 3-D image. Density of manure can be estimated or calculated from the weight of manure in a known container volume (i.e. bucket).

Average nutrient content values are available for different manure types (see Table 30). However, it is important to note that the actual nutrient content of manure sources on any farm can vary widely from published values, so laboratory analysis of farm-specific manure stores is recommended.

Collecting a representative sample of manure sources is important. This is particularly challenging in single or primary ponds where stratification occurs. Sampling methods for different manure and effluent sources are provided in the Australian dairy effluent and manure management database.

The minimum recommended laboratory analysis of manure should include moisture content, total and mineral nitrogen, total phosphorus, potassium and sulphur.

Collecting effluent and sludge samples from manure ponds can be dangerous. Ponds can be deep and viscous, with organic matter crusts and vegetation concealing the pond surface and edges. A safety assessment is essential prior to sampling.

e) Identifying nutrient deficiencies and excesses through soil testing

Soil testing and plant analysis are invaluable tools to diagnose constraints to crop and pasture production and may also assist to identify nutrient loss risk areas. Fertiliser recommendations for agriculture require supporting soil and plant chemical analysis and interpretation, underpinned by samples that represent the relevant soil environment.

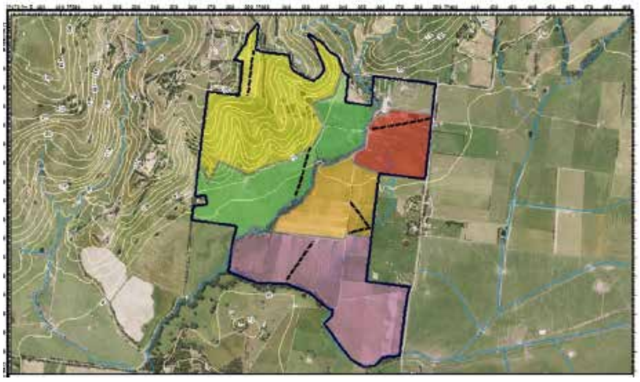
An on-farm soil testing program should adhere to the Australian Fertcare® Soil Sampling standard (Fertilizer Australia 2019) and be conducted at a time that allows for analysis of the sample and its interpretation in advance of the recommended fertiliser treatment.

It is important that a farm specific soil sampling map be developed. Paddocks or blocks that have differing management regimes and different soil types that need to be identified and categorised. In grazed dairy pasture systems, these regimes may include day and night paddocks, regular fodder harvesting, high feeding areas, regular effluent application areas and extensively managed out-paddocks. Areas that may be prone to greater nutrient loss should also be identified.

- The most comprehensive strategy is to sample every paddock (or even sub-paddock areas) every year to support an evidence-based approach to fertiliser decision making.
- Other options include cycling around the farm over a 3-4-year period until the whole farm is completed or selecting 'typical or representative' paddocks with similar characteristics.

The number of areas selected to be sampled should recognise the diversity of groups identified. Setting up a simple matrix based on paddock ID and matched against defined management practices (i.e. production potential, grazing practices, manure and effluent applications, previous fertiliser inputs, etc.) can assist in grouping paddocks and identifying representative areas to sample. For paddocks or blocks with the same soil types, and that have a similar management regime, an individual or group of paddocks with an average productivity can be selected to represent the rest of the paddocks or blocks in that group (Figure 103).

Figure 103. Example – five identified dairy farm management zones showing soil sampling transects



Note: The paddocks and transect paths used to collect representative soil samples.

Source: Fertilizer Australia 2020

The number of areas to sample should consider the cost of soil testing against the potential production benefits, savings in fertiliser, and costs to implement alternative approaches to fertiliser management.

It is important to record the specific location sampled (i.e. using GPS or recording/marking the transect on fence posts) within each representative paddock, block or management zone, so that you can return to the location and identify trends in fertility status site over time.

The sampling approach adopted should have an organized and systematic pattern to ensure that a collected bulk paddock sample is repeatable, labour efficient, adequately addresses the variability within the paddock and minimised bias. For information on sampling techniques, see *Fert$mart Chapter 8 – Assessing soil nutrients*.

Within-paddock variability in nutrient or other soil parameters can be significant. Some atypical paddock areas may be easily identified (i.e., current fence lines, gates, troughs, stock camps, feed-out areas, stock tracks), while others may not (previous fence lines, fertiliser or lime dumps, timber burns).

- Collecting an adequate number of cores to account for within-paddock variability is critical to achieving a representative sample.
- Paddocks with high variability require more cores to achieve the same error estimate than paddocks with low variability.
- At a minimum, the number of bulked soil cores should be 30–40 for 19mm diameter cores and 20–30 for 25mm diameter cores (accepting a ±15% error), irrespective of paddock size.

Soil sampling depth should reflect the zone of root activity and align with nationally accepted soil test calibration experiments for relevant pastures and crops. The required soil sampling depth is 10cm for pastures and forage crops in all States and Territories.

Soil analysis and interpretation

The quality of analytical services is critical in determining fertiliser and soil amendment advice provided to producers. In selecting a laboratory service provider, the following factors need to be considered and confirmed:

1. Participation in independent laboratory proficiency testing programs, whereby common homogeneous samples are sent for analysis to laboratories. The Australasian Soil and Plant Analysis Council (ASPAC) conducts the Proficiency Testing Programs for Australian laboratories. Laboratories are certified for particular test analytes if their results meet the qualifying criteria, with their annual certification status updated on the ASPAC website.
2. The use of recognised analytical methods which generate results that can be interpreted for Australian conditions, published interpretation data and/or historical records,
3. Presence of a quality control system, by way of internally-driven procedures or by verification to the AS/ISO 17025 standard through an authority such as the National Association of Testing Authorities (NATA).

Interpretation of soil test results must be underpinned by the national and soil specific soil test – pasture yield response functions and the derived critical soil test values for near-maximum growth of improved pastures across Australia.

Soil testing will also identify potential soil constraints (e.g. soil acidity, soil sodicity, soil salinity and soil dispersion) that will impact on pasture nutrient uptake and that soil amendment requirements will also be identified.

Derived relationships for phosphorus, potassium and sulphur form the basis of national standards for soil test interpretation and fertiliser recommendations for Australian pastures (Gourley *et al*. 2019) and are incorporated within the major Australian fertiliser company decision support systems. The most common tests are Olsen P (Victoria and Tasmania), Colwell P (NSW, SA, WA, ACT), Colwell K and exchangeable potassium (nationally), and MCP S or KCl40 S (nationally). Colwell P also requires the phosphorus buffering index measure for interpretation (Table 33). Soil testing for nitrogen in dairy pastures may be useful in determining residual mineral nitrogen in the soil profile but is generally poorly related to responses to applied nitrogen fertiliser.

Optimum nutrient status will be in the lower ranges on farms where pasture utilisation is low or when pastures contain poorer producing species. Whist 95% of pasture production potential is regarded as ideal in grazing-based dairy systems, optimum soil nutrient status is often regarded as 95–98% of pasture production potential (Table 33). It is a business decision where a producer chooses to operate, but it is not economically or environmentally sensible to operate above the 95% pasture performance level.

It is important to recognise that with increasing soil nutrient levels comes diminishing economic, and ultimately negative financial returns, as well as an increased risk of nutrient losses and offsite impacts.

Table 33. National interpretation guidelines for common soil tests for dairy soils

Soil test targets for 0–10cm samples accounting for pasture performance goals					
			Critical value range		
Pasture yield performance compared with potential	80–89%	90–94%	95–97%	98–99%	>99%
			Olsen P (mg/kg)		
All soils	8–10	11–14	15–20	21 –26	>26
PBI value			**Colwell P (mg/kg)**		
<5	7 - 8	9–11	12–15	16–19	>19
10	9–12	13–16	17–22	23–27	>27
20	13–17	18–23	24–30	31–37	>37
50	16–21	22–28	29–37	38–44	>44
100	18–24	25–32	33–42	43–51	>51
200	21–29	30–38	39–50	51–60	>60
350	25–35	36–46	47–60	61–72	>72
600	32–45	46–59	60–77	78–92	>92
1,000	45–64	65–83	84–109	110–129	>129
			Colwell K (mg/kg)		
Sand	85–94	95–125	126–155	156–200	>200
Sandy/Silty loam	94-104	105–138	139–175	176–210	>210
Sandy/Silty clay loam	99–109	110–142	143–185	186–220	>220
Clay loam and clay	110–119	120-160	161–210	211–270	>270
			Exch K (meq/100g)		
Sand	0.19–0.23	0.24–0.31	0.32–0.39	0.40–0.51	>0.51
Sandy/Silty loam	0.21–0.26	0.27–0.34	0.35–0.44	0.45–0.54	>0.54
Sandy/Silty clay loam	0.22–0.27	0.28–0.35	0.36–0.46	0.47–0.56	>0.56
Clay loam and clay	0.24–0.30	0.31–0.40	0.41–0.53	0.54–0.68	>0.68
			Sulfur (KCl-40) (mg/kg)		
All soils	4.5–5.5	6.0–7.5	8.0–10.0	10.5–12.0	>12.0
			Sulfur (CPC S) (mg/kg)		
All soils	1.6-2.2	2.0–3.0	3.1–3.8	3.9–4.5	>4.5

1. Critical value defined as 95% of potential maximum yield for grass – legume pastures.

2. Production goals defined by management.

f) Developing specific management-zone nutrient recommendations

Soil fertility and chemical condition mapping allows translation of soil test results into a visual representation of fertility and chemical conditions across the farm and highlights between-paddock or block variability (Figure 104). Mapping of soil test results across the farm is also useful in defining nutrient transfers such as regular forage harvesting, animal feeding areas and application of manure and effluent, or identifying the risk of metabolic problems in livestock. This approach can also identify areas close to dairy sheds that often have high or excessive nutrient levels, and those further from the dairy that may have nutrient levels below critical values which can accept effluent.

Different colours, depending on the context, may be used to correspond to soil nutrient status and targets (i.e. very high, high, adequate, marginal and deficient). Paddocks or blocks are then colour coded based on soil test results. Soil pH and salinity maps similarly determined are useful for targeted soil amendment decisions such as lime and gypsum.

g) Targeted manure and fertiliser applications

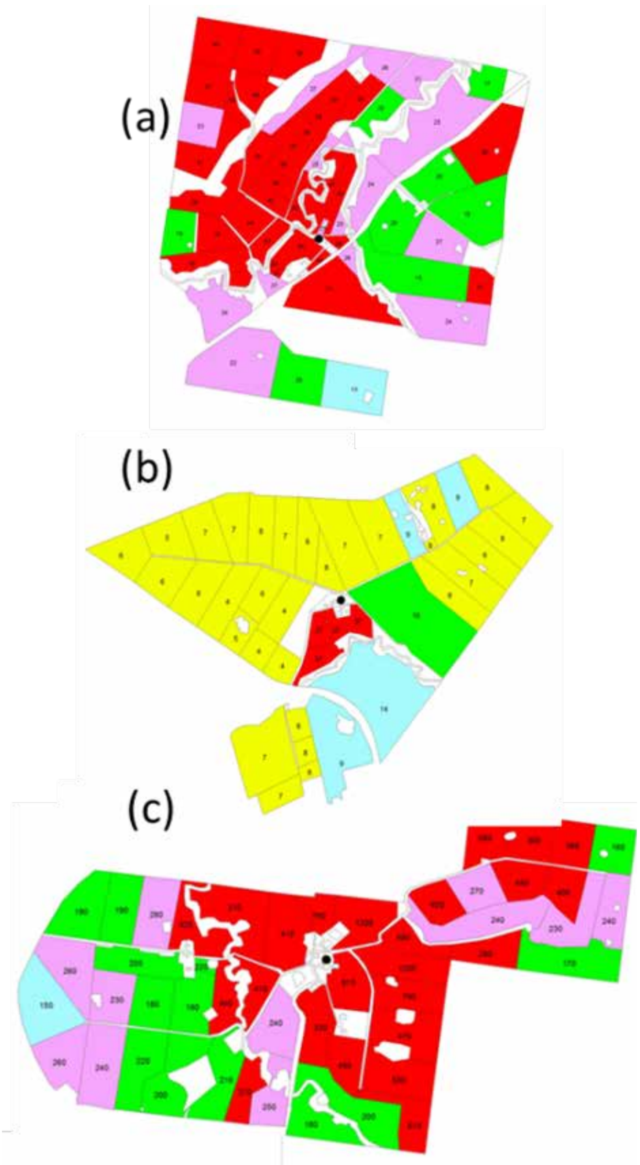
The 4R nutrient stewardship principles (IPNI 2020) are globally recognised, but how they are used locally varies depending on site-specific characteristics such as pasture and cropping system, soil and topography, climate and management techniques. The scientific principles of the 4R framework include:

- **RIGHT SOURCE –** Ensure a balanced supply of essential nutrients, considering both available sources and characteristics of specific fertiliser products, in plant available forms.
- **RIGHT RATE –** Assess and make decisions based on soil nutrient supply and plant demand.
- **RIGHT TIME –** Assess and make decisions based on the dynamics of plant uptake, soil supply, nutrient loss risks, and field operation logistics.
- **RIGHT PLACE –** Ensure that spatial variability within the paddock is addressed to meet site-specific plant needs and limit potential losses from the paddock.

Manure nutrient applications

The manure inventory enables an estimate of the total nutrients currently available for land application from stored manure and effluent. Matching this nutrient supply with estimated nutrient requirements across the farm is an important part of a dairy farm nutrient management plan.

Figure 104. Nutrient distribution map of Australian dairy farms



a) Olsen P levels on a conventional farm, (b) Olsen P on an Organic farm, (c) Colwell K on a conventional farm. Red indicates very high, purple is high, green is adequate, light blue is marginal and yellow is deficient nutrient phosphorus or potassium availability. The dot represents the location of the dairy shed.

The nutrient requirements of pastures and crops on a dairy farm may be totally, partially or only marginally met by the generated and stored manure. This will be influenced by the intensity of the dairy operation, informed by the whole-farm nutrient balance for nitrogen, phosphorus, potassium and sulphur, but also depend on the efficacy of manure collection, storage and land application.

Manure applications to deliver phosphorus, potassium and sulphur should be based on soil testing of identified farm management zones. Nitrogen inputs should be applied to optimize pasture and crop yields and use efficiency.

The 'fertiliser value' of nutrients in manure should be discounted depending on the manure source (LPELC 2019). Nutrients in manure are present in inorganic and organic forms, and hence are often not all immediately available to plants. Organic sources of nutrients must be mineralised into inorganic forms. For example, proteins need to be mineralised to ammonium, where it can be directly adsorbed or further transformed to nitrate. Organic forms of nitrogen will continue to mineralise and become available to crops in subsequent years after the initial application. In contrast, potassium remains in an inorganic form and is immediately plant available.

The rate of mineralisation will depend on the manure composition and load applied as well as the soil conditions such as clay content, biological activity, moisture content and temperature.

Most manure nutrient availability tables and decision support calculators will provide discounting factors to use when calculating nutrient availability.

Dairy manure sources rarely provide the correct balance of nitrogen, phosphorus, potassium and sulphur when manure is applied to land. Manure applications to meet nitrogen requirements will generally result in an oversupply of phosphorus and potassium, above pasture or crop requirements, with potential environmental and animal health impacts. If potassium application rates are optimised, then nitrogen and potentially phosphorus rates are likely to be sub-optimal and require additional commercial fertiliser.

It is important to calculate the required manure application to land, based on the target nutrient application rate (kg/ha).

This may require the calibration of manure application equipment. For irrigation systems the volume of effluent applied will be required (i.e. ML or mm applied per ha). For more solid material, this requires the mass or volume of manure applied (i.e. ton or cubic metres/ha). In both cases the mass or volume is multiplied by the nutrient concentrations (volumes need to be adjusted for density).

Figure 105. A trailing hose tanker spreading effluent from an agitated first pond

Preferred timing of manure applications must balance multiple factors including timing of pasture and crop uptake of nutrients and probability of rainfall events following manure application. The location of manure applications must consider site specific characteristics that influence environmental risks, such as existing soil test values, soil phosphorus buffering, slope, erosion potential and proximity to waterways. Effluent and sludge should not be applied to waterlogged or excessively wet soils.

Calculating effluent/manure land application rates:

Effluent/sludge

Target nutrient application (kg/ha) ÷
((Nutrient concentration (kg/ML) x availability factor))
= Effluent application rate (ML/ha).

Example for potassium:	60kg/ha ÷ (462kg/ML x 1) = 0.13ML/ha or 13mm
Example for nitrogen:	50 kg/ha ÷ (211kg/ML x 1) = 0.24ML/ha or 24mm

Solid stockpiled manure

Target nutrient application (kg/ha) ÷
((Nutrient conc. (%) x availability factor x DM content
= Solid material application rate (tonne/ha).

Example for phosphorus:	30kg/ha ÷ (0.2% x 0.75 x 50%) ÷ 1000 = 40 tonne/ha wet weight
Example for nitrogen:	60kg/ha ÷ (1.2% x 0.50 x 50%) ÷ 1000 = 20 tonne/ha wet weight

Note: Targeting the land limiting constituent avoids environmental impacts, so select the lowest of the two application rates.

