Feedlot covered housing systems

Best practice design and management manual

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Contact

Meat & Livestock Australia

P: 02 9463 9333

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Summary of important considerations

Item	Considerations
Approval	Various approvals may be needed to meet legal obligations. It is important to confirm the approvals required under planning, building and environmental legislation for a new covered housing system or a proposal to cover part or all of an existing cattle feedlot very early in the feasibility stage.
Siting	A range of siting factors need to be considered when considering a covered housing development. Separation distances to sensitive land uses, topography, soil properties and risks to the environment are important.
Building orientation	An east-west orientation will reduce the heat load on the building. However, wind direction should also be considered. Orienting the sheds so winds predominantly blow through the long side of the building will promote better natural ventilation.
Pen configuration	Good functional design that enables ready access and movement by feeding equipment, pen cleaning equipment, cattle and staff is required. Providing sufficient bunk space and a suitable stocking density are important to good cattle performance and pen function. Pen slope is less important in covered housing systems than uncovered feedlots. A level pen floor is suitable.
Water and power	Sufficient water and power are vital for operating a covered housing system. Roofs offer an opportunity for water harvesting and mounting of solar PVs to provide an alternative power source.
Covered housing system internal environment	A well-designed covered housing system will optimise the thermal comfort of the animals and provide sufficient ventilation to remove excess moisture and maintain good air quality.
Ventilation	A covered housing system needs to have enough ventilation to remove excess moisture and gases. In a well-designed system, natural ventilation will suffice. Optimising the ventilation system is complex and specialist advice should be sought. The building width, eave height, overall height, roof pitch and nearby obstructions all influence ventilation.
Lighting	There should be sufficient light to provide a safe work environment for staff and promote ease of cattle movement. In some circumstances, lighting may also be used to increase daylength, which may improve cattle performance.
Building height	The building height will need to provide sufficient clearance for all machinery that will need to access pens or operate under the eaves (typically ~5m) whilst also considering effects on natural ventilation.
Building width	Building width is a critical design parameter as wider sheds are more difficult to naturally ventilate. Gable roofs with vents offer the ability to have a wider building due to the chimney effect on ventilation. For retrofits over existing pens, the sheds will often need to be wider or the pen depth can be reduced to make a narrower shed.
Building length	Building length will be governed by the required capacity, stocking density, shed width and topography.
Support structures	The foundations and structural members should be professionally engineered to suit the conditions of the site. Materials should be selected to suit the harsh environment within a covered housing system. Surface treatments and impact protection are important to ensure structural integrity.
Roof	Roofs can be monoslope or gable (including straight, concave and convex variations). Single monoslope roofs are generally most suited where a narrow width is needed (e.g. partial pen covering). If wider cover is needed, consider multiple monoslope roofs in a sawtooth arrangement with openings between roofs for ventilation or gable roofs. For gable roofs, a steeper pitch (minimum 15 degrees) with a roof vent will promote natural ventilation.
Vents and roof caps	Roof vents are essential in promoting ventilation in buildings with gable or sawtooth monoslope roofs. The design and sizing of these is complex. Roof caps are recommended if the vent is over a pen area but open vents are suggested if these are positioned outside the pen area (e.g. feed road).
Roof materials	Consider corrosion protection when selecting roofing materials. Roof colour or finish may be restricted by the planning/development approval and this may affect material selection and cost.

Roof drainage	Roofs of covered housing buildings generate significant rainfall runoff. How this water is managed off the roof to surface drainage requires consideration. Suitably sized eave gutters and downpipes or lined catch drains in freefall off the roof systems will be needed. Roof runoff can be collected in tanks or dams to provide a clean water source for a covered housing system. It could also become part of an effluent stream, however because there will be more runoff from a roof than a feedlot pad, an effluent holding pond at an existing feedlot may be undersized if roof runoff is directed into it.
Flooring	Flooring needs to be able to withstand the loading from cattle and equipment. An advantage of a fully covered housing system is that pen floor maintenance is reduced due to the exclusion of rainfall when compared with uncovered feedlots.
Fences and gates	Fence and gate configurations are generally the same as for an uncovered feedlot. Nib walls under fence lines can help to contain bedding to pens. Covered housing systems with bunks on both long sides will usually have gaps in the bunks on one side to provide for gates for stock and pen cleaning equipment. These need to have adequate width to suit equipment that will access the pen.
Feeding	Most covered housing systems will use pre-cast bunks, although self-feeders are an option. Slip form bunks are difficult to construct if there are structural columns in the way. If using self-feeders, there will need to be sufficient roof clearance to fill these.
Water requirements	A well-designed water reticulation system is essential to ensure the required supply to the cattle. Consider pen cleaning operations when selecting the location of water troughs.
Drainage	Roofing a feedlot offers the opportunity to reduce the size of the controlled drainage area and effluent storage/s by separating the collection of roof runoff from effluent. Those areas of a covered housing system complex from which stormwater runoff would result in an adverse environmental impact must be contained within a controlled drainage area. The controlled drainage area must be designed to an acceptable hydrological standard that prevents unauthorised discharges of runoff from the complex.
Bedding	Most covered housing systems will use loose bedding for at least part of the year. This may be replenished throughout the feeding period before being removed and replaced at regular intervals. The type of bedding used will depend on availability and cost with sawdust, woodchips and straw being the most common options. Using sufficient bedding is important in maintaining suitable pen conditions to keep cattle clean and healthy and control emissions. Bedding addition rates will vary with the stocking density, seasonal conditions and bedding type.
Manure management	Pens will need to be regularly cleaned in accordance with approval conditions. The removed manure will need to be managed in a similar way to manure from uncovered feedlots. Because bedding is generally used, there may be more manure to manage. Any manure storage or composting area will need to be contained within a controlled drainage area.
Welfare	Good welfare is essential for good animal performance. State welfare regulations generally specify a minimum space allowance for feedlot cattle, including for covered housing systems.
Animal health	In fully covered housing systems, vitamin D_3 supplementation is required as exposure to direct sunlight is limited or prevented completely

Glossary

Annual exceedance probability (AEP)	The probability that a flood of a given (or larger) magnitude will occur within a period of one year.
Asphalt	Asphalt or hot mix is a surfacing material composed of about 95% stone, sand, and gravel and about 5% asphalt cement.
Average recurrence interval (ARI)	The average or expected value of periods between exceedances of a given rainfall total accumulated over a given duration.
Beams	Beams are long structural elements that attach to the top of the columns to provide support for the roof and transfer loads to the columns and foundation.
Bunk-to-bunk pen layout	A pen layout in which two rows of pens share a common feed alley. Also called a back-to-back pen layout.
Bay width	Space between building support columns perpendicular to long edge of building.
Biochemical methane potential (BMP)	The maximum volume (litres or cubic metres) of methane produced per unit weight (gram or kilogram) of volatile solids in a substance. It provides an indication of the biodegradability of a substance and its ability to produce methane under anaerobic conditions.
California bearing ratio (CBR)	A measure of the strength or bearing capacity of the subgrade of a material.
Columns	Major structural components that fix to the foundation, rising to support the roof (and walls).
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 controlled, aerobic process that converts organic matter into a nutrient-rich soil amendment.
Computational fluid dynamics (CFD)	Computational fluid dynamics uses applied mathematics, physics and computational software to simulate how a gas or liquid flows, as well as how the gas or liquid affects objects as it flows past.
Concave roof shape	A roof shaped curving inwards like the inside of a bowl.
Convex roof shape	A roof shaped curving outwards like an upside down bowl.
Controlled drainage area	A self-contained catchment surrounding those parts of the feedlot complex from which uncontrolled stormwater runoff would constitute an environmental hazard.
Covered housing system	A feedlot that is partly or fully covered with waterproof fabric or roofing that provides shelter for the cattle.
Crossflow	Term used in ventilation that describes where wind (fresh air) enters one sidewall opening and exits via the opposite side wall opening.
Drain slope	The longitudinal fall parallel with the feed alley or the long edge of the building.
Eave height	The distance from the base or base plate and the point at which the roof structure and the sidewall structure intercept.
Feeding table	A simple open feeding system where the feed is placed directly on a concrete slab. This design is widely used in dairy barn systems.
Footings	A building foundation that is typically consisting of reinforced concrete poured into an excavated trench forming a strip.
Frame	The support for the roof, the building frame comprises several components including columns, beams, trusses and purlins.
Gable roof	A roof consisting of two sections that slope upwards with the upper horizontal edges meeting in a peak to form a ridge.
Eave height	The distance from the base or base plate and the point at which the roof structure and the sidewall structure intercept.
Greenhouse gas (GHG)	A gas that absorbs and emits radiant energy at thermal infrared wavelengths, causing the greenhouse effect.

Herringbone gates	Gates inset into a pen on an angle to provide better cattle and machinery access.
High density polyethylene (HDPE)	A type of high density plastic commonly used for piping.
Hob	A concrete layer or other barrier around a post to protect it from machinery impacts.
Hoop structure	A form of convex roof and typically consisting of a polyethylene fabric tarp or similar material that is supported by an arched or hoop metal frame, similar to the plastic greenhouses used in horticulture.
Lux	Unit of measurement for light.
Loose bedding	A bedding system in which bedding is added over the pen floor area to absorb manure and enhance cattle comfort. The bedding is not actively managed. However, in most cases bedding will need to be regularly added to maintain suitable conditions.
Manure	In the context of this manual, manure means either manure (urine + faeces) or a mixture of manure and bedding that is periodically cleaned from the pen surface.
Methane conversion factor (MCF)	The proportion of volatile solids that are biologically available for conversion to methane based on the temperature of the system it is being degraded in.
Monoslope	A roof that has a uniform slope down from the front eave of the building down to the rear eave.
National Feedlot Accreditation Scheme (NFAS)	Feedlot industry quality assurance system.
Optimum moisture content	The moisture content at which the soil attains maximum dry density.
Panel width	Distance between fence posts.
Pen slope	The slope down the pen perpendicular to the bunk side or the long edge of the building.
Purlin	A longitudinal horizontal member in a roof that is used to span the trusses or beams and support the roof cladding.
Pier	A strong column to support the roof structure.
Pitch	Steepness of roof.
Precast bunks	Precast bunks are created by pouring concrete over a pre-shaped mould.
Photovoltaic (PV) system	A power system consisting of multiple solar panels, an inverter and other electrical and mechanical equipment.
Panel width	Distance between fence posts.
Polyvinyl chloride (PVC)	A tough, chemically resistant plastic used for a range of purposes including pipes.
Polyethylene (PE)	A tough, durable plastic used for a range of purposes including pipes and waterproof fabric roofing.
R-value	A measure of thermal resistance, or how effectively a material can block the flow of heat. A material with a higher R-value has greater insulating potential.
Relative dry density	The ratio of the difference between the void ratios of a cohesionless soil in its loosest state and existing natural state, to the difference between its void ratio in the loosest and densest states i.e. its state of compactness with respect to its loosest and densest possible state.
Ridge vent	The opening at the peak of a roof.
Ridge vent cap	A cover that sits over a ridge vent to prevent rain entering a building.
Roller compacted concrete (RCC)	A surfacing material composed of coarse and fine aggregates, cement, fly ash, water, and in some cases, water reducing additives.
Sawtooth pen layout	A covered housing system pen layout in which each feed alley services only one row of pens.
Self-feeder	A feeding method consisting of a hopper that can hold multiple days' feed requirement, with a trough or troughs at the bottom from which cattle feed.
Self-supporting roof	A type of convex (hoop) roof style that has no supporting roof structures (e.g. trusses). The strength of the roof is derived from the profile of the cladding which is typically metal ribbed profile and its curvature. The roof is supported at the edge beams.

Slipform bunks	Slipform bunks are constructed on the long fenceline/s of pens using formwork that is filled with concrete in a continuous process.
Solar absorbance	The amount of solar radiation that is absorbed by a surface.
Solar reflectance	The proportion of solar radiation reflected by a surface.
Space allowance	Space provided per SCU, usually expressed as m^2/SCU.
Span width	Space between columns on a building parallel to the long edge of the building.
Standard cattle unit (SCU)	Equivalent to an animal with a liveweight of 600kg.
Standard compaction	Soil compaction at a given water content in a standard mould with standard compaction energy.
Stocking density	Number of SCU in a given area (SCU/m^2).
Sub-base	The layer of gravel on top of the subgrade.
Subgrade	the subgrade is the native material underneath the sub-base or imported material that has been used to build and fill embankment.
Total solids	The total of all solids in a sample, or the dry matter.
Truss	The main structural framework designed to provide support and strength to a roof.
Volatile solids (VS)	Volatile solids is a measure of the organic matter content of a substance or the difference between the total solids and ash contents.
Venturi effect	An effect that occurs when wind flowing over a roof draws hot air out through the vents.

1 Introduction

The feedlot sector is an important and growing contributor to both the beef industry and to Australia's economy. To date, most cattle feedlots in Australia have been constructed as uncovered feedlots. However, summer heat and wet winter weather raise potential welfare and productivity concerns in uncovered feedlots. While many uncovered feedlots have installed shade, there is heightened interest in covering the pens with solid, waterproof roofing that may be installed over part of the pen or the entire pen. Potential benefits of covered housing systems could include:

- ability to control the impacts of climatic conditions, including summer heat waves and wet weather
- better animal welfare outcomes
- improvements in feed efficiency
- cleaner cattle for presentation at slaughter
- meat quality improvements
- ability to turn off heavier cattle, or more cattle, more quickly
- a smaller footprint and controlled drainage area for the feedlot, meaning there is less or no effluent to manage
- reductions in pad maintenance requirements
- possible improvements in manure quality because there will be less contamination with soil, and more carbon depending on whether bedding is used
- possible reductions in odour generation which may translate to being able to run more cattle at constrained sites in the future
- opportunities to capture and use roof water
- reduction in drinking water requirements
- better working conditions for staff
- the roof providing a site for PV (solar) panels to generate power
- potential for reductions in greenhouse gas emissions and energy capture from manure in the future
- satisfying customer and consumer expectations for how food is produced.

It is important to recognise that Australian covered housing systems are being built to provide protection from heat and also ongoing wet conditions. By contrast, facilities in the northern hemisphere are designed to provide protection from extreme cold and associated winds and snow. The design criteria and recommended cattle and manure management are therefore completely different.

This manual provides siting and design guidance that will be useful for any business planning to install a covered housing system under Australian conditions.

2 Design principles

To be successful, covered housing needs to:

- ensure optimal animal welfare
- optimise cattle performance
- provide protection from the elements
- be structurally sound with a long expected life
- promote good natural ventilation
- provide for ease of pen management including the addition of bedding and the removal of manure
- minimise ongoing maintenance
- provide a safe working environment.

There are a range of ways to satisfy these objectives, with different solutions needed depending on the site, budget and other factors. In particular, the options will vary depending on whether the roofing is being installed as a greenfield development or as a retrofit over existing pens. A greenfield development, which could be a new pen area at an existing feedlot or a completely new facility, offers complete flexibility in design. There are more limitations for a retrofit over existing pens.

In a retrofit, the layout of rows of pens will dictate the building orientation. Pens are likely to have a slope of at least 2–4% which needs to be managed within the design. Existing infrastructure such as feed bunks, water troughs and pipelines, roads and lanes need to be considered for any retrofit. Pens will typically provide 15–20m^2/head of space, which is considerably more than most greenfield covered systems would provide. Covering the entire pen area is therefore expensive. Covering only part of the pen is an option but this only delivers some of the benefits of a fully covered system. For example, rather than eliminating effluent production, this will be reduced. The pen depth can be reduced to provide for more economical full pen coverage but relocation of pen and lane fences and possibly water troughs will be necessary.

This manual provides design alternatives that can be incorporated into greenfield and retrofit systems but does not preclude other design solutions.

3 Design and construction

After deciding to undertake a construction project, one of the first decisions to make is how to manage the project from concept through to completion.

Section 45 – Feedlot construction delivery in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) outlines a framework for managing construction of a beef cattle feedlot. The concepts and principles presented can be applied to a covered housing system, with the emphasis on design and construction.

3.1 Design

The process of designing a covered housing system involves a number of stages to arrive at the final design of the building. The process can be complex and lengthy as there are usually numerous parties involved. The design process can be broadly divided into four stages:

- consultation
- concept design and planning
- site survey and geotechnical
- detailed design.

Unlike other farm buildings in which kit form design can be readily sourced, in most cases a covered housing system will involve a custom design considering factors like existing infrastructure and proposed feeding system, drainage and pen cleaning method.

3.1.1 Consultation

The consultation stage involves ideas and information collection. Drawing on the knowledge and experience of a range of people, including other lot feeders, engineers, building designers and others, allows more informed decisions to be made about how the building can be designed to be fit-for-purpose and eliminate or minimise animal welfare and safety risks.

Early consultation with those who will design and construct the building is also important. The best strategy is for the lot feeder to be involved in the design team, moving the approach from 'designing for' where the designing remains with the professionals (e.g. builders/engineers) to 'designing with'. A fit-for-purpose building will be more easily achieved when people involved at the design stage communicate with each other about desired outcomes and work together to find solutions.

3.1.2 Concept design and planning

The conceptual design stage defines the broad outcomes to be achieved by the project and will ultimately shape how the development will be realised. This stage can also provide a high level budget estimate for construction that includes building fabrication, fittings and inclusions and exclusions.

The concept design should be reviewed in detail to ensure that it meets all expectations identified in the consultation.

3.1.3 Site investigations

This stage is important as it determines the site-specific information required for detailed design and construction. It involves physical investigations such as topographic and feature survey, geotechnical investigations and environmental assessment to collect all relevant samples and data required.

This stage is the same whether the project is on a greenfield site or a retrofit over existing production pens.

Section 7 – Site investigations of *Beef cattle feedlots: Design and construction* (Watts et al., 2015) provides further detail of site investigations for the establishment of a beef cattle feedlot and these can be applied to a covered housing system.

When constructing buildings, design of foundations is critical and geotechnical investigation should be undertaken by a suitably qualified and experienced geotechnical engineer or a company specialising in this area.

3.1.4 Detailed design

The detailed design stage develops the approved conceptual design into working drawings.

In this stage, the full design of the building should be worked through, including fine details such as fixings, structural elements and material protection to ensure that the exact requirements are met and that the design is fit for purpose.

The result of the detailed design is the complete and precise physical description of all parts of the structure and how they will fit together. It also involves confirming the stability, strength and rigidity of the structure to be built, based upon the physical requirements of the building and an understanding of the structural performance, materials, and geometries used.

Adequate detail should be provided by the drawings to allow reasonably accurate estimates of construction and construction scheduling.

3.2 Construction

Each project has a delivery method that is determined by site constraints and business conditions.

The concepts and principles provided in Section 45 – Feedlot construction delivery in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) can be applied to the construction of a covered housing system. For smaller projects, the design and construct model will be the most suitable method due to its smaller user group and the reduced need for user reviews and mid-course design changes. Photograph 1 illustrates a covered housing system under construction over an existing production pen.

Photograph 1: Covered housing system under construction

3.2.1 Design-bid-build

The design-bid-build method is the traditional method of construction delivery. This method is characterised by a linear process where one task follows the completion of another, with virtually no overlap. Construction does not begin until the design process is complete and a bid accepted.

The design phase is outlined in the previous section. In the design phase a design engineer is engaged to develop a comprehensive set of construction drawings that form the basis of the subsequent bidding process.

General contractors bid on the design documents, usually after consulting with subcontractors for various aspects of the construction process.

The general contractor begins and completes the construction of the project, usually while supervising the work of various subcontractors.

Engaging with a builder early in the process is essential to avoid increased costs, significant delays and rework if the building cannot be practically constructed or is bespoke and requires specialist manufacturing.

3.2.2 Design and construct

In a design and construct (design-build) method, a single contract with one legal entity or consortium covers design and construction services, usually by a construction firm or builder. The design-builder is retained by the lot feeder to deliver a complete project, inclusive of design services.

Firstly, the lot feeder develops (with or without the aid of a design consultant or builder) a project brief. The project brief defines the project requirements and typically includes the functional, performance, quality and design life requirements.

The designer-builder is responsible for meeting the contract requirements. They are also responsible for identifying and communicating about any inconsistencies between the design and what can be practically achieved.

The designer-builder may also be responsible for obtaining relevant approvals and arranging certification of the works.

3.2.3 Owner-building

In owner-building, the lot feeder procures the design and materials and either undertakes or manages the construction themself. In some states, an owner-builder permit may be required for this type of construction. A covered housing system will most likely require development and building approval as outlined in Section 4.

As an owner-builder there are other responsibilities under work, health and safety laws such as being the head contractor.

Consequently, whilst some members of a lot feeder's workforce may have relevant construction experience, this may not be a practical option.

4 Regulatory approvals

A new covered housing system or a proposal to cover part or all of an existing cattle feedlot will typically require approval under planning and building legislation, and sometimes under environmental legislation. Most covered housing systems will also need building approval. This section outlines regulatory approval requirements at the time of writing. However, as these are subject to change, it is important to consult with local government planners and the applicable environment regulator early in the planning process.

4.1 Planning/development

Planning approvals give permission to develop or use land in a particular way. The development potential of the site is determined by its characteristics and the applicable planning controls. In all states, it is usually necessary to obtain planning or development approval before constructing or operating a beef cattle feedlot development. Feedlots are an allowable use in only some land use zones and site constraints may also exclude the use of land for a feedlot development. Consultation with the planning department of the local council will identify siting and application requirements.

At the front end of the development planning and assessment process is the pre-lodgement stage. It is recommended that pre-lodgement advice is sought from the regulatory authority in the early stages of a proposal so that the proposal can be reviewed with the objective being to identify potential issues and also the documentation needed to enable a proper assessment to be undertaken against the relevant legislation. Providing the regulatory authority with an assessment-ready application including all required information will not guarantee approval but it will promote an efficient process, saving time and money.

Table 1 provides a summary of planning or development requirements for each state.

4.1.1 Queensland

In Queensland, the *Planning Act 2016* establishes the planning framework for development and building work and is supported by other acts and regulations such as the *Regional Planning Interests Act 2014* and *Planning Regulation 2017*.

The establishment (or expansion) of a beef cattle feedlot, including a covered housing system, may comprise several aspects of development as defined under the *Planning Act 2016*. These include:

a. carrying out:
    i. building work; or
    ii. plumbing or drainage work; or
    iii. operational work; or
b. reconfiguring a lot; or
c. making a material change of use of premises.

If the development will involve an increase in the intensity or scale of the existing use on the subject land, it is considered a material change of use. Other ancillary works such as construction of buildings and domestic wastewater may constitute building work and plumbing and drainage work and earthworks may constitute operational works.

Under Schedule 24 of the *Planning Regulation 2017*, a beef cattle feedlot meets the definition of intensive animal industry.

Table 1: Summary of planning requirements by state

State	Requirements
Queensland	In most local government areas beef cattle feedlots are impact assessable or code assessable. Small development less than 150 SCU may be self assessable or exempt. See also: planning.statedevelopment.qld.gov.au.
New South Wales	Planning approval is required for a new (or expansion of a) beef cattle feedlot. A feedlot for >1,000 head of cattle is considered to be designated development and an EIS must accompany the development application. See also: planning.nsw.gov.au/sites/default/files/2023-03/planning-guidelines-intensive-livestock-agricultural-development.pdf
Victoria	Up to 1,000 head capacity: planning approval is generally not required but proposal must be lodged with council and approved *(note: the Victorian government is currently reviewing planning requirements, so these planning triggers may change).* >1,000 head capacity: planning approval needed. See also: deeca.vic.gov.au
South Australia	Development approval needed. No minimum size trigger specified. See also: plan.sa.gov.au
Western Australia	Planning approval is required. See also: wa.gov.au/organisation/department-of-planning-lands-and-heritage
Tasmania	Development approval needed. See also: planning.tas.gov.au

Each local government has their own local planning scheme that set outs:

- what development should occur and where it should occur by including each parcel of land in a zone (i.e. rural, rural residential, township, industrial; commercial etc);
- how development should occur by outlining assessment benchmarks against which development must be assessed; and
- what assessment process is required – by stating whether a development application is required, and if so, what process needs to be followed (e.g. impact assessment, code assessment, self assessable, exempt development).

The proposed capacity of a beef cattle feedlot usually determines the assessment process. In most local government areas beef cattle feedlots are impact assessable or code assessable. Small development less than 150 standard cattle units (SCU) may be self assessable or exempt.

All development applications require the submission of development application forms, supporting information (e.g. planning assessment, environmental assessment, traffic impact assessment and air quality assessment) and mandatory plans.

In addition to the local government planning, the State Planning Policy (SPP) makes sure the state's interests in planning are protected and delivered as part of local government planning across Queensland. All development applications are determined by the relevant council.

Early consultation with an intensive livestock development consultant or planner is recommended as each local government planning scheme regulates development differently. For example, earthworks may constitute operational works in a particular planning scheme but may be exempt in an adjoining one.

4.1.2 New South Wales

New South Wales has a risk-based approach to development. The *Environmental Planning and Assessment Act 1979* provides the framework for development and is supported by regulations such as the *Environmental Planning and Assessment Regulation 2000*. The *Environmental Planning and Assessment Act 1979* also provides for state environmental planning policies (SEPPs) and regional environmental plans (REPs).

Each local government area in New South Wales has a local environment plan (LEP). These provide a local framework for the way land can be developed and used and includes provisions to control and guide infrastructure and development.

Planning approval is required for the establishment or expansion of a beef cattle feedlot. All development applications require completion of a development application form and supporting information (e.g. statement of environmental effects (SEE) or environmental impact statement (EIS)).

In New South Wales, pursuant to Schedule 3 of the *Environmental Planning and Assessment Regulation 2000*, a feedlot is considered 'designated development' if it meets the following criteria:

- feedlots that accommodate in a confinement area and rear or fatten (wholly or substantially) on prepared or manufactured feed, more than 1,000 head of cattle, 4,000 sheep or 400 horses (excluding facilities for drought or similar emergency relief).

For 'designated development' an EIS must accompany the development application.

4.1.3 Victoria

The *Planning and Environment Act 2007* governs planning in the state of Victoria, providing a framework for the use, development and protection of land. The Victoria Planning Provisions (VPP), which sit under this Act, are a set of standard provisions that provide a template for all Victorian planning schemes. Under the VPP, a cattle feedlot is a form of intensive animal production which 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. At the time of writing this manual, a cattle feedlot was defined as "land used for a cattle feedlot as defined by the Victorian Code for Cattle Feedlots 1995." The Victorian Code for Cattle Feedlots is a state planning document that is incorporated into all Victorian planning schemes. It provides the basis for the planning, design and assessment of feedlot proposals. Under the Victorian Code for Cattle Feedlots, the term cattle feedlot means land on which cattle are restrained by pens or enclosures for the purposes of intensive feeding and includes any structure, work or area:

a. in which such cattle are handled, fed, loaded and unloaded;
b. where the animal wastes from the feedlot are accumulated or treated pending removal or disposal;
c. where the animal wastes from the feedlot are treated, placed or dispersed on the land. (NB: This does not include land that does not form part of the land on which the feedlot pens and associated works are located);
d. in which facilities for feeding such cattle are maintained and the feed for such cattle is stored; or
e. set aside for the purpose of landscaping and planting of vegetation.

It does not include any area in which cattle are penned or enclosed for:

a. grazing; or
b. hand feeding prior to 12 weeks of age or for weaning, or for the provision of subsistence rations due to fodder shortage, abnormal seasonal conditions or other like events; or
c. the provision of supplementary rations for cattle which have daily access to pasture.

Anyone planning to develop a cattle feedlot must lodge a proposal in the prescribed form with the responsible authority (council) (see Appendix 4 – Victorian Code for Cattle Feedlots for the proposal template). Cattle feedlot proposals for:

- 1,000 cattle or less which demonstrate that they meet the requirements of the Code may proceed without a planning permit*
- greater than 1,000 head of cattle require formal planning approval.

** Note: A planning permit may be required for a cattle feedlot proposal of 1,000 cattle or less, due to Victorian planning scheme zone or planning overlay requirements.*

The Victorian government is currently reviewing its planning requirements for cattle feedlots and these requirements may change.

4.1.4 South Australia

In South Australia, the *Planning, Development and Infrastructure Act 2016* and associated *Planning, Development and Infrastructure (General) Regulations 2017* provide the framework for development and building work. The Planning and Design Code sets out planning controls for the state of South Australia.

Under the Planning and Design Code, feedlots fit under the definition of intensive animal husbandry. This means 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.

Agricultural building 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.

As the development of a beef cattle feedlot is considered a change in land use, a development application must be lodged through the PlanSA website. No minimum size trigger is specified. The documentation to accompany the application is specified in Schedule 8 of the *Planning, Development and Infrastructure (General) Regulations 2017.*

Referral of a feedlot development application to EPA is triggered if the facility will be carrying on an operation for holding in a confined yard or area and feeding principally by mechanical means or by hand:

1. Not less than an average of 500 cattle (EPA licence), or 4,000 sheep or goats per day over any period of 12 months;
   or
2. Where the yard or area is situated in a water protection area – not less than an average of 200 cattle (EPA licence), or 1,600 sheep or goats per day over any period of 12 months

but excluding any such operation carried on at an abattoir, slaughterhouse or saleyard or for the purpose only of drought or other emergency feeding.

4.1.5 Western Australia

The *Planning and Development Act 2005* is the primary piece of legislation governing development in Western Australia. While other legislation sets up separate planning regimes for specific locations, these are mostly in urban or semi-urban areas, for example the *Swan Valley Planning Act 1995*. It is unlikely that a beef cattle feedlot would be established in these areas.

The *Planning and Development Act 2005* defines development as:

“development means the development or use of any land, including:

a. any demolition, erection, construction, alteration of or addition to any building or structure on the land;
b. the carrying out on the land of any excavation or other works;
c. in the case of a place to which a conservation order made under section 59 of the *Heritage of Western Australia Act 1990* applies, any act or thing that –
   i. is likely to change the character of that place or the external appearance of any building; or
   ii. would constitute an irreversible alteration of the fabric of any building”.

Development relates to both physical works and to the actual use of any land or building. Development requires approval under planning legislation if a planning scheme or interim development order specifically states that it does.

Each local government area has a local planning scheme that sets out the way land is to be used and developed; zones land for land use; includes provisions to control and guide infrastructure and development; and sets out procedures for assessment and determination of planning applications.

Planning approval is required for a beef cattle feedlot. All development applications require submission of a complete development application form and supporting information (e.g. planning assessment, environmental assessment, traffic impact assessment, air quality assessment) and development plans.

In addition to the local government planning, the state planning policy (SPP) ensures the state’s interests in planning are protected and delivered across Western Australia.

The property on which the development is proposed and/or the proposed development site and/or the proposed development may trigger a statutory referral or non-statutory consultee role to one or more state government departments. Their involvement may vary from specialist strategic advice (e.g. the long term impact on the environment through Department of Water and Environment Regulation (DWER)) to site specific infrastructure (e.g. roads through Main Roads WA).

The state development assessment panel (SDAP) sets out the matters of interest to the state for development assessment in addition to any local planning matters. Common examples are state-controlled roads, environmentally relevant activity, clearing of native vegetation.

Development applications are determined by the relevant local government or a joint development assessment panel (JDAP) depending on the capital cost of the Development. Any development application for a beef cattle feedlot that has a construction value greater than $10 million shall be determined by a JDAP.

4.1.6 Tasmania

The *Land Use Planning and Approvals Act 1993* is the key legislation for planning processes in Tasmania. It specifies the requirements and timeframes that apply for making an application for permit. It is supported by the *Land Use Planning and Approvals Regulations 2014* that include requirements for notification and fees.

The Land Use Planning and Approvals Act 1993 has been modified to include The Tasmanian Planning Scheme which was released in 2017. This is a single, state-wide planning scheme to deliver consistent planning rules across Tasmania. The Tasmanian Planning Scheme consists of state planning provisions (SPPs) and local provisions schedules (LPS). The SPPs include up to 23 generic zones and 16 codes. Each zone indicates what land use and development is appropriate for that zone. The SPPs include a standard set of planning rules for each zone. The codes provide clear pathways and controls for dealing with local issues. The SPPs only come into effect when a Local Provisions Schedule is in place in a council area to describe how the zones and codes will apply. The Tasmania Planning Scheme is being progressively rolled out across Tasmania, with most of the councils now having an LPS in place.

Under the SPPs, feedlots fall under the definition for intensive animal husbandry which means 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 itself a sub-category of resource development and a discretionary use. Consequently, the public may make representations in relation to a feedlot development application. The planning authority must consider all representations when assessing the application and deciding what (if any) conditions to apply.

4.2 Environmental

Environmental permissions are administered by environmental regulators. In most Australian states, beef cattle feedlots above a particular size require an environmental approval, permit or licence to operate and may require an environmental approval for construct works. Table 2 provides a summary of environmental approval requirements by state.

The following sections outline the environmental approval process within each state.

4.2.1 Queensland

In Queensland, the Department of Agriculture and Fisheries issues environmental approvals for beef cattle feedlots under the *Environmental Protection Act 1994.* A beef cattle feedlot is defined as intensive animal feedlotting, an environmentally relevant activity (ERA) under the *Environmental Protection Regulation 2008*.

The definition of intensive animal feedlotting under the *Environmental Protection Regulation 2008*: Schedule 2 Part 1:2 is:

feedlot means a confined yard or enclosure that—

a. contains watering and feeding facilities where cattle or sheep are fed entirely by hand or mechanically; and
b. is designed, constructed or used in a way that does not allow cattle or sheep in the yard or enclosure to graze.

A permit for an ERA is required to operate a beef cattle feedlot with a capacity exceeding 150 SCU. There are three thresholds for cattle feedlotting being:

- ERA 2, 1(a): Cattle feedlotting – more than 150 but less than 1,000 SCU;
- ERA 2, 1(b): Cattle feedlotting – more than 1,000 but less than 10,000 SCU; and
- ERA 2, 1(c): Cattle feedlotting – more than 10,000 SCU.

4.2.2 New South Wales

In New South Wales, the Environment Protection Authority issues environmental approvals for beef cattle feedlots under the *Protection of the Environment Operations Act 2017.* An Environmental Protection Licence (EPL) is required to operate a beef cattle feedlot with a capacity exceeding 1,000 head.

The risk-based licensing system aims to ensure that all environment protection licensees receive an appropriate level of regulation based on the environmental risk of the activity.

4.2.3 Victoria

In Victoria, the Environment Protection Authority issues environmental approvals for beef cattle feedlots under the *Environment Protection Act 2017.* Schedule 1 of the *Environment Protection Regulations 2021* specifies prescribed permission activities and fees. Activity B01a animal industries (waste solely to land) includes operating a cattle feedlot for more than 5,000 head concentrated for the purposes of agricultural production; and (b) discharges or deposits waste solely to land. B01a animal industries (waste solely to land) is both a prescribed development activity and a prescribed permit activity. As such, a development licence is needed to construct a beef cattle feedlot with a capacity exceeding 5,000 head and an operating permit is needed to operate such a facility. Other permissions may be needed for other site activities, for example waste tyre storage.

4.2.4 South Australia

Under the *Environment Protection Act 1993*, a cattle feedlot feeding an average of >500 cattle per day over any period of 12 months; or an average of >200 cattle per day over any period of 12 months in a water protection area is a prescribed activity of environmental significance. As a result, it requires a licence to operate.

Table 2: Summary of environmental permission requirements by state

State	Requirements
Queensland	>150 SCU capacity triggers the need for an Environmental Authority.
New South Wales	>1,000 head capacity triggers the need for an Environmental Protection Licence.
Victoria	>5,000 head capacity triggers the need for a development licence and also an operating permit.
South Australia	Licence needed if feeding an average of >500 cattle per day over any period of 12 months; or an average of >200 cattle per day over any period of 12 months in a water protection area.
Western Australia	Works approval needed to construct, licence required to operate.
Tasmania	Generally no licence required.

While it is possible that a works approval could be required for the construction, alteration or installation of buildings, structures, plant or equipment to be used for a licensed activity, this is unlikely to be needed if the proposal has been subject to a development application process.

4.2.5 Western Australia

In Western Australia, a works approval to construct a feedlot and a licence to operate one are both required as a feedlot is a ‘prescribed premises’ under Schedule 1 of the *Environmental Protection Regulations 1987*. These permissions are issued by the Department of Water and Environmental Regulation (DWER).

Licence conditions relate to pollution prevention and monitoring, and cleaner production through recycling and reuse and the implementation of best practice.

4.2.6 Tasmania

The Environmental Management and Pollution Control Act 1994 is the primary environment protection legislation for Tasmania. It is part of the Resource Management and Planning System of Tasmania. A licence is not generally required to develop or operate a feedlot in Tasmania.

4.3 Building

The minimum provisions for the safety, health, amenity, accessibility and sustainability of buildings in Australia are governed by the *National Construction Code* (NCC). The NCC is a performance-based code that includes technical design and construction provisions for buildings.

Volumes One and Two of the NCC together make up the Building Code of Australia (BCA) and Volume Three is the Plumbing Code of Australia (PCA).

In the BCA, buildings and structures are grouped by the purpose for which they are designed, constructed or adapted to be used. Each type of building or structure is assigned a classification or subclassification. A covered housing system would be classed as a Class 10a non-habitable building. Some states or territories may exempt some Class 10 buildings or structures (often on the basis of height or size) from the need to have a building permit.

4.3.1 Queensland

In Queensland, the *Building Act 1975* and *Building Regulation 2021* apply to building development. Building is defined under the Act as fixed structure that is wholly or partly enclosed by walls and is roofed, and includes a floating building and any part of a building.

Guidance should also be taken from the classification of buildings in the BCA.

In general, a building development approval (or building permit), granted by the relevant local government, is required before building work can be carried out.

An application can be made for a building or one or more stages of a building.

Building approval can be obtained from the local government or a building certifier. All building development applications require a completed building work details application form and supporting information such as mandatory plans.

4.3.2 New South Wales

In New South Wales, the *Environmental Planning and Assessment Act 1979* applies to building development. Two approvals are required: a development approval (refer to section 4.1.2) and a construction certificate.

The development approval is an early stage, high-level approval where the focus is on whether the proposed structure complies with the respective LEP (e.g. Council schemes, zoning requirements and overlays).

A complying development certificate may be applied for with some straightforward buildings.

The construction certificate covers all the engineering and structural plans, as well as the detailed building plans and ensures that the construction plans and development specifications are consistent with the development consent and comply with the Building Code of Australia and any other council requirements.

A complying development certificate or construction certificate will need to be in place before any building or construction work commences. Council or a Registered private certifier can issue a complying development certificate or construction certificate.

4.3.3 Victoria

In Victoria, the *Building Act 1993* and *Building Regulations 2018* provide the framework for building work. For building work, a planning permit may be required and a building permit will be required. A planning permit gives permission to use or develop land in a particular way and is issued by the local council.

A building permit is written approval from a registered building surveyor and shows the approved plans and specifications comply with building regulations and allows building work to start. A building permit can be obtained from a registered private or council building surveyor. A building permit building permit will state whether an Occupancy Permit or a Certificate of Final Inspection is required. A building permit allows building work to go ahead and provides protection in relation to the safety, health, amenity and sustainability of the work.

For a Class 10 building an Occupancy Permit is not required.

4.3.4 South Australia

In South Australia, the *Planning, Development and Infrastructure Act 2016* and associated *Planning, Development and Infrastructure (General) Regulations 2017* provide the framework for development and building work.

Building work is broadly defined under the *Planning, Development and Infrastructure Act 2016* as:

work or activity in the nature of:

a. the construction, demolition or removal of a building (including any incidental excavation or filling of land); or
b. any other prescribed work or activity, but does not include any work or activity that is excluded by regulation from the ambit of this definition.

Development and building work that requires a building consent will need an assessment and must comply with the building rules.

The building rules prescribe the minimum technical requirements that apply to building and construction work and consist of the Planning, Development and Infrastructure (General) Regulations 2017, the Building Code of Australia and where applicable, Ministerial Building Standards.

Various maps showing details such as climate zones, bushfire protection, earthquake hazard, and corrosion environment provide a basis for determining the technical building issues. Guidance should also be taken from the classification of buildings in the BCA.

Building rules assessment involves appraisal as to whether the proposal meets the requirements of the Building Code of Australia, various Australian Standards, the South Australian Housing Code and other relevant Council and state requirements. In general, building consent is granted by the local Council or Building Level 1 Accredited Professional before building work can be carried out.

All building rules assessments require the submission of a building consent application form and supporting information such as mandatory plans.

For a Class 10 building a Certificate of Occupancy is not required.

4.3.5 Western Australia

In Western Australia, the *Building Act 2011* applies to buildings and structures attached to or incidental to a building. There is no formal definition of a building in the act. Consequently, guidance shall be taken from the classification of buildings in the BCA.

In general, a building permit, granted by the relevant local government, is required before building work can be carried out.

An application can be made for a building or one or more stages of a building. There are two types of building permit applications, “certified” and “uncertified”.

As a covered housing system is a Class 10a building, an uncertified application can be submitted to the relevant local government without a certificate of design compliance.

As building work is considered development under the *Planning and Development Act 2005* section 4, a copy of the planning approval or its reference number will need to accompany the building application.

4.3.6 Tasmania

In Tasmania, the *Building Act 2016* applies to building development. Planning approval and building may both be needed, but some low and medium risk building work can be done without seeking a building permit from council. When a planning permit is required, this will need to be approved prior to a building determination being provided. Building approval must be consistent with the requirements of the planning permit. Building determinations are done by private registered building surveyors.

5 Siting

Good site selection is important to ensure good economic, environmental and management performance of a covered housing system. Site selection plays an important role in natural ventilation (refer to Section 7.2 for more information). Poor site selection may complicate the approval process and significantly increase capital costs (e.g. through additional earthworks or high infrastructure costs) operating costs (e.g. through long distances for transporting commodities, livestock or finished cattle) and building ventilation. A retrofit of roofing over existing pens will not involve site selection, hence this section applies to greenfield sites for a completely new covered housing system or for a new covered housing system as part of an existing feedlot.

Section 1 – Feedlot site selection in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) details the site selection criteria for an uncovered feedlot. These also apply to the selection of a site for a covered housing system.

Important factors to consider include:

- Regional issues:
  - » prevailing climatic and seasonal conditions
  - » proximity to major arterial road networks
  - » location of other feedlots or intensive livestock facilities (biosecurity)
  - » distance to backgrounding facilities, abattoirs, saleyards and other services
  - » labour availability
  - » local availability of feedstuffs.
- Site-specific issues:
  - » Regulatory requirements: as part of the planning/development and environmental permissions application processes, the siting of a proposed covered housing system will be assessed. Any covered housing system must comply with relevant Commonwealth, state and local council regulations. Most councils will also rely on the *National Guidelines for Beef Cattle Feedlots* (MLA, 2012a) and the *National Beef Cattle Feedlot Environmental Code of Practice* (MLA, 2012b) for siting guidance.
  - » Separation distance between the site and any sensitive land uses that will need to be protected from odour, dust, noise or visual impacts. Some councils may insist that covered housing systems have muted colouring to minimise possible visual impacts.
  - » Suitability of topography for construction. Covered housing systems don't require sloping pens so flatter sites will lend themselves to these developments. For sites with more complex terrain, it may be necessary to consider how topography may influence cost of construction and air movement (refer to Section 7.2).
  - » Availability of pad construction materials (e.g. clay and gravel).
  - » Access to sufficient quantities of suitable quality water.
  - » Groundwater depth and vulnerability to nutrient contamination.
  - » Risk of impacts to surface water quality.
  - » Any areas of Aboriginal cultural heritage significance or other heritage concerns.
  - » Potential for impacts to threatened or endangered flora or fauna species or ecological communities.
  - » Flood risk.
  - » Bushfire risk.
  - » Suitability of site access for heavy vehicles
  - » Land availability, including for by-product waste utilisation.

When choosing a site for a new covered housing system within an existing feedlot, consider the location in relation to existing facilities such as cattle handling yards and the feedmill.

6 Design considerations

Initial design considerations influencing the footprint of a covered housing system include:

- building type
- building orientation
- pen layout
- water and power infrastructure.

6.1 Building type

The types of buildings used for covered housing systems can be divided by roof style or flooring and manure management. Roof styles are shown in Figure 1.

Within these roof types, there are two types of flooring and manure management options:

- solid with or without bedding
- slatted with under-floor manure collection pits.

Each type of roofing has been adopted in Australia. To date, only solid flooring has been adopted. However, some producers may be familiar with the slatted flooring with under-floor manure collection pits that is widely used in the Australian pig industry and in housing for various types of livestock internationally. Consequently, there may be future interest in this type of flooring.

6.1.1 Roof shapes

Roof shapes include:

- monoslope
- gable
- concave
- convex.

Ventilation in relation to roof shape is discussed in Section 7.2.

6.1.1.1 Monoslope

Monoslope roof buildings are simple structures with a uniform single-slope roof from the front eave of the building down to the rear eave. They may also be referred to as a skillion roof or lean-to roof. They are typically constructed with steel supports and corrugated iron (or similar) and may have gutters, depending on design. Figure 2 and Photograph 2 illustrate a monoslope roof design.

The rear eave height will be governed by the type and height of machinery required to access the building (Refer to Section 7.2.1 on minimum eave height). The front eave height will be determined by the building width and the roof slope. A slope of at least seven degrees (~1 vertical:8 horizontal (1V:8H)) is recommended for this type of roofing to provide good ventilation and to allow sunlight to reach the back of the pens in winter and provide shade in the summer.

Steeper pitched roofs (in excess of 15 degrees (1V:3.75H) will provide a greater airspace for a given floor space, improving ventilation.

Photograph 2: Monoslope roof design

Figure 1: Covered housing roof styles

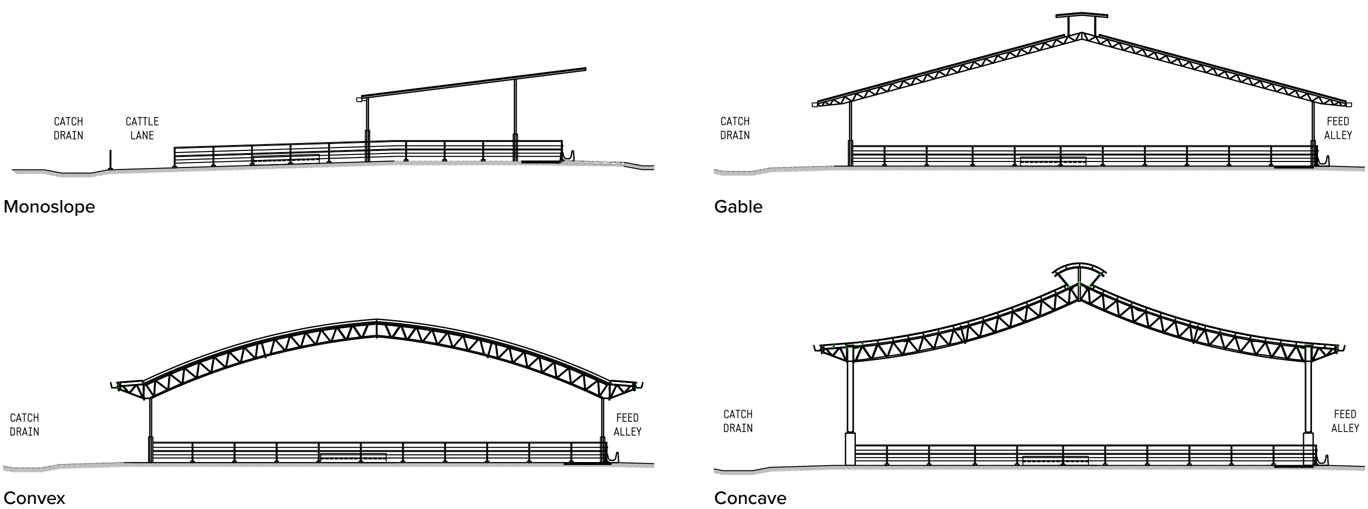
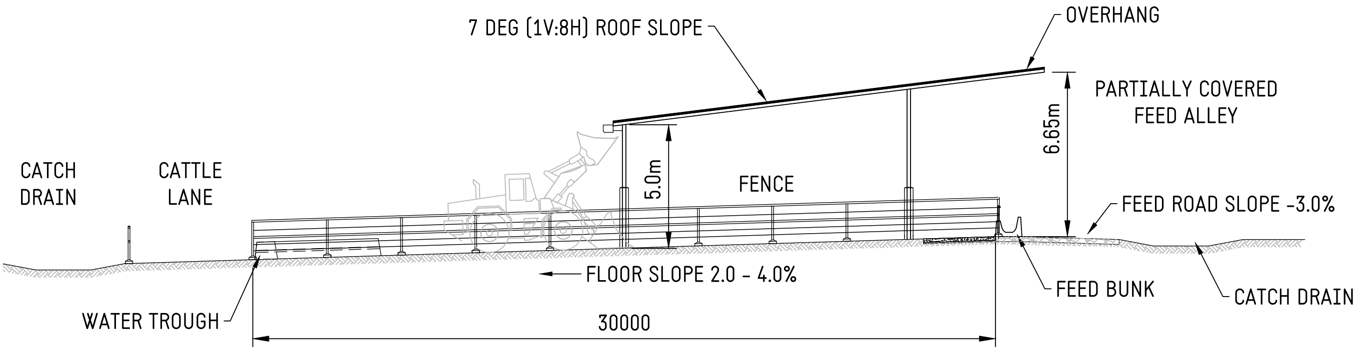


Figure 2: Example of monoslope roof



A monoslope roof is supported by steel members such as trusses and purlins. As truss members are underneath the roof and their physical size depends on the size of the building and structural loadings, trusses can lower the effective clearance height of the machinery that can operate within the building.