Inorganic fertiliser nutrient applications

Nutrients contained in manure should be used first. After that, inorganic fertilisers can be used to plug any gaps.

- Fertiliser applications to meet phosphorus, potassium and sulphur requirements should be based on existing soil test results of the identified farm management zones as well as nutrient budget calculations.
- Fertiliser applications need to also account for nutrient removal and soil retention or losses (soil phosphorus fixation, potassium leaching) when determining 'maintenance fertiliser rates', and surplus nutrient inputs ('capital fertiliser applications') when the build-up of soil nutrient reserves is justified.

The rate of phosphorus, potassium and sulphur should be determined with the use of an accredited nutrient decision support system (i.e. Fertilizer Australia, Fertcare accredited), or alternatively a transparent calculation process which clearly identifies the scientific justification for the recommended fertiliser application.

Nitrogen fertiliser applications, often dominated by urea, is increasingly being used on dairy farms to increase pasture yields. Nitrogen fertiliser can substantially increase pasture yield and feed on offer when conditions are optimal for plant growth (i.e. adequate soil moisture and temperature, appropriate pasture species composition and maturity, and adequate supply of other nutrients). In contrast, yield responses can be low or negligible if soil, season and climate conditions are restricting plant growth, grazing pressure is too harsh or too little, or soil nitrogen supply from legumes, manure or mineralisation is meeting or exceeding plant demand.

National nitrogen management guidelines (Dairy Australia 2020) aim to improve nitrogen use efficiency and reduce avoidable environmental nitrogen losses. Best practice should also include determining the economic optimum nitrogen fertiliser rate.

- Optimum nitrogen fertiliser rates usually range between 30 and 60kg nitrogen per hectare per application.
- Total nitrogen applications for most pastures should not exceed 250kg nitrogen per hectare per year.

Ready reckoners such as 'Dairy N Fertiliser Advisor', based on a database of national nitrogen fertiliser response experiments, enables paddock specific nitrogen fertiliser recommendations for pastures based on regional, pasture production, season and cost-benefit analysis.

h) Incorporating management strategies to reduce nutrient losses

The main environmental issues which relate to nutrients include phosphorus and nitrogen losses to surface waters - leading to excessive growth of aquatic plants and algae and reduced oxygen availability (anoxia), and excess nitrogen leading to nitrate leaching to groundwater. The loss of ammonia, nitrous oxide and methane from the storage and land application of manure, is of increasing importance due to their contribution to greenhouse gas emissions.

On-farm nutrient use is highly regulated in many regions of the world. Some regulations are now evident in Australia, with controls on fertiliser use being introduced to protect the Great Barrier Reef (Qld). In other regions there are 'softer' options occurring, with combinations of research, extension, incentives and regulation, supported by Federal and State governments, industry organisations, producers, processors and retailers. Wise use of nutrients, and demonstration of nutrient management planning, will reduce the risk of increased regulation of farming activities.

Beyond the economic benefits of reducing expenditure on fertilisers, there are potential positive water quality outcomes using soil testing and adherence to agronomic critical values.

- Water quality risks will be reduced by allowing current soil phosphorus levels to rundown to the critical values.
- The Phosphorus Buffering Index (PBI) soil test provides an estimate of the potential phosphorus retention of a soil.
- Soils which have a low to very low phosphorus retention may be prone to leaching of stored and applied phosphorus (fertiliser or manure) through the soil profile and increased horizontal phosphorus losses through surface water movement.

Use of tools such as the Farm Nutrient Loss Index (FNLI) can assist in determining the risk of phosphorus and nitrogen losses at the landscape and paddock scale.

Minimising direct losses from fertiliser applications

- Know the soil fertility levels and do not fertilise or apply manure and effluent to soils with levels above-optimum soil fertility targets.
- Ensure fertiliser applications do not directly impact surface waters such as waterways, drainage lines and water storages – maintain the appropriate buffer distance when spreading.
- Avoid spreading fertiliser on critical source areas with connectivity to waterways, such as excessively wet paddocks adjacent to streams.
- Avoid areas with potentially above optimum nutrient levels (i.e. around gateways, feed pads, etc).
- Do not apply fertilisers to buffer strips or the end of irrigation bays.
- Do not apply nitrogen and phosphorus within 5 days of an anticipated rainfall runoff event.
- Ensure adequate ground cover and minimise soil erosion potential.
- Minimise urea applications to warm, wet soils and excessively short pasture to reduce ammonia volatilisation.

Minimising losses from storing and mechanically spreading manure

- Designing, maintaining and correctly sizing pre-treatment systems, ponds and manure stockpiles is critical to the effective capture and storage of dairy manure and minimising greenhouse gas losses.
- Ensure no direct overflow or leaching losses from ponds or stockpiled manure. Earthen or concrete bunding, drainage lines and ponds to contain leakage may be required.
- Dairy effluent and manure applications should be directed to areas in need of nutrient applications and applied at the required nutrient rates, accounting for slope, soil moisture content, leaching potential and ground cover.
- Ensure appropriate setbacks from waterways, buffer strips and native vegetation.
- Breakdown alerts and automatic shut-off systems should be used to address effluent irrigation system blockages, disconnections and overflows.
- Minimise the use of splash-plates and muck-spreaders. Concentrating effluent and slurry applications using trickle, trailing hose, or injection applicators will reduce nitrogen losses.

Minimising losses from animal deposited manure

- Manure deposited on hard stand areas (i.e. holding yards, feedpads, loafing areas etc) should be contained and managed within the manure management system.
- Keep stock out of waterways. Fence creek crossings and provide alternative watering points.
- Remove grazing animals from excessively wet soils and poor pasture cover. Restricting grazing to 8 hours a day over the autumn/winter period, and use of 'off-paddock' facilities, such as feed and stand-off pads can reduce nitrogen leaching losses.
- Ensure laneway runoff does not concentrate and drain direct to waterways. Construct drainage diversion humps to direct laneway runoff to grassed areas.
- Designated feeding areas, troughs and gateways should also be carefully sited.

i) Opportunities and strategies to export excess nutrients

The distribution of nitrogen, phosphorus, potassium and sulphur across a dairy farm is related to the intensity of the dairy farm system, paddock use (e.g. feeding areas, routinely grazed pastures, routinely cut and carry forage), and distance of grazed pastures from the dairy shed. A key influence of nutrient loads in particular areas, depends on how a dairy farm manages stocking density and the distribution of collected manure and effluent. Paddocks closer to the dairy shed are likely to be grazed more frequently, or used as holding or feeding paddocks, and hence will have a higher animal density and nutrient load. Those same paddocks are also more likely to receive mechanically applied effluent as they are more conveniently located to ponds. Be aware that:

- The nutrient concentrations of harvested forage are low relative to inorganic fertilisers, and manure and effluent application rates are generally much higher than the forage yields removed.
- Running down excessive nutrient levels such as phosphorus and potassium in soils is therefore a much slower process than the accumulation due to excess fertiliser, manure or effluent applications.

Nutrient accumulation within paddocks should be managed by monitoring the nutrient inputs and outputs associated with management decisions, assisted with soil test information about nutrient status. Forage harvesting may result in some significant net removal of nutrients but will depend on forage type, DM yield and nutrient concentrations (Table 34). For example, a good quality pasture silage will remove nearly twice the nitrogen, phosphorus, potassium and sulphur of an average pasture hay, while corn silage may produce higher yields, but a lower proportion of nutrients removed. It should also be noted that while legume crops such as lucerne may result in a net removal of phosphorus, potassium and sulphur, there is likely to be a net input of nitrogen through nitrogen fixation.

j) Planning and record keeping

Record keeping improves the planning and reviewing process. It is beneficial to keep structured annual records which include details of farm layout and identifies the principal productivity area, paddock uses, management zones, as well as any setback areas. Information on farm maps should also include soil sampling pathways and be linked to current and previous soil test results.

Manure, effluent and fertiliser applications to individual paddocks or at least management zones, should include the type, timing and rate of application and associated nutrient rates applied. Other useful information may include weather conditions and observed or measured pasture or crop yield responses to applied nutrients.

Table 34. Typical nutrient removal[1] when forage is exported

	Crop removal (tonne/ha)	Nutrient removal (kg/ha)			
		Nitrogen (N)	Phosphorus (P)	Potassium (K)	Sulphur (S)
Pasture hay	2	34	5	35	4
	4	68	10	70	9
Pasture silage	2	74	9	55	7
	4	147	18	111	14
	6	221	27	166	20
Lucerne silage	2	60[2]	8	43	6
	4	120	17	86	11
	6	180	25	129	17
Maize silage	4	67	10	41	4
	6	101	16	62	7
	8	134	21	82	9

1 Forage nutrient concentrations based on average farm data from Rugoho *et al.* 2016.

2 Lucerne cropping will increase nitrogen inputs through nitrogen fixation.

Dairy farm nutrient management planning checklist

- [ ] Farm area defined, paddocks identified and grouped into farm management zones.
- [ ] Regulatory requirements and environmentally sensitive areas identified.
- [ ] Whole-farm nutrient budgets and nutrient use efficiencies determined.
- [ ] Soil sampling areas and sampling routes identified according to Fertcare® soil sampling guidelines.
- [ ] Soil analysis and interpretation according to accepted science in Australia e.g. Making Better Fertiliser Decisions for Grazed Pastures in Australia.
- [ ] On-farm manure nutrient sources quantified and use optimised.
- [ ] Pasture and crop composition and growth performance assessed and considered.
- [ ] Basic soil health indicators have been assessed and considered e.g. waterlogging, pugging, sodicity and soil structure.
- [ ] A manure and fertiliser application strategy incorporating the 4Rs for each farm management zones have been developed.
- [ ] Environmental risks associated with nutrient applications have been identified and documented, and measures to minimise environmental risks implemented
- [ ] Adequate records are created and retained.

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13

Greenhouse gas emissions in dairy

13.1 Climate change and the role of greenhouse gas emissions in dairy

Climate change refers to long-term shifts in temperature and weather patterns. Climate is determined by many factors that influence flows of energy through the climate system, including greenhouse gases (GHGs). Human activities, including food and fibre production, are directly increasing atmospheric concentrations of GHGs (mainly carbon dioxide, methane and nitrous oxide). That is, GHGs from human activities are being released into the atmosphere at greater rates than they are absorbed by plant growth and other carbon storage processes. In turn, this contributes to the ongoing rise in the Earth's average surface temperature.[1] This can be observed in a range of impacts, including changes in global, regional and local climates (rainfall, temperature and/or extreme events).

The United Nation's Intergovernmental Panel on Climate Change indicates that crossing agreed temperature threshold risks unleashing far more severe climate change impacts, including more frequent and severe droughts, heatwaves and rainfall. The Paris Agreement is the international treaty agreed in 2015 that set the goal to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels." This equates to reaching peak emissions as soon as possible and aiming for Net Zero by 2050. In line with this, Australia has committed to achieve 43% emissions reduction by 2030, and Net Zero by 2050.

GHGs emitted by livestock, manure, energy and other sources on dairy farms are contributing to GHG emissions and farming is also impacted by the effects of climate change. All GHG emissions are estimated and converted to a common metric being carbon dioxide equivalents (CO_2-e) based on their different warming potential in the atmosphere. This metric is used for estimating both total (net) emissions from a entity or farm, and for the emissions intensity (EI) which is the emissions per unit of product from the business.

Emissions intensity is useful as a comparison of relative efficiency between farms and systems, as total emissions are heavily influenced by the size of each individual farm. Given there are normally two main products produced from a dairy farm – milk and meat, the EI for dairy is measured as kg of CO_2-e per kg of milk solids (MS) OR per kg of fat and protein corrected milk (FPCM) and kg of CO_2-e per kg of meat (liveweight).

Although the carbon footprint of Australian dairying is one of the lowest in the world, there is still potential to improve efficiency.[2] Some of these emissions can be mitigated through changing practices and technologies on-farm and throughout the supply chain. The Australian dairy industry has voluntarily committed to reducing GHG emissions intensity by 30% by 2030, compared to 2015 levels, as part of a commitment within the **Australian Dairy Sustainability Framework**.

Tracking supply chain emissions

To support the Paris Agreement, countries will be required to report transparently on actions taken and progress in managing emissions towards their target. Of the largest economies, there are a large majority that are corporations/companies and not countries. **Emissions reduction and associated emissions reporting are increasingly being driven by company commitments.**

As of January 2025, some companies are required to report on their emissions as part of their annual reporting requirements. Entities are separated into three groups, and their obligations are phased in over a period of three years. See **cer.gov.au/schemes/national-greenhouse-and-energy-reporting-scheme/assess-your-obligations** for more information on these measures and whether your farm meets the requirements for this reporting.

Farm businesses being asked for this information should work with their supply chain to ensure their data and the methods they use are compliant with the required standards.

1 Source: **science.org.au/our-focus/science-everyone/science-climate-change/1-what-climate-change**
2 Source: **dairyaustralia.com.au/climate-and-environment/greenhouse-gas-emissions/dairy-farm-emissions**

13.2 Understanding dairy greenhouses gas emissions in Australia

There are three major GHGs emitted from dairy farms:

1 Methane (CH_4) from cows belching as part of their ruminant digestion process, as well as from the breakdown of effluent and manure, most significantly in anaerobic conditions.

2 Carbon dioxide (CO_2) from the production of electricity, the burning of fossil fuels, and which is also produced by lime application and in the manufacture of purchased products such as urea.

3 Nitrous oxide (NO_2) from urine and dung, fertiliser and through leaching and runoff.

A smaller proportion of emissions can also be embedded in the main products purchased and contracted services used in the farming operations.

The estimation of a farm's **net** GHG emissions includes all GHG emissions minus any CO2 removal and storage in vegetation and soils. The sources of emissions will vary between farms but the estimated proportion of each gas is proportionally similar across dairy farming systems in Australia with methane being the largest source, followed by carbon dioxide and then nitrous oxide (Figure 106).

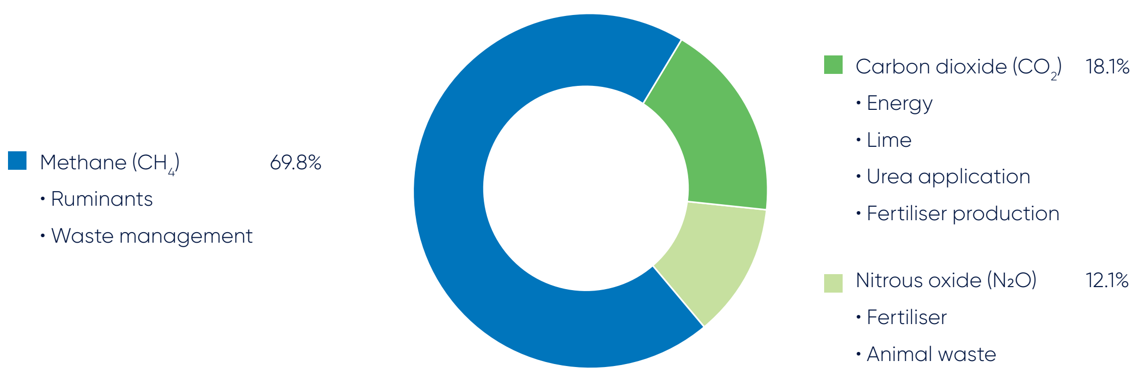
Estimating GHG emissions should align to international and national GHG accounting standards. Within these standards, GHG emissions are grouped into three categories known as 'scopes'. An explanation of each Scope and how it relates to dairy has been provided below and in Figure 107.

Scope 1, the emission is a direct result of an activity within the entity's business footprint, and they have direct control over the emission-causing activity (for instance, enteric methane emissions from livestock – happen on the farm and occur directly because the farm has livestock).

Scope 2, energy (generally electricity but in some instances can include waste heat) related emissions which occur outside of the business footprint and the entity has partial indirect control (can choose to not turn on the light, or elect to source energy from a lower emissions energy provider, but can't directly influence the energy sources used by the energy provider).

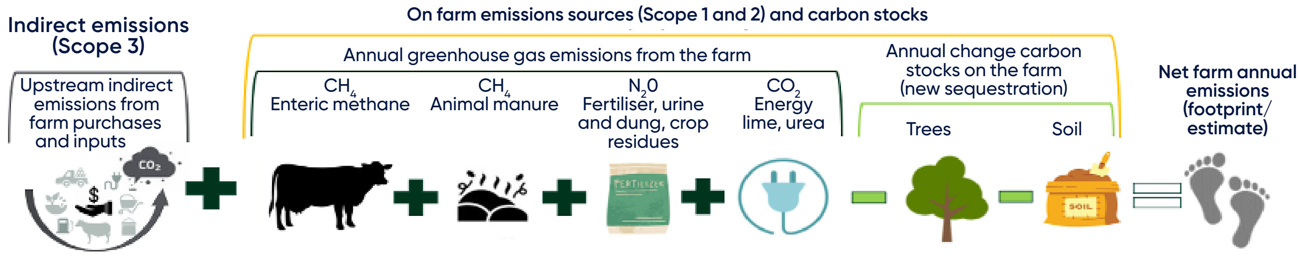
Scope 3, emissions which occur outside of the business footprint, and indirect control – embedded emissions associated with the product being produced (eg for a dairy processor, the milk they purchase from dairy farms. They can choose to source milk from farms with lower emissions intensity, or source less milk to reduce their emissions, but do not have direct control over how their suppliers run their farms).