As wider monoslope roofs restrict ventilation, this design is often best suited to partial coverage of pens. However, depending on climatic conditions, wider monoslope roofs may be suitable at some sites. This should be confirmed by individual site assessment.

6.1.1.2 Gable

Gable roof buildings are easily recognisable from their two adjoining faces and triangular shaped end section. The two faces slope upwards towards each other, meeting to form a ridge. True gabled roof buildings have a symmetrical triangular section. An asymmetrical gable roof will have sides with different lengths, widths and slopes. Concave roofs are another variation. Figure 3 and Figure 4 illustrate gable roof configurations with feed bunks along both long sides and bunks on one side respectively.

The rear eave height will be governed by the type and height of machinery that will need to access the building. (Refer to Section 7.2.1 on minimum eave height). The ridge height will be determined by the required width of the building and the slope/s of the roof side/s.

A minimum slope of 15 degrees (1V:3.75H) is needed to provide suitable ventilation, but steeper gables of up to 22 degrees (1V:2.5H) will provide improved air flow patterns and ventilation.

Similar to a monoslope roof, a gable roof is supported by steel members such as trusses and purlins. Consequently, the height of the underside of the truss should be determined by the required clearance height for the machinery that will need to access the building.

Figure 3: Example of symmetrical gable roof with bunks on both long sides

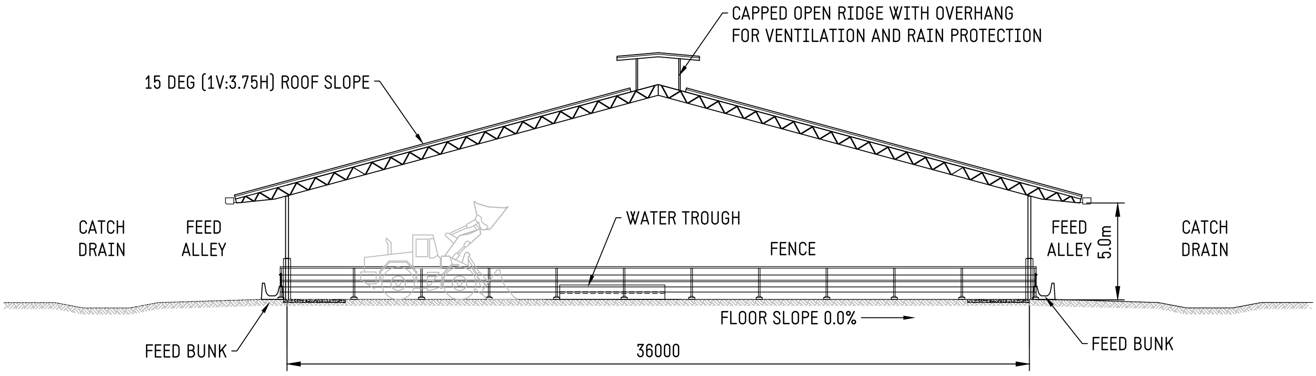


Figure 4: Example of symmetrical gable roof with bunks on one side

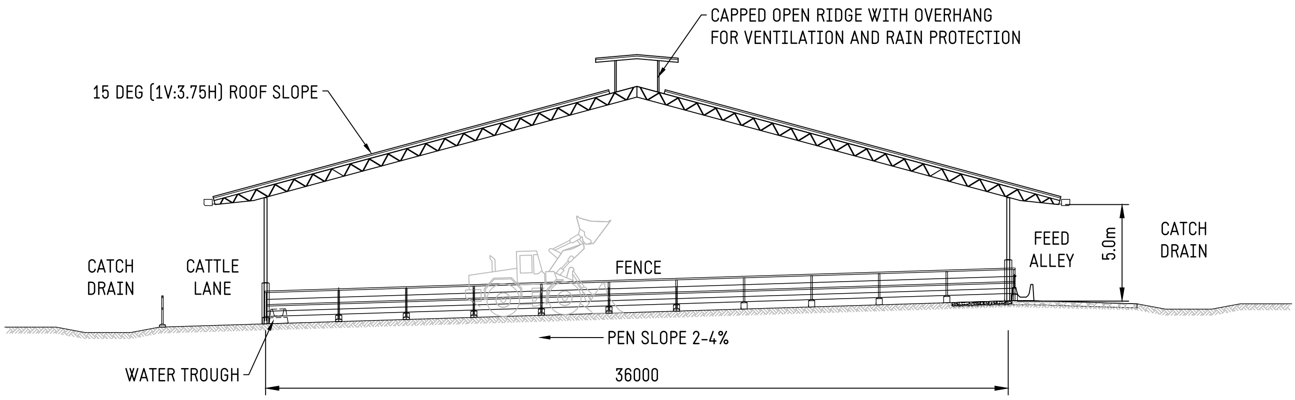


Figure 5: Asymmetrical gable roof with covered feed alley retrofitted over existing feedlot pens

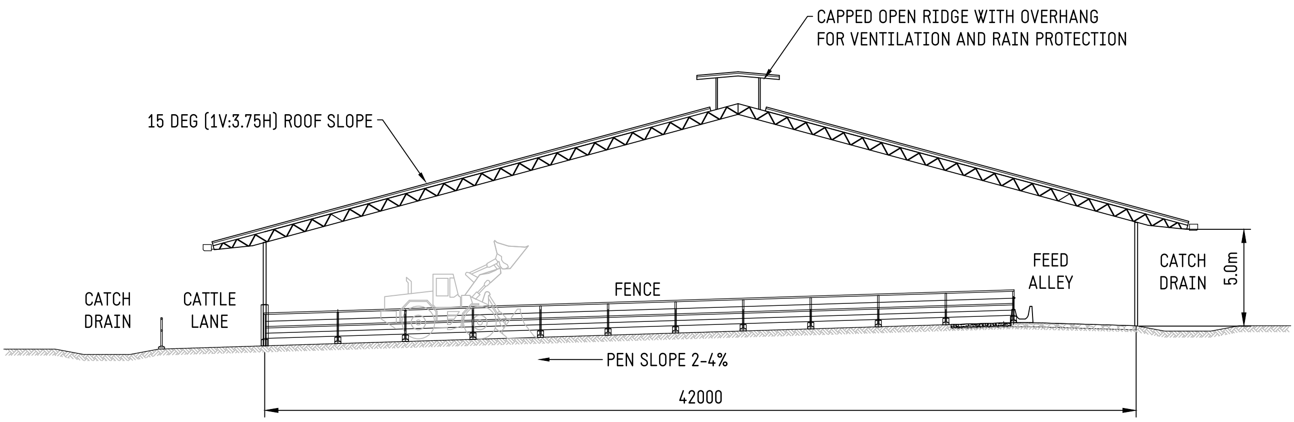
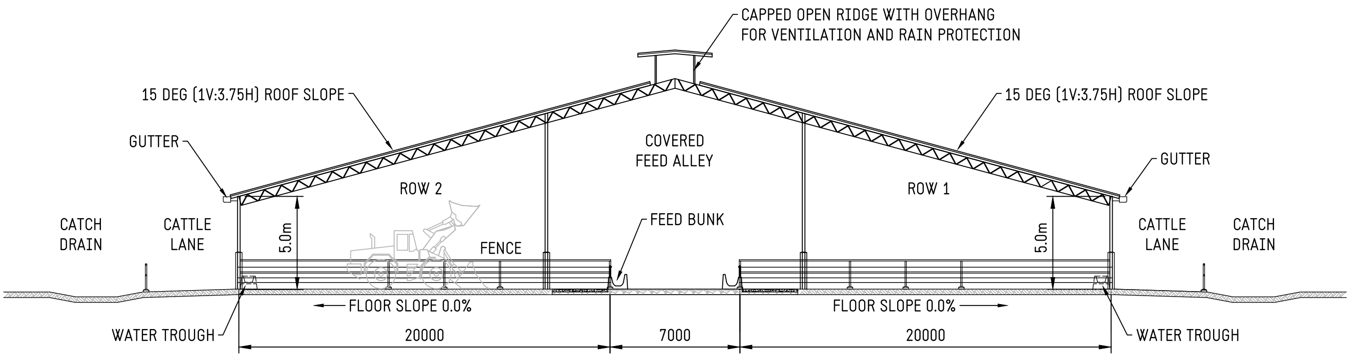


Figure 6: Gable roof with central feed alley



To date, most of the covered housing constructed in Australia is a variation of a gable design with a range of configurations developed.

An illustration of an asymmetrical gable covered housing system with ridge vent retrofitted over existing pens at an Australian covered housing system is shown in Figure 5.

Figure 6 shows a symmetrical gable roof design with a central feed alley with pens either side. In this design, a feed bunk runs along one side of the pens only. However, as shown in Figure 2, a single row of pens under the roof can be designed with the feed bunk along both of the long sides.

A gabled roof can be configured with an open ridge, open ridge with vent or covered ridge that runs along the edge where the two sides of the building intersect. A covered ridge, with no opening is not recommended as it will impact ventilation. A covered ridge will also cause corrosion of the underside of the roof structural members from cattle and manure emissions.

Spans of 40–45m are workable and these styles of roofs can be readily retrofitted to production pens within existing feedlots which typically have a depth of 40–50m. To minimise the length of frames, an asymmetrical geometry may need to be considered.

Photograph 3 illustrates a covered housing system with asymmetrical gable roof and ridge ventilation retrofitted over existing feedlot pens.

Photograph 3: Covered housing system with asymmetrical gable roof and ridge ventilation retrofitted over existing feedlot pens

Image: Rarcoola

6.1.1.3 Concave

A concave roof style is a form of gable roof building with two adjoining concave curved roofs and a triangular shaped end section. The two faces form a concave curve upwards towards each other, meeting to form a high-pitched ridge. The high-pitched ridge permits good air flow in warmer months.

A concave roof is supported by steel members such as trusses and purlins. There need to provide sufficient clearance for the full extension height of the machinery that needs to access the building.

Photograph 4 illustrates the concave roof configuration with the feed bunk along one side.

Spans of 40m are possible and these styles of roofs can be readily retrofitted to production pens within existing feedlots which have a typical depth of 40–50m.

Photograph 4: Concave roof

6.1.1.4 Convex

A convex roof style has a curved roof which may be self-supporting or supported on structural members forming an upside-down bowl shape. Photograph 5 illustrates a convex roof supported on trusses.

Hoop structures are a form of convex roof and typically comprise a lightweight roof consisting of a polyethylene fabric tarp or similar material that is supported by an arched or hoop metal frame, similar to the plastic greenhouses used in horticulture (see Photograph 6). The hoop frame usually consists of two to three inch round tubular steel formed into a truss system and supported by posts. A range of frame widths are commercially available.

The eave height of a convex-roofed building will be governed by the type and height of machinery that will need to access the building. (Refer to Section 7.5.1 on minimum eave height).

Photograph 5: Convex roof profile with truss

Photograph 6: Hoop structure convex roof

Self-supporting roofs are a type of convex (hoop) roof style. In this configuration, there is no support roof structure (e.g. truss). The strength of the roof is derived from the profile of the cladding which is typically metal with a ribbed profile, and its curvature. The roof is supported at the edge beams, which allows a wide span of up to 50m with no intermediate structures. Self-supporting roofs are in use at some Australian saleyards.

These structures offer reduced weight in comparison with the traditional truss system and rapid assembly as it is a prefabricated system. However, a self-supporting roof is non ventilated and without good natural or mechanical ventilation, corrosion on the roofing materials can reduce the lifespan of the building.

The clearance required for the type and height of machinery required to access the building will determine the eave height. (Refer to Section 7.5.1 on minimum eave height).

6.1.2 Coverage

The production pens of a feedlot may be partly covered or fully covered. The decision on the amount of coverage will depend on:

- the issue/s to be addressed, usually weather-related (exclusion of rainfall, cold stress, heat stress) and/or animal-related (e.g. cattle comfort, dags, performance, stocking density, bunk space etc.)
- site constraints such as topography, area available, soil strata/ground conditions etc.
- cost considerations (capital and operational)
- drainage design e.g. separating dirty and clean stormwater runoff
- management – such as bedding, manure etc.
- for retrofits, existing pen configuration and infrastructure (bunk-to-bunk, sawtooth, back-to-back, depth, width, lane/drain width, water trough location, pen slope etc.).

The housing system configuration is frequently influenced by cost considerations. Covering a full pen will be more costly then partially covering a pen. However, long-term investment in a structure that will optimise animal health and performance and provide a better payback outcome should take priority over any short-term cost savings.

6.1.2.1 Fully covered pen

In this housing configuration the entire pen is covered and the roof usually extends over the feed bunk. The cattle lane may also be covered. There is generally no cladding on the sides or rear of the structure.

The advantage in covering the entire pen is that rainfall is excluded and therefore animal comfort and performance are improved (when adequate bedding is supplied for a given stocking density); odour emissions area may be reduced and pen surface maintenance is reduced when compared to an uncovered or partially covered pen. Other benefits include the ability to separate 'clean' water runoff from 'dirty' water within the controlled drainage area thus facilitating its use as non-potable or potable supply within the development and minimising the capacity of 'dirty' water containment infrastructure in which effluent is evaporated or sustainably utilised via irrigation of crops.

Fully covering the feed alley may reduce feed wastage associated with rainfall events and reduce rainfall ingress into the covered area. However, bunk hygiene could also be reduced by preventing exposure to direct sunlight. A fully covered drive-through feed alley may make it easier for the operator to observe cattle while feeding, reduce maintenance requirements of the feed alley surface and provide a route for cattle movement and handling.

The housing design consists either of a single row of pens or a double row of pens in a bunk-to-bunk design with pens on either side of a central feed alley as shown in Figures 3 to 6. In either design, it is recommended that the roof extend over the bunk area as a cantilevered overhang or fully supported structure to maximise the benefits of this configuration.

Where a separate cattle lane will be installed along the rear edge of a housing system, whether the roof extends over the entire cattle lane (Figure 5), will largely depend on personal preference and budget. With additional coverage, the slope of the roof will reduce the height of the lower edge unless there is an increase in the overall height of the structure. The additional coverage offers little environmental or practical benefit other than being able to manage the water that would otherwise run off the cattle lane separately as 'clean' water and providing a better working surface.

Whether the cattle lane is covered or not, little manure will be deposited in this area as this will only occur when cattle move in and out of pens.

Whilst the height of the eave will largely influence rainfall ingress and shade into the pen, providing at least 3m overhang minimises rain entry into the pen.

The roof structure may be fitted with gutters or may be built without gutters. Section 7.7.6 provides further information on roof drainage systems. For a roof without gutters, the runoff will need to fall onto a lined catch drain area to prevent erosion.

Table 3, Table 4, Table 5 and Table 6 in Section 6.3.1 provide shed depth and pen lengths for various stocking densities and bunk space per head.

6.1.2.2 Partially covered pen

For both new developments and retrofits, some producers will choose to cover only part of the pen area, allowing the cattle access to roofed and uncovered areas to use. Partial pen coverage may be a good option for retrofits where pens have been designed for typical uncovered stocking densities (e.g. 12–20m^2/SCU). In this instance, bunk space will usually limit the number of cattle that can be held in a pen and covering the entire pen may be cost prohibitive. Partially covering the pen minimises the cost of providing the cattle with shade and shelter from rain, may protect feed from wetting (depending on the location of the structure) and could reduce odour emissions from the pad beneath the covered part of the pen since this will not be subject to rainfall-driven odour events. While most partially covered pens will have roofing across the width of the pen (see Photograph 7), some lot feeders may opt for less coverage and look for alternative solutions. For example, hay sheds have been used to provide low-cost waterproof housing that was quickly installed and offers summer shade and relief from wet, muddy conditions in winter (see Photograph 8).

There are, however, a number of disadvantages to partial pen coverage. It is inevitable that there will be posts within the pens; these provide an obstacle to avoid during pen cleaning. As cattle tend to prefer the covered area for resting, a greater percentage of manure may be deposited mostly under the roofing, necessitating more frequent cleaning of this area. While odour emissions may be lower for the covered area, the uncovered area is likely to have similar emission rates to an uncovered feedlot. Hence, odour may not be reduced as much as for a fully covered housing system. An effluent holding pond will still be needed, along with a utilisation area if the effluent cannot be managed through evaporation. Unless the roof runoff is collected and directed away from the pen drainage system, the existing drains and effluent holding pond may be undersized since a greater percentage of rain will runoff the roofs than off the previously uncovered pen area (see Section 7.7.6). The pen surface will also need to be protected from runoff falling off a roof without gutters or appropriate gutter infrastructure installed.

It may be possible to convert a partial pen cover to full cover in the future, depending on the design of the roofing. For a retrofit where bunk space limits the number of cattle that can be kept in a pen, it may be possible to shorten the pens to provide a more workable stocking density and pen area under the installed roofing. Where multiple rows of pens will be covered, this also has the advantage of providing additional space between buildings, assisting with natural ventilation (refer to Section 7.2 on ventilation). However, it may be necessary to move water troughs and pipework. An alternative is to place feed bunks along part of the lower fenceline, enabling more cattle to be kept in the pen (refer to Section 7.11.1 on feed bunks). The feasibility of this depends on the initial roof design. Consequently, the potential for fully covering pens in the future is worth considering from the outset. If bunks on both sides of the pens were being contemplated for a partially covered system, the design would need to consider the management of runoff drainage around the lower feed bunks.

Photograph 7: Partial pen covering is an effective option for retrofits

Photograph 8: Hay sheds can provide a low cost partial pen cover

6.1.3 Enclosed building

This housing configuration is similar to the fully covered pen arrangement except there is full or partial cladding on the sides and rear walls of the structure.

Covered housing with cladded walls or side curtains that can be opened for ventilation are common in the northern hemisphere, providing protection against extreme cold and snow. As these climatic conditions do not occur in the Australian lot feeding regions, enclosed buildings are generally not justified.

There may be a need to enclose one or more building sides in some circumstances. Examples may include providing protection from weather extremes such as wind/rainfall which may predominate from one direction or in specialised facilities such as dairy beef calf rearing ahead of lot feeding.

When cladding is being considered on walls of naturally ventilated buildings, the orientation of the building to minimise solar gains and maximise ventilation during summer months will become a more important design criterion.

Enclosed buildings are unlikely to have significant adoption in Australia, except perhaps for specialised production systems involving dairy poddy calves.

6.1.4 Flooring

The floor of a covered housing system is of critical importance to the performance of the facility. The floor is subjected to substantial physical and chemical stress and must be strong enough to support the loads from cattle and equipment that will access the building. The flooring should provide a comfortable and safe surface for cattle movement and resting and allow for good pen hygiene through easy pen cleaning and drainage. If a floor is well constructed and maintained, it will benefit the business by providing for optimal animal comfort and reduced pen maintenance costs.

From a foundation perspective, the flooring of a covered housing system must support the weight loads of built infrastructure, cattle and operational machinery used in the facility. However, it is also important from an environmental viewpoint as it protects groundwater from nutrients contained in manure.

Flooring systems can be broadly separated into solid floors that are constructed either directly from the in-situ material or engineered from imported materials laid on a foundation and slatted floors through which manure falls into tanks or channels underneath.

6.1.4.1 Solid flooring

To date, all Australian covered housing systems have been constructed with solid flooring which is usually used in conjunction with loose bedding, although compost bedded packs may be an option in some cases. When provided with options, cattle prefer to lie on a soft, dry surface with their next choice a harder, dry surface and least favourite a muddy or wet surface (Mader, 2011). Consequently, a dry surface ideally with bedding is likely to be the animal's preference.

Solid floors can be constructed directly from the in-situ material or manufactured from imported material placed over a prepared foundation. Most Australian covered housing systems have adopted compacted clay or gravel bases, although asphalt and concrete placed on a prepared foundation have also been used. In most situations, loose bedding covers the flooring to improve animal comfort and to absorb animal generated moisture. Chapter 8 provides further details on bedding requirements.

Because of its chemical composition, manure is corrosive, placing extra demands on the quality of materials such as concrete, roller compacted concrete and asphalt that could be used for flooring. Concrete and asphalt flooring are expensive options which may not be necessary given the exclusion of rainfall that could exacerbate the breakdown of the pen surface that typically occurs in southern feedlots in winter.

The physical properties of in-situ soil or rock strata at a site need to be assessed to determine the suitability of the material for construction and to allow accurate design of earthworks and foundations to be undertaken.

Section 7 – Site Investigations in the *Beef cattle feedlots: Design and construction* (Watts et al., 2015) outlines a process for conducting geotechnical investigations.

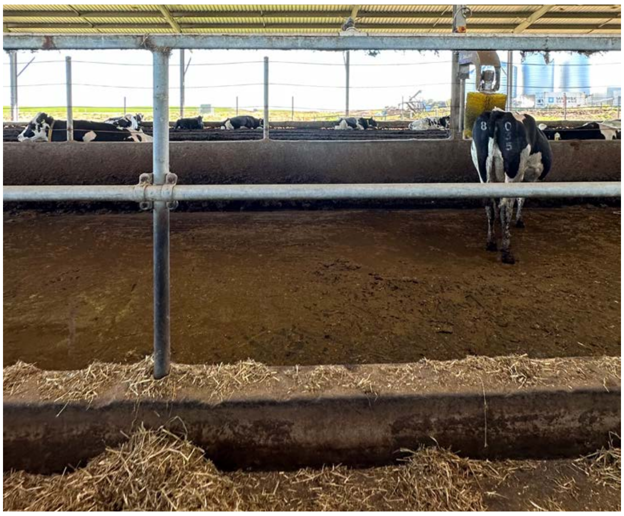
The *National Guidelines for Beef Cattle Feedlots* (MLA, 2012a) and *National Beef Cattle Feedlot Environmental Code of Practice* (MLA, 2012b) state that an impermeable barrier will need to be installed if there is a high risk of groundwater contamination because of leaching of nutrients through underlying soil or rock strata.

Similar to uncovered feedlots, the formation of a soil-manure interface layer probably occurs in covered housing systems. Care is required during cleaning to retain the interface layer prior to re-distribution of bedding. An impermeable barrier may be required by the environmental regulator in some states if the interface layer is not maintained. The preparation of a groundwater risk assessment for the site will assist in the type of impermeable barrier required.

The design requirements for various solid flooring options are detailed in Section 7.9.

The compost bedded pack system used in some Australian dairy farms could be adapted as a feedlot covered housing system. These systems are often divided into a compost bedded area along the full length of the back of the pen area, a feeding area along the full length of the front of the pen area and a feed alley for feed delivery. Additional design requirements apply to these systems. Compost bedded pack systems require solid flooring, a significantly larger building (m^2/SCU) and a commitment to intensive bedding management (refer to Section 8.3) to be effective.

The compost bedded pack area is at the back of the building and is confined by concrete walls that are typically 0.6–0.75m high. As a significant weight of composting bedding will accumulate over a period of months or years, the walls must be designed to withstand the weight of this material. For a feedlot covered housing system, cattle and machinery access to the compost bedded pack area would be provided between the pen side fence line and a side wall that confines the compost. A compost ramp will form in this area, providing easy access. A nib wall between the feeding area and the beginning of the ramp area helps to retain the compost within the bedded pack area. Two access points per pen are recommended. A fence should be constructed above the wall between the feeding area and the compost bedded pack area to prevent cattle from walking or being pushed over the wall. For dairy cows, a compost bedded area of 10m^2/Jersey cow and 12m^2/Holstein cow is typically provided (Dairy Australia and Agriculture Victoria 2023).



Compost bedded system showing feeding area in foreground, bedded area at rear

Ramp from feeding area to compost bedded pack area

The feeding area may be cleaned by flood or pressure washing (with effluent collection) or scraping. This high-use area should be constructed from concrete designed to withstand the weight of the cattle and pen cleaning machinery. Feed may be provided using feed bunks or a feeding table (refer to Sections 7.11.1 and 7.11.3 for details). Water troughs should only be situated within the feeding area. Typically, these are located on and parallel with the wall between the feeding area and the compost bedded pack area.

6.1.4.2 Slatted flooring

Slatted flooring is commonly used in Europe. In buildings with slatted flooring, the manure is trodden through the slats into impervious channels or pits underneath. The slats themselves are usually constructed from concrete with or without a surface treatment such as rubber to increase cattle comfort. A major advantage of slatted flooring is that it removes the need to use and manage bedding materials. There is, however, a need to manage the slurry produced.

Rubber mats can easily be overlaid onto concrete slats and may improve cattle comfort. However, while numerous types of rubber mats are commercially available, the structure of individual products can vary greatly in terms of hardness, friction, compression and abrasiveness, so effects on animal performance and welfare vary greatly between studies. It is also worth noting that rubber matting is a consumable product with a variable lifespan (Dawson et al., 2022).

Solid or slatted flooring?

When offered a choice between flooring type, cattle display a strong preference for straw or loose bedding and would rarely choose to lie on a slatted floor if there is any other floor type available (Lowe et al., 2000; Lowe et al., 2001).

Unfortunately, research comparing the welfare and performance of finishing beef cattle on straw loose bedding on solid flooring with those on concrete slats is often confounded by the fact that loose bedding on solid flooring systems are typically operated at lighter stocking densities than systems with slatted concrete floors. When space allowance is the same, Ingvartsen & Andersen (1993) suggested that cattle performance is not affected by the type of floor. However, this was not the finding of all researchers.

Hickey et al., (2003) investigated the effect of loose bedding on solid flooring versus slatted flooring on cattle welfare and performance. Although they examined a range of space allowances for the slatted floors (~1.5, 2.0, 3.0 and 4m^2/hd), the loose straw bedding on solid flooring was tested only at a space allowance of approximately 4m^2/hd. They found that cattle kept on the loose bedded solid flooring were cleaner and spent more time lying down than the animals housed on concrete slats. However, there were no differences in average daily gain between floor types. Cattle on both flooring types kept at space allocations of less than 3.0m^2/hd had reduced performance and welfare status.

Brscic et al., (2015) also examined the effect of flooring type (straw/sawdust bedding at 3.5m^2/hd vs. concrete slats at 2.9m^2/hd) on the welfare and performance of beef bulls. While the type of flooring did not affect the rate of weight gain, the straw/sawdust bedding improved the health and welfare status of heavy weight finishing bulls when compared to concrete slatted floors. Good bedding management was necessary to maintain satisfactory cleanliness of the animals.

Keane et al., (2017) investigated the effect of floor type on the performance and welfare of beef heifers kept on concrete slatted floors (3.0, 4.5 and 6.0m^2/hd) or loose bedding (straw) on solid floors with a space allowance of 6.0m^2/hd. Space allowance had no effect on the carcase weight of the cattle kept on slatted flooring. The cattle kept on straw had better average daily gains and feed conversion and also spent more time lying down than heifers kept on slatted flooring.

In a review of the literature from 1975 to 2018, Park et al., (2020) investigated 19 different flooring types which included loose bedding (straw) on solid flooring, flat concrete, fully slatted concrete and fully slatted rubber mats. They found that loose bedding (straw) on solid flooring provided the best animal behaviour, production and hygiene outcomes.

However, loose bedding on solid flooring has its limitations in relation to labour efficiency, space requirements, straw availability and cost (Tuyttens, 2005).

Concrete versus rubber matted slats

Keane et al., (2018) reviewed data on floor type and space allowance and their effect on the average daily gain, feed conversion, carcase weight, lying time and dirt scores of feedlot from 22 papers. They concluded that there was no difference in average daily gain, feed conversion or carcase weight between cattle kept on concrete slatted floors or rubber matted slats.

Lowe et al., (2001) and Schulze Westerath et al., (2007) also found no differences in the average daily gains and carcase weights of cattle finished on concrete slats with or without rubber mats. However, the cattle kept on rubber-coated slats exhibited fewer behavioural changes and lesions. By contrast, studies by Graunke et al., (2011), Earley et al., 2015, 2017; and Keane et al., 2015) found that cattle kept on rubber matted slats develop more leg swellings and hoof lesions compared to those on concrete slatted floors. In the Keane et al., (2015) study, the bulls kept on rubber matting had improved daily liveweight gains. While there was no evidence of lameness, the increased number of hoof lesions in the bulls suggests that hoof health may be compromised when cattle are kept on rubber matting.

Elmore et al., (2015) found no differences in weight gains or average daily gains in steers housed on fully slatted concrete, fully slatted rubber mats and solid rubber mats. The cattle kept on solid rubber flooring had more lesions than the other treatments, although there were no differences between cattle kept on rubber covered concrete slatted floors and those kept on concrete slats.

Dewell et al., (2018) reported no difference in in average daily gain, mean feed intake or mean feed conversion between cattle kept on concrete slatted floors with or without rubber matting. While their study demonstrated potential health and welfare benefits from the use of rubber matting, no performance benefits were determined.

Slat cleaning scrapers, including robotic versions, can be used to clean the slats. If channels are installed beneath the flooring, a scraper blade dragged over the channel surface directs the manure to a storage. Manual or automatic cable or chain drawn systems are available. Alternatively, a deep liquid manure storage pit sized for twice yearly pump out can be installed beneath the slatted flooring. These types of pits are typically 2.5–3.5m deep. Additional pit capacity may be provided by including the area under the feed and cattle lanes.

Similar to structures with solid flooring, a geotechnical investigation is needed to evaluate the physical properties of in-situ soil/rock strata at a site to determine the suitability of the material for construction (see Section 7 – Site Investigations in *Beef cattle feedlots: Design and construction* (Watts et al., 2015)).

The storage beneath slatted flooring is usually constructed from reinforced concrete. If this cracks, there may be a high potential for contamination of groundwater because of leaching of nutrients through underlying soil or rock strata which has a permeability that exceeds 0.1mm/day (35mm/year; 1×10^{-9} m/s). Hence, any cracks need to be detected and repaired quickly.

The design requirements of the concrete slabs and foundations elements are outlined in Section 7.6.

6.2 Building orientation

While covered housing offers a range of benefits, one of the most important functions is summer cooling. In the Australian climate, naturally ventilated animal housing is usually oriented with the long side in an east-west direction to reduce solar heat load from the sun. With this orientation, the sun moves across the top of the building throughout the day, not along the building. This, however, needs to be weighed-up against the advantages of facing the long opening of the building towards the direction of the predominant summer wind. In hotter locations, capturing natural breezes is critical in maximising ventilation rates. In summer conditions in Australia, the most important factor is to provide maximum exposure to the effects of wind and sufficient air exchange to ensure the apparent (feels like) temperature for the cattle is lowered.

Site topography also influences the temperature, wind speed and wind direction of a given location. Sites with higher elevations or on hill tops will generate higher average windspeeds and may also be cooler. It is important to consider the proximity of other natural and man-made features, including other buildings and vegetation, to ensure prevailing summer breezes are not impeded. For groups of multiple buildings, natural ventilation works best when the buildings are orientated perpendicular to the direction of the summer winds so wind flow can access the full length of the building.

Before deciding on building orientation for sites where maximising ventilation is critical for certain times of the year, collecting accurate wind speed and direction data is crucial. For some locations, this data is available from the Bureau of Meteorology, but this is often limited to hourly recordings, where the preference is to have at least six-minute or preferably one-minute data. This could be obtained from a nearby weather station or by installing a weather station and collecting data for at least one year prior to construction. Site specific data is most valuable, as areas with complex terrain, wind speed and direction data can vary significantly even within a few kilometres.

Some general rules on positioning a building in hotter localities are:

- Orientate the long axis perpendicular to prevailing summer winds by first obtaining wind speed and direction data for a proposed site.
- Ensure any natural features or structures such as wind breaks or buildings are at a sufficient distance to avoid the swirling effect caused by the wind flow over and around those obstructions.

Formulas to calculate the separation distance between buildings are included in Section 7.2.1.

In cooler climates and where there is no prevailing wind direction, the best orientation for buildings is in an east-west direction along the long axis. For monoslope buildings, the high side of the shed should be open to the north to encourage pen drying. If this is the case, ensure the direction is based on true north, not magnetic north, as this can vary by 10 degrees in some locations in Australia.

6.3 Pen configuration

This section provides an overview of the configuration of pens within a building. It covers the key design elements of stocking density, pen slope, pen dimensions and bunk space. The number of cattle per pen, stocking density and bunk space together dictate the pen dimensions. The production pens provide the housing for the cattle. Sound design is necessary to ensure good animal welfare, optimise animal productivity and ensure the environment is protected.

The pen layout must:

- provide an environment that ensures good production performance and optimal animal welfare
- ensure safe access for cattle entering and exiting the pens
- promote good environmental outcomes, in particular acceptable odour and dust levels
- allow for easy management and removal of manure from the pens
- minimise ongoing maintenance costs
- provide a safe working environment for pen riders and other personnel.

Section 9 – Overall pen layout in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) provides pen layout recommendations for uncovered feedlots. While some of these recommendations also apply to a covered housing system, there are some key differences. For instance, stocking densities are generally considerably higher in covered housing systems. Also, fully covered housing systems do not need pen slope as they do not need to drain rainfall from the pen surface.

6.3.1 Bunk space

Feed may be delivered to the cattle using a range of systems as detailed in Section 7.11. From a pen layout perspective, the bunk space provided (mm/SCU) is important since bunk space and pen capacity (SCU/pen) influence the pen length. Feed bunks should always be located along the fence line, never within the pen, to provide for efficient filling and so they do not become an obstacle when pen cleaning. While they are usually found on the top slope pen fence line on uncovered feedlots, for retrofits and other situations when a deeper pen is needed, bunks can also be added to the parallel long (lower) fence line if necessary to achieve a suitable combination of stocking density and bunk space. If bunks are installed on the lower pen slope of partially covered pens, allowance must be made for drainage of runoff from the pens. There will need to be breaks in the lower bunks to provide for gates to move cattle and for pen cleaning machinery.

Section 19 – Feeding Systems in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) provides detailed guidance on feed bunk space for uncovered feedlots. This manual recommends providing 250–300mm/head of bunk space. It identifies that providing less space may restrict access by shy feeders, particularly during the introductory phase and change feeding behaviour. This may result in some cattle taking longer to adapt to feeding, increased digestive challenge, depressed feed intake, less uniform finishing of cattle within pens and feed efficiency reductions. Unless feeding activity is being modified through day length manipulation (by the use of lighting) it could be expected that feeding activity would be similar for cattle kept in uncovered feedlots or covered housing systems.

In practice, most existing Australian covered housing systems are providing bunk lengths of between 250–300mm/SCU which is within the recommended range for uncovered feedlots. However, no publicly available research into the effect of bunk space on production has been undertaken in Australia to date.

Photograph 9: Providing sufficient bunk space is important in optimising cattle performance

6.3.2 Stocking density

Stocking density refers to the number of SCU kept in a unit of area. The space allowance is the area provided per SCU and is usually expressed as m^2/SCU. Stocking density and space allowance influence welfare and production as well as the environmental performance of the covered housing system.

Element EM1 of the Environmental Management of the National Feedlot Accreditation Scheme (NFAS) specifies a minimum space allowance of 2.5m^2 per head/SCU for cattle kept indoors (AUS-MEAT 2021).

This originated from Section 2.2.6.4 of the Model Code of Practice for the Welfare of Animals *Cattle* (2004) (now superseded) which stated that:

"The stocking density of pens or yards must take into account age, size, behavioural needs, movement and feeding patterns of cattle. In any event, an absolute minimum space requirement of 9m^2 must be provided. In the case of shedded animals, concrete flooring may be used, with suitable bedding material, for example sawdust, of sufficient depth to minimize feet and leg problems and to provide for acceptable absorption of moisture. An absolute minimum area of 2.5m^2 must be provided for each animal."

In the time since the Model Code of Practice for the Welfare of Animals *Cattle* (2004) was developed, the Australian Government has worked with states and territories to develop and implement nationally consistent standards and guidelines for farm animal welfare. For beef cattle, the Australian Animal Welfare Standards and Guidelines for Cattle (Animal Health Australia 2016) updated and replaced the Model Code of Practice for the Welfare of Animals. The standards contained in the Australian Animal Welfare Standards and Guidelines for Cattle are designed to be implemented in state and territory legislation. The included voluntary guidelines set out recommended practice for the care and husbandry of cattle.

For cattle feedlots, standard S10.1 specifies that: "A person in charge must ensure a minimum area of 9m² per Standard Cattle Unit for cattle held in external pens." No space allocation is specified for cattle kept in covered housing systems.

The Australian Welfare Standards and Guidelines for Cattle were agreed by state and territory Governments in 2016 and are being regulated into law by most state and territory governments. Despite this, it is important to note that each state and territory has its own standalone animal welfare legislation or regulations, and these should be reviewed when planning a covered housing development. In some states, a minimum space allowance of 9m²/SCU is currently regulated for all feedlots.

In Australia, there is currently little adoption of very low space allocations (e.g. 2.5–3.5m²/SCU) within covered housing systems. These space allocations are usually restricted to the slatted floor systems used in Europe and North America, rather than buildings with solid flooring. Space allowances ranging from 6–8m²/SCU have been used in covered housing systems with solid flooring under Australian conditions, although tighter space allocations (e.g. 4–6m²/SCU) may be possible depending on site factors (weather) and bedding management. A tighter stocking density will increase the manure (faeces and urine) deposition rate to the pen and can result in a wetter, loose bedded surface. This needs to be managed through a combination of bedding and evaporation. It may be necessary to provide more bedding or replenish bedding more frequently to manage the moisture added by the increased manure load. It may also be necessary to clean the pens more frequently.

Space allocations currently being used in Australian covered housing systems vary widely, ranging from approximately 4–12.5m²/SCU, although a space allocation of ~6m²/SCU could be considered most typical.

A Victorian covered housing system was using the highest space allocation (12.5m²/SCU) (lightest stocking density) only because this was a constraint of their planning approval. They were intending to apply to run more cattle on the site at a lower space allocation (higher stocking density).

A covered housing system in Western Australia has used a space allocation as low as ~4m²/SCU in summer with bedding rate of 0.9kg/SCU/day but has found that a higher space allocation of approximately ~6.5m²/SCU with a bedding rate of 2kg/SCU/day is better in winter, when low evaporation rates make it more difficult to maintain a dry pen surface.

It can more be difficult to adopt these recommended space allowances for retrofit designs since uncovered feedlot pens are typically designed to provide at least 12–20m²/SCU. Bunk space will usually limit the number of cattle that can be held in a pen, therefore dictating the stocking density. This can be overcome by either shortening the depth of pens or by installing bunks on the side of the pen parallel with the bunks (refer to Section 7.11.1 on feed bunks). Shortening the depth of pens is worth considering as this may assist natural ventilation by providing more space between buildings (refer to Section 7.2 on ventilation).

A greater pen area will need to be provided for a compost bedded pack system compared with a standard bedded system. When used in the dairy industry, a bedded area of 10m²/Jersey cow and 12m²/Holstein cow is typically provided in a compost bedded pack system. Overstocking is the most common cause of compost bedded pack failure (Dairy Australia and Agriculture Victoria 2023). Additional space is needed for the feeding area and the feed alley (see Section 6.1.4.1 for more details). However, Australian research is required to determine appropriate space allocations for compost bedded pack facilities for lot fed beef cattle.

For partially covered feedlot pens, providing at least 2.5–4.0m²/SCU of cover is recommended. A total pen area of at least 9m²/SCU (i.e. 5.0–6.5m²/SCU of outdoor area) is suggested under these conditions.

Meat & Livestock Australia has been funding research into the use of a waterproof fabric that partly covered the pens at the University of New England Tullimba feedlot. In the summer research, some 163m² waterproof coverage was provided, with total pen space of 500m² (approximately one-third of pen; 40 head per pen). This provided 4.7m²/SCU waterproof allocation in 14.5m²/SCU of pen space allocation in the summer trial (average BW 483kg), and 4.07m²/SCU waterproof allocation in 13.1m²/SCU of pen space allocation in the winter trial (average BW 555kg). The use of this material significantly improved average daily gain (+100g/hd/day), feed efficiency (4%) and hot standard carcase weight (7kg) in the summer with significant improvements in average daily gain (+100g/hd/day) and feed efficiency (5.3%) in the winter when compared with cattle in shaded or unshaded pens (Meat & Livestock Australia, 2022).

A commercial feedlot in Victoria is providing about 11m²/SCU of pen space, with cover over almost half the area, or covered space of 5.3m²/SCU. The 24m wide roof runs parallel with the feed bunks but is set back about 5m behind these and about 21m from the lower pen fence. The water troughs are not under cover. The owner is hoping that by providing shade that does not cover the troughs, all cattle will have ready access to water under hot conditions because most cattle will mainly stay under the shade rather than hovering at the troughs and restricting access by less dominant animals.

Photograph 10: Under higher stocking densities, more bedding may be needed to keep the floor dry

6.3.3 Pen dimensions

The dimensions of a production pen will depend on cattle number, stocking density, bunk placement (one or both sides of pen) and bunk space requirements. For a pen stocked with 100 SCU provided 6m²/SCU of space and with a feed bunk length of 250mm/SCU on one side of the pen, the pen will be 25m wide and 24m deep.

Table 3, Table 4 and Table 5 show pen dimensions for various space allocations and feed bunk lengths for a 100 SCU pen, a 150 SCU pen and a 200 SCU pen with a feed bunk on one side of the pen, respectively. If the pen will have bunks on both sides, the pen width is halved and the length doubled. Table 6 shows pen dimensions for two feed bunk lengths for a 200 SCU pen with a feed bunk on both sides of the pen. Given that building width restricts natural ventilation rates within covered housing systems, pen capacity may be limited by space provided per head/stocking density and feed bunk length. For most locations, the maximum recommended building width for a gable roofed structure is generally about 30m while for single monoslope spans it is 10m (Vickers, 2018; Taylor et al., 1994). Wider sheds may be possible for sites with cooler climates or those that experience good natural breezes during the hotter parts of the year. Refer to Section 7.2 for more details.

Table 3: Pen dimensions for various space allocations and bunk lengths for a 100 SCU pen with a bunk on one side of the pen

Space provided (m²/SCU)	5		7		9	
Bunk length (mm/SCU)	250	300	250	300	250	300
Pen/bunk length (m)	25.0	30.0	25.0	30.0	25.0	30.0
Pen depth (m)	20.0	16.7	28.0	23.3	36.0	30.0

Table 4: Pen dimensions for various space allocations and bunk lengths for a 150 SCU pen with a bunk on one side of the pen

Space provided (m²/SCU)	5		7		9	
Bunk length (mm/SCU)	250	300	250	300	250	300
Pen/bunk length (m)	37.5	45.0	37.5	45.0	37.5	45.0
Pen depth (m)	20.0	16.7	28.0	23.3	36.0	30.0

Table 5: Pen dimensions for various space allocations and bunk lengths for a 200 SCU pen with a bunk on one side of the pen

Space provided (m²/SCU)	5		7		9	
Bunk length (mm/SCU)	250	300	250	300	250	300
Pen/bunk length (m)	50.0	60.0	50.0	60.0	50.0	60.0
Pen depth (m)	20.0	16.7	28.0	23.3	36.0	30.0

Table 6: Pen dimensions for various space allocations and bunk lengths for a 200 SCU pen with bunks on two sides of the pen

Space provided (m²/SCU)	5		7		9	
Bunk length (mm/SCU)	250	300	250	300	250	300
Pen/bunk length (m)*	27.5	32.5	27.5	32.5	27.5	32.5
Pen depth (m)	36.4	30.8	50.9	43.1	65.5	55.4

* It is assumed that there is a 5m wide gate at the bottom of the pen, hence for 250mm/SCU space there is 27m of bunk space at the top of the pen and 23m at the bottom. For 300mm/SCU space there is 32m of bunk space at the top of the pen and 28m at the bottom.

Different dimensions will be needed for a compost bedded pack system. Assuming the system has a bedded space of 8m²/SCU, a feeding area that is 5m wide and 300mm/SCU of feed table or bunk length, the pen dimensions per 100 SCU are: 30m wide and 31.7m deep (9.5m²/SCU). If the system has bedded space of 8m²/SCU, a feeding area that is 4m wide and 250mm/SCU of feed table or bunk length, the pen dimensions per 100 SCU are 25m by 36m (9.5m²/SCU).

6.3.4 Pen slope

Pen slope is the slope down the pen perpendicular to the bunk side in an uncovered feedlot or the long edge of a covered structure. The drain slope is the longitudinal fall parallel with the feed alley or the long edge of the covered structure.

Pen and drain slope are usually defined as a percent (%) slope. Most uncovered pens have a pen slope of between 2% and 4% to ensure rapid drainage of rainfall, but without runoff scouring excessive amounts of manure from the pen surface.

When covered housing is used, there is no need to have any pen slope for drainage as rainfall is excluded from the pens. Hence, greenfield (new) sites may be built with little or no pen slope, although this may depend on natural topography and earthworks costs.

Sites with partially covered pens will need to provide 2–4% pen slope on the outside area to provide for drainage since rainfall will affect part of the pen area. Consequently, these developments should be designed in a similar way to uncovered pens. To minimise earthworks, the downslope can commence part way under the cover with a level grade from the feed bunk as shown in Figure 7. This arrangement may make pen maintenance more problematic as the inflection point may be worn down by pen cleaning over time.

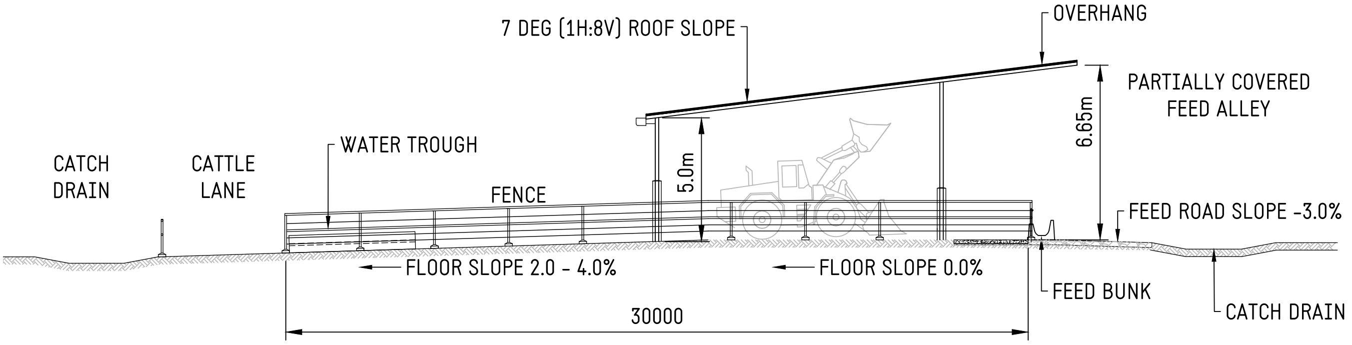
For a retrofit situation, the existing pen slope will be maintained. There is no requirement to reduce the slope as the building design can incorporate longer columns on the downslope edge or the roof pitch can be adjusted if column length is to be maintained. However, it is important that the designers know that pen slope is usually expressed in percent (%), while roof angle is usually expressed in degrees (°) which are not the same units.

For relatively level greenfield sites, there is generally no need to construct a pad to provide drain slope or longitudinal slope along the long edge of the building as catch drains can be cut down to a grade to provide the necessary drainage or gutters provided with the required fall. However, in some higher rainfall areas, particularly if a long shed will be constructed, it may be difficult to obtain the required grade on the gutter, and some longitudinal slope (>0.1%) will be beneficial.