Figure 106. Sources of emissions from an Australian dairy system



Source: Understanding Farm Carbon Workbook, Dairy Australia, 2025. This represents the average greenhouse gas emissions estimate of all Dairy Farm Monitor participants in Australia (2023-24, ~250 farms, across all dairy farm systems, Scope 1-3, but not carbon removals).

Figure 107. Scope 1, 2 and 3 emissions for an Australian dairy system



Source: On Farm Emissions Action Plan Pilot, Agriculture Victoria (2025). Visual representation of sources of emissions for an Australian dairy system, showing Scope 1, 2, 3 and carbon removals (sequestration).

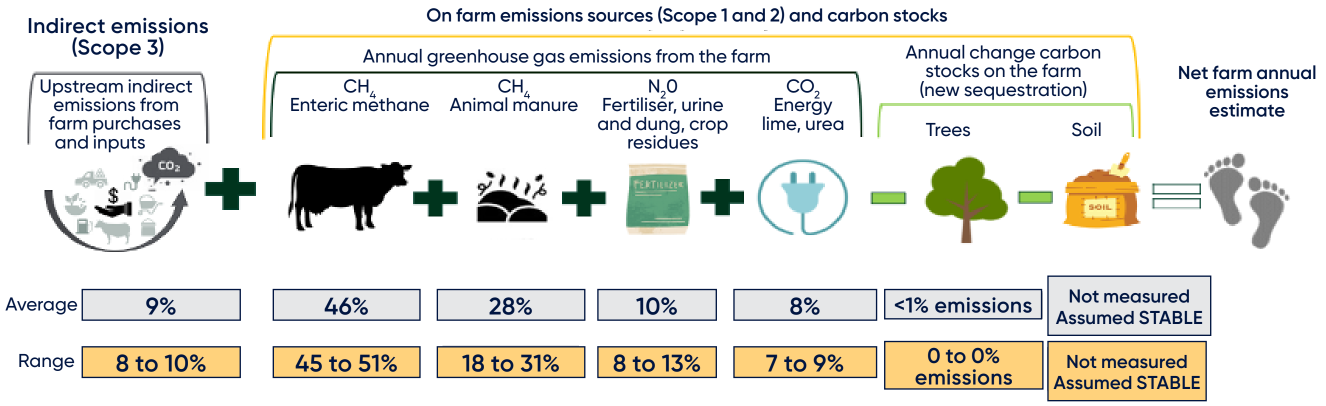
It helps to consider the level of control an entity has over the emissions contributing activity across these Scopes, as this can differ across farms and the supply chain. Table 35 outlines how this plays out for a dairy farm when compared to a milk processor, for example. Farmers will therefore have different levels of ability and willingness to manage each area of their emissions, depending on their farming system and the scope of emissions.

Table 35. GHG Accounting definitions of Scope 1, 2 and 3

		Example	
Emissions	**Definition**	**Dairy farm**	**Milk processor**
Scope 1	Direct emissions from owned or controlled sources e.g. operating buildings and other facilities, or a vehicle fleet.	Enteric methane, fertiliser use, fuel, waste management etc.	Factory, transport, waste management
Scope 2	Indirect emissions from the generation of purchased energy. Scope 2 emissions are the result of the reporting organisation's activities but the emissions occur at a facility owned by another organisation (e.g. electricity generator or utility).	Purchased electricity	Purchased electricity steam, heat or cooling
Scope 3	All indirect emissions (not included in Scope 2) that occur in the value chain of the reporting company. This includes both upstream and downstream emissions.	Upstream: Purchased feed, production of fertiliser	Upstream: Farm and farm inputs, production materials e.g. packaging
		Downstream: Processing and consumption of farm outputs	Downstream: Sale of products and consumption

Source: Understanding Farm Carbon Workbook, Dairy Australia, 2025. Includes GHG Accounting definitions of Scope 1, 2 and 3 as they apply to a dairy farm and milk processors

Figure 108. The sources and types of farm emissions for TMR farms



Source: Dairy Farm Monitor Project Inland NSW & Northern Victoria total mixed ration (TMR) feeding systems 2023/24, Dairy Australia 2025. The sources and types of farm emissions for TMR farms, adapted from Agriculture Victoria's On-Farm Emission Action Plan Pilot. Percentages reflect averages and range from 2023/24 financial year for the 14 TMR farms (Note: This is published data and may not include other TMR participants in DFMP or QDAS, it is a subset for illustrative purposes only).

Even though farms may not currently have mandatory reporting requirements, they are part of a dairy processor's **Scope 3 emissions** because they sit within the processor's supply chain. While businesses cannot require suppliers to provide their carbon emissions data at this stage, some processors and financial institutions are already offering incentives to encourage farmers to share their emissions estimates.

Influence of farming system on GHG emissions estimates

GHG emissions and sequestration estimates for a small sample of total mixed ration (TMR) farms were reported for the first time in 2025 (Figure 109). Fourteen NSW and Victorian based TMR farms from within the Dairy Farm Monitor Project (DFMP) were used to illustrate the sources of emissions and compare the emissions intensity with pasture-based DFMP farms in the same regions.

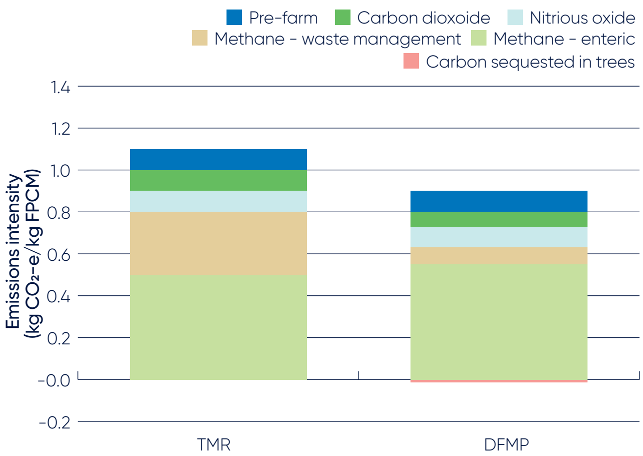
While the sources of emissions from a TMR farm are similar to grazing systems, the proportion and total amount of emissions differ.

Methane is typically the largest GHG emission in ruminant livestock and dairy farming systems. This is especially the case for housed dairy farms (Figure 109). The main reason is that a large proportion of manure is flushed into ponds or other anaerobic effluent management systems, where methane is produced, rather than being deposited directly onto pastures. That said, every individual farm system will have a different emissions profile, with scale (size of herd) and manure management being the greatest influences on net farm emissions.

This means that dairy farms operating TMR feeding systems have the greater ability to manage the effluent portion of their emissions. For example, depending on how the effluent system has been designed on a TMR farm, they have a greater opportunity to separate the solids earlier in their effluent management system, potentially lowering their effluent emissions.

When compared to grazing farms, TMR farms have a higher share of their total emissions from CH_4, particularly from manure management (Figure 109). The emissions intensity from each source was similar. Tree sequestration contributed less than one per cent to net emissions for TMR farms and around one per cent for grazing-based DFMP farms, on average. While not representative of the industry, this highlights the different contributions of CH_4 in these systems.

Figure 109. Comparison of TMR and pasture-based dairy farm



Source: Dairy Farm Monitor Project Inland NSW & Northern Victoria Total Mixed Ration Feeding Systems 2023/24, Dairy Australia 2025. Note: Includes Scope 1–3 emissions, with emissions intensity apportioned to milk only. The figure shows the average contribution of different emission sources to the emissions intensity of total mixed ration (TMR) and pasture-based dairy farms.

13.3 Estimating emissions on-farm

The first step towards reducing GHG emissions is understanding the sources of emissions within your farm boundary and then identifying the most effective options for reducing them.

Emissions from a dairy farm can be estimated using several tools, available online or as a standalone worksheet. The **Australian Dairy Carbon Calculator** is Dairy Australia's tool, which is based on national and international standards and emissions factors and is integrated with DairyBase.

Note

If you already use DairyBase to manage your farm productivity reporting, you can simply answer a few additional questions to get your greenhouse gas emissions report.

Emissions estimates are reported using annual inputs and outputs for a dairy farm and are underpinned by farm data. Most tools will require similar data to generate an emissions estimate for a dairy farm:

- Animal numbers (milking herd and other livestock classes), weights, and movements on and off farm
- Milker average diet intake and quality
- Quantities of purchased feed/supplements
- Milk production, fat and protein content, and lactation period
- Fertiliser applications
- Fuel and energy use (including use by subcontractors)
- Manure management methods (system design, waste treatment and time milking herd spends in dairy, yards and feedpad/loafing areas)
- Tree plantation area, age and species.

An example **data collection sheet** is available on the Dairy Australia website.

Farm emissions estimate calculators are based on peer-reviewed science and aligned to national and international GHG accounting standards. In other words, emissions are calculated using national and international standards and emission factors, which might not fully capture the unique conditions or practices on your farm.

Farm emissions estimates are highly dependent on the accuracy of the data entered, as well as any assumptions made and the seasonal conditions at the time of calculation. A useful rule of thumb is that these estimates are likely to be "generally right, but precisely wrong".

Before starting...

Consider the current farming system and confirm the scope and boundary of the enterprise/s and farm block/s to be included in the emissions footprint. For example, consider leased properties, agistment arrangements, and subcontractor activities that might need to be captured in the data.

Note

The more confidence in the farm data entered into the calculator, the higher quality the emissions estimates will be. Good record-keeping of the key data sources is required.

Consistent national standards for estimation of agricultural GHG Emissions

Voluntary farm-level GHG Emissions Estimation and Reporting Guidelines (VEERG) are being developed to improve the quality and consistency of estimation methods and tools. Once released, tools will be reviewed to ensure they meet these guidelines. These are due for release in mid-2026.

Source: ***dcceew.gov.au/climate-change/emissions-reporting/voluntary-emissions-estimation-reporting-standards***

13.4 Comparing your emissions

National and regional estimates of emissions intensity exist for the Australian dairy industry, and these vary on an annual basis. These are available through the GHG emission data reported in the aggregated DFMP data.

> **Note**
>
> DFMP collects data from both pasture-based and intensive dairy systems across Australia and does not currently separate EIs for these farming systems in their annual updated figures, so care should be taken in any comparison with TMR systems. The TMR GHG comparison values in Figure 109 were a separate study only looking at emissions from TMR systems.

Estimates of emissions intensity (EI) help farmers compare performance, understand their emissions footprint, and identify the main opportunities to reduce emissions. The goal is to achieve a lower EI.

The Australian Dairy Industry annually reports a national EI, as per its reporting on progress against the industry 2030 EI target within the **Australian Dairy Sustainability Framework** annual statements. In 2023 the national average for EI was 0.93 kg CO_2-e/kg FPCM (ADSF 2024 report [latest report available at time of this publication], sourced from national DFMP dataset). This EI includes the full DFMP dataset, which includes a combination of TMR and grazing systems.

For comparison, the recent TMR GHG analysis estimated EI from TMR farms was in the range of 1.0-1.3 kg CO_2-e/kg FPCM (Table 36).

When comparing emissions intensity, consider the following:

- Is the EI below, within range or above the industry average yearly estimate?
- Is the EI for the farm being analysed a TMR or grazing system, or in-between, and are comparative figures available?
- Were there any seasonal conditions that may explain why the current EI is outside the range, or different from the previous year? For example, a significant change in milking herd numbers.
- What are the largest sources of emissions within that emissions footprint?
- Was an estimate provided for the carbon sequestration from any trees on your property? Any information about tree plantations on the property could contribute to lowering the emissions estimate.

Dairy Australia publishes GHG updates and resources – visit **dairyaustralia.com.au** and search for greenhouse gas emissions.

Table 36. Comparing net emissions and emissions intensity

Farm group	Dataset size	Net emissions	EI - milk	EI - milk	EI - meat
	Number of farms	t CO_2-e/farm	kg CO_2-e/kg MS	kg CO_2-e/kg FPCM	kg CO_2-e/kg lwt
TMR	**14**	**13,600** (9,300 to 14,600)	**16.2** **(14.3 to 17.8)**	**1.2** **(1.0 to 1.3)**	**7.6** **(5.6 to 7.5)**
Inland NSW TMR	6	9,900 (6,900 to 13,500)	15.5 (14 to 16.1)	1.1 (1.0 to 1.1)	6.5 (5.5 to 7.5)
Nth Vic TMR	8	16,400 (9,500 to 18,400)	16.8 (14.7 to 18.3)	1.2 (1.0 to 1.3)	8.4 (5.9 to 7.0)
DFMP	**30**	**3,700** **(1,900 to 4,800)**	**12.4** **(11.7 to 13)**	**0.9** **(0.8 to 0.9)**	**5.4** **(4.4 to 5.7)**
Inland NSW DFMP	6	6,200 (2,900 to 9,600)	12.6 (12.4 to 13.1)	0.9 (0.9 to 0.9)	5.9 (5.1 to 6)
Nth Vic DFMP	24	3,100 (1,800 to 4,600)	12.3 (11.6 to 12.9)	0.9 (0.8 to 0.9)	5.2 (4.4 to 5.4)

Average and range (shown by quartile 1 to quartile 3 in brackets) are provided.

Source: Dairy Farm Monitor Project Inland NSW & Northern Victoria total mixed ration feeding systems 2023/24, Dairy Australia 2025. Shows the 2023-24 average and range of net emissions and emissions intensity (EI) measures for the different farm groups.

13.5 Emissions reductions in contained housing dairy systems

Greenhouse gas (GHG) emissions highlight opportunities to improve efficiency within a farming system. Reducing emissions can help capture more energy and nutrients for production, supporting both environmental outcomes and farm productivity.

When methane (CH_4) and nitrous oxide (N_2O) are released into the atmosphere, energy and nitrogen that could otherwise support production are lost. While some level of emissions is unavoidable, dairy systems have many opportunities to reduce GHG emissions while also improving efficiency and profitability. There are also growing expectations from markets and stakeholders for farms to understand and reduce emissions, while ensuring that any actions taken remain practical and economically viable.

For a business looking to reduce its carbon footprint, or to achieve net zero status, there are three types of actions that can be taken (see Figure 110):

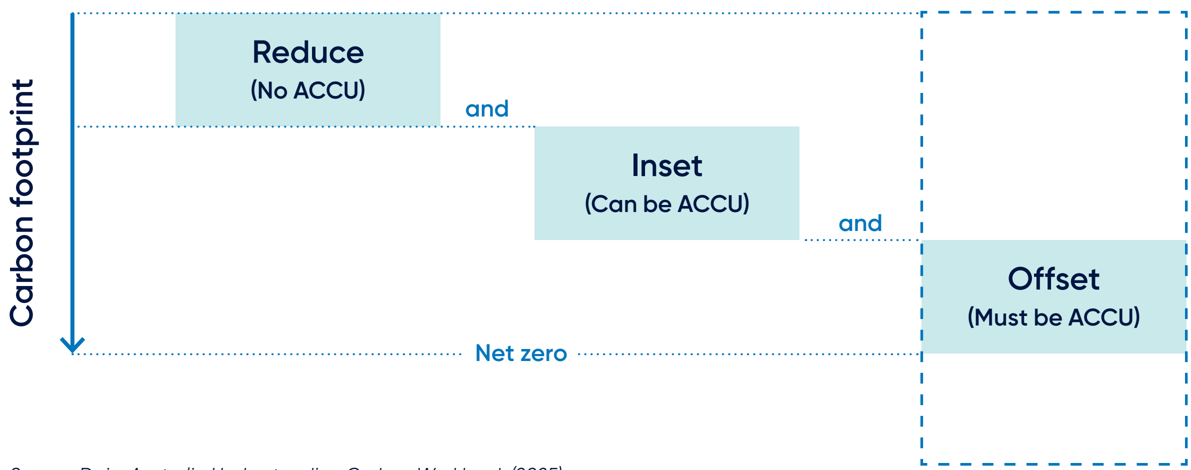
- **Reduce:** Reducing within their business footprint as much as practical and economically feasible – prioritising efficiency actions which reduce emissions while maintaining or increasing productivity.
- **Inset:** Taking actions to support emissions reduction within their supply chain – either by incentivising their suppliers to reduce emissions or purchasing carbon credits from businesses within their supply chain.
- **Offset:** Purchasing carbon credits (known as ACCUs) from the open market to counter any residual emissions that cannot be otherwise abated.

Corporate integrity schemes such as the **Science Based Targets initiative (SBTi)** encourage businesses to reduce their emissions as much as possible first. This means focusing on cutting emissions within their own operations and supply chains, aiming to get as close to net zero as they can, and only using offsets for any remaining emissions.