For land with a natural fall exceeding 0.5% along the proposed long edge of the building, the site will provide the drain slope to allow gutters to be set at the same height from the ground along the building. In this case, the support columns for the building are the same height at each end of the building. Catch drains will need to be lined with grass, concrete or gravel to prevent excessive erosion as the velocity of the water typically exceeds 1.0m/s.

The floor of the building should be cut and trimmed to a smooth and even surface. Where no longitudinal fall is provided, the feed alley should have a slope of at least 3% perpendicular to the bunk with water directed to a table or catch drain with an appropriate longitudinal fall for good drainage.

Figure 7: Partly covered pen with change in pen slope



For a retrofit situation, there is no requirement to amend the drain slope to accommodate the building. However, more runoff will be generated from the roof of the building than from the uncovered pen surface which may have implications for drain sizing and surface treatment if the building design does not include gutters.

6.3.5 Cattle movements

When planning a covered housing system, it is important to consider access to the building by cattle and machinery used for feed delivery and pen cleaning, maintenance, bedding addition and removal of dead cattle. Access can be from the front, rear or the end (with internal dividing fence gates) depending on configuration and layout of the feed bunks and cattle lanes.

Gates and laneways provide a way of safely moving cattle around a covered housing system in a controlled way, in all weather conditions, and with minimal disruption to other covered housing system operations. In most cases, the design criteria are the same as for an uncovered feedlot. These criteria are detailed in Section 15 – Fences, gates and lanes in *Beef cattle feedlots: Design and construction* (Watts et al., 2015).

Cattle must be able to move easily in and out of the pens for handling. Where practical, cattle movements should be separated from feeding delivery and pen cleaning movements so these operations can occur concurrently with cattle movement. In a conventional uncovered feed pen configuration, the bunk would be on one long edge of the feed pen and the cattle access would be on the opposite long edge. However, some retrofit designs include bunks along both long edges to provide the necessary bunk space. In this configuration, cattle should still only access the pen from one side to minimise interaction with feeding equipment. Usually this is via gaps in the bunks along one side of the structure.

As cattle entry/exit locations are a high use location that may be exposed to some rainfall, the pad should be constructed with a well compacted gravel or concrete surface. If concrete is used, the surface should be stamped with a grooved pattern to prevent cattle slipping. See Section 24 – Buildings in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) for further information on non-slip concrete surfaces and Photograph 34.

Cattle gates should open into and across the laneway. These will usually also provide access for pen cleaning equipment. Space is needed between covered buildings for ventilation and this space can be partly used for cattle lanes. Photograph 11 illustrates a gateway in the feed alley. Wide gates are needed to provide sufficient turning radii for machinery to enter without hitting feed bunks. Access could also be provided from the short sides of the pen (end of the building) as shown in Photograph 12, however this makes cattle movements between individual pens more difficult.

Laneways may be positioned outside the building or inside (covered) as shown in Figure 6 and Figure 7, respectively.

Photograph 11: Gates in the feed alley

Photograph 12: Gates on the edge of a building

6.3.6 Pen operations

Access to pens will be needed for pen cleaning, maintenance, bedding delivery and removal of dead cattle. Consequently, the design of the building access has to account for the expected mix of vehicles.

The primary access to a covered housing system will usually be through gates located on the long side of the building on the side opposite the feed bunk, although some pen configurations will have feed bunks along both long sides. These may also be gates across feed bunk aprons that provide more direct access between pens.

The two key design criteria for access are the fixed height and turning radii of the machinery; this needs to provide adequate clearance without the need for unnecessary backing manoeuvres.

The implication of building eave height for equipment clearance are discussed in Section 7.2.1. For equipment that has a variable height such as front-end loaders or tipping trailers, it may be assumed that the equipment enters and exits the building in the fully lowered position however, this may not always be the case and the working height of equipment should also be considered in the design.

Pen gates arranged at an angle to the cattle lane in a herringbone arrangement are commonly used in uncovered feedlots to allow improved access for machinery and cattle flow. Covered housing designs may not include herringbone gate arrangements due to loss of covered pen space. If this is the case, equipment will need to make a tight 90 degree turn in and out of each pen.

Therefore, lane width along with clear area along the front or rear of a building is important. For buildings with a formal cattle lane, a lane width of 5–6m is recommended to allow vehicles to turn into the pen. Cattle lane widths exceeding 6m are not recommended from a cattle flow perspective. Hence, if a width of 6m will not provide sufficient turning radii, then an external road parallel with the cattle lane that allows the vehicle to straighten before entering the building or a herringbone gate arrangement may need to be considered.

The minimum turning radius of a rigid vehicle 8.8m long for various travel speeds is shown in Table 7.

Table 7: Turning radii of an 8.8m long body truck at different speeds

Vehicle	Turning speed km/hr	Minimum radius m
Body truck (8.8m)	5	9
Body truck (8.8m)	10	12.5
Body truck (8.8m)	5–15	15

The method of loadout of manure from the pen and bedding placement should be given careful consideration. Loading manure over the pen fence into a truck parked in the cattle lane will require the greatest eave height. However, the clearance height to the building structure will also need to be considered if loading within the pen.

The roads providing building access must be constructed for all weather access. The principles for design of the access roads are detailed in Section 13 – Pen and drainage systems and Section 17 – Pen and road surfaces in *Beef cattle feedlots: Design and construction* (Watts et al., 2015).

6.3.7 Feeding

When planning a covered housing system, the layout of the feed road system must consider the variety of vehicles such as commodity delivery, feed delivery, maintenance and other operational vehicles that will all use the internal road network. Vehicles will range from semi-trailers, trucks with dogs, b-doubles and road trains, to agricultural equipment such as tractors and front-end loaders. Refer to Section 13 – Access and internal roads in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) for further information on layout, widths, turning radii of the internal road network.

For greenfield sites, the feed road should be connected with a continuous circuit and include a dedicated turnaround at the end of each building to improve efficiency.

When the feed alley is fully covered and not exposed to rainfall, there is no need to grade the feed alley away from the feed bunk. The alley can be designed with a level grade between the bunks with the longitudinal fall on the pad providing for drainage.

In this situation, the feed alley should be at least 5m wide to provide adequate clearance from the bunk for delivering the feed. Typically, there is no need to allow additional width to allow vehicles to pass each other which differs from the requirements of feed alleys for uncovered pens. As covered housing alleys are usually shorter in length the feed delivery system can be managed so that two vehicles will not be required to use the same feed alley at one time.

For gabled roof designs where the feed alley is uncovered and exposed to rainfall, the feed alley should be designed with a crossfall away from the feed bunk to the centre of the feed alley so that rainfall is directed away from the feed bunk to a 'V-drain' where it can flow out the end of the building.

For all other designs in which feed alleys are exposed to rainfall, the alley should be designed with a crossfall at a slope of 3% to direct water away from the bunk to a table or catch drain on the edge of the feed alley.

Without good drainage, roads will start to degrade quickly so a table or V-drain should be constructed where possible to remove the runoff water from the edge of the road. Photograph 13 illustrates a partly covered concrete feed alley with a concrete v-drain.

The same principles for design of the feed alley table drain or V-drain for road drains as for uncovered feedlots apply. Refer to Section 17 – Pen and road surfaces and Section 10 – Pen and drainage systems in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) for further detail on drain configuration and design.

Photograph 13: Partly covered concrete feed alley

6.4 Water and power

6.4.1 Water supply and reticulation

A covered housing system needs a legal right to use and access the required water volume. Water is needed for cattle drinking, feed processing, cleaning (including yards and machinery) and other general operations around the facility. An uninterrupted supply of good quality water with supply able to meet peak demand is needed.

Planning and designing a water reticulation system for a covered housing system depends on its access to water, location, site, size and operation. Water reticulation systems can be either gravity flow or pressurised or a combination of both. Gravity flow avoids any potential equipment failure in a pumped system. The water reticulation system must be sized to supply water at sufficient pressure throughout the covered housing system during peak demand periods, particularly livestock drinking.

Whilst the diurnal pattern of drinking water consumption is expected to be similar to cattle in uncovered feedlots, the total and peak water demand of cattle within covered housing systems may be less due to environmental factors. Until water use requirements in covered housing systems are quantified, the water reticulation system in a covered housing system should be designed to deliver the total and peak water demand equivalent to an uncovered feedlot of the same capacity. Guidance on total and peak water requirements is provided in Section 7.12.

Therefore, a covered housing system should have a contingency plan for pump or pipeline failure. Water supply may be interrupted for hours or days due to equipment damage (natural disasters; motor or pump breakdown; pipeline failure etc.) or supply failure (electricity blackouts). A temporary emergency (back-up) water supply and suitably sized contingency water storage close to the covered housing system that can gravity feed to the buildings are essential.

Designing a covered housing system water reticulation system can be complex. Refer to Section 3 – Water supply sources and onsite water storages and Section 14 – Water reticulation in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) for further information on water supply and water reticulation requirements. Professional assistance from a suitably qualified and experienced water engineer or a company specialising in water supply and reticulation systems should be obtained to determine system layout, pumping capacity and pressure, pipeline sizes and valve locations. The designer should locate air relief valves, vacuum relief valves, isolation valves, water storage and thrust blocking as well as pipeline and fittings.

6.4.2 Power

A covered housing system may need power to prepare feed, supply water, provide lighting, operate fans for ventilation, irrigate effluent and run the office. Section 6 – Energy sources and supply in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) provides further detail of energy infrastructure, requirements and demand for a beef cattle feedlot that can be similarly applied to a covered housing system.

Electricity – planning and infrastructure

When planning a covered housing system, consider the electricity source early in the planning process. This could be grid electricity, generators, renewable (solar, wind and bioenergy) or a combination of these. With grid electricity, it is important that the nearest point of supply is identified early. The local power authority can provide information on supply options and costs but will first require details on anticipated overall use and peak demand.

Specialist advice regarding expected electricity demand and supply options should be obtained from a consultant who is suitably qualified and experienced in this area. Some of the variables to manage could include single-phase versus three-phase supply, peak demand versus average loading, and high voltage versus low voltage metering.

The infrastructure associated with the electric power system includes supply-side infrastructure, such as overhead lines and transformers, equipment at the point of supply such as metering, switchgear and earthing, underground cable networks and feeder circuits, and switchgear associated with individual pieces of equipment. All overhead electrical services must be installed in accordance with the requirements of the Australian Standard, AS/NZS 7000:2016, *Overhead line design* (Standards Australia, 2016). This standard provides general requirements for the design and construction of new overhead lines to ensure that the line is suitable for its intended purposes and provides acceptable levels of safety for construction, maintenance and operation and meets requirements for environmental standards.

Electrical services and cabling

All underground electrical services must be installed in accordance with the requirements of the Australian Standard, AS/NZS 3000:2018, *Wiring rules* (Standards Australia, 2018). Accurate plans should show underground services with the quantity and size of cables and conduits marked. Underground cable routes must be marked with manufactured cable markers indicating the presence of underground cables.

Distribution boards should be located near electricity usage points so that the length of connection cable is kept as short as possible to reduce line losses.

All electrical installations must be carried out by an appropriately licensed electrical contractor.

Solar

The installation of a photovoltaic (PV) system consisting of multiple solar panels, an inverter and other electrical and mechanical equipment may be used to meet all or part of the electric power demand of a facility. Whether a PV system will be economically viable depends on the cost of the PV system, power demand and the cost of supply from more conventional sources of energy. PV systems can be used in a wide variety of applications and are increasingly becoming more versatile and economical to operate.

PV can be an effective source of electrical energy for covered housing systems that use mechanical ventilation, as the peak diurnal energy demand mirrors peak solar energy production. For feed milling, PV could be used, as processing can be scheduled to also match peak solar energy production.

PV systems may reduce greenhouse gas (GHG) emissions compared with alternative power sources. The reduction in GHG emissions from offsetting grid electricity with PV is, however, dependent on which state of Australia the grid electricity is supplied from. Operations located in states which have a large proportion of renewables supplying their grid (e.g. Tasmania) will have a smaller emission reduction opportunity from solar than operations located in states with a smaller proportion of renewables in the grid (e.g. Victoria).

PV has the limitation of not being able to offset electricity in the evening and during cloudy periods unless a battery storage is installed. Alternatively, a diesel generator, can provide back-up power.

PV systems require suitable areas for mounting panels. Covered feedlots offer ample space for roof-top installations or land surrounding the production area can be used to install more efficient ground-mounted, tracking solar systems.

Photograph 14: Solar panels on a covered housing system in Australia

Image: Action Steel

In most Australian states and territories, rooftop PV panels are considered attachments to a building and exempt from requiring a building permit. There are exceptions in some locations, however, and the local authority should always be consulted before installation.

When considering rooftop PV installation, both the ability of the roof frame to support the additional load and the method of fixing of the panels must be considered. Panels should not adversely affect the structural integrity of the building and the safety of people working under or near the structure. It may also be worth seeking advice as to any insurance implications.

Both heat and dust can reduce the efficiency of PV panels. The optimum temperature for PV panels is 25°C, with energy generation potential decreasing as the temperature of the panel rises above this. In hot climates it may be necessary to cool the units with water sprays. Similarly, dust from covered housing system activities can coat PV cells and reduce their ability to generate electricity. If the PV cells have been installed at the correct angle to the horizontal, regular washing with water will remove the dust, and permanently installed water sprays operating on a timer can resolve both heat and dust problems. However, the water used must be free from salts that can coat the surface of the panels and reduce their performance.

Every PV installation must be carried out by an accredited installer to meet the relevant Australian standards, including:

- AS/NZS 5033:2016, Installation and safety requirements for photovoltaic (PV) arrays (Standards Australia, 2016)
- AS/NZS 1170.2:2021, Structural design actions, Part 2: Wind actions (Standards Australia, 2021)
- AS/NZS 4509. 1:2009, Stand-alone power systems, Part 1: Safety and installation (Standards Australia, 2009)
- AS 4086.1:1993, Secondary batteries for use with stand-alone power systems, Part 1: General requirements (Standards Australia, 1993)
- AS/NZS 3000:2018, Wiring rules (Standards Australia, 2018)
- AS/NZS 1768:2021, Lightning protection (Standards Australia, 2021)
- AS 4777.1:2016, Grid connection of energy systems via inverters, Part 1 Installation requirements (Standards Australia, 2016).

To maximise the power output from PV (solar) panels, these are best angled to optimise sunlight exposure. This occurs when they are positioned perpendicular to the sun with the rays hitting the panel at a 90° angle. Facing the panels to true north and at an angle close to the latitude of the location will maximise sun exposure. Approximate latitudes for selected locations are Emerald 23.52296°S, Dalby 27.18169°S, Wagga Wagga 35.12577°S.

One Victorian producer has installed PV panels on the roof of their covered housing system. The roof has a relatively steep pitch of 21° meaning the solar exposure of the panels is better than if a flatter roof was used. The panels have been installed flat on the roof.

A covered housing system in South Australia has used frame-mounting to optimise the angle of the PV panels (see below).

7 Detailed design

7.1 Covered housing systems: internal environment

A primary purpose and advantage of covered housing is to provide a more controlled and better environment for the cattle year-round to improve welfare and productivity outcomes. For this to occur, the design must provide sufficient ventilation to:

- optimise the thermal comfort for the animals (i.e. control of temperature)
- remove excess moisture from the building and bedding
- maintain good air quality.

7.1.1 Temperature control

Cattle have a temperature range in which no additional energy is required to maintain body temperature. This temperature range is known as the thermo-neutral zone. For unadapted British-bred cattle, this range is 15–25°C (NRC, 1981). Control of the environment with covered housing systems via moisture control, through management of stocking density and use of bedding and sufficient air exchange and ventilation, plays a crucial role in reducing energy required to maintain body temperature.

Cattle have a range of adaptive techniques to maintain body temperature. As temperatures fall below the thermo-neutral zone, an animal can increase feed intake to enhance metabolic rate and reduce blood flow to the skin to reduce heat transfer from the body to the surface. The animal can also use 'hair raising' to hold and heat air close to its skin. However, with sufficient moisture, mud can adhere to the coat of cattle (dags) preventing hair trapping heat and increasing heat loss. Existence of wind chill can further increase heat loss. Conversely, when ambient temperature rises, the animal will increase blood flow to the skin. This raises the skin temperature above the environmental temperature, promoting heat transfer. At this stage, increased respiration and sweating also occurs and the animal will reduce its feed intake and increase its water intake to lower body heat production and maintain its core temperature.

The internal ambient temperature within a naturally ventilated covered housing system will be within a few degrees of the outside temperature. However, the protection of cattle from direct radiation, rainfall and presence of mud will reduce the time cattle are exposed to apparent temperatures beyond their thermo-neutral zone.

7.1.2 Removal of moisture

It is important to remove moisture from the housing as humidity can impact an animal's health and production via several pathways. Relative humidity is a measure of the amount of water vapour in the air compared with the amount the air can hold when it is saturated. A relative humidity of 50% means that the air is 50% saturated. Inadequate ventilation leads to high humidity that can cause moisture condensation and contribute to animal health problems. Relative humidity levels have a direct link to bacterial survival and respiratory issues, with:

- high levels (>80%) being conducive to the survival of bacteria and spread of disease
- relative humidity of <80% generally reducing the survival of airborne bacteria found in livestock buildings
- both high (>80%) and low relative humidity (< 25%) able to promote respiratory ailments.

High relative humidity levels also contribute to the faster deterioration of building infrastructure and equipment, especially when combined with high ammonia levels.

Relative humidity is not generally continuously measured in livestock buildings, as the indoor environment is not compatible with equipment accuracy, reliability and longevity. Moisture levels are best controlled by constantly providing sufficient ventilation to remove excess moisture added via animal excreta and respiration. The amount of moisture that needs to be removed depends on the size of the animals, the stocking density and the air temperature. Targeted relative humidity monitoring may be useful if there are indications of insufficient ventilation.

The type of floor also affects the amount of moisture to be removed. For example, slatted or partly slatted floors allow a percentage of the moisture added by excreta to fall into pits, rather than needing to be removed via evaporation or absorption into bedding material.

The water balance of cattle kept in a covered housing system demonstrates the importance of natural ventilation in removing excess moisture from buildings. For cattle stocked at 6m^2 per SCU, some 500–700L/m^2 of moisture from excreta will be added every 100 days. This is the equivalent of a 50–70cm depth of water over the entire floor. Hence, the constant transfer of moisture from a solid-floored covered housing system via evaporation is critical. This is necessary to prevent:

- wet floors/bedding
- animal health and welfare problems
- environmental impacts (odour generation).

If the water activity in the bedding is lower than the relative humidity of the air, then the bedding or manure will absorb moisture from the air. If the situation is reversed, water will transfer to the air. Water activity is a thermodynamic property relating to the relative availability of water in a substance (e.g. bedding) and its tendency to escape to another media (e.g. air above the bedding surface). Thus, to ensure that water evaporates from the bedding, the relative humidity of the air at the bedding surface must be kept as low as possible by providing adequate ventilation at floor level.

7.1.3 Air quality

Within a covered housing system, the exchange of stale air with fresh air needs to ensure adequate oxygen is supplied and conversely, that unwanted gases such as carbon dioxide, ammonia and hydrogen sulphide are removed. Ventilation that generates sufficient air exchange will also remove odour and dust, which is important for both the housed animals and farm workers.

Providing adequate ventilation also helps to prevent animal respiratory (and other) diseases. When buildings are poorly ventilated, high relative humidity levels may create an environment more conducive to the survival of airborne pathogens which is further exacerbated by higher pathogen concentrations due to lower air exchange rates. Conversely, with good ventilation rates, respiratory pathogens do not survive long following exhalation, provided ventilation is sufficient to prevent high humidity levels. Research has shown that 100% clean, fresh air will kill airborne bacteria and viruses 10–20 times more quickly than 50% clean, fresh air (Vickers, 2018).

An indicator of insufficient air exchange is ready detection of an ammonia smell within a covered housing system. A good rule-of-thumb is that there is a complete air exchange in a building at least every six minutes.

The performance of calves is adversely affected at ammonia concentrations exceeding 50ppm ammonia. The respiratory system of cattle is poorly adapted to cope with elevated ammonia levels. High ammonia concentrations can cause coughing, rapid breathing and inflammation of the lower respiratory tract in cattle, which may predispose them to pneumonia. Hence, for welfare and production reasons, 25ppm is a suitable critical value for atmospheric ammonia (Costa et al., 2003).

Some dust may be generated when bedding (particularly sawdust) is distributed over the pen surface. However, under the stocking densities typically used in covered housing systems dust is most unlikely to be an issue at other times since the moisture added by manure acts as a dust suppressant. Consequently, the potential spread of zoonotic pathogens from cattle to people via dust from pens is also unlikely to be a concern, although risks should be assessed for activities such as pen cleaning.

7.2 Ventilation

The principal role of ventilation in covered housing systems is to draw fresh air in, while replacing and removing stale air containing moisture, heat and gases (e.g. ammonia). Ventilation can be mechanical (fan forced) or natural. Natural ventilation is generally adequate for the types of open buildings being built in Australia.

7.2.1 Natural ventilation

In well-designed, naturally ventilated buildings, the two main forms of ventilation that can occur are from natural convection and wind. The effectiveness of natural ventilation is influenced by building design features including building width, height at eaves, height of roof peak, angle of roof and provision and size of ridge gap or vent. These design features reduce the sole reliance on wind speed and direction for ventilation and instead promote air exchange by creating wind pressure differences across the roof and also thermal buoyancy, where heat generated within the building rises and escapes through a ridge vent, pulling fresh air in from the open sides.

Natural convection occurs due to thermal buoyancy or the 'stack' or 'chimney' effect as shown in Figure 8. Thermal buoyancy happens when warm air rises above the surrounding denser, colder air. In covered housing systems, heat (warmed air) is generated via a range of pathways, that include metabolic heat produced by the cattle, solar radiation on the roof and as a result of aerobic decomposition of bedding on the floor. If the internal building temperature exceeds the external temperature, the air inside will rise. With natural ventilation, this warm air will exit via the roof vents (if provided). This natural extraction of warm air also removes moisture and gases contained within the airflow. With greater temperature differentials between the internal and external environments, a greater level of thermal buoyancy will occur and the exchange of air by this process will increase. Conversely, if it is warmer outside, this buoyancy becomes ineffective, and a naturally ventilated building will need to rely on wind to remove excess heat, moisture and gases.

Wind driven ventilation occurs via two modes, firstly, when wind flows through and across the building (crossflow ventilation) as shown in Figure 9 – secondly if the building has a ridge vent, by wind flowing over the roof, drawing air up through the vent as shown in Figure 10. This second process is also known as the 'venturi effect'. The rate of ventilation (air exchange) is driven by the difference in pressure inside and outside the building which is generated by the wind.