When deciding where to focus emissions reduction efforts, it is important to look at the main sources that are within the farm's control. In dairy systems, the largest source of emissions is methane, produced through enteric fermentation and manure management. As a result, changes that affect methane—such as cow numbers, milk production, or effluent management—will have the greatest impact on a farm's greenhouse gas footprint.

There is a range of solutions available now, and some still in development, that can support emissions reduction efforts on a dairy farm. Figure 111 highlights the current opportunities to consider.

Figure 110. Options to reduce a dairy carbon footprint



Source: Dairy Australia Understanding Carbon Workbook (2025)

Figure 111. Summary of available emissions reduction options

Livestock and feed

- Efficient feed utilisation and conversion
- Balanced diet (protein to energy)
- Cow health and animal husbandry
- Feeding fats and oils
- Culling unproductive cows
- Lactation length
- Cow longevity
- Herd testing
- Transition cow management/calf rearing
- Feed budgeting
- Infrastructure to support cow health
- Selection for high EBV/genomic traits
- Genetic testing
- Sexed semen
- Right cow for your system
- Vaccines to reduce methane*
- Feed additives to reduce methane
- Early life programming*

*Denotes technologies currently under development or not yet commerccially available in Australia

Fertiliser and effluent

- Efficient fertiliser use – The 4Rs (Right: Source, Rate, Time, Place)
- Soil and tissue testing
- Coated nitrogen/nitrogen inhibitors
- Best practice nitrogen use
- Nutrient budgeting
- Timely application of effluent
- Testing effluent
- Sufficient effluent storage
- Solid separation
- Biodigesters and covered anaerobic ponds
- Composting of effluent/manure
- Agitators
- Effluent additives*

*Denotes technologies currently under development or not yet commerccially available in Australia

Energy and fuel

- On-farm solar and renewable energy
- E-vehicles
- Batteries
- Energy audit
- Maintenance of dairy plant
- Maintenance of pumps and irrigators
- Purchased renewable energy
- Alternative renewable fuels
- Energy efficient upgrades

Trees and soil

- Shelter belts and environmental plantings
- Fencing off creeks, wetlands and remnant vegetation
- Agroforestry
- Pasture species selection
- Composting
- Managing stocking rates/rotation
- Pest plant and animal control
- Managing soil constraints

Emissions reduction can be achieved by implementing one option, or many options concurrently. Each will have different results depending on how they are implemented and incorporated into the farm system.

Methane - enteric

Enteric methane (CH_4) is produced during the digestion process of ruminant animals, so it is an unavoidable part of dairy systems. The proportion of emissions from enteric methane can be higher on TMR farms where manure methane is reduced through practices such as effective solids separation and keeping feedpad or shed manure out of anaerobic effluent systems. For example, a Northern Victorian farm that milked cows in batches (limiting time on the dairy yard), used a screen and screw press, scraped and stockpiled feedpad manure, and operated a compost pack shed recorded 53% of emissions from enteric methane and only 8% from manure methane (Dairy Australia). In the broader TMR analysis, enteric methane accounted for 46% of total net emissions (2023-24 financial year, 14 TMR farms, Dairy Australia, 2025). The main drivers of enteric methane emissions are animal numbers, dry matter intake, and diet quality.

Ways to reduce this source of emissions can include herd management, such as removing unproductive animals from the herd as soon as possible, selective breeding for low methane and selecting animals for maximum efficiency, and/or tailoring diets to reduce excess methane production (e.g. nitrate supplementation).

Feed additives also have significant emissions reduction potential in intensive systems. Research and development work is well underway to develop feed additives for ruminant animals to reduce enteric CH_4 emissions. There are some currently available feed additives, such as Agolin, that have shown a ~10% reduction in methane emissions and efficiency gains, and **recent results** from a study undertaken at the Ellinbank Smartfarm in 2025 also demonstrate more effectiveness in TMR systems than in pasture. Other examples of feed additives include *Asparagopsis taxiformus* (red seaweed) or Bovaer® (3-NOP). While most products are still in early stages of commercialisation, farms using feedpads and contained housing systems will be well-placed to deliver additives via existing feeding infrastructure when they are on the market and commercially viable.

Before incorporating feed additives, consider if the feeding system is appropriate for their use (feed-out infrastructure and timing of doses) and for monitoring herd performance over time to capture any co-benefits for production (if any). Additionally, seek advice from the supply chain on whether feed additives meet market requirements and confirm any data/measurement requirements for evidence.

Other prospective solutions being researched include anti-methanogen vaccine, synthetic forms of bromoform (main active compound in red seaweed), probiotics, garlic and citrus extracts, essential oil extracts, biochar feed supplementation and early life rumen programming for low methane traits.

Some mitigation options may be less suitable for TMR systems. For example, lipid or fat supplementation is often not appropriate because dairy TMR diets already include fat sources close to the recommended upper limit. Similarly, tannin-rich legumes are mainly relevant to pasture-based systems. However, suitability depends on a careful review of the herd's current diet to determine whether any additives could still be included without negatively affecting rumen function or overall herd health.

More information

For more information visit **dairyaustralia.com.au and search for emissions reduction strategies.**

Methane – manure management

Manure methane (CH_4) is produced when effluent breaks down in an anaerobic environment (that is, without oxygen). On dairy farms, this commonly occurs when effluent is washed into and stored in lagoons. As a result, manure methane can be a major source of emissions in contained housing systems, where larger volumes of effluent are collected and stored.

In TMR systems, manure methane was found to account for up to 28% of net emissions (2023-24 financial year, 14 TMR farms, Dairy Australia, 2025). However, emissions profiles can vary between farms depending on their system and effluent management practices. For this reason, individual farms should use their own emissions estimates to guide decision-making.

Ways to reduce this source of emissions include removing as much of the solid fraction of effluent before the lagoon as possible (by scraping and storing, using weeping walls or separating screens, and chemical flocculants* like lime and polyferric sulfate), regularly spreading effluent, and preventing anaerobic conditions by using an agitator or effluent stirrer to ensure that lagoons are aerated. Understand that using technology such as this may introduce new emissions sources from the use of non-renewable energy sources.

Another approach is to allow anaerobic fermentation to occur, but to cover the pond and collect the methane gas produced, which can then be flared off. Covered anaerobic ponds (CAPs) or biodigesters allow for the potential of effluent to be used for energy generation. Feeding highly digestible diets to limit the amount of manure produced is another way to reduce overall effluent emissions.

There is research and development underway to consider the application of effluent additives in Australian systems. Consider monitoring progress with these emerging technologies.

Spreading effluent on crops and paddocks is also a way to reduce the quantity of purchased fertiliser and fully utilise resources (nutrients and water) already in the system.

**While technically proven, flocculant use is not yet widespread in the Australian dairy sector. Adoption is limited to a few demonstration sites or research-linked farms. Barriers include cost, regulatory uncertainty, and lack of farmer familiarity. Source: DAFF/CSIRO Emissions technology readiness analysis (in draft, 2025).*

> **More information**
>
> For more information about effluent management and system design, see Chapter 7 or visit **dairyaustralia.com.au** and search for emissions reduction strategies.

Energy

Energy-related CO_2 emissions come from the use of grid electricity and fossil fuels (such as diesel, petrol, and LPG), affecting both Scope 1 and Scope 3 emissions. Dairy farms require significant energy for activities like milking, milk cooling and storage, cleaning and sterilisation, water and effluent pumping, and shed operations in housed systems. In addition, fossil fuel use by machinery, equipment, and subcontractors contributes substantially. On TMR farms, energy-related emissions can account for up to 8% of net emissions (2023/24 financial year, 14 TMR farms, Dairy Australia, 2025).

Ways to reduce this source of emissions is to complete an energy audit, to assess current usage and identify any inefficiencies. Implementing renewable energy and energy storage systems to reduce consumption of grid energy to reduces emissions and costs simultaneously.

Consider the option for the electrification of vehicles and equipment where possible. Electric and hybrid tractors are in early development; once issues of battery runtime and power are resolved, they could eliminate on-farm diesel use. Similarly, farm equipment running on biogas (from a covered lagoon digester) or hydrogen fuel cells is being explored (*DAFF/CSIRO Emissions technology readiness analysis, in draft, 2025*).

> **More information**
>
> For more information on energy, see Chapter 14 or visit **dairyaustralia.com.au** and search for emissions reduction strategies.

Nitrous oxide

Nitrous oxide (N_2O) emissions are driven by manure deposited or stored on concrete surfaces and urine excretion. For example, diets high in crude protein increase the amount of nitrogen excreted in urine. Additional sources can include effluent spread on paddocks and the use of nitrogen-containing fertilisers or amendments, if these are used in TMR or PMR systems. On TMR farms, N_2O emissions can account for up to 10% of net emissions (2023/24 financial year, 14 TMR farms, Dairy Australia, 2025).

Ways to reduce this source of emissions is to balance the ratio of energy to protein in an animal's diet to improve the nitrogen efficiency of a dairy cow's digestive processes. For example, using grain as a feed supplement can boost the energy content of a cow's diet to counteract the seasonal rises in crude protein.

When applying effluent to paddocks, it's best to do so regularly but only when agronomically appropriate, and to avoid spreading on wet soils. Nitrous oxide (N_2O) emissions can occur in wet conditions through denitrification, or in hot, windy conditions through volatilisation. Following the 4Rs of fertiliser use—right place, right product, right rate, and right time—is the most effective way to minimise emissions.

Additives (inhibitors) that reduce N_2O emissions can be included in fertilisers or applied directly to urine patches. However, several knowledge gaps remain: the effectiveness of these inhibitors can vary, optimal application rates compared with traditional fertilisers are not fully established, international market acceptance of milk from farms using these products needs confirmation, and the economic impacts require careful evaluation.

> **More information**
>
> For more information visit **dairyaustralia.com.au** and search for emissions reduction strategies.

Purchased Inputs (Scope 3)

This source of emissions **comes from the embedded emissions** in all products purchased for the farm, including their manufacture and transport. These are classified as Scope 3 emissions, since the emissions occur off-farm during production and delivery rather than on the farm itself. On TMR farms, Scope 3 emissions can account for up to 9% of net emissions (2023/24 financial year, 14 TMR farms, Dairy Australia, 2025).

Ways to reduce this source of emissions are to minimise the amount of inputs purchased and ensure that inputs are used in the most efficient way possible, which has the double advantage of reducing costs and lowering a farm's emissions. In farm systems that incorporate cropping or forage production, maximising the amount of homegrown feed can help by reducing purchased feed inputs. Growing rather than purchasing feed may also save money and help to reduce exposure to the fodder market. For these systems, ensuring maximum efficiency in the use of fertilisers and chemical applications also reduces the overall total amount of product purchased, reducing scope 3 emissions.

In the future, farms can consider sourcing products with low-emission or carbon-neutral claims. As the energy grid shifts toward renewable sources and agricultural suppliers reduce their own emissions, more low-emissions products will become available.

Building strong relationships with suppliers and requesting emissions intensity or footprint information for the products they provide is a practical first step toward understanding and reducing Scope 3 emissions.

Sequestration (trees and soil)

Carbon sequestration is measured annually by tracking changes in the carbon stored in vegetation and sometimes soils on the farm. This process removes carbon dioxide from the atmosphere rather than producing emissions. For carbon sequestration to effectively offset or inset greenhouse gas emissions, it ideally needs to be permanent or long-term (over 25 years), with the sequestered carbon maintained and protected over that period. In intensive dairy systems, opportunities for long-term sequestration are often limited by available land. In a sample of TMR farms, carbon sequestration accounted for less than 1% of total emissions (2023/24 financial year, 14 TMR farms, Dairy Australia, 2025).

Planting trees is the easiest way to sequester carbon, and for farm systems that incorporate grazing, has the added benefits of providing shade and shelter to livestock. Trees on-farm can also increase biodiversity and aesthetics. Eventually as trees mature, their annual growth and sequestration rates will slow, which will reduce how much they balance your annual farm emissions over time (faster growth and higher sequestration occurs in the first 25 years). Due to its age remnant vegetation is likely to be sequestering carbon at a lower rate and may not be considered a valid offset or inset depending on the accounting rules of a program. However, these trees have other value on farm and in the environment.

Soil carbon is an important asset for farm productivity and soil health, but there is a limit to how much carbon can be stored (and increased) per hectare. With good management, soil carbon levels usually reach a new equilibrium, largely determined by rainfall and, to a lesser extent, soil type. While changing soil management can help increase soil carbon, many dairy farms—particularly those with high rainfall or irrigated pastures—already have high soil carbon levels. A practical first step is to conduct soil tests across the property to establish a baseline and see if there is potential to build additional carbon stocks.

Points to consider:

- Review the whole farm plan to assess current and future tree planting opportunities.
- Map and record the species and age of existing vegetation areas on the farm, and estimate the current sequestration rate (t CO_2-e/ha/yr) for the trees.
- Determine how much carbon the trees inset (sequester) against the farm's footprint, either as total sequestration (t CO_2-e) or as a percentage of the farm's emissions.
- Conduct soil tests to measure soil organic carbon in the paddocks.

More information

For more information visit **dairyaustralia.com.au** and search for emissions reduction strategies and see the Soil Carbon Snapshot: **agriculture.vic.gov.au/climate-and-weather/understanding-carbon-and-emissions/soils-and-carbon-for-reduced-emissions**

13.6 Profitable emissions action plan

Dairy Australia has developed guidance to support the creation of an individual farm emissions action plan. Table 37 provides a summary of potential interventions and actions across the key emission drivers: Livestock, Fertiliser, Effluent and Manure, Energy and Fuel, and Trees and Soil.

Table 37. Outline of a profitable emissions action plan

	1. Livestock					
High level theme	Feedbase and diet			Choosing the right genetics	Day to day herd management	
Intervention	Reducing protein to energy ratio	Supplementing with (protected) fats and oils	Increase homegrown pasture and forage crop use	Cow genetics and breeding performance	Lactation length and longevity	Preventing herd health problems
What action can I consider?	Implement best practice nutrition	Consider including protected fats within your supplements	Maximise homegrown feed through optimising pasture, matching feed supply and demand	Understand your herd's genetic potential	Prioritise cow health and reproduction	Optimising milk performance

	2. Fertiliser	**3. Effluent and manure**	**4. Energy and fuel**		**5. Trees and soil (Carbon storage)**	
High level theme	Reduced fertiliser inputs	Managing effluent effectively	Optimising energy on farm		Improve carbon storage on farm	
Intervention	Optimising your fertiliser use	Effluent management system upgrades	Analyse your energy use	On-farm renewable energy	Improve carbon storage on farm with trees	Increase soil carbon storage
What action can I consider?	Efficient fertiliser and effluent use	Assess your effluent management system	Conduct an energy audit	Investigate options and suitability for your farm	Protect and increase native vegetation on farm	Consider reduced tillage and increase perennial pasture species and/or mixed sward plantings

Source: Dairy Australia 2026

Final note

Once the farm's emission sources, quantities, and proportions have been identified, along with their drivers and available reduction options, consider the following:

- Determine obligations to monitor progress in the farm's emissions footprint and/or reduction actions over time. Where required, repeat emissions estimates to track changes and assess the impact of reduction actions.
- Identify major changes in the production system (e.g. milking herd size) that could affect key emission sources. Monitor trends in emissions intensity and document assumptions that influence total emissions or EI figures for verification.

Further resources

For further resources visit **dairyaustralia.com.au** and search for emissions reduction strategies.

14

Energy efficient systems

Introduction

The development of a feedpad or contained housing facility may increase total energy requirements for the dairy operation leading to increased energy costs and greenhouse gas emissions. Upgrades to electricity grid connection including transformer upgrades may be required when electricity demand increases or if excess on-site renewable electricity generated is fed into the grid.

Steps can be taken in the design, development and operational phases to improve the site's energy efficiency through:

- Equipment selection
- Regular maintenance
- Renewable energy generation.

Energy consumption and costs will change over time and will vary from farm to farm. Understanding the energy requirements and site operational issues can assist to identify where efficiency gains can be made.

14.1 Reviews of energy use on dairy farms

Energy audits completed on 1,400 Australian dairy farms between 2012 and 2015, by the Smart Energy Use project, identified milk cooling, milk harvesting and water heating as the top three uses of electricity, totalling 81% of a dairy's electricity usage on average.

- Average electricity usage was 48 kilowatt hours (kWh) per kilolitre (kL) of milk.
- There was a range with two thirds of the farms falling into the range of 31 to 66 kWh per kL milk.
- These audits were completed for a range of dairy types and herd sizes in predominately grazing systems as there were limited contained housing systems in Australia at the time.

Mohsenimanesh *et al.* (2021) reviewed 37 international electricity studies from across five continents from both grazing and contained housing systems reported that the average energy use of:

- The contained systems were 92 watt-hours (Wh) per kg milk and 769 kW per cow per year
- The pasture systems had an average energy use of 66 Wh per kg milk and 475 kWh per cow per year.