Figure 8: Natural ventilation via thermal buoyance or 'stack/chimney' effect

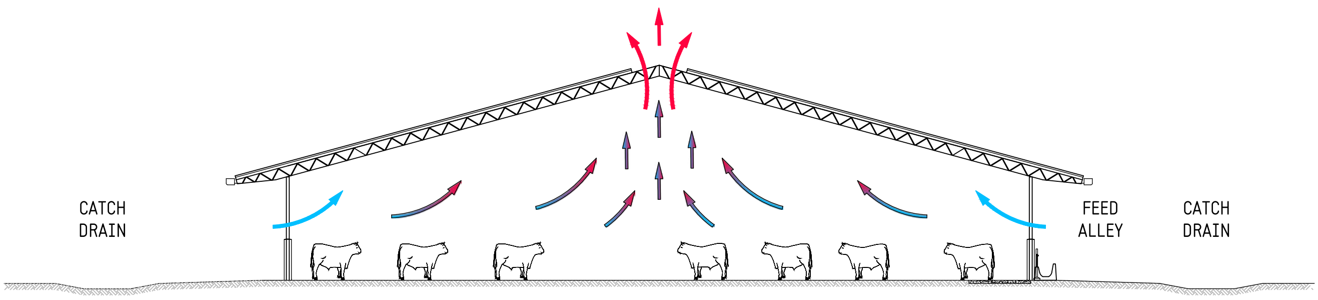


Figure 9: Wind-driven natural ventilation via crossflow

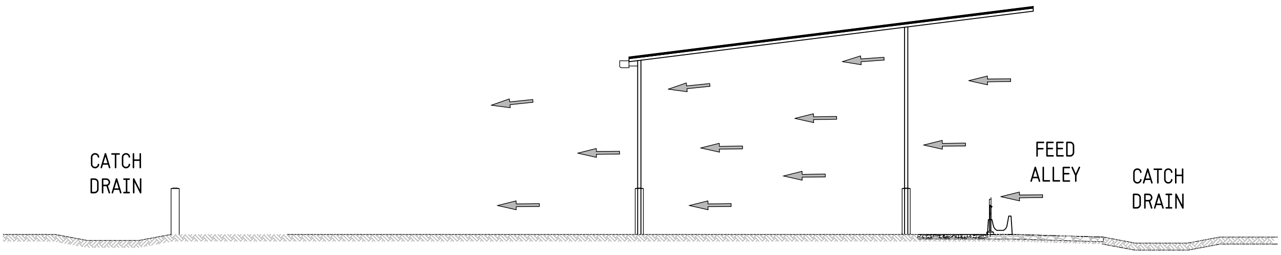
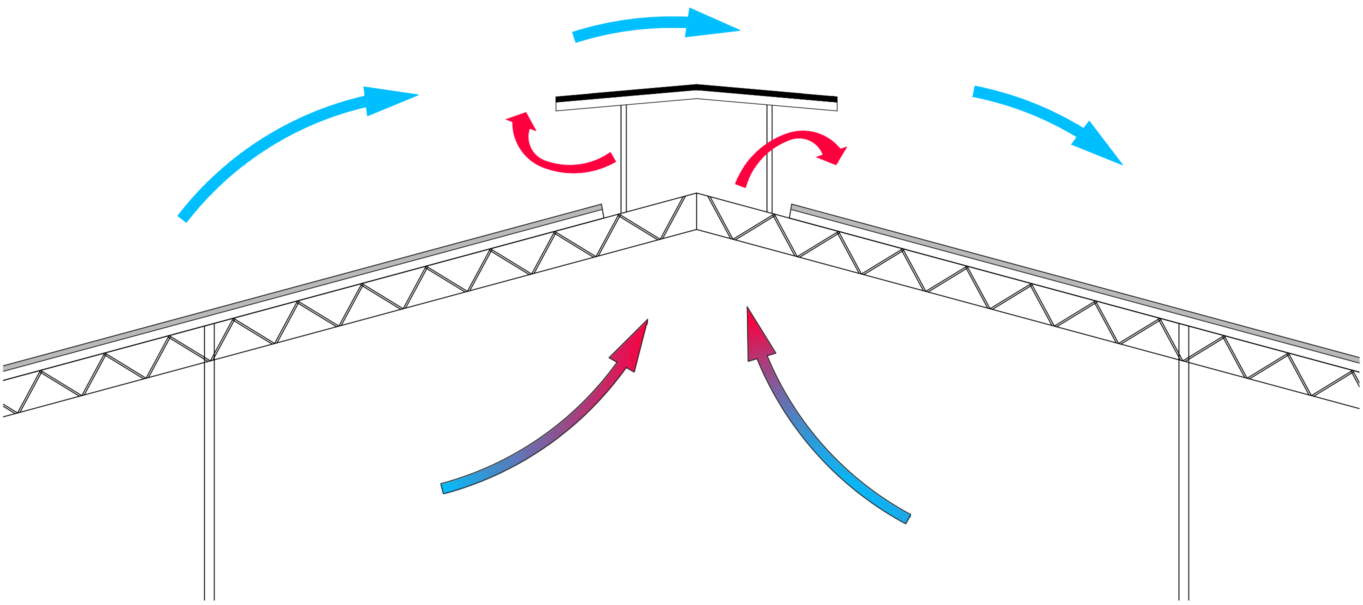


Figure 10: Wind-driven natural ventilation via the 'venturi' effect



To achieve a cooling effect when most required (hot summer days), the ventilation needs to primarily rely on the wind effect rather than buoyancy and the design of covered housing systems should maximise the use of any available breezes during these periods.

Building width can have an important impact on ventilation. Due to the reliance on wind driven, crossflow ventilation most of the time, wider buildings are more difficult to ventilate naturally compared with narrower buildings in the same location.

Naturally ventilated covered housing systems need to be carefully sited to avoid any restrictions from nearby obstructions, including other buildings. The University of Wisconsin-Madison (2023) provide a simple formula to determine the minimum distance (Dmin) that a building in a covered housing system needs to be separated from other upwind buildings or obstructions:

$Dmin = (L \times H)^{0.5}$

Where Dmin = the minimum distance needed from upwind obstruction (m)

H = height (m) of upwind obstruction (i.e. ridge height of adjacent building)

L = length (m) of upwind obstruction (i.e. length of adjacent building)

For example, if a new covered housing system is to be located downwind of an existing building that is 200m long and 9m high at the ridge, the minimum distance to maintain adequate natural ventilation will be:

$Dmin = (200 \times 9)^{0.5} = 42.4m$

Optimising the ventilation system in covered housing systems can be complex and advice from a mechanical engineer or specialist in heating, ventilation and air conditioning (HVAC) should be sought when considering the design of a covered housing system. The width of a building, eave height, overall height, roof pitch and nearby obstructions (e.g. other buildings), are all design features that will interact with each other and change ventilation patterns under different climatic conditions. The heat balance of a system should also be considered, with animal size, stocking density, bedding system (e.g. compost bedding will generate heat) and the solar gain on the roof, all influencing ventilation, particularly during calm wind conditions. For example, increasing the building width will likely change the size of the ridge vent opening required and increase the overall height to maintain the same roof pitch. (refer to Section 7.7.3). This may also alter windspeeds at animal level during calm conditions if side wall openings are fixed and are unable to be changed. Having the ability to reduce the side wall opening outside of an access point to a pen by using shutters or curtains under the eaves is one option that may overcome this issue. The aim would be to enhance fresh air windspeed into the building at animal height and mix with stale air, rather than 'short-circuiting' under the roof-line and exiting the ridge cap without mixing.

7.2.2 Mechanical ventilation

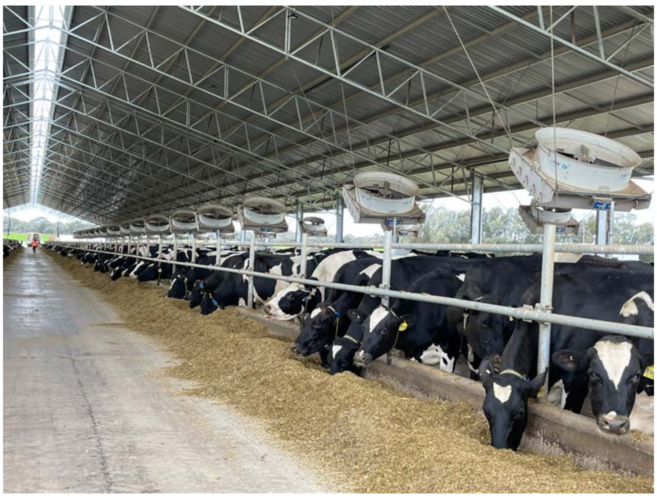
In situations where natural ventilation is unable to supply sufficient air movement and air exchanges, mechanical ventilation may be required. In fully open buildings, this would generally only be required in poorly designed covered housing systems or where the location is sub-optimal due to topographic constraints, orientation in relation to winds or close to other buildings.

It would be very expensive (capital and operating costs) to fully mechanically ventilate a covered housing system, although this would usually only be required in building spaces that are ‘dead zones’ that cannot be effectively ventilated naturally. These zones can be ventilated either by blowing air into the space (positive pressure ventilation) or by sucking air from the area (negative pressure ventilation). Both systems require sufficient inlet and outlet areas to ensure they operate at their designed capacity.

Positive pressure ventilation systems in covered housing systems would generally use an air straightener and duct to maximise the performance of the fan and distribute fresh air along the full length of the building via an inflatable duct. The basic design principles include adequate fan capacity, calculation of duct diameter, and varying hole diameters and spacings to distribute air evenly at animal height.

Negative pressure ventilation systems are not usually installed in beef cattle covered housing systems, being mostly used for pig and poultry housing. For these systems, the inlet area design and how well the building is sealed are particularly important in ensuring the performance of the fans is not compromised. Another important design feature is that the fan generated windspeed is delivered at animal height to maximise the cooling benefits.

Mixing fans are an alternative to positive and negative pressure systems. These are sometimes used with housed dairy cows to provide summer cooling as shown in Photograph 15. The fans should blow in one direction and be angled downwards to ensure air flows over the backs of the animals. This also means they are angled towards the floor, which enhances drying. The objective is to ensure an air velocity of at least 1.5m/s. Suppliers will be able to provide advice on the required number, type, size and spacing of fans.



Photograph 15: Incline mixing fans over dairy cows

7.3 Insulation

Insulation is mostly used to reduce the solar heat load on buildings, although it can also prevent condensation from excessive water vapour.

Insulation materials are rated by R-value. The R-value is a measure of thermal resistance, or how effectively a material can block the flow of heat and a material with a higher R-value has greater insulating potential. If insulation is to be used under steel roofs, it should have an R-value of between 5–10 to reduce condensation and keep the building cooler.

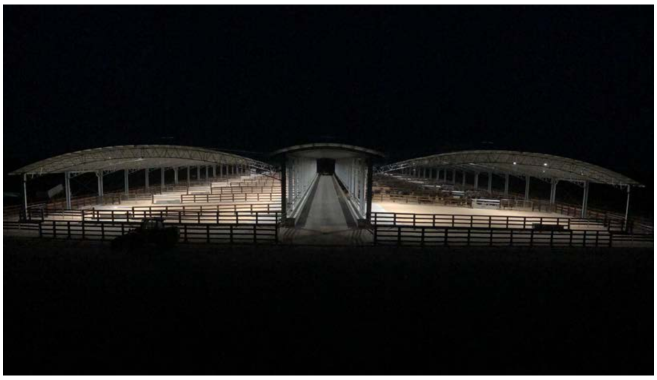
Insulation is likely to provide only a marginal benefit for temperature control in Australian covered housing systems because there is generally little variation in temperature between the inside and the outside of the building, due to them being fully open.

Most of the water vapour generated within covered housing systems is from the evaporation of manure moisture, however, a large animal can respire 20–25L/day. As water vapour rises, it can condense if the air carrying it cools off sufficiently. Insulation assists by keeping the roof surface warm enough to prevent condensation from forming when moist air contacts it. Condensation problems are likely to be minimal in fully open buildings as there will be less variation in temperature between the inside and the outside compared with enclosed buildings.

7.4 Lighting

Covered housing systems need good light to provide a safe work environment for staff and to promote ease of cattle movement by removing areas of shadow that may cause animals to baulk when being moved. Facilities with large side openings for ventilation may provide sufficient natural light to meet these requirements. Penetration of natural light can also be improved by providing translucent panels within the roofing. While a translucent area equivalent to 8–10% of the floor area is recommended, the exact area required depends on the design and orientation of the roof structure.

Artificial lighting (see Photograph 16) has been assessed as a method of promoting cattle performance, however research has provided variable results. Roche et al., (1980) reported increasing daylength to 16 hours had no effect on daily gain or carcase weight of 15 month old steers and Phillips et al., (2010) reported no effect on feed intake, daily gain or feed efficiency in finishing heifers and steers exposed to 16 hours of light. In contrast, Riaz et al., (2021) reported improved feed intake and daily gain of growing yearling Sahiwal heifers exposed to 16 hours of light. Manipulating light relates to changes in the animals’ melatonin levels. The light phase generates a virtual absence of melatonin, whereas melatonin levels increase with darkness. The melatonin pattern and duration of elevated levels (dark phase period) influence the circadian rhythm of the animal, which in turn change the levels of hormones – affecting immune response, reproduction, lactation and growth.



Photograph 16: Lighting may be used to extend day length
Image: Spanlift

Lighting characteristics to consider, include light duration, intensity and uniformity.

- **Light duration.** The light phase should be 16–18 hours followed by a dark phase of 6–8 hours. It takes 3–4 weeks for the response to extending daylight to occur (Marai and Forbes 1989). A dark phase is required. Continuous lighting will disrupt the relationship between melatonin and the circadian pattern.
- **Light intensity.** The standardised unit for measuring illuminance or light intensity is the LUX. Examples of light intensities include 10,000 LUX for a sunny day, 3,000 LUX for an overcast day and less than 30 LUX for darkness. For cattle, a light intensity of at least 200 LUX at the animals' eye level is needed to generate a response. However, in an open sided building, greater light intensity of up to 600 LUX may be required (Small et al., 2003).
- **Light uniformity.** Uniform light throughout the covered area avoids the creation of shadows and the related stress response in cattle.

The most efficient lighting systems use light emitting diodes (LED). Compared with alternatives such as fluorescent, incandescent (halogen), high pressure sodium, and metal halide, LED lights last longer, use less electricity, produce little heat and offer greater flexibility for dimming, operating time and the type of light produced. Light defined as cool white light (shortwave 460–480nm) is very efficient at reducing melatonin levels. However, light that matches the characteristics of natural daylight appears to be just as effective.

7.5 Building geometric design

7.5.1 Height

The minimum eave height will depend on the fixed and working height of machinery that will access or operate within the building (e.g. pen cleaning equipment) or under any overhang (e.g. feed wagon or truck) along with ventilation requirements. A suitable clearance (600mm minimum) needs to be provided to the underside of overhead structural elements such as beams, trusses, roof sheets. Table 8 provides some heights of various equipment commonly used in uncovered feedlots. As shown in Table 8, the fixed height of equipment typically ranges from 3–3.5m with a full lift height of a front end loader up to 5.25m. Fixed and operating heights of equipment vary considerably depending on configuration, tyres, attachments, exhaust stack height etc. so all equipment should be measured to confirm fixed and working height.

The full extended height of machinery operating within the building should also be considered to failsafe the structure from machinery impacts and to ensure functional operation.

The recommended eave height for a building with a width of 30m is 4.9m to provide for good ventilation under most climatic conditions. Therefore, a minimum eave height of 5.0m is recommended as this also provides clearance for most typical feedlot equipment.

Table 8: Height of typical feedlot equipment

Equipment	Model	Fixed height m	Extended height m
Front-end loader	CAT930K	3.34	5.12 (Standard)
	VOLVO L60H	3.27	5.24
Skid steer loader	CAT 262D	2.11	4.17 (Bucket hinge pin)
	BOBCAT S76	2.08	4.26 (Bucket hinge pin)
Compact track loader	Kubota 72-SVL	2.08	4.03 (Bucket hinge pin)
Truck	Mack	2.91	3.39 (Rotomix 920)
	Kenworth (T360)	2.91	3.38 (Rotomix 920)
Tractor	John Deere (6110M)	2.94	4.12
	New Holland (T6020)	2.97	-
Tractor drawn vertical mixer	Supreme 1200T	3.07	-

7.5.2 Width

The width of the building is a critical design parameter, since wider buildings are more difficult to ventilate naturally than narrower buildings in the same location. The total width of the building includes the span width and any overhang.

In naturally ventilated animal housing, gable roofs generally offer better natural ventilation rates than single monoslope roofs under a wider range of environmental conditions. Consequently, gable roofs can be wider. For monoslope buildings, the general recommendation is that single roof widths do not exceed 10m to provide adequate air crossflow (Vickers, 2018; Taylor et al., 1994). Wider spans may be suitable in some locations that are subject to sufficient natural breezes, however, these should be evaluated on a site-specific basis. To cover wider pens, the building can be constructed as a series of two or more monoslope roofs together in a saw-tooth pattern with a vertical gap between the low side of one roof and the high side of the next. The sawtooth configuration effectively reduces the overall width and allows for hot air and gases to be exhausted via the ventilation gaps between roof spans. A gable roof with ridge ventilation that is about 30m wide is able to maintain adequate ventilation. However, it is difficult to deliver clean, fresh air into the centre of wider buildings under low windspeed conditions when relying solely on natural ventilation. If a wider shed is needed, natural ventilation can be supplemented with mechanical ventilation, but this will increase the capital and operating costs.

The span width will be governed somewhat by the typical spans or multiples thereof provided by manufacturers as these will be more cost effective than custom designs. Single span buildings do not have any supporting internal columns. Where practical, single spans should be used as this avoids columns within the pen providing a large clear area for manoeuvring of pen cleaning equipment.

An overhang may be installed to cover the feed bunk and sometimes the cattle lane. It directs rainwater away from the building foundation, reducing the amount of rain that enters the building. A cantilevered overhang avoids the use of columns where this is not practical, such as on the feed bunk side of the building.

Typically, the width of a building will be determined by the capacity of the pen, stocking density, the amount of feed bunk required and the span widths possible for the given structural design of the roof type. Typically, span widths are in the order of 30–40m.

Construction costs will rise with increasing span width due to an increase in the size of structural elements required. Further, it is more difficult to deliver clean, fresh air into the centre of a wider building (>40m) with natural ventilation.

Therefore, a narrow but longer building is preferred over a wider, shorter building for the same cattle capacity and stocking density.

For retrofit situations, reducing the pen depth will allow for construction of a narrower building. This may allow the same number of cattle to be kept but at a tighter density and the building construction cost will be cheaper. There will also be more space between buildings which will enhance natural ventilation.

7.5.3 Length

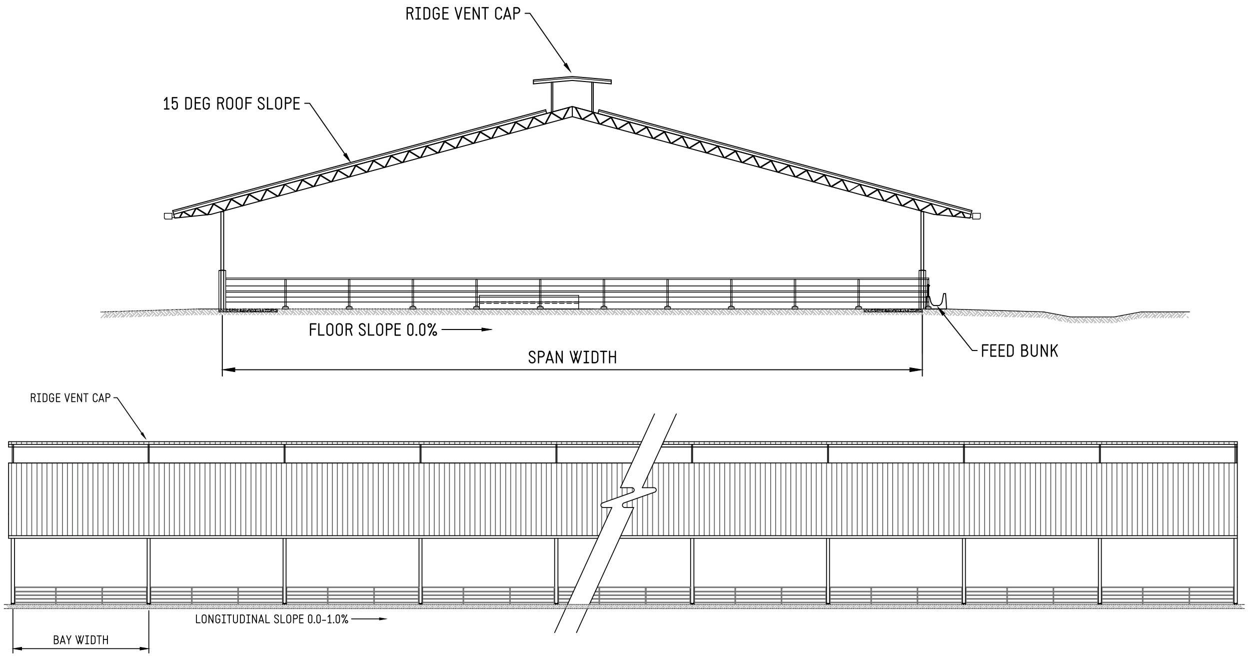
The length of the building will be determined by site constraints such as topography, available area for example, or capital cost. There are no specific minimum or maximum recommended lengths. However, as the length of the building increases, the roof catchment area increases, thus requiring a proportionately larger guttering system or more downpipes.

A longer building with a narrow span will provide greater bunk space than a wider, shorter building.

The longer the building, the greater the number of spans, but the bay width may be able to be widened with a narrow span width.

Figure 11 shows an end view and elevation view of a building describing the span width and bay width.

Figure 11: End view and elevation of a covered housing system



7.6 Support structures

7.6.1 Footings

The foundation is a structure beneath a building that supports its weight and transfers the load to the ground. The loads imposed on the structure (e.g. static, dynamic loads), ground condition (e.g. soil type) and environmental conditions, all influence foundation design. Piers and footings are terms used to describe the type of foundation.

- Pier foundation:
  Pier foundations support structural loads at a number of distinct points, not continuously. Pier foundations can be constructed by screw piling or they may be bored into the ground and concrete filled. Pier foundations are found in covered housing structures.
- Footings:
  Footings are typically made of concrete with reinforcing steel that has been poured into an excavated trench, forming a strip. Footings are commonly used in clad frame buildings.

7.6.1.1 Bored concrete piers

Bored concrete piers provide a foundation solution on sites where ground conditions are generally fair to good, with a ground mass of rock, firm strata, or cohesive soil. When drilled into rock, bored piers help to minimise foundation settlement.

Bored concrete piers, involve boring a hole with a diameter (0.9m/1.2m), installing a steel reinforcement cage and pouring concrete into it. Generally, the columns are base plate mounted (circular, octagonal or polygonal on a steel flange) rather than being buried directly into the concrete pier. Foundation bolts that are ‘U’ or ‘J’ shaped are embedded into the concrete piers to allow anchoring of the columns as shown in Photograph 17. The anchor bolts should be hot dipped galvanised. Photograph 18 and Photograph 19 illustrate a bored concrete pier footing set below and above the pen surface. Aboveground casing or formwork (steel, cardboard) will be required for this construction. Extending the pier in this way will raise the baseplate above the manure layer, reducing the likelihood of corrosion of the baseplate and anchoring system. Some form of impact protection is needed on columns and this arrangement will also serve this purpose. Refer to Section 7.6.3 for details.

If the concrete pier will not be above ground level, then it should be set below the subgrade to allow the anchoring system to be encased in concrete by the column protection system.

The design of foundations for building structures needs an appreciation of many factors and should therefore be carried out by a suitably qualified and experienced designer (usually a structural, civil or geotechnical engineer).


Photograph 17: Concrete pier footing with anchor bolts


Photograph 18: Bored concrete pier footing set above pen surface


Photograph 19: Bored concrete pier footing set below pen surface

7.6.2 Frame

The building frame comprises several components including columns, beams, trusses and purlins.

Columns are major structural components that fix to the foundation, rising to support the roof (and walls). They therefore usually comprise hot-formed structural steel sections such as a universal beam (I-Beam, H-beam, RSJ), welded truss web, round or rectangular hollow section. These sections come in various shapes, sizes, and thicknesses. Photographs 20a and 20b show a universal beam and circular hollow section as a support column.

Photograph 20a: Universal beam

Photograph 20b: Circular hollow section

Photographs 20a and 20b: Building support columns – Structural steel

Columns may also be constructed by cold roll forming lightweight steel sheets into the desired C or Z shape with several bolted together to give strength as shown in Photograph 21. However, these sections have strength and structural limitations for spans and require extra bracings. As they are also more susceptible to corrosion and damage from equipment compared to structural steel sections they are therefore not recommended.

Photograph 21: Building support columns – Cold roll formed

The location of columns is an important consideration. Ideally there will be no columns within a pen to provide a clear unobstructed area for pen cleaning. However, this may not be possible when retrofitting a building over existing pens or in new builds, depending on the size of the building. In this case the number of columns should be minimised by increasing the width between columns or bays so that the interval allows columns to land on the dividing fence line.

There is no set span width as this will depend on the total width of the proposed building and structural design considerations.

Due to the section size of columns, their vertical geometry, and the presence of existing concrete aprons at the bunk end of an existing uncovered pen, there are some challenges for retrofits. Additionally, it is necessary to avoid creating areas where cattle can get heads, legs or feet caught. Hence, for pens in a bunk-to-bunk configuration, the preferred column location is setback from the feed bunk apron. For a sawtooth pen layout, this may result in the need for a larger member to support the overhang or alternatively the column can be set outside the feed road.