Table 38. Electrical energy consumption breakdown statistics of studies found in literature

Study	Total Wh/kg	Milk cooling Wh/kg	Milk harvesting Wh/kg	Water heating Wh/kg	Water pumping Wh/kg
Mean AMS – Contained	n/a	17.45 (13.20–21.90) N=2	14.54 (11.13–29.30) N=3	10.67 (2.2–5.05) N=2	n/a
Mean Conventional – Contained and Grazing	48.91 (38.68–73.00) N=4	15.32 (9.85–21.7) N=7	13.97 (6.91–23.01) N=7	9.45 (3.43–16.30) N=7	3.28 (1.51–6.57) N=5
Mean Conventional – Contained	57.92 (42.84–73.00) N=2	16.68 (9.85–21.7) N=5	16.54 (8.14–23.01) N=5	9.80 (3.43–16.30) N=5	4.27 (1.51–6.57) N=3
Mean Conventional – Grazing	39.89 (38.68–41.11) N=2	11.94 (11.24–12.64) N=2	7.55 (6.91–8.19) N=2	8.60 (7.66–9.54) N=2	1.79 (1.51–2.07) N=2

Note: Brackets is range of averages in the studies, N=number of studies, Wh/kg = watt-hours per kg milk, AMS = Automatic Milking System, Conventional = Conventional milking system

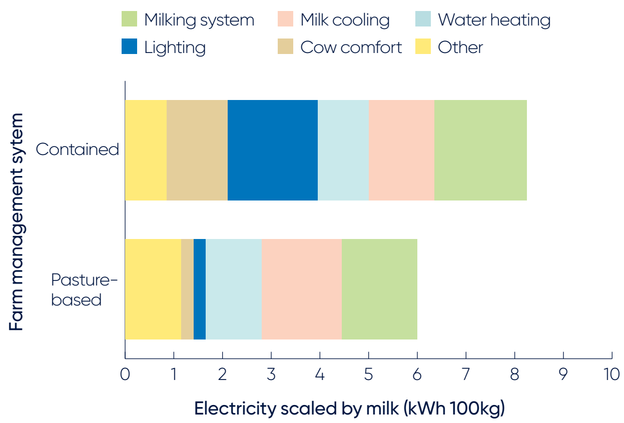
Source: Adapted from: Shine et al (2020)

Shine *et al.* (2020) also reviewed a number of international studies looking at electricity consumption in both grazing and contained housing systems, excluding automatic milking systems (AMS), showed the mean electricity usage was 48.9 watt-hours per kg of milk. The three top uses were milk cooling (15.3 Wh/kg), milk harvesting (14.0 Wh/kg) and water heating (9.5 Wh/kg) (Shine *et al.*, 2020). Table 38 shows the mean and range of electricity consumption of the studies identified by Shine *et al.* (2020).

The findings from Shine *et al.* (2020) are consistent with the energy assessments completed on Australian dairy farms (RMCG, 2015) while the average electricity use figures for grazing systems from the study by Mohsenimanesh *et al.* (2021) are at the higher end of the Australian dataset range.

Figure 112 shows the energy use profile for contained housing systems compared to grazing systems. The studies reviewed by Mohsenimanesh *et al.* (2021) show the main area where there is an increase in electricity use is fans for cow comfort and lighting, with these accounting for 15% and 20% respectively in the studies available. This study noted there is a gap in data available in electricity consumption of fans and lighting.

Figure 112. Electricity use in contained housing vs grazing systems (pasture-based)



Note: Confined = Contained. Electricity use in kWh per 100kg milk broken down into the component of the dairy operation the energy is used in.

Adapted from: Mohsenimanesh et al (2021)

Energy audits completed in New York State, United States of America indicate that ventilation and lighting may be two areas where energy requirements increase in contained housing systems. These audits, completed on 32 contained housing systems, saw milk cooling (25%), lighting (25%), ventilation (22%) and milk harvesting (17%) being the largest uses of electrical energy with a combined usage of 88%.

These studies show the electricity consumption per kilogram of milk tended to be higher in contained housing systems than grazing systems. This indicates there may be an increase in electricity use per unit of milk produced when moving to a contained housing dairy system.

14.2 Identifying energy opportunities on farm

While energy surveys in the United States of America have shown that newer facilities are more energy efficient due to the implementation of newer energy efficient technology, that data, and others, also shows that there is a large variation in energy use between dairy operations. Therefore, it is important to understand the energy use of the dairy operation you are working with.

In Australia, the Energy Efficiency Council and National Farmers Federation have identified four steps that assist farm businesses through the process of identifying and implementing energy management upgrades.

Four steps to identify energy efficiency on-farm - Energy Efficiency Council, 2021

1 Reach out

Contact farm groups, industry associations and governments for ideas and resources. This support provides farms with confidence and information to start their energy management journey.

2 Walk the farm

Scan the farm for visible issues and opportunities, review habits and routines. Diving into existing data leverages the knowledge of the team on the ground to identify quick wins.

3 Work with an external expert

Find the right auditor for your farm, specify the audit you need and prepare a post-audit action plan that gives you a detailed understanding of energy performance and upgrade opportunities. This builds the case for more significant investments.

4 Integrate energy management into farm management

Establish processes for continuous improvement in energy performance to ensure that smart energy management becomes a part of farm management, and is a way to make farms more productive, especially in peak season.

Energy audits can identify how efficiently energy is being used and identify energy and cost saving measures as well as process and productivity improvements. National standards are available for energy audits. There isn't a specific standard for agriculture, however, AS/NZS 3598.2:2014 Industrial and related activities is most commonly used for agricultural operations (Energy Efficiency Council, 2021).

There are three audit types set out by the standard which should be selected based on the dairy operation's needs:

- Type 1: Basic energy audit
- Type 2: Standard energy audit
- Type 3: Precision subsystem energy audit.

More information on energy Audits can be found at: **energybriefing.org.au/energy-audits-101**

Figure 113. A Gekko Systems biodigester on a dairy farm at Bungaree

14.3 Electricity supply

If total energy use and demand of the dairy operation increases, there may be a need to:

- Ensure the grid and connection can meet future electricity demand.
- Review electricity tariff structures.
- Consider back-up power requirements.

Grid connection

Electricity supply should be considered in the planning stages. Connecting to the grid or altering grid connection, due to increased electricity demand or to enable energy to be fed into the grid, can take several months. The time taken will vary based on the type and complexity of the connection. Work with your electrician, electricity retailer and electricity distributor through the process.

During the dairy design stage an assessment of current and future energy requirements should be completed.

- The electricity distributor should be contacted to ensure there is capacity in the local grid and existing connection to supply the required electricity.
- If a new grid connection is required, the existing connection requires alteration to increase capacity or renewable electricity is to be generated on site, for use on site or to be fed into the grid, it is the distributor who is responsible for these upgrades.

The electricity distributor may require a contribution for a new connection or connection upgrades.

- Where a contribution is required, a formal connection offer, setting out the cost of the works and the terms and conditions, must be provided.
- The Australian Energy Regulator preapproves most costs and publishes them on their website (Australian Energy Regulator, 2013).
- Distributors cannot charge more than the approved amount.

If unsure of the energy distributor for the area contact the existing electricity retailer or a list of distributors can be found on the Australian Energy Regulators website: **aer.gov.au/consumers/who-is-my-distributor**

More information on supplying energy into the grid can be found in *Energy generation and storage*.

Electricity tariffs

The electricity tariff structure determines how a dairy operation is charged for electricity usage. Transitioning to new or upgraded feeding and/or contained housing facilities may increase the operation's electricity demand, alter time of use and/or the daily peak electricity demand. These changes in electricity usage may affect which tariff structure is most cost effective for the site and should be reviewed periodically.

Tariff components

Energy tariffs vary between electricity providers, from state to state and over time. They are typically made up of three basic charges: supply, electricity consumption and demand.

Supply charge

The supply charge is a cost per day for providing electricity to the farm and covers costs associated with operation and maintenance of the grid infrastructure.

Electricity consumption tariff

This charge is based on the amount of electricity consumed with a rate charged for each kWh consumed. Consumption charges depend on the tariff structure. The most common consumption charge arrangements are single rate pricing and time of use pricing.

Single rate tariffs

Single rate tariffs apply the same rate for all electricity consumed, regardless of the time of day this occurs. This arrangement is also referred to as 'anytime' or 'flat rate'.

Time of use tariffs

Time of use tariffs apply different rates depending on the time of day and day of the week the electricity is used. There are generally three periods: peak, off-peak and shoulder.

- **Peak:** This is the highest cost period. Peak period is typically during the evenings of weekdays when there is a high demand for electricity.
- **Off-peak:** This is the cheapest cost period. Off-peak is typically overnight and on the weekend when there is low electricity demand.
- **Shoulder:** This is charged at a rate lower than peak. Shoulder periods are typically between peak and off-peak periods when there is moderate demand for electricity.

Controlled or dedicated loads

A controlled or dedicated load tariff option may be available in conjunction with flat rate or time of use tariffs. This tariff provides a lower rate for a dedicated circuit supplying a single large load such as a hot water service, irrigation pump or ice banks. The dedicated load is charged at a lower rate or at off-peak rates. This option is not available in all locations. It will need to be confirmed with electricity retailers if this option is available for the situation.

Demand tariff

Some tariff structures include a demand tariff. For large customers this is often a mandatory tariff. Demand is a measure of how intensely electricity is used at a point in time. The demand tariff is a charge based on the peak energy use during the billing period and charged for the entire billing period. Demand tariffs encourage electricity use to be spread out over time.

Demand charges are based on the peak load of the system regardless of how many hours the system operates at the peak load. A demand charge is incurred even if the high load occurs for just one 30-minute interval during the entire billing period. Depending on the retailer this may relate to any time during the day or may only be within the peak demand hours.

Demand tariffs do differ, so it is important to understand:

- How the retailer calculates demand charge
- The demand charge threshold
- The peak and off-peak periods and the rates associated with these
- If the demand charge is applied to the maximum demand or average demand.

Reducing peak demand may reduce the demand tariff charged.

Loss factors

Loss factors allow retailers to account for the losses that occur in distribution and transmission between the electricity generators and the site. This factor is applied to various charges on the electricity bill.

Power factor

Power factor is a measure of how efficiently electricity is used at customer's premises. It is the ratio of real power (the power actually consumed, measured in kW) to apparent power (the power delivered by the network, measured in kVA). Some electrical items such as motors and fluorescent lighting can require large currents to operate, giving them a poor power factor and often high demand charges. Power-factor correction equipment can stabilise the load for these items, which improves energy efficiency and reduces demand charges.

Feed-in tariff

Feed-in tariffs are determined by each state with each having a different feed-in tariff structure. In general, these rates have been reducing over time.

In Victoria the Essential Services Commission sets the minimum feed-in tariff that energy companies pay for power exported to the grid. Retailers can offer solar system owners above this price but not below. These rates change each year.

As the minimum feed in tariff is much lower than the price paid for electricity consumed from the grid, the best value for energy is gained when renewable energy is used on-farm to displace energy consumed from the electricity grid.

For more information including the current Victorian feed-in tariff visit: **esc.vic.gov.au/electricity-and-gas/electricity-and-gas-tariffs-and-benchmarks/minimum-feed-tariff**

Finding a plan or energy provider

There are a range of plan types depending on energy consumption with differing tariff structures for residential, small business, and large business accounts.

Each state and electricity retailer have varying criteria for large business accounts. Large business accounts usually have bills in excess of $30,000 per year, or greater than 40,000–100,000kWh per year power consumption, depending on the retailer. Bills for large energy users are more complex with different charge rates than those described in this document and may include additional items such as Loss Factors which is broken into marginal loss factor (MLF) and distribution loss factor (DLF).

Each retailer has different cost and tariff structures. Contact several retailers to get the best deal for the operation's energy needs. Provide actual or predicted energy data to compare different plans. Energy consumption data at 30-minute intervals or less can be obtained online from the electricity distributor using the electricity meter's national metering identifier (NMI).

Private energy brokers and comparison sites operate for small and large electricity customers. Using these may assist in finding an offer that suits the site. There are also government comparison sites available including the two below:

- Energy Made Easy (National): **energymadeeasy.gov.au**
- Victorian Energy Compare (Victoria): **compare.energy.vic.gov.au**

Understanding electricity bills

Each electricity retailer structure bills differently. Information on understanding energy bills can be found on the electricity retailer's website. Useful links to a range of retailer's bill structures can be found here: **aer.gov.au/consumers/understanding-energy/understanding-your-energy-bill**

Back-up power

A generator or another form of back-up power is essential to be able to continue operation of the dairy operation when a power outage occurs. If generators or other forms of back-up power already exist on site, the size of these should be reviewed and may require upgrading due to increased energy requirements.

Power outages can have immediate and ongoing impacts on the site and may affect many aspects of the system including, but not limited to:

- Milk harvesting - delayed milking may result in production loses with the cow's udder beginning to shut down after 36 hours not being milked and increase the risk of mastitis, impacting on milk quality.
- Inadequate milk cooling.
- Water and feed supply – electric pumps and machinery may impact on the ability to supply water and feed to the herd.
- Ventilation and cooling systems - it is important in mechanically ventilated sheds to have appropriately sized back-up systems and/or an evacuation plan to remove cows as a closed up shed becomes warm quickly due to the heat the cows generate and air quality declines when fans are not operating. An alarm or other warning system may be required to alert staff. Loss of cooling system operation may impact cow comfort and welfare, particularly during warm days.
- Alley cleaning and the effluent management system.

Ensure the site electrical system is capable of being isolated from the grid to allow generator and other back up power sources to function when there is a power outage.

Other forms of back-up power may include batteries or biogas generators powered by on site anaerobic digestion. The suitability and limitations of the technology as back-up power supply for the operation should be considered when selecting.

14.4 Energy efficient design and operation

The energy required to operate the site can be reduced through energy efficient design, equipment selection and regular maintenance.

Selection of energy efficient equipment

Selecting energy efficient and fit-for-purpose equipment can lead to energy savings. Energy efficient equipment may have a higher upfront cost but will save in energy consumption which can outweigh the higher capital investment. The cost of the equipment and operating costs should be considered over the working life of the equipment.

Energy surveys in the United States of America have shown that newer facilities are more energy efficient due to the implementation of newer energy efficient technology (Capareda et al., 2010).

There are many areas in the system where energy efficiency measures can be implemented including:

- Upgrading lighting to LED.
- Reviewing the performance of milk harvesting and milk cooling equipment as changes in herd production and numbers occur.
- Preheating of water using heat recovery, heat pump or solar hot water systems.
- Have an experienced technician select the appropriate type and sized pump for the task with variable speed drives used in situations where there are varying pressures or flow rates (multiple duty points).

More information on these energy efficiency measures, including a checklist for dairy shed energy savings, can be found in Dairy Australia's *Saving energy on dairy farms booklet* (2018).

In Australia energy efficiency of equipment is regulated through the Equipment Energy Efficiency program. The program is underpinned by the *Greenhouse and Energy Minimum Standards (GEMS) Act 2012*. The program provides energy efficiency standards and energy labelling for equipment and appliances. Limited agricultural equipment is currently regulated under the program with minimum energy performance standards for three phase motors and standards for incandescent and fluorescent lighting. For more information visit **energyrating.gov.au**

Layout and operation

Layout of the infrastructure and day to day activities can impact on energy use and efficiency as well as impacting on other areas including labour and machinery maintenance. Aspects of layout and operation to consider:

- Create flow and minimise the distances between areas which are frequently used. This may impact on operation and driver behaviour. For example, locate feed storage areas in close proximity to the feed out area.
- Use of electric vehicles, such as side by side vehicles, that can be charged utilising solar or other renewable energy generated on farm.
- Utilise gravity, where possible, within the effluent system reducing the requirement for pumps and hence energy.
- Have an experienced technician size pumps and pipes while minimising distances effluent needs to be pumped. Consider the location of storage ponds to minimise the distance recycled effluent needs to be pumped for washdown.
- Effective alley slope reduces the volume of water required to be pumped for alley wash down reducing energy for pumping. The concentration of effluent may also affect the viability or processing required for the end use of the manure e.g. anaerobic digestion, manure bedding, application on pastures or crops.

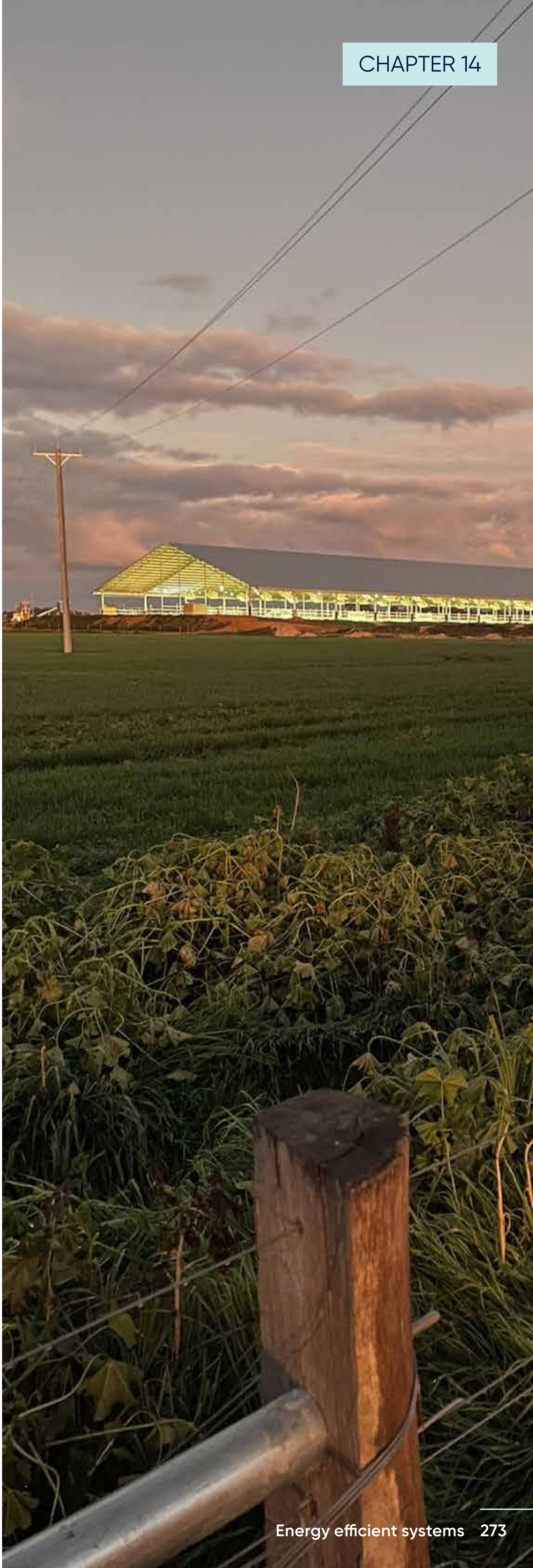
Fans and ventilation

Ventilation and cooling systems limit extremes in temperature and humidity and maintain good air quality to ensure cattle welfare (Chapter 9). While the ultimate goal of the fans is to provide an ideal environment for cattle welfare, energy efficiency should still be considered when designing the system and selecting fans.

Understanding the purpose of the fans in the contained housing system, the difference between ventilation fans and cooling fans, the location within the system and the operation is important. The effectiveness of fans will vary depending on the climate. Shed design will also interact with natural air flow and fan function and can have a big impact on fan efficiency and effectiveness. See *Chapter 9 Facility design and management* for more information on fans.

Mondaca and Cook (2019) modelled the costs of operating a range of ventilation systems including natural, tunnel, hybrid and cross-ventilation across various climates in the United States of America. The key findings of the study were:

- Select high energy efficiency fans, although typically more expensive upfront, over the lifetime of the fans there will likely be higher savings. Regardless of regional



variations, the cost of ventilation lies mainly in the operating costs of the fans. The modelling showed on average the capital cost of the ventilation system was 11% to 26% of the operating cost depending on climate.

- Ensure fan layout is configured for maximum efficiency.
- Fans can be automated to turn on at set temperatures. This can ensure fans are used when required and turned off when not. Variable speed drives or ventilation ramping functions may be suitable to increase air flow as temperatures increases to cool the cows.
- Maintenance is required for effective fan function. Fans can lose as much as 30% to 50% efficiency due to poor maintenance e.g. dust and dirt build up on blades and shutters. A 3 mm build up can reduce efficiency by 30%. Fan maintenance is often overlooked and should be considered in the design stages to ensure maintenance processes are thought out. For example, being able to lower fans for cleaning rather than having to climb up and clean them will make fan maintenance easier and more likely to be carried out regularly.

If a contained housing system is to be mechanically ventilated a back-up power supply, for example a generator or other alternate power source, is required to ensure ventilation can occur when there is a power outage. The sizing of the generator or other alternate power source should account for the ventilation energy requirements as well as the other energy requirements of the site.

Regular maintenance and monitoring

Maintenance is a low-cost way to maintain energy efficiency. Regular maintenance on equipment including milking plant, ventilation, lighting, pumps, vehicles and machinery, can assist to ensure efficient operation of equipment. Follow manufacturer recommendations for maintenance. Factor equipment maintenance into the design of the system to make it easier.

Monitoring energy use is important in managing energy use and can provide indication of how equipment and behavioural practices are contributing to energy efficiency. Monitoring electricity and fuel usage via bills is one way to monitor over all energy usage. Some technology has integrated monitoring systems, such as inverters for solar systems, or relatively cheap monitoring devices which allow for monitoring of individual equipment or systems. An asset register can assist in monitoring energy. Corelating data from the assets register with energy bills can assist to better understand energy use. It can assist to track planned maintenance and replacement of equipment.

A checklist including maintenance for dairy shed energy savings, can be found in Dairy Australia's *Saving energy on dairy farms* booklet (2018).

14.5 Energy generation and storage

Renewable energy generation on farm is an option to reduce energy costs and reduce greenhouse gas emissions. The greatest return on investment is achieved when the energy is utilised on farm to reduce the electricity use from the grid or other forms of energy.

Before investing in renewable energy review the energy efficiency of the dairy operation. There may be major energy savings that can be made reducing the overall energy required and therefore the level of investment required for renewable energies.

When selecting a technology consider the time of day the energy generation occurs and the operation's time of demand. Matching the generation and use enables maximum utilisation of the energy generated, ensuring a shorter payback period. It is generally more cost effective to utilise energy generated directly on farm where possible due to the high costs of storage options and the low feed in tariffs available. There may also be limits to the amount of electricity that may be able to be fed into the grid.

Some forms of energy can be more cost effectively stored than others. Electrical energy generated from solar panels requires batteries for storage while the same energy converted to heat can be cost effectively stored as hot or cold water in insulated tanks.

Connection agreements for electricity feed-in

Before considering feeding electricity into the grid, work with the equipment installer to consult with the electricity distribution network service provider. There are technical requirements for connection to the electricity grid which vary depending on the size of the system, the local electricity grid infrastructure and exporting excess energy into the grid. The distributor has an obligation to ensure grid stability and reliability and if there is a sound technical basis may refuse connection. There may be costs associated with meeting the technical requirements of grid connection.

An export agreement will need to be negotiated with the distributor to export energy into the grid.

There will be a cost for connection. This cost generally covers:

- Network connection application fee
- Connection feasibility study
- Network stability study (if required)
- Cost of network extensions or augmentations specific to connection
- Metering charges.

A new meter may be required to be installed if there is not already a smart meter or interval meter in place. Refer to *Section 14.3 Grid Connection*.

Solar photovoltaic (PV)

Solar is an established and widely used technology which generates electricity by capturing the energy of light. The generation curve for solar and the time of energy use needs to be considered. The majority of the energy is generated during the middle of the day, when the sun is highest in the sky and the solar energy intensity hitting the earth is highest. However, in a typical dairy system the energy demand is greatest in the morning and late afternoon, during milking, when solar energy generation is lower. There may be opportunities to alter the time of use of other equipment e.g. hot water service or water cooling which generally operate during the night to maximise off peak rates, to better match the time of energy generation.

Orientation

In Australia a northern solar panel orientation generates the greatest electricity production as it maximises solar interception. The optimum angle for maximum year-round solar interception is the same as the latitude of the location in which the panels are installed. However, if the installation is on a roof the additional cost of frames to achieve a small change in tilt may not exceed the benefit of additional energy generation. The cost benefit should be assessed and looked at over the lifetime of the system. The ideal angle can vary for the system depending on the aims of the system. For example, a system which aims to minimise seasonal variation, which is common for off-grid systems, may set the angle to maximise the solar capture of the winter sun which sits lower in the sky. Solar panels should be at a minimum angle of 10 degrees to allow rain to wash them clean.

However, the orientation of the shed may not be north facing or energy generation in the morning or evening may be more highly valued due to the dairy operation's electricity use profile. Typically, dairy systems have higher demand for electricity during the morning and evening when milking occurs. This may mean there may be a benefit from orientating panels in a north east or north west direction or even east and west. This orientation will decrease generation by up to 15% however it will extend the solar exposure time to increasing generation in the morning and evening when milking is occurring and there is a demand for energy.

It is best to investigate the options for each unique situation using actual or predicted energy use data. Work with your accredited solar installer to determine the best system size and orientation for your energy demands on site.

Renew Australia (2017) have a free solar calculator which can be used to look at the potential feasibility of different scenarios including different sizes of solar array or panel orientations, or different amounts of battery storage to meet the site's energy requirements. See 'Sunulator' **renew.org.au/resources/sunulator/**

If intending to put on roof top solar ensure the proposed shed structure is rated to take the load of the panels and any required mounting structures. The decision for solar may also impact on design features including:

- Orientation of the shed
- Locations for equipment such as inverters and batteries
- Potential shading from surround tress or infrastructure which would reduce the efficiency of the panels.

Renewable Energy Certificates

The Small-scale Renewable Energy Scheme and Large-scale Renewable Energy Target provide financial incentive for investment in solar. Renewable Energy Certificates are used as a measure of renewable energy that can be traded or sold.

Systems less than 100kW may be entitled to small-scale technology certificates under the Small-scale renewable Energy Scheme which can be sold to recoup a portion of the cost of purchasing and installing the system (Clean Energy Regulator, 2018a). To be eligible these systems must meet the eligibility criteria including being installed by a Clean Energy Council accredited designer and installer and meet the Clean Energy Council design and install guidelines. Systems over 100 kW are classified as renewable energy power stations and may be eligible to be accredited to create Large-scale Generation Certificates (LGC) under the Large-scale Renewable Energy Target (Clean Energy Regulator, 2018b).

Accredited Solar Installer and Approved Solar Retailers Program

The Clean Energy Council operate the Accredited Installer and Approved Solar Retailer programs. The Accredited Installer program certifies and trains individuals in the design and installation of solar and battery energy storage systems and ensures systems installed meet industry best practice and the relevant Australian Standards (Clean Energy Council, 2018a). Approved solar and battery retailers have been approved by the Clean Energy Council as showing a commitment to responsible sales and marketing activities and solar industry best practice and committed to complying with the program's Code of Conduct (Clean Energy Council, 2018b). A list of accredited installers and approved retailers can be found here: **cleanenergycouncil.org.au**

Batteries

Storage batteries provide the opportunity to store excess generated energy for use at another time when electricity generation doesn't meet requirements or is not able to be generated. Over the last decade the price of batteries has significantly reduced making them a potential option. There are several situations where batteries may be applicable including:

- Store excess energy for utilisation at another time when electricity is not being generated or generation is limited.
- Off grid sites where large grid connection costs inhibit grid connection.
- Replacement for diesel generators which also has the additional benefit of reduced maintenance cost.
- In situations where equipment needs a stable supply and to provide an uninterruptable power supply (UPS) before a generator can be started.
- Managing energy demand during peak charge periods and to reduce peak demand therefore reducing electricity costs.
- Offsetting upgrades to mains supply.

An economic feasibility should be completed to ensure batteries are a suitable option for the situation.

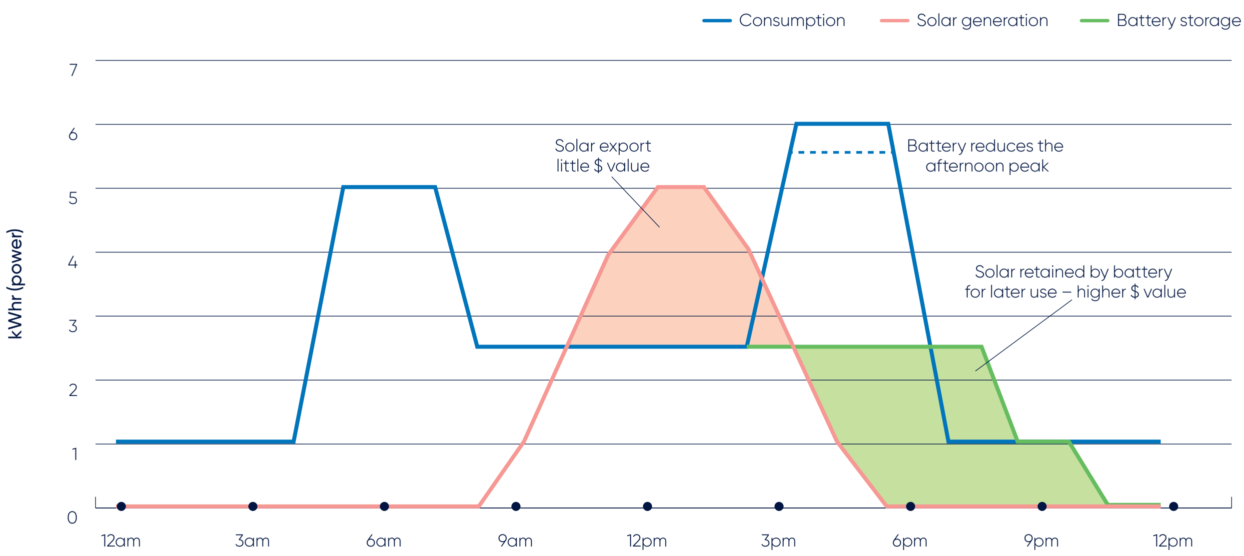
There are a number of different types of battery chemistries commercially available including, but not limited to:

- Lead-acid
- Lithium-ion
- Flow
- Flywheels.

Each type of chemistry can perform a variety of applications. The system design should take into account the application and be able to identify the chemistry which will provide the best performance.

The Accredited Solar Installer and Approved Solar Retailer program also covers the retail and installation of battery storage. See section on Solar photovoltaic (PV).

Figure 114. Graph of energy consumption and solar generation in a typical dairy



Note: Graph demonstrating how batteries can be utilised to capture energy for utilisation when there is increased demand.

Source: Dairy Australia Feasibility of stand-alone renewable energy systems

14.6 Anaerobic digestion

Installing an anaerobic digester is another option for reducing energy costs involving the capture of biogas, containing methane, associated with the decomposition of manure under anaerobic conditions. It is a commercially proven method for reducing greenhouse gas emissions.

- The biogas can be ignited (flared), converted to electricity, used to generate heat or upgraded to biomethane and stored as an alternative fuel.
- The most popular option is conversion to electricity and heat recovery to offset energy requirements, which is a major and growing cost on dairy farms.

In addition to reducing energy costs and supplementing income through emissions reduction funds, other benefits of anaerobic digestion include:

- Improved management of manure
- Decreased odour
- Reductions in animal, human and plant pathogens as well as weed seeds
- Improvement in air quality where biogas is used to replace traditional fuels that generate particulates.

Feedpads and contained housing systems increase the potential feasibility of an anaerobic digester, due to the greater amount of manure that is collected in the effluent system when compared to grazed dairy systems. Cows in contained housing spend more time on areas where effluent is collected resulting in a greater volume of feedstock being available for anaerobic digestion. Contained housing systems often also have higher numbers of cows and production per cow than grazing systems.

The product of anaerobic digestion, biogas, contains 50–70% methane and 30–50% carbon dioxide along with other minor components including water vapour, nitrogen and hydrogen. Biogas can be used to fuel a boiler for heat generation or an engine for electricity and heat generation. Biogas may be upgraded to increase the methane percentage for use in vehicles or injection into the gas grid. This can increase the energy security of the dairy operation. The capture and burning of the biogas provide the additional benefit of reducing farm odour and greenhouse gas emissions. The digestion process also increases the amount of nutrients in a form biologically available for crop or pasture uptake.

Anaerobic digestion processes

In anaerobic digesters, organic material such as dairy manure undergoes a four-stage chemical transformation in the absence of oxygen, producing biogas mostly consisting of methane (Figure 115).