Beams or trusses attach to the top of the columns to provide support for the roof and transfer loads to the columns and foundation. Beams are long structural elements designed to carry a load applied at an angle of 90 degrees (perpendicular) to the direction of the beam. Trusses consist of several structural elements joined together which enables them to carry structural loads over longer distances.

Therefore, for small spans, roofs may be supported on beams whilst trusses are used for larger spans. Beams comprise hot-formed structural steel sections such as RHS or cold roll-forming lightweight steel sheets into the desired C or Z shape. The span (width) of the building and wind loading will determine the size of C/Z section used. Trusses comprise hot-formed structural steel sections such as rectangular hollow section (RHS) or circular hollow section (CHS) etc.

Purlins, which are formed by cold roll-forming lightweight steel sheets into the desired C or Z shape, are used to span the trusses or beams and support the roof cladding.

The use of UB columns and a truss will allow greater height and span in a building.

As frame design needs an appreciation of many factors, it should be undertaken by a suitably qualified and experienced designer structural engineer.

The careful consideration of the placement of support columns of the covered housing system will ensure that their location does not:

- impede cleaning of the pen, in particular the feed bunk apron
- conflict with feed delivery equipment
- introduce any 'pinch points' where a cattle body part might get trapped between
- reduce the bunk space as support columns can have a width equal to or greater than an animal space (250–300mm).

One uncovered feedlot in New South Wales has recently retrofitted a covered housing system over a row of pens. The placement of the support columns within the pen area required critical thinking so as not to create issues. For example, the support column itself is less than half the diameter of the hole required for the pier foundation. This made it almost impossible to place the support column close enough to the feed bunk to avoid any gaps that would allow a cattle body part to become trapped. Further, the slip form concrete bunks have a tapered back wall as part of their design. As a result, the distance between the bunk wall and the support column is tapered and therefore difficult to cover or infill. The sawtooth design of the pens did not allow a column to be placed outside the feed alley. Consequently, the support column was setback off the feed bunk apron. This allows unimpeded access for bunk apron cleaning and does not reduce bunk space. This configuration resulted in a longer truss to support the overhang canopy to ensure the feed bunk was covered. The photo below illustrates the placement of the support column.

7.6.3 Protection

7.6.3.1 Surface treatments

The pen environment with a covered housing system is harsh and metal corrosion is precipitated by environmental factors like humidity and moisture and from contact with manure. The breakdown of manure to release moisture, ammonia and carbon dioxide in conjunction with naturally excreted chlorides is very corrosive to steel structures. The most cost-effective method of inhibiting corrosion of structural steel is through the use of protective coatings, including painting or galvanizing.

Some form of protective coating should be applied to structural steel members including fasteners, particularly in areas that give rise to higher corrosion rates such as at the pen surface level and areas that have been subject to heating, such as welds. Photograph 22 illustrates a bitumen emulsion treatment applied to a galvanised support column prior to construction of a concrete hob.

Hot dip galvanised sections are recommended. If the cost is prohibitive then marine grade two part epoxy paint may offer a suitable alternative to reduce the ravaging effects of corrosion.

Good building ventilation will minimise moisture-related deterioration in steel members and fasteners in the roof by controlling air temperature and relative humidity and reducing condensation.

Various Australian Standards (e.g. AS/NZS 2312 set (Standards Australia, 2014)) provide guidance on the protection of structural steel against atmospheric corrosion by the use of protective coatings.

Concrete may also assist in slowing corrosion at the interface between the ground and columns and also protects these structures from potential impacts by pen cleaning equipment.

Photograph 22: Building support column with painted bitumen emulsion treatment

7.6.3.2 Impact protection

Impact protection should be considered for building columns even when these are placed in the dividing fence lines as it is inevitable, even with the best trained operators, that there will eventually be collisions between pen cleaning equipment and a column.

Typically, columns will be protected with a concrete hob. The hob should extend at least 2.0m above the pen surface. The top of the hob should be sloped down away from the column so that any moisture does not accumulate against the structural steel.

For construction, the hob will be poured into some type of formwork so that the concrete is contained. Typically, hobs have no reinforcing steel.

Various types of formwork may be used, including temporary material such as timber or cardboard, or permanent forms such as polyvinyl chloride (PVC) or high density polyethylene (HDPE) pipe.

As cardboard forms are easily affected by weather conditions, they need to be protected if rainfall is expected when set in position.

Permanent forms need to be placed prior to the column and should extend 300mm below the pen surface so that the cold joint between the hob and footing is encased by gravel or earth and not directly exposed to manure. A PVC or HDPE pipe form may be damaged by pen cleaning equipment during operation however this doesn't matter too much as the main function of the pipe is as a form for the concrete. Ribbed HDPE pipe as a form is shown in Photograph 23 and does offer some absorption of the energy from collisions.

Photograph 23: Ribbed HDPE poly pipe protective hob

7.7 Roof

7.7.1 Profile

The covered housing systems built in Australia to date, generally feature completely open sides, sometimes with ridge openings for ventilation. The shape of the roof has a significant impact on the ventilation and vent options.

Roof profiles include monoslope (single span or sawtooth arrangement comprising of multiple roofs in a sawtooth arrangement), gable roofs with ridge vents and hoop structures.

Photograph 24 shows a gable roof with ridge ventilation.

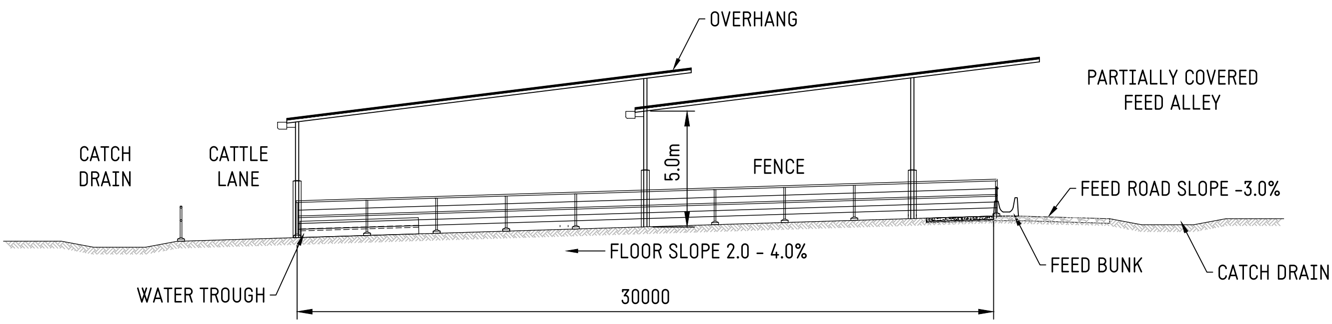
Photograph 24: Gable roof design with ridge ventilation

If a monoslope roof is the preferred design, an alternative can be a series of two or more roofs together in a sawtooth pattern, which effectively reduces the overall width and allows for air to be exhausted via the roof. Figure 12 shows a sawtooth monoslope roof layout with a ventilation gap between roofs.

Due to their inherent design, monoslope roofs have no centre ridge opening. They are generally open, with the high side facing the prevailing wind to maximise natural ventilation. Ventilation only occurs via the crossflow of air from one sidewall to the other. As building height decreases towards the shorter sidewall, the air velocity increases, essentially creating a funnelling effect. This increase in windspeed assists in cooling the animals by lowering the apparent temperature.

Hoop structures are a form of convex roof distinguished by an arched or hoop metal frame. Roof ventilation is needed to exhaust hot air and gases.

Figure 12: Sawtooth monoslope roof

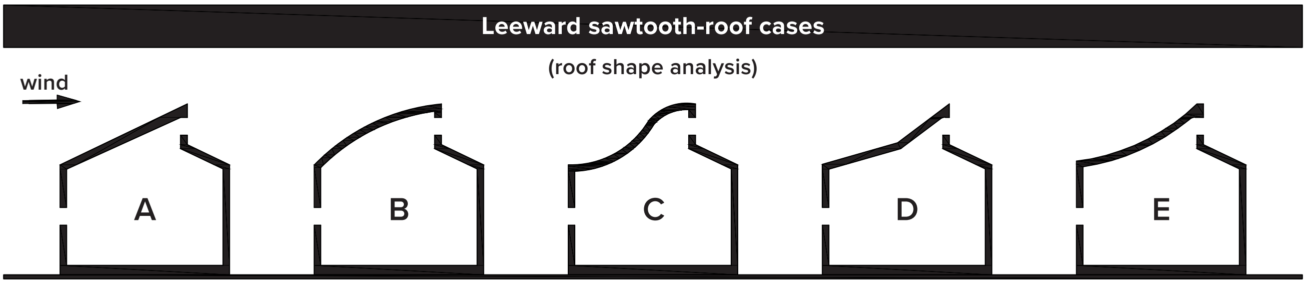


The geometry of a roof (e.g. straight, convex, concave) also affects ventilation rates under different windspeed and direction scenarios. This is complex and is best understood using Computational Fluid Dynamics (CFD) modelling. Two CFD modelling studies that investigated roof geometry are described below.

Peren et al., (2015) used CFD modelling to investigate the effect of roof geometry on ventilation performance. The five different roof geometries studied included one straight and four curved roofs. The roofs shown in Figure 13 can be described as:

a. monoslope
b. convex
c. hybrid concave/convex
d. concave flat
e. concave curve.

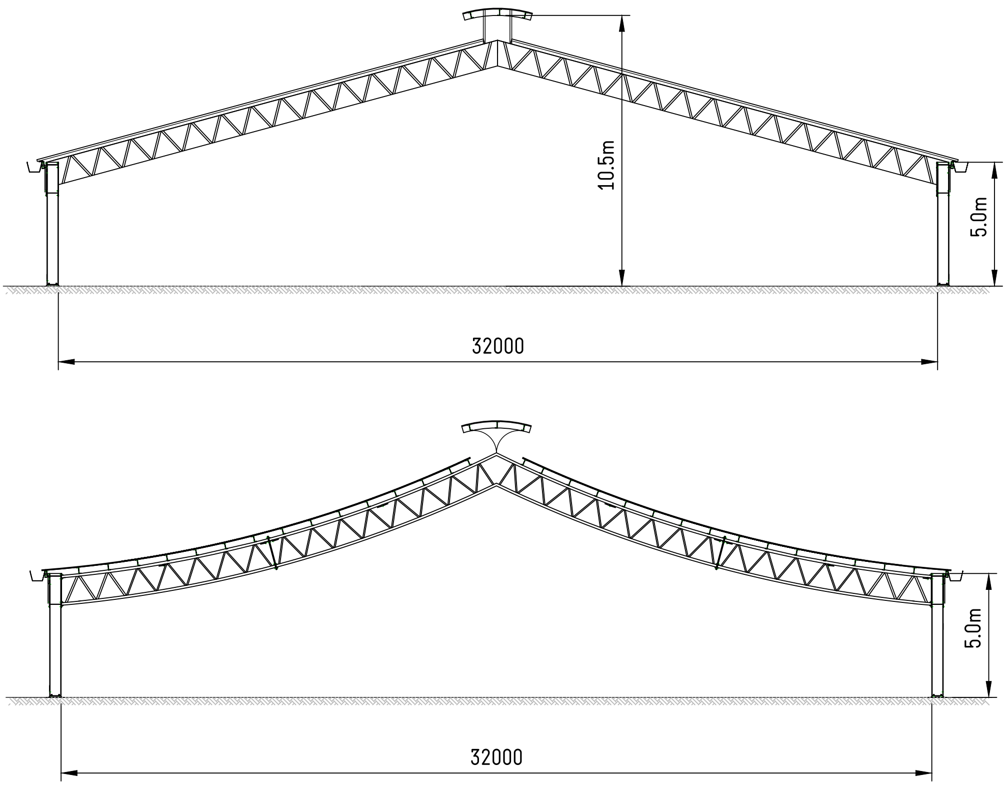
Figure 13: Various roof shapes investigated by Peren et al., (2015)



The study showed that:

1. Monoslope (A) or concave roof geometries (D and E) can maximise the under pressure zone in the wake (down-wind side) of the building, thus enhancing wind-driven crossflow ventilation.
2. Analysis of the results showed that for a normal wind angle (0 degrees), the monoslope and concave roof geometries (A, D and E), increased the volume of air between 12–13%, compared with the convex roof geometry (B). The value of increase was slightly lower for C of 108.4% compared to B.
3. In some circumstances, the increase of the indoor air velocity can be as high as 90% for concave (D and E) versus convex roofs (B) in the upper part of the roof.
4. Roof geometry is an important design parameter to maximise the size and magnitude of the under pressure zone in the wake of the building and the pressure difference over the building, which then influences that ventilation rate through the building.
5. Convex roof designs (B) performed the worst for ventilation.
6. There was little difference between the monoslope (A) and concave designs (D and E).
7. Roofs that direct the external wind flow behind the building and upwards will result in higher ventilation rates.

Figure 14: Roof geometries modelled: Straight gable and concave gable or ridge



In another CFD modelling study, Swan Hill Engineering Pty Ltd commissioned SLR Consulting Australia Pty Ltd (2015) to investigate the effect of roof geometry (straight gable roof versus concave gable roof (ridge roof)) on ventilation rates in naturally ventilated covered housing systems. The site modelled was in western Victoria, with a meteorological file from Horsham used.

The study was undertaken to estimate the wind velocity and pressure profile during both a moderate wind speed of 2m/s and a near calm wind speed of 0.2m/s, with six different wind directions. The site modelled a total of eight building options of varying length.

When the modelling was undertaken for a single building at a site under near calm conditions and with the wind flow set close to perpendicular with the building ridgeline, the concave roof had 20% greater ventilation, with 14 air exchanges per hour, compared to 11.5 for the standard gable roof.

The results of the modelling with multiple buildings showed that the concave roof design tended to lift more air upwards, resulting in less wind being diverted closer to the ground in the immediate leeward (downwind) side of the building. Hence, for sites with multiple buildings, the leeward buildings could have lower ventilation rates and building spacing becomes a critical parameter in determining the resulting airflow through all buildings.

This CFD modelling study concluded that:

1. The curvilinear form of the concave roof generated significant zones of negative pressure in the leeward side of the building, on its roof at the ridgeline and on the underside of the leading edge of the roof. This created a greater pressure differential between the windward positive pressure of the approach wind and the negative leeward pressure behind the building. This pressure differential is what promoted greater airflow through the building with this roof profile.
2. For multiple buildings, natural ventilation works best when the buildings are orientated perpendicular to the direction of the summer winds so wind flow can access the full length of the building.

Building spacing and shielding, as well as building roof design, are important for sites with multiple building configurations. Maximising the exposure of buildings to direct incoming wind flow will result in the highest ventilation rates.

7.7.2 Pitch

Covered housing systems must be designed to provide adequate air space in the building. A high roof and pitch that increases air space will also assist with ventilation and provide greater protection from solar gain (heating caused by the sun). In Australia, the solar gain on a covered housing system can cause a wide daily variation of temperatures within a building in winter and can increase temperatures to levels that impact production during summer if there is insufficient ventilation.

The literature reports a range of suggested roof heights to optimise natural ventilation, with the local climate, building height and building width all influencing the most appropriate pitch. As a rule, the steeper the roof pitch, the better the ventilation rate, with a pitch of at least 15 degrees (~1V:3.7H) being required for wider, gable shaped roofs and 22 degrees (~1V:2.4H) providing improved air flow patterns and ventilation (Vickers 2018). For monoslope roofs, a slope of at least seven degrees (~1V:8H) is recommended, when coupled with sidewall openings at least 3m high (Euken et al., 2012). Note that when designing a facility, it is important to recognise that the slope of roofs is generally quoted in degrees, whereas pens and drains are designed in percent; these are not the same.

Building height is also an important design feature in covered housing systems. Studies in hot climates overseas have shown internal ambient air temperatures can be 5°C hotter for a 3m high building, compared to the temperature within an 8m high building.

The minimum eave height must allow for the type and working height of machinery that will be used (e.g. pen cleaning equipment, augers for filling self-feeders) plus a suitable clearance to overhead structural elements such as beams and roof sheets.

For monoslope buildings, as the pitch of a roof line increases, the overhang on the high side also needs to increase to prevent rain from entering the building. Conversely, less overhang is needed on the low side.

7.7.3 Vents and roof caps

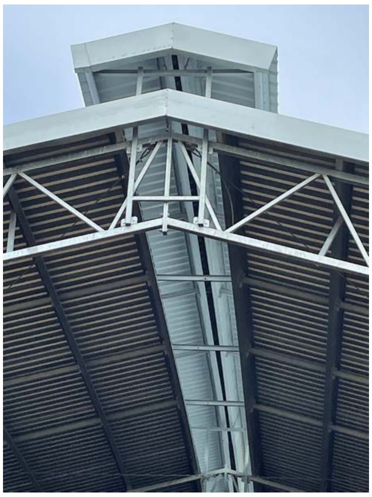
As detailed in Section 7.7.1, natural ventilation can occur via two modes, firstly when wind flows through and across the building (crossflow ventilation) and secondly by wind flowing over the roof, drawing inside air up through a ridge vent (the 'venturi effect'). The rate of ventilation (air exchange) is driven by the difference in pressure inside and outside the building generated by the wind.

A single-span monoslope roof has no centre ridge opening, so ventilation only occurs via a crossflow of air from one side to the other. Convex roofs can be fitted with a roof vent to improve ventilation (see Photograph 25).

Gable roofs are often fitted with ridge vent openings. A variety of designs are possible, but these will either be fully open or covered with a ridge cap. The ideal ridge opening depends on local weather conditions and the location of the structure on the building. Photograph 26 shows a covered ridge cap on a concave roof. Photograph 27 shows a ridge vent on a straight gable roof.

Photograph 25: Ridge vent in convex roof

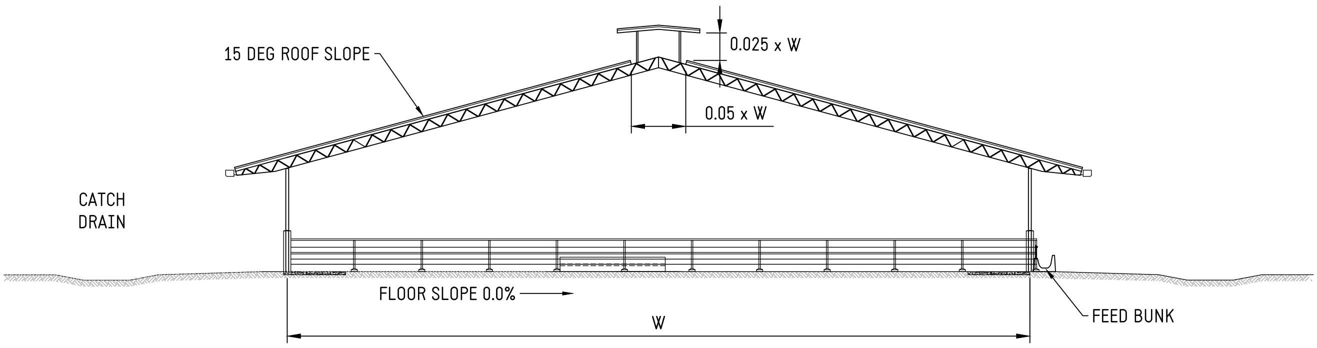
Photograph 26: Covered ridge vent on a concave roof



Photograph 27: Ridge vent on gable roof

Open ridge vents promote better air movement, as there are no obstructions to restrict flow, but they can allow rainfall to enter the building. This is not a concern if the water falls on a hard surface (e.g. central feed alley) and drains outside the pen, but is less desirable if rainfall will wet the bedding within pens. This can be avoided through the addition of a ridge cap, although these can impede air flow, may be subject to corrosion and will increase building costs and maintenance. Ridge vent caps therefore need to be carefully designed

Figure 15: Ridge opening and cap geometry



to ensure the required ventilation rate is not compromised, which may mean increasing or decreasing the width of the opening or the height of the ridge cap. The optimum opening depends on a number of factors, including animal size, stocking density, eave height, shed width, roof height and pitch, and local climatic conditions. A general design principle is to provide an unimpeded ridge vent opening of 5% of the building width – thus for a 20m wide building, the opening should be 1m with half this distance provided between the cap and the roof (see Figure 15).

7.7.4 Materials

Roof material

Most Australian covered housing systems use corrugated galvanised iron or Zincalume® roofing, although Colorbond® is an option. Most roofs have gutters and downpipes to manage stormwater.

Self-supporting roofs have no support roof structures (i.e. trusses), with the strength of the roof derived from the profile of the cladding (typically metal ribbed profile and curved). Photograph 28 shows a self-supporting roof.

Photograph 28: Self-supporting roof

The coating on galvanised iron is almost 100% zinc. In comparison, Zincalume® steel is coated with an alloy comprising approximately 1% silicon, 43.5% zinc and 55% aluminium. Even though both are coated using a hot dip method, these two roofing products have different levels of corrosion resistance.

Colorbond® steel is made from a durable Zincalume® core with a baked-on corrosion inhibitor that is sealed with a tough painted finish and therefore a longer lifespan. An advantage of Colorbond® is that a range of colours is available if aesthetics are important. It is, however, more expensive than Zincalume®.

Galvanised steel is cheaper than other steel products including Zincalume® and Colorbond®. However, galvanised steel primarily depends on sacrificial protection from corrosion while Zincalume® uses both sacrificial and barrier protection to keep from corrosion, giving it a lifetime four times greater than galvanised steel.

Whilst the rate of corrosion of galvanised steel and Zincalume® is similar initially, the corrosion rate for Zincalume® slows down as it is exposed to the weather elements since its coating forms an additional barrier protection over time.

Waterproof fabric is usually used to cover hoop structures. Similar fabrics have also been used on some gable roof structures in Australia and for partially covered housing systems (see Photograph 29). Retractable roofs made from waterproof fabric have also been used. These roofs are designed to open to promote bedding drying and under suitable conditions. Gutters can be incorporated into the design.

Photograph 29: Waterproof fabric used as partial pen cover

While opaque roofing is needed for solar protection, transparent materials like clear polycarbonate and acrylic roofing materials can be strategically used to increase natural light within the building. As these materials won't rust and corrode like metal sheeting, they are a good solution for areas that can readily corrode from moisture and ammonia, such as ridge caps (see Photograph 30).

Photograph 30: Clear ridge vent cap in roof

The roof colour has an important influence over the solar properties (rate of heat transfer into a building). These properties are known as solar absorptance (amount of solar radiation that is absorbed by a surface) and solar reflectance (proportion of solar radiation reflected by a surface).

For a given material, solar absorptance is generally reported as a value between 0.0 and 1.0. If a material has a solar absorption value of 0.5, this means that 50% of the solar radiation that hits it will be absorbed. Solar reflectance is also measured on a scale between 0.0 and 1.0 and is equal to 1.0 minus the solar absorption value. For example, if the solar absorptance of a surface is 0.4, then the reflectance is equal to 0.6. These values are generally available from steel manufacturers for the different colours of their roofing products.

Solar radiation is reflected more effectively from light coloured roofs compared to darker coloured ones. Highly reflective materials, such as Zincalume® sheeting, are also superior at reflecting solar radiation compared with darker coloured roofs.

Roof colour or finish may be restricted by local council planning rules. In some local government areas, the use of light coloured or highly reflective materials may be restricted to protect the visual amenity of neighbours. For instance, shiny Zincalume® may be unacceptable, but dull galvanised iron or Colorbond® allowed. If muted, darker tones are required, consideration may need to be given to the use of roof insulation in warmer regions to counteract the effect of the increased solar absorbance.

Insulation

Unless required to reduce the solar heat load in hot climates during the peak of summer, insulation is likely to be of marginal benefit for covered housing systems in Australia. Refer to Section 7.3 for details.

7.7.5 Overhang

A roof overhang should also be considered to keep water away from the structural elements at the roof-to-wall transition, keep water away from the foundations and reduce the amount of sun and rain which enters the building. There are two types of roof overhangs two consider. A rake is an overhang located on the gable end of the roof. A rake overhang is created by extending the roof beyond the gables of the building.

An eave overhang is the edge of the roof that overhangs the face of a wall and normally projects beyond the side or long edge of a building. An eave is created by extending the slope of the roof beyond the supporting columns or walls of the shed or fitting a cantilever arrangement.

The length or width of overhang will depend on how much protection is required from weather and the clearance height for machinery.

Due to the height of typical covered housing systems, the minimum recommended width is 900mm. The overhang on the feed bunk side would be at least 1,200mm to avoid a drip line in the feed bunk.