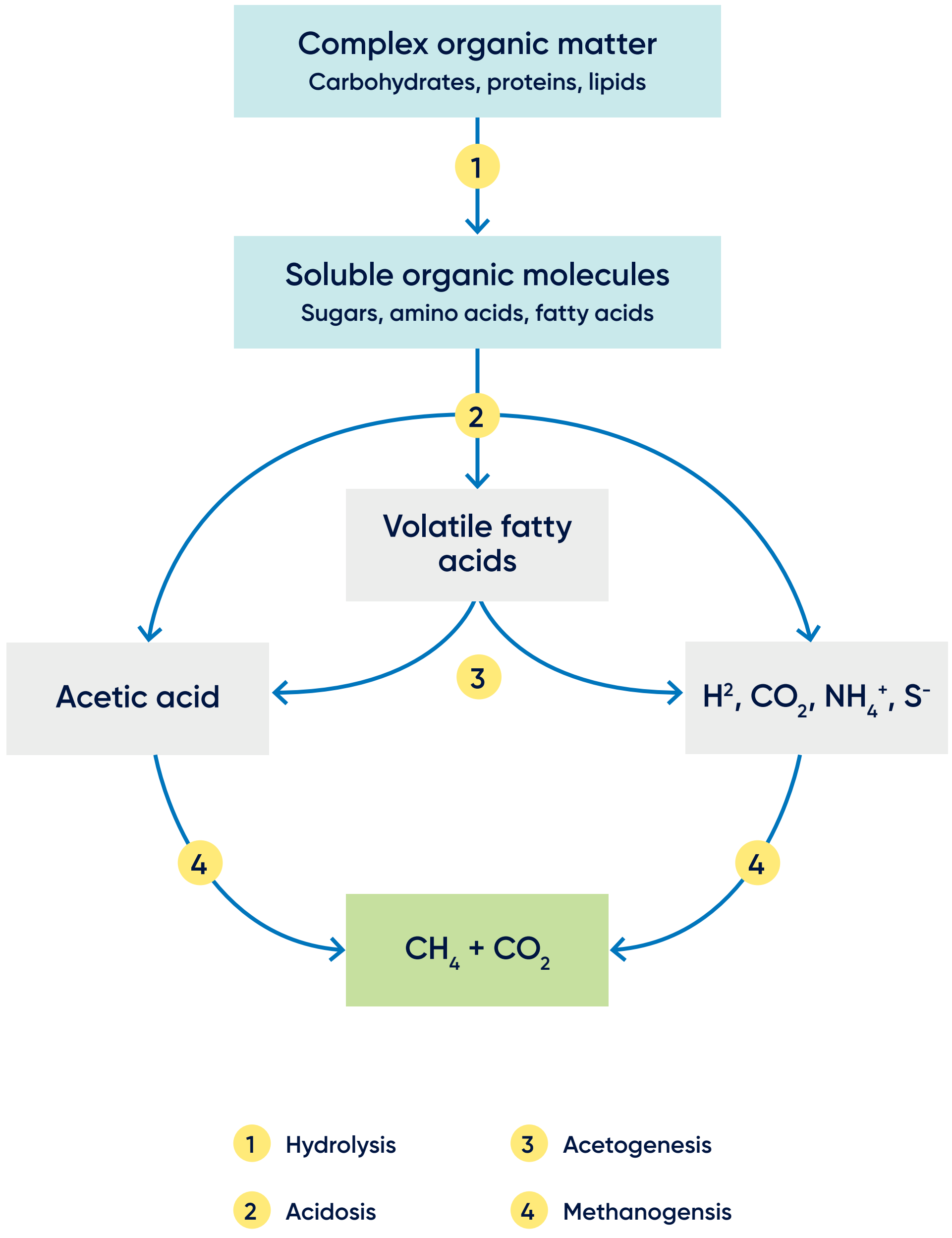
- The first step in anaerobic digestion is hydrolysis where complex materials such as proteins and fats are broken down into smaller molecules.
- In the second stage fermentation (acidogenesis) products include volatile fatty acids, carbon dioxide, and hydrogen.
- The volatile fatty acids are converted during the acetogenesis stage to acetate which the methanogens use in the final stage to produce biogas consisting of methane (45 to 75%), carbon dioxide (20 to 50%) and small amounts of other gases.

The type of methanogens will depend on whether they primarily use hydrogen or acetate to produce methane.

Factors such as the chemical and physical characteristics of the organic material to be degraded, pH, temperature, and the length of time the organic material is retained, also known as, hydraulic retention time (HRT), can all affect digestion and therefore, the volume and composition of the biogas produced. Typical inhibitory substances that can occur in dairy manure include antibiotics, sanitisers, cleaners, disinfectants, salts, ammonia and sulphide; with the latter two influenced by pH.

Temperature is one of the most important factors that influence aspects of anaerobic digestion, which is particularly relevant for digesters in temperate climates. Dairy Australia (2008) suggests that at temperatures 10°C lower than the optimum for mesophilic microorganisms, hydraulic retention times need to be increased which could mean a larger digester, although a variety of other factors, such as reduced ammonia inhibition at lower temperatures as well as mixing, could reduce the effects of lower temperatures.

Figure 115. Four stages of anaerobic digestion



Note: Hydrogen = H^2, Carbon Dioxide = CO_2, Ammonium = NH_4^+, Sulphide = S^-, Methane = CH_4

Source: Adapted from Hamilton, 2017

Anaerobic digestion substrates

Organic materials used in anaerobic digestion are often referred to as feedstocks or substrates. In addition to dairy manure, other organic materials can be included in the anaerobic digester to increase biogas production. These additional feedstocks are called co-digestion substrates, and the process of digestion two or more feedstocks is called co-digestion.

- Dairy producers will often have on-farm waste/spoiled feeds such as silage, hay, feed concentrates, or other plant-based organic materials.
- Off-farm sources include organic by-products and waste streams from processors, other primary producers and even urban wastes such as food or garden cuttings.
- Co-digesting dead animals can increase the risk of pathogens and is not advised.
- In Europe and other countries, crops grown specifically for biogas production (energy crops) are another feedstock for digesters, although these crops divert land from food production.

Organic materials vary in their potential to produce biogas. Three tests can be used to indicate the how effectively manure or other organic material will produce biogas. These measure the volatile solids content, the chemical oxygen demand and biochemical methane potential.

- Ideally material to be digested should have a volatile solids content greater than 60%.
- Chemical oxygen demand is relatively easy to perform and gives the maximum methane that a material could produce. However, the test may over or underestimate oxygen demand, due to inherent toxicities in the material, unrepresentative sampling and laboratory analyst's method.
- Biochemical methane potential is likewise a relatively simple test of the amount of methane produced from a material under anaerobic conditions, usually at 35°C, the optimum temperature for most methanogenesis. The total methane produced over a specified time is called methane yield (Table 39).

If materials other than manure are available on farm, or will be obtained from off-farm, it is also important to measure their chemical characteristics to determine if they could enhance biogas production of dairy manure. However, potential to increase biogas production from manure based on laboratory tests of co-digestion substrates needs to be confirmed at a bigger scale to ensure that the additional feedstock does not inhibit digestion in larger amounts.

Table 39. Theoretical methane yield of different anaerobic digestion substrates

Substrate	Methane yield (m^3/t VS)
Manure (pigs, cattle, chickens)	100–300
Food waste	400–600
Fruit waste	200–500
Grass	200–400
Straw	100–320
Municipal sludge	160–350
Protein wastes	496
Slaughterhouse waste	700
Cereals	300–400

Note: VS=volatile solids

Source: Adapted from Patinvoh, Osadolor et al. 2017

Anaerobic digestion pre-treatment

Manure and co-digestion substrates may need pre-treatment for anaerobic digestion. Pre-treatment aims to remove debris and unwanted material, to increase the dry matter content of the material by reducing the liquid content, to breakdown complex chemical components that are difficult for microorganisms to degrade such as ligning in the cell walls of straw and woody materials, to reduce the size of material that will be digested (e.g. bulky or long), or to remove inhibitory constituents. For instance, while some materials are easily digested, others, such as straw, have molecular structures that anaerobic digestion microorganisms are unable to breakdown. Extra energy may need to be expended to mix materials where large clumps are present. The aim of pre-treatment is to enhance biogas production, speed up anaerobic digestion and create a more homogeneous material that does not stratify and therefore does not require agitation. Mechanical screens are generally used for the removal of debris and poorly-degradable materials.

Types of digesters

There are a number of types of anaerobic digesters with covered anaerobic ponds, continuously stirred or complete mix tank digesters and plug flow digesters being the most commonly utilised to capture biogas on dairy farms. In recent times there have been on-farm trials and pilots of modular container systems employing complete mix tank digesters.

Covered anaerobic lagoons or ponds require the least management of the digestion process, although the removal of sludge and sedimented material that accumulates at the base of ponds remains a challenge. In temperate regions gas production from covered anaerobic lagoons is likely to be limited during cold weather when temperatures fall below 20ºC.

Complete mix or continuously stirred tank digesters comprise one or more tanks with a residence time between 20 and 30 days. As the name implies the contents are mixed; continuously (Continuously Stirred Tank) or intermittently, and as these systems are usually heated, are best suited to effluent with a solids content of more than 4%.

Plug flow digesters use material of 12 to 15% solids content to allow the material to move as a 'plug' through the digester over a 15 to 20-day period. These digesters are heated and are designed with a specific length to width ratio to maintain plug flow conditions.

The suitability and type of anaerobic digester implemented is specific to the individual dairy operation and needs to meet the characteristics and needs of the farm. The advantages and disadvantages of each digester type are outlined in Table 40. On an annual basis, the quantity and quality of biogas produced by these technologies is similar. However, the rate of biogas production will vary with temperature, and feedstock retention times are higher in unheated systems. Rule of thumb values for production can be found in Table 41.

While there are high-rate digestion systems that offer a reduction in hydraulic residence time to as little as five days. These systems are not generally found on farms due to more intensive management and maintenance requirements.

Table 40. Parameters for covered anaerobic ponds, stirred/mixed tank and plug-flow digester systems

	Passive system	Low rate systems		
		Covered anaerobic ponds	**Continuously stirred/ complete mix tank digester**	**Plug flow digester**
Description		In-ground earthen or lined lagoon with impermeable gas-collecting cover. Contents can be heated or mixed but are not typically due to volume. Covered lagoons work best with manure handled via flush or pit recharge collection systems in warmer climates.	Above- or below ground heated or unheated tank with impermeable gas-collecting cover. Contents mixed by motor or pump. Complete mix digesters work best when there is some dilution of the excreted manure with water (e.g., milking centre wastewater); manure should be handled via slurry	Long, narrow tank, typically heated and below ground, with impermeable gas-collecting cover. Contents move through the digester as new manure is added. Modified plug-flow systems can use vertical mixing techniques. These systems work best with dairy manure, handled by scraping, with minimal bedding.
Substrate dry matter (DM) concentration		Less than 5%	4-12%	12-15%
Operating temperature		Varies with ambient temperature (5–25°C)	Heated: 35–39°C or 50-60°C	Typically heated: 35–39°C
Hydraulic retention time (HRT)	40 to 60 days	15+ days	15+ days	
Co-digestion	Not optimal	Yes	Not optimal	
Advantages		Lower cost construction using local resources, lower operation and maintenance requirement, no heat demand, tolerant of shock loads, cover also provides biogas storage, easier to get through planning regulation.	Applicable to a wide range of materials, shorter treatment time, small size, standard designs, applicable for use in all climates.	Mid-range construction cost, shorter treatment time, lower operation and maintenance requirement, applicable for use in all climates, reduced water volume to manage.
Disadvantages		Large size, suitable only for liquid organic materials and temperate to warm climates lower yield rates.	Higher construction and operation costs including heat demand, requires skilled operation.	Not suitable for dilute effluent, bedding material or co-digestion, prone to build up of solids on bottom requiring clean out.

Adapted from: Is Biogas Technology right for Australian Dairy Farms? (Dairy Australia, 2015) and AgSTAR Project Development Handbook (US EPA, 2020)

Table 41. Rule of thumb values of emission/abatement from different dairy systems

No. of cows	Farm system intensity (manure collection location/s)	Organic load per cow (kg VS/cow/d)	Total daily organic load (kg VS/d)	Waste concentration (%VS)	Daily methane yield (m^3 CH_4/d)	GHG emission/ abatement (t CO_2e/d)
400	All pasture fed (milking shed only)	0.25	100	0.7–1.0	20	0.35
600	With feedpad (milking shed and feedpad)	0.6	360	1.0–1.5	70	1.3
1,000	Fully housed (milking shed and housing)	5.0	5,000	3.0–7.0	1,000	18

Note: kilograms of volatile solids per cow per day (kg VS/cow/d), and biogas yield, cubic metres methane per day (m^3 CH_4/d), for hypothetical dairy farms of increasing size and system intensity, from grazing to freestall.

Source: Adapted from: Is Biogas Technology right for Australian Dairy Farms? (Dairy Australia)

For dairy farms the common end use of biogas is combustion to produce hot water or as a fuel for combined heat and power generators (CHP generators). A combined heat and power generator can generate electricity and capture the heat for use for thermal (heating and cooling) processes. To utilise biogas in a combined heat and power generator the gas may require cleaning to remove water vapour and to reduce hydrogen sulphide as these can be corrosive to the engines. If biogas production levels are sufficient the biogas generator may be able to be utilised as a back-up power source, complementing periods when solar or wind is unproductive.

For larger farms or co-digestion systems there may be opportunity for electricity or methane export. The gas may be utilised to generate electricity and feed into the electricity grid. For electricity export, like with solar connection, the distributor should be consulted in the design stages of the project. Excess methane may be able to be exported into the gas network. This would require the farm to be located close to the gas network and upgrading of the gas to meet the required minimum quality standard.

- Before implementing, an anaerobic digester a feasibility study should be completed to understand the economic feasibility and operational impacts of implementation of an anaerobic digester to the business.
- The decision of anaerobic digestion should take into account the additional benefits mentioned above as well as the additional costs including labour and safety requirements.

An anaerobic digester may provide the opportunity to diversify the business with co-digestion substrates such as horticultural waste or municipal food waste may be able to be fed into the digester to increase biogas yield.

A consistent supply of feedstock is required as not to upset the pH of the anaerobic digester while potentially decreasing payback time. Feeding an anaerobic digester is much like feeding a cow's rumen – any changes must be gradual.

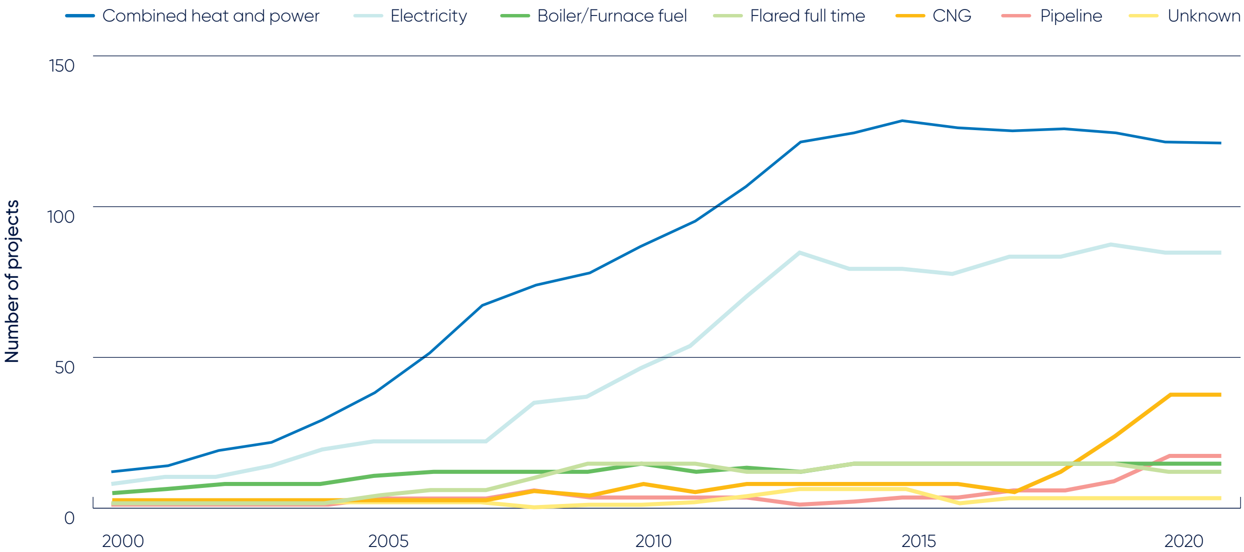
Feasibility

Feedstock from about 1,000 dairy cows that are fully housed are required for traditional biodigesters with an output of 100 kilowatt equivalent (kWe) combined heat and power (CHP), noting that manure has low energy value due to pre-digestion that occurs in the rumen.

Producers are encouraged to consider all options and to include heating and cooling of the whole farm rather than just the dairy shed. Policy instruments, such as feed-in tariffs and the Emissions Reduction Fund for Animal Effluent can also contribute to reducing costs and providing income. Increasing the productivity and value of on-farm manure and improving its management should be considered valid justification for adoption of small-scale anaerobic digestion, in contrast to the focus on electricity generation of many larger farms or commercial anaerobic digestion systems. Associated environmental benefits to support small-scale anaerobic digestion can include reduced GHG emissions, decreased odour as well as plant and animal pathogens and weed post-digestion treatment of biogas and digestate.

The outputs of anaerobic digestion are biogas and digestate. Biogas uses include flaring, electricity generation, combined heat and power, boiler fuel, upgrading for injection in natural gas pipelines or upgrading and compressing for use in vehicles and other uses. Data from the United States of America show changes in use over the past 20 years, with electricity and combined heat and power the major uses (Figure 116).

Figure 116. Uses for biogas produced from manure-based anaerobic digesters in the USA



Note: CNG = Compressed natural gas

Source: Biogas facts and trends in US EPA 2021a

In Australia, flaring and generating electricity or heat are emissions destruction activities supported by the Emissions Reduction Fund.

- The proposed use of the biogas will determine how the gas should be treated and the equipment that will be required.
- Both water vapour and corrosive hydrogen sulphide (H2S) are some of the impurities that need to be removed from raw biogas prior to use.
- The digestate produced is often mechanically separated to produce solids that are easier to handle and a liquid fraction that can be readily land applied or reused.

Digestate has similar nutrient concentrations to the feedstock (i.e. manure and any co-digestion substrates) and requires careful management to ensure that nutrient losses to air (ammonia), and to waterways are minimised.

Potential manure collection for biogas production

Grazing based Australian dairy farms generate smaller manure volumes and when flush wash systems are used in dairy sheds and yards, the DM content of effluent is usually less than 5%. This dilution of manure will generally reduce biogas production, requiring pre-treatment to reduce water content (e.g. solid-liquid separation) and/or larger infrastructure and longer retention times during digestion.

Summary of factors to consider before installing an anaerobic digester

A variety of anaerobic digestion systems have been installed on dairy farms with various herd sizes worldwide. A detailed assessment for each dairy farm is required to identify the most appropriate anaerobic digestion system. Factors to consider include:

- The volumes of manure that will be deposited in areas where manure can be collected
- The method of manure collection, including volumes of wash water used
- Manure solids content
- Methane potential of the collected manure.

If considering co-digestion, other feedstocks will be required and identified i.e. whether they will be sourced on-farm (e.g. spoilt silage and unused feed supplements) or brought from off farm. Appropriate storage facilities may also be needed.

The dairy farm will need to identify if pre-treatment of manure is required before digestion and post-treatment of digestate, as well as storage requirements of digestate fractions. Consideration must also be given to how the biogas will be used and any cleaning that is required. Likewise post-treatment and management of digestate will need to be accommodated to minimise environmental impact.

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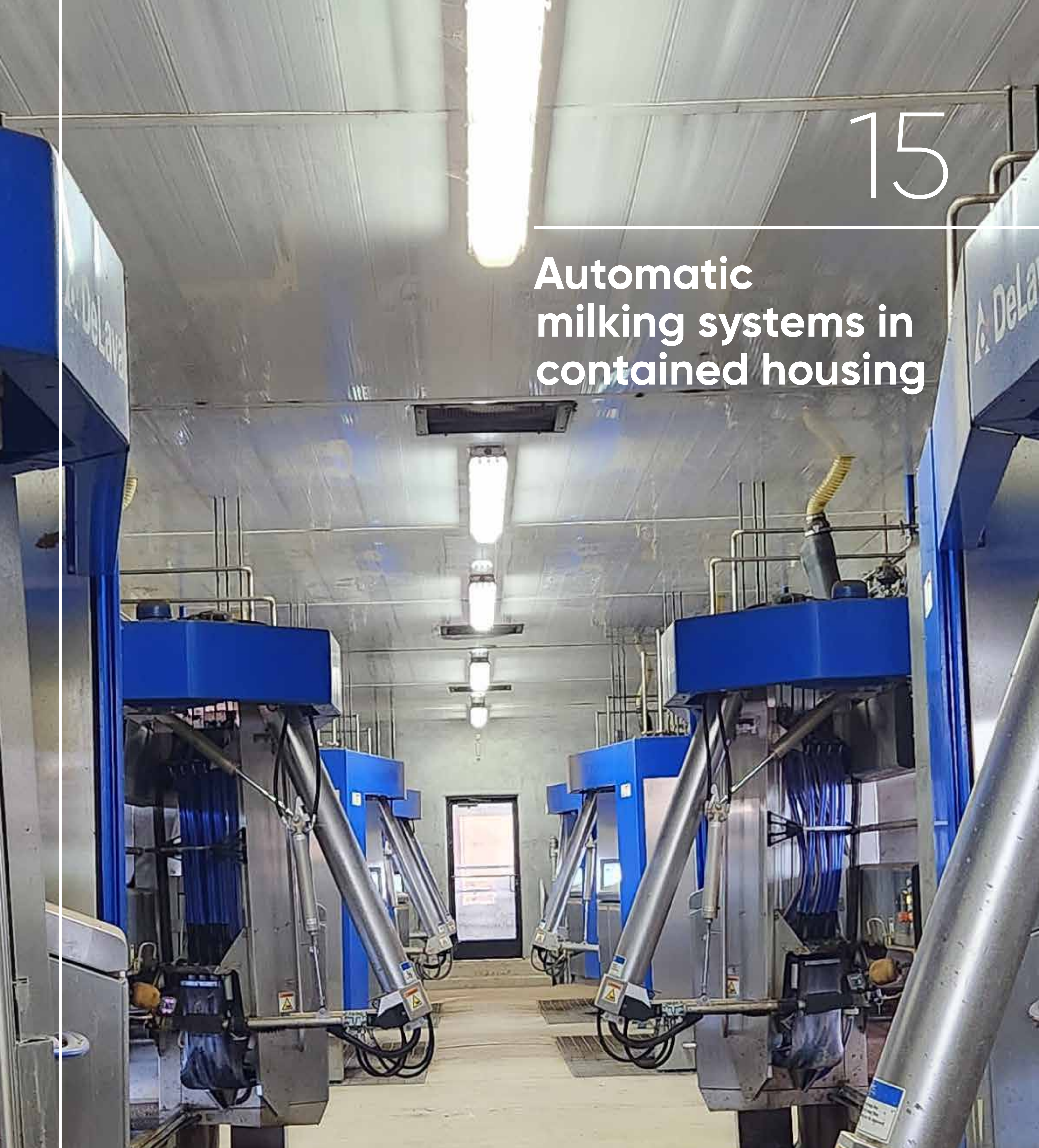


15

Automatic milking systems in contained housing

Introduction

The first commercial automatic milking system (AMS) installation took place in The Netherlands in 1992. In 2001, the first Australian, pasture-based AMS was installed in Gippsland on a commercial farm. To date:

- Over 38,000 farms globally have adopted this technology.
- Most operate in indoor-housed systems – often grazing occurs during certain periods of the year.
- Around 35% of current AMS producers have already increased the number of robots since they originally commissioned and about 50% expect to continue to expand in the future.

In Australia there is a strong interest in contained housing systems, and many producers considering changing to these systems often consider incorporating AMS.

15.1 Overview of AMS

The main characteristic of AMS is that milking-related tasks are automated.

- A robotic arm cleans, attaches, and sprays teats of each cow individually.
- Cows' traffic voluntarily and unassisted through the farm system – feed acts as the main incentive to encourage cow traffic and gain access to the milking unit.
- Milking events are distributed throughout the day and night - there are no set defined milking sessions.

Anecdotal evidence from AMS operators suggests that consistency in cow body type, size and teat placement may be important to reduce the time required to train a robot to an individual cow's teat placement when first introduced to the robot and subsequently reducing the proportion of incomplete attachments per day.

The most common type of automatic milking unit configuration to date is known as 'single box'. These units:

- Milk one cow at a time via a dedicated robotic arm that performs all milk harvesting tasks for the cow present in the milking box.
- Normally cater for a cow group of around 50 to 70 cows milked between 2 and 3 times per day (per unit).
- Can handle an average harvest up to 2,000-2,500kg milk per day.
- Pasture-based systems can handle between 1,500-2,000kg milk per day depending on pasture distances and other variables.

Other options available in Australia include 'multi box' robots or robotic 'rotaries'. Some dairy producers use AMS systems with batch milking times of 2-3 times per day.

15.2 Impact on farm workforce

There are many reasons why producers consider moving from a conventional milking system to AMS including expectations around milk production, animal health, better control of the business due to the available data, or workforce availability. For many producers this is based on increased milk production per cow and/or workforce savings (more cows per full-time equivalent or FTE) or the ability to have a more flexible on-farm workforce. The assumption is that less people will be needed to operate the farm given milk harvesting will be automated. However, recent research indicates that this may not be the case.

An Australian study (Gargiulo et al., 2020) compared 3-years of physical and economic performance of 100 conventionally milked herds with 14 AMS herds - all AMS herds had pasture-based feeding systems milking between 130 and 395 cows.

- No significant differences were found in cows per FTE or milk solids harvested per FTE.
- A large-scale Dutch study (Steeneveld *et al.*, 2012) compared 63 AMS milked herds with 337 conventionally milked herds over one year.
- No differences were observed in the number of farm workforce members between the two groups.
- There was no evidence that an investment in capital (through AMS) led to a decrease in workforce size.
- This study assessed technical efficiency which is a comparison measure of capital inputs per milk output vs labour inputs per milk output.
- No differences in technical efficiency using this method were observed.

Note that neither the Dutch nor Australian study reported on any changes in workforce flexibility as it was not measured as part of the study design.

The inference from both studies is that an increase in capital investment in the AMS farms, to establish this milking system, did not lead to an immediate or obvious decrease in workforce size by default. Rather, the existing farm workforce was re-deployed to other tasks once the robots were installed. It has also been assumed that the farm workforce were then able to operate with a higher degree of flexibility around start and finishing times.

15.3 Box efficiency metrics and utilisation

Feed is the main incentive to motivate cow traffic through the AMS, and consequently cows presenting themselves at the dairy facility to get milked.

- Cows prioritise feeding rather than milking when given the option.
- Feed management is a strategic tool to encourage cow traffic through the system.
- Utilisation is defined as the amount of time each robotic arm or AMS unit operates per 24 hours, or as a proportion of 24 h.
- Allowing time to perform system washes and technical maintenance usually means that robots are available to milk cows for approximately 21 h per day.
- This means that the greatest sustainable and achievable utilisation targets of AMS units are generally between 85 and 90% of total time available for milking.

For example, a large observational study of 635 North American AMS farms found there were relatively few units that recorded greater than 15% robot free time (or more than 85% milking utilisation).

Utilisation of milking units is related to box occupancy time per milking (which is in turn influenced predominantly by milk volume, attachment speed and milking speed) and is commonly termed milking duration (minutes per cow). Additionally, milking frequency (or the related reverse metric: milking interval), the number of non-milking visits, completeness of milking events and number of cows per robot also affect utilisation percentage.

Milk harvested per milking unit has been previously identified as the primary variable associated with AMS profitability). While there are many factors that influence profit, there are two main considerations in maximising milk production per AMS unit per day:

- Milk more animals at a lower milking frequency, or
- Milk less animals more frequently.

Observational study estimates of milk harvested per box per day include:

- 1,626kg – standard deviation 397kg (Tremblay *et al.*, 2016)
- 1,506kg – range 650–2,182kg (Castro *et al.*, 2012)
- 1,073kg – range 597–1,367kg (Gargiulo *et al.*, 2020) – this Australian study involved AMS herds in pasture-based systems only.

15.4 Layout and design

Layout is important on every dairy farm as it will have an impact on cost as well as on the day to day management activities of both cows and people. In order to achieve high utilisation of robots, the first important step is for producers to spend adequate time and thinking in the planning and design phase.

Layout is particularly important in AMS because:

- Layout has an impact on cow willingness to move around the system voluntarily - people will not always be around cows to encourage them to move.
- Cow traffic has an impact on the visitation pattern to the dairy, regularity of milking interval and milking frequency, as well as machine utilisation.
- Poor cow flow can reduce milking frequency, increase adaptation periods for new or inexperienced cows and have a negative impact on labour.
- Areas to hold cows that require the farm team's attention need to be included in the layout design and are critical to successful operation.

In every case, good layout design should then be followed by best management practice to ensure cows visit the robotic units the desired amount of times in a day, spread throughout the whole day.

15.5 Fetching routine

Besides AMS maintenance tasks, routine cow fetching is one of the main activities involving the farm workforce related to milk harvesting on a daily basis.

In housed systems it is a common routine to fetch selected cows between two to five times per day, the focus is on any cow that has not presented for milking in the last 12 to 14 hours.

This is possible given that on average these herds have less than 100 milking cows close to the milking robot and to housed areas associated with one or multiple AMS units.

15.6 Cow traffic systems for contained housing systems with AMS

A contained housing system with AMS will have three key distinct areas:

- Feeding area: where cows have access to either forages or a partial/total mixed ration.
- Resting or lying area: multiple options but some of the most common ones include compost bedded pack and freestall, with different configurations and bedding material.
- Milking area: where the robots will be located.

The type of cow traffic system will depend on whether these areas being separated or not.

In 'free traffic systems' cows have unrestricted access from feeding to lying areas and the main motivation to attract cows to the milking unit is the provision of concentrate feed during milking (Figure 117).

Free cow traffic systems achieve greater and regular feeding frequency, yet milking frequency is usually lower.

Free cow traffic often also results in increased fetching but possibly improved cow welfare, in comparison to controlled or guided traffic systems, given that lying and standing times are not compromised.

Figure 117. Free cow traffic

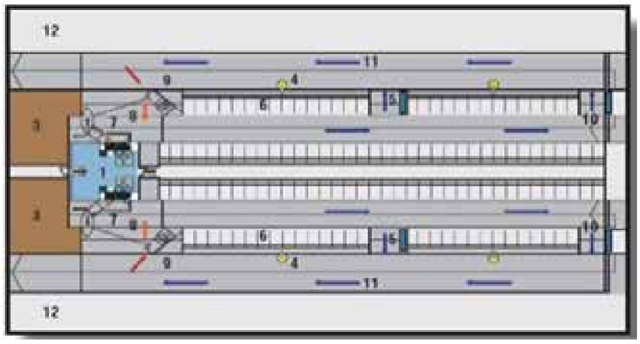
Source: Lely

In controlled or guided traffic systems, cows are required to visit the milking unit when trafficking from lying to feeding areas (Figure 118).

The decision for a cow to be milked or not is made at the milking unit.

Although a greater milking frequency (and lower milking interval) has been reported for cows managed under a controlled traffic system they also report a greater proportion of non-milking visits that use effective available robot time.

Figure 118. Diagram of guided cow traffic



Source: DeLaval

With semi-controlled or guided traffic management, cows are required to present themselves at selection gates when trafficking between feeding and lying areas. At these gates each cow is identified and only cows with milking permission are routed towards the milking units.

- Cows without milking permission are directed to other areas of the farm (such as feeding or lying areas).
- This minimises non-milking visits and maximises utilisation of the milking units.

Some producers might decide to install a pre milking waiting yard that commits cows to walk through the robotic units before accessing another area on the farm. Normally one of the following type of gates would be placed at the entrance to the yard:

- **Smart gates:** only cows with milking permission will enter the yard, you can also control the number of cows inside the yard and/or send cows to a specific robot or area within the yard, if its divided (this is the most common design in Australia currently).
- **One-way gates:** all cows will be able to enter the yard. Milking permission will be granted or refused at the robot.

Longer than desired pre-milking waiting area times, in which cows remain standing for extended periods of time, can be observed under controlled or semi-controlled cow traffic managements, which could particularly affect less dominant cows.

Observations across 635 North American AMS herds indicated that free traffic systems were associated with an extra 67 kg milk harvested/box/day (approximately 67 litres) compared with forced traffic systems.

A 12-month study conducted on a single farm utilising 20 individual AMS units with one pen per box found a significantly higher cow milk production rate in pens using semi-guided traffic versus a guided traffic system.

15.7 Milking frequency

Overseas, AMS in contained housing systems have on average, smaller herd sizes (96 versus 159 cows) and fewer robotic units (1.7 and 2.6 AMS units per farm) than pasture-based AMS. It should be noted that there are likely marked increases in average herd size and robotic units per farms for more recent Australian AMS installations.

Farms with contained housing systems have a higher milking frequency (2.7 and 2.4 milkings per cow per day) but similar cows per robot than pasture-based AMS (55 and 57 cows per AMS unit).

The greater milk harvested for AMS in contained housing systems is mainly explained by the higher milk yield per cow (28 and 21 kg per cow per d), possibly associated with the greater dry matter intake typically achieved in those systems.

15.8 Milk transport and general layout in multi-box designs

Normally in a housed AMS it can be common to split the herd in smaller groups, depending on herd size, shed design and setup. These groups can be based on attributes such as age, days in milk, lactation number or production level. Groups are kept separate and have access to a dedicated number of robots (usually 2 or 3 at maximum per cow grouping).

The largest study to examine differences in milk harvesting efficiency between a configuration (either one unit per pen or 2 or more units per pen), accounting for traffic system, found that two or more robots per pen was associated with an increased milk harvested per box per day compared with only one robot per pen although the difference was not significant for all years of the study.

- Some housing designs may require significant engineering to facilitate milk transport to a central vat location and the associated daily plant cleaning. This is due to the total length of milk transport piping involved.
- Producers and advisers should discuss design information the AMS manufacturer.

15.9 Which design to consider?

When deciding on a design for your housed AMS, it is important to consider these factors:

- Management preferences
- Layout constraints
- Future growth or expansion
- Feeding strategy
- Labour requirements
- Investment
- Cow behaviour preference.

When managed well, both free or guided cow traffic systems work and can be efficient. It is up to the producer to apply the right management tools to make the system work.

The recommendation is to visit established AMS farms wherever possible, discuss with your farm team (including employees and consultants) and work with your equipment supplier to ensure that an appropriate solution is developed for your own farm. Most suppliers should be able to advise you on dairy layout and provide plans that fit particular constraints or specifications on-farm. It is in their best interest to have well-designed systems that work well for cows and people!

Information on the design, management and operation decision making in AMS are available on the Dairy Australia learning and development platform: Enlight (search on **dairyaustralia.com.au**). These modules were developed by the Miking Edge project (2018–2022) under the leadership of NSW Department of Primary Industries. The Milking Edge project was supported and funded by NSW Department of Primary Industries, DeLaval and Dairy Australia.

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Notes

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