Overhangs should be designed and constructed to withstand wind or other lateral loads and live loads with due allowance for shape, open construction and similar features that relieve the pressure or loads.

7.7.6 Drainage

Because of the size of covered housing systems, a large amount of roof runoff may be created during rainfall events. This may either be collected in gutters prior to diversion to the ground or storages using downpipes or can freefall off the roof and be collected directly in a surface drainage system. Building regulations may govern the drainage system allowed.

Regulatory requirements for the management and control of roof runoff (prior to hitting the ground) and stormwater (once it reaches the ground) may vary between states. Consequently, advice on this aspect should be sought from relevant regulatory authorities during the design process.

7.7.6.1 Gutter system with downpipe

In this system, the stormwater from the roof falls towards an eaves gutter. The gutter conveys the water to box gutters above vertical downpipes connecting the discharge to the main drainage system. Photograph 31 shows a roof system with gutters and downpipes.

Gutters minimise the entry of rainwater into the building (or feed bunk) but also the risk of property damage or injury to persons due to large volumes of water running off roofs or from the ends of gutters without downpipes.

This system suits situations where the eaves gutter design results in a box gutter size that enables free flow of roof runoff into downpipes or when a retrofit design over existing production pens makes the implementation of a ground surface drainage system problematic.

A general method for designing roof drainage systems can be found in AS/NZS 3500.3.2 Part 3.2: Plumbing and drainage Sanitary plumbing and drainage (Standards Australia, 2021). However, because the Plumbing Code AS/NZS 3500 set (Standards Australia, 2014; 2021) caters for domestic and commercial buildings, it only allows for design flows of between 3L/s and 16L/s in eaves gutters. In industrial buildings, the flows within gutters may be much greater. The roof requires a structural element system and fixings designed to support the gutter to resist wind forces, the weight of water, forces due to arresting the fall of the water stream and miscellaneous forces such as being stood on by someone mounting the roof. Nevertheless, the general design method in AS/NZS 3500.3.2 for roof drainage can still be generally applied.

The general design method for a complete roof drainage system is broadly outlined below:

1. Determine the rainfall intensity (millimetres per hour) for the location and average recurrence interval (ARI) [AEP 5%] for 20 years and a duration of five minutes.
2. Calculate the total roof catchment area from the plan (refer to AS/NZS 3500.3 Table 3.4. 3 2: catchment slope factor area multiplier) (Standards Australia, 2014).
3. Select the eaves gutter design and the slope. Refer to the manufacturer's guidelines for the effective cross-sectional area of the eaves gutter. If the flow exceeds AS3500 3.2 requirements, then the formulas developed by CSIRO Division of Building Research Technical Paper No 1, 1973. (Martin 1973) provide an alternative method for sizing eaves gutters.
4. Determine the downpipe size.
5. Determine the maximum catchment area per downpipe.
6. Determine the minimum number of downpipes required.
7. Determine the most advantageous downpipe positions.

The gutter must provide suitable fall towards a vertical downpipe. A box gutter collects the water, providing free drainage directly into the downpipe or via a rain head that discharges stormwater at ground level to a catch drain or storage. Photograph 32 illustrates a box gutter and rain head.

Typically, a system with gutters is designed by a suitably qualified and experienced hydraulics engineer or a company specialising in hydraulic engineering services.

Photograph 31: Roof with gutters and downpipe

Photograph 32: Gutter and downpipe rain head system

7.7.6.2 System with gutters but no downpipes

This system has gutters without the downpipes. The stormwater from the roof falls towards an eaves gutter. The gutter then takes water to the end of the roof where it falls to the ground and is collected, generally in an open or grated catch drain.

This system may be appropriate in situations where the gutter system design does not allow for multiple downpipes and results in the need for a very large downpipe (e.g. retrofit situation), or in greenfield sites where an open catch drain system can be readily incorporated into the design.

Due to the velocity of the falling stormwater, the catch drain will need to be lined with robust material such as rock pitching, concrete or bitumen to prevent channel scouring. In most situations, the catch drain will be relatively clean as little extraneous material (straw, string, leaf litter) or manure will end up in the drain.

The design of the catch drain can be trapezoidal to allow vehicles to drive through or grated to allow vehicles to drive over.

7.7.6.3 No-gutter system

In this system the roof has no eaves gutters or downpipes and stormwater is allowed to fall off the eave for collection at ground level, generally in an open or grated catch drain.

The advantage of this system is its simplicity and reduced maintenance requirements when compared to gutters and downpipes.

This system may also suit situations where the eaves gutter design will result in a very large box gutter or in greenfield sites where an open catch drain system can be readily incorporated into the design. This design avoids the significant cost of installing and maintaining gutters and downpipes. However, it needs a well-designed catch drain.

The catch drain would usually have either trapezoidal or vee-shaped cross-sections. As the catch drain in this application is fundamentally the same as the diversion drains/catch drains referred to in the *National guidelines for beef cattle feedlots* (MLA, 2012a) and Section 10 – Pen and drainage systems of the *Beef cattle feedlots: Design and construction* (Watts et al., 2015) the design principles and performance standards for these can be adopted.

The catch drain needs to be wide enough to intercept the falling spout. Generally, the velocity of the stormwater runoff off the roof will be relatively small and the runoff will fall vertically or close to it. Wind particularly effects lighter precipitation and is more likely to influence the trajectory of the falling spout. Consequently, the receiving top of the catch drain should be setback 500mm under the edge of the roof. This means the roof needs to overhang the pens by 500mm or more. However, the extent of the stormwater trajectory off the end of the roof should also be checked to ensure that roof runoff will not overshoot the catch drain.

In order to prevent scouring of the catch drain due to the velocity of the falling stormwater, it should be lined with material other than earth or vegetation, such as rock pitching, concrete or bitumen. In most situations, the catch drain will remain relatively clean as little extraneous material or manure will end up in the drain.

Typically, the design of a catch drain for a system with no gutters is undertaken by a suitably qualified and experienced hydraulics engineer, an engineer experienced in feedlot design or a company specialising in hydraulic engineering services.

The catch drain can direct stormwater to storage for reuse as non-potable or potable water (subject to appropriate treatment). Section 7.13 provides information on site drainage.

One Victorian covered housing system initially constructed their shed with no gutters on one side of a gable roof as there was a concrete lane/drain underneath that could convey runoff away from the building. However, the wind blew rain falling from the roof into the building, wetting the bedding. Guttering and downpipes were added to solve this problem. However, providing at least 3m eave overhang would minimise rain entry into the pen.

7.8 Walls

Full sidewalls are seldom installed on covered housing systems in Australia, although they may provide an advantage in cold locations with a predominant winter wind. Partial walls below the eaves improve ventilation at animal height during calm wind conditions. Photograph 33 shows an example of a cladded end wall on a covered housing system. Gable designs typically include cladding at the end of the pitched roofs from the eave edges to the intersecting pitches. Wall cladding is typically galvanised steel (iron) or Zincalume®, although Colorbond® is an option. The most common profile is corrugated (a series of parallel ridges and furrows) but other profiles with different trapezoidal rib and fluting profiles such as Trimdek® are available.

Photograph 33: Cladded end wall on covered housing system

Wall cladding colour or finish may be restricted by local council or state planning regulations (e.g. glare from buildings near major roads). In some local government areas, the use of light coloured or highly reflective materials may be restricted to protect the visual amenity of neighbours. For instance, shiny Zincalume® may be unacceptable, but galvanised steel or Colorbond® allowed. For further information on wall materials, refer to Section 7.7.4.

Wall cladding should not extend to the floor level as it will be damaged by cleaning equipment; manure build-up will accelerate corrosion and ventilation will be restricted. As a guide at least 2m should be allowed between the bottom of the cladding and floor. On the side edge of a fully enclosed building, a concrete tilt panel vertical wall with a height of 2m will offer more durability with cleaning equipment and may be a suitable alternative. The cladding would extend down to the top of the tilt panel wall for fully enclosed buildings.

7.9 Flooring

From a detailed design perspective, flooring can be separated into two components, being the subgrade and the pen surface.

When specifying surface treatments, the designer must consider a range of factors including protection of the environment, the loadings imposed by animals and equipment, surface durability and whether bedding material is to be used.

7.9.1 Subgrade

The overarching design criteria for the subgrade is to prevent or minimise the risk of adverse impacts to groundwater and to provide the necessary strength to support the surface treatment and loads from cattle and equipment that will access the building.

The design of subgrades for building structures needs an appreciation of many factors including foundation design and should therefore be carried out by a suitably qualified and experienced designer (usually a structural, civil or geotechnical engineer).

A materials quality test should be conducted in accordance with relevant Australian Standards. A list of appropriate engineering tests to assess the engineering properties of materials proposed to be used for the subgrade is provided in Table 2 – Recommended engineering tests for soil samples in Section 7 – Geotechnical investigations in *Beef cattle feedlots: Design and construction* (Watts et al., 2015).

With the exception of sandier soils, most soils can provide the necessary strength to support the loads from the cattle and equipment that will access the building. The California bearing ratio (CBR) is typically used to measure the mechanical strength of material to determine its ability to handle a load. The *National guidelines for beef cattle in Australia* (MLA, 2012a) specify a minimum standard for CBR wet and dry of 20% for pen surfaces. This standard can be equally applied to the foundation material of covered housing systems.

If there is a high potential for contamination of groundwater because of leaching of nutrients through underlying soil or rock strata, then an impermeable barrier will be needed between the contaminant and the groundwater. As outlined in the *National guidelines for beef cattle* (MLA, 2012a), a clay or synthetic liner must provide a design permeability of less than 1×10^{-9} m/s (~ 0.1mm/d).

For sandier soils, an engineered sub-grade treatment such as compacted clay, synthetic liner, concrete slab with clay liner or concrete slab with synthetic liner may need to be installed to provide the permeability standard required to protect groundwater.

The *National guidelines for beef cattle* (MLA, 2012a) and Section 8 – Bulk Earthworks in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) provide guidance on the selection of the materials suitable for use as clay lining. There are also various Australian and state guidelines providing standards for lining systems (compacted clay, synthetic liner etc.) for the protection of groundwater for intensive livestock developments. State environmental guidelines may also prescribe material specifications for this purpose.

Bulk earthworks may be required to prepare a site and subgrade for the construction of the covered housing system. The design and construction objectives of the subgrade of uncovered pens can be applied to the subgrade of covered housing systems with compacted clay floors. Section 8 – Bulk Earthworks in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) provides further detail on bulk earthworks and building foundations.

The site should be cleared and grubbed. All trees that are not designated to remain should be removed above ground level. Grubbing should be carried out to remove from the ground all trees, roots, stumps, rocks and other obstructions to a depth of 500mm below the surface of the existing ground. All grub holes and localised depressions in the cleared and grubbed areas should be filled to the level of the surrounding ground surface.

Fill material shall be similar to the surrounding ground material or selected fill material. Such material shall be compacted to achieve a relative dry density of 95% (standard compaction) within (±2%) of optimum moisture content (OMC).

Unless other drainage works will divert stormwater flows around the covered housing system, the subgrade should be raised to provide a finished floor level that is at least 300mm above natural surface level to ensure that stormwater cannot enter the building.

7.9.2 Surface treatments

The design, construction and maintenance of covered housing pen surfaces are important for their long-term performance.

Unlike road surfaces, pen surfaces will typically only include one layer (i.e. a base course) that is supported by a strong and stable underlying subgrade. If the surface treatment is weak through inadequate design, poor-quality materials, poor construction techniques or poor maintenance practices, the final surface will have reduced life.

Surface treatments are generally unbound natural material such as compacted clay, gravel or rubble, but bound pavements (concrete, roller compacted concrete (RCR), asphalt) have been used in some covered housing systems. Further detail on pen surfacing is provided in Section 17 – Pen and Road Surfaces in *Beef cattle feedlots: Design and construction* (Watts et al., 2015).

The design, construction and maintenance of covered housing pen surfaces are important for their long-term performance.

Most covered housing systems use compacted gravel as a surface treatment. However, one Victorian covered housing facility has used asphalt within the controlled drainage area of their existing pens. The site preparation included earthworks to establish a 1% grade on the pens and the preparation of a clay subgrade compacted to 98% relative dry density (RDD) to ensure a strong and stable underlying base for an asphalt surface treatment. The asphalt surface treatment was 50mm thick. The aim of the asphalt surface is to minimise pen maintenance requirements. However, the durability and lifespan of this surface has not yet been confirmed.

7.9.2.1 Compacted clay

A compacted clay floor is an acceptable surface treatment in a covered housing system since rainfall is excluded from the pen surface.

As a minimum, a compacted clay floor should receive treatment equivalent to that required for the subgrade, with the exposed subsoil material loosened to a depth of not less than 200mm, the moisture of the loosened material conditioned and the material compacted to the levels stated in the earthworks specifications. Typically, material should be compacted to achieve a relative dry density of 95% (Standard Compaction) within (±2%) of OMC.

7.9.2.2 Gravel

A compacted gravel floor will provide better durability than a compacted clay floor and will allow for the use of heavier equipment loadings.

The design and construction objectives for pen surfaces in uncovered feedlots can be applied to the gravel surface treatment of covered housing systems. Chapter 17 – Pen and road surfaces in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) provides further details on the selection of gravels, grading requirements and structural thickness.

As a minimum, a gravel floor should receive treatment equivalent to that required for road construction. Gravel should be spread and compacted in layers to achieve a compacted layer thickness of at least 75mm, but not more than 150mm.

Generally unbound materials should be compacted near OMC to achieve maximum density. A field moisture content during placement and compaction within 95% of OMC is acceptable if less time is required to reduce the moisture content of the upper most layer (dry back) before placement of the next layer. Typically, compaction shall proceed until the material attains a minimum density of 100% relative dry density (standard compaction).

7.9.2.3 Concrete

There are no Australian Standards for the construction of concrete floors for use in cattle housing. However, there are Australian Standards for steel structural detailing and construction practice and concrete reinforcement (AS 4100) (Standards Australia, 2020) and concrete quality (AS 3600) (Standards Australia, 2018).

A concrete slab requires a well-compacted subgrade and sub-base. The subgrade is the native soil and is usually compacted. The sub-base is the layer of gravel on top of the subgrade. Some situations may also have a base course which is the layer of material on top of the sub-base.

Concrete floors are usually laid over a gravel sub-base or base course. If the subgrade and sub-base are not well constructed, the concrete floor is likely to settle and crack. Strengthening the support system once the floor is placed is costly and either impossible or impractical so the concrete slab must be placed on a strong and stable base at the start. The design of the subgrade and sub-base should be part of the specification for the concrete slab. The sub-base should be even to ensure the floor has the same thickness throughout and is not too thin (and weak) in places and too thick (thereby wasting concrete) in others.

The structural design criteria for concrete flooring within a covered housing system are similar to those for other structural elements around the covered housing system such as concrete aprons (feed bunk, water trough), footings, foundations and floor slabs in grain commodity storage areas and vehicle washdown bays.

A minimum thickness of 125mm with a strength of 32 MPa on an even and stable subgrade, reinforced with square mesh to handle the equipment loadings and edge thickening is recommended.

A non-slip finish should be implemented in high traffic or wetter areas such as gateways and around water troughs. Photograph 34 illustrates a non-slip stamped concrete feed bunk apron.

The design of the subgrade and concrete slab is critical and should be undertaken by a suitably qualified and experienced structural engineer or a company specialising in geotechnical and structural design.

The concrete floor specification should indicate the thickness of the slab, steel reinforcing requirements, minimum 28-day strength to be achieved, treatment of joints and any surface treatment for corrosion.

The floor slabs shall achieve the structural provisions of the Building Code of Australia (BCA), be designed in accordance with the relevant Australian standards and comply with local building regulations as relevant.

Photograph 34: Non slip stamped concrete feed bunk apron

7.9.2.4 Asphalt

To increase durability and cater for heavier equipment loadings on compacted clay floors, dense graded asphalt or stone mastic asphalt may offer a suitable alternative surface treatment. An asphalt floor will need to be laid over a gravel sub-base.

Asphalt is an engineered product composed of about 95% stone, sand and gravel by weight, and about 5% asphalt cement, which is a petroleum product. Asphalt cement acts as the glue to hold the surfacing together. The impermeability of asphalt surfacing is directly proportional to the amount of asphalt cement (bitumen) included in the mix. Asphaltic surfacing is often referred to as ‘hot mix’. Asphalt has been used in dairy cattle buildings as a coating on both solid concrete and concrete slatted floors to offer a more yielding and comfortable surface. It has been recently installed in at least one new Australian covered housing system but is yet to be properly tested. Asphalt seems to be a durable coating with high grip for a period of 8–10 years, even if the micro-roughness changes.

Asphalt requires a well-prepared surface before installation. Consequently, the clay content, plasticity and grading of the placed gravel material is more selective than that required for a concrete slab.

Asphalt is typically placed with a minimum thickness of around 20–25mm. Mixing and placing asphalt should not be permitted when the surface of the subgrade is wet or is at a temperature of less than 10°C, or if there is a likelihood of cold winds chilling the mix to an extent that spreading and compaction are adversely affected. Photograph 35 illustrates an asphalt floor laid within an Australian covered housing system.

Specialist advice should be obtained on surfacing options from an experienced road pavement designer.

Photograph 35: Asphalt surface and stamped concrete water trough apron

7.9.2.5 Other materials

Roller compacted concrete (RCC) or cement stabilisation may offer suitable alternative floor surface treatment. A compacted depth of at least 150mm is recommended.

RCC is similar to concrete, being composed of coarse and fine aggregates, cement, fly ash, water, and in some cases, water reducing additives. However, it is mixed in different ratios and contains much less water than traditional concrete. RCC was first used successfully in Australia in road pavements. However, it is now more commonly used in North America where the process has been refined and developed. It has a demonstrated life span of 40+ years in dams, heavy industry areas (logging, lay down areas, container yards, etc) and roads. Since RCC is a relatively new product compared to asphalt and concrete, there is not the long history of performance in different types of settings and uses. However, its adoption as a pen floor surface treatment is gaining in popularity in Alberta, Canada for uncovered feedlots where pen floor deterioration typically occurs when snow melts and rainfall mixes with manure and bedding. The advantages of RCC in a covered housing system would appear to be reduced as rainfall is excluded. However, it may have usefulness as a pen, road or drain lining when those areas are exposed to the elements and where suitable gravel material is not available.

Similarly to RCC, the advantages of a cement stabilised pen surface in a covered system would appear to offer few benefits given rainfall is excluded and the deterioration of the pen floor currently experienced by uncovered feedlots under wet winter conditions is not expected. Recent work under Australian conditions on a clay-based floor found that cement stabilisation offered few advantages (Wells and Haege, 2020).

7.9.3 Feed bunk and water trough aprons

The areas surrounding the feed bunks and water troughs are high traffic areas. An apron helps prevent holes developing thereby reducing pen maintenance requirements and promoting ease of manure removal from around these areas (see Photograph 36).

Feed and water trough aprons in covered housing system are fundamentally the same as aprons in uncovered feedlots. Section 19 – Feeding systems and Section 20 – Water trough design and sewer systems in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) provides more detail and design considerations for feed bunk apron and water trough apron design.

Feed bunk aprons should be 2.5–3m wide, although a width of 3m is recommended as pen cleaning machinery (e.g. skid steer loader) is typically 2.4m wide. Wider aprons also minimise damage to the pen surface by cattle hooves. Concrete aprons are preferred over compacted gravel as these will provide better longevity and cleanability. Gravel aprons may also be more difficult to repair due to building frame constraints. These aprons would be level if the pen surface is level or if the pen has a slope, they should grade uniformly away from the feed bunk at the same slope as the pen. Concrete aprons may also be constructed on the road side of a feed bunk to provide greater durability in this high use area. These aprons should be at least 1.5m wide to ensure the wheel of the feed delivery wagon is well on the apron and not on the edge.

A concrete apron at least 3m wide should surround each water trough. A width of 3m allows full access and supports the full width (2.4m) of pen-cleaning machinery. Ideally these aprons will grade down away from the trough.

Water troughs need to be level when installed. Unlike uncovered pens, covered pens may have no pen slope. If this is the case, water troughs placed in the dividing fenceline will be level on the pad. However, if the pen does have a slope, a level base will need to be installed.

Concrete aprons should be reinforced with steel (or fibre) to support the weight of pen cleaning machinery. A moulded rough surface can reduce slippage by the cattle. Damage to the edge of the apron by pen cleaning equipment will be minimised by edge thickening. Aprons are typically 125–150mm thick with a minimum concrete strength of 32 MPa.

Photograph 36: Water trough surrounded by concrete apron

7.10 Fences and gates

To enable the efficient movement of cattle and machinery, covered housing systems need well-designed fences with gates that provide good pen access. This section provides recommendations for the design of fences and gates based on Section 15 – Fences, gates and lanes of *Beef cattle feedlots: Design and construction* (Watts et al., 2015).

The design objectives for fences, gates and lanes are to:

- securely contain the cattle
- provide for safe and efficient movement of cattle
- minimise the risk of stress and injury to cattle
- enable efficient pen and drain cleaning
- provide movement of feed trucks and pen cleaning equipment
- minimise ongoing maintenance costs
- provide a safe working environment for pen riders and other personnel.

7.10.1 Fencing

Fencing for a commercial covered housing system should include the following elements:

- posts
- cables and/or rails
- top rail
- belly rail
- concrete hob around base of post – a concrete base around steel fence posts that protects the posts from the corrosive effects of manure.

However, for covered housing systems where manure/bedding material will increase in depth over time, modifications to fencing include:

- nib wall with fitted fence posts
- combination concrete wall and pipe top rail
- greater concrete hob height surrounding fence posts
- removal of lower cables.

Pen fences are usually about 1.4–1.5m high, but higher fences (1.6–1.8m) are recommended if the facility will accept cattle not accustomed to handling. The panel width is the distance between fence posts. Fences with wider panels are more economical to construct and more efficient to clean under. However, as wider panels may compromise fence strength, the panel width should not exceed 3.2m. Strainer panels or end assemblies are needed on corners for added strength.

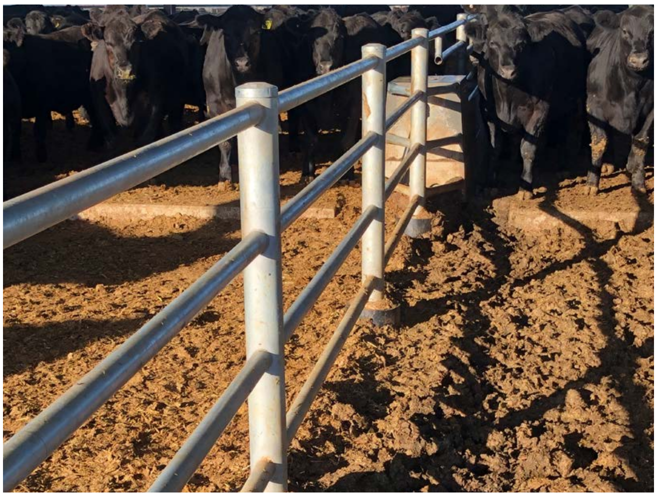
Fence posts can be made from either timber or steel. Timber posts should be at least 250mm in diameter with corner and gate posts 300–350mm in diameter. Timber posts should be set at least 900mm into the ground and they can be concreted into the ground. Steel posts should be set in concrete 900mm below ground level with the concrete extending about 200mm above ground level to prevent corrosion at ground level.

Fences will ideally consist of five evenly spaced cables and/or rails, or four rails for a rail only fence. The lower cable or rail must be low enough to prevent cattle escaping by rolling underneath, but high enough to enable under fence cleaning if there is no nib wall underneath the fence line. Cables should be kept reasonably tight to ensure the cattle are well confined (see Photograph 37). Cables can be either curly or straight wire. Straight wire cable will need a turnbuckle on the strainer posts to allow for periodic tightening. Curly cables are self-tensioning and do not need a turnbuckle (see Photograph 37). Providing alternative structures for cattle scratching could be considered. Rails can be made of strong steel round pipes, heavy walled rectangular hollow section (RHS), steel cattle rail or timber rails at least 100mm wide (see Photograph 38).

Cables can be run through holes in wooden posts while steel posts will require hollow sleeves or external eyelets attached to the posts. The cables must run through smooth holes or fittings to minimise wear on the cable as it moves back and forth under pressure from the cattle.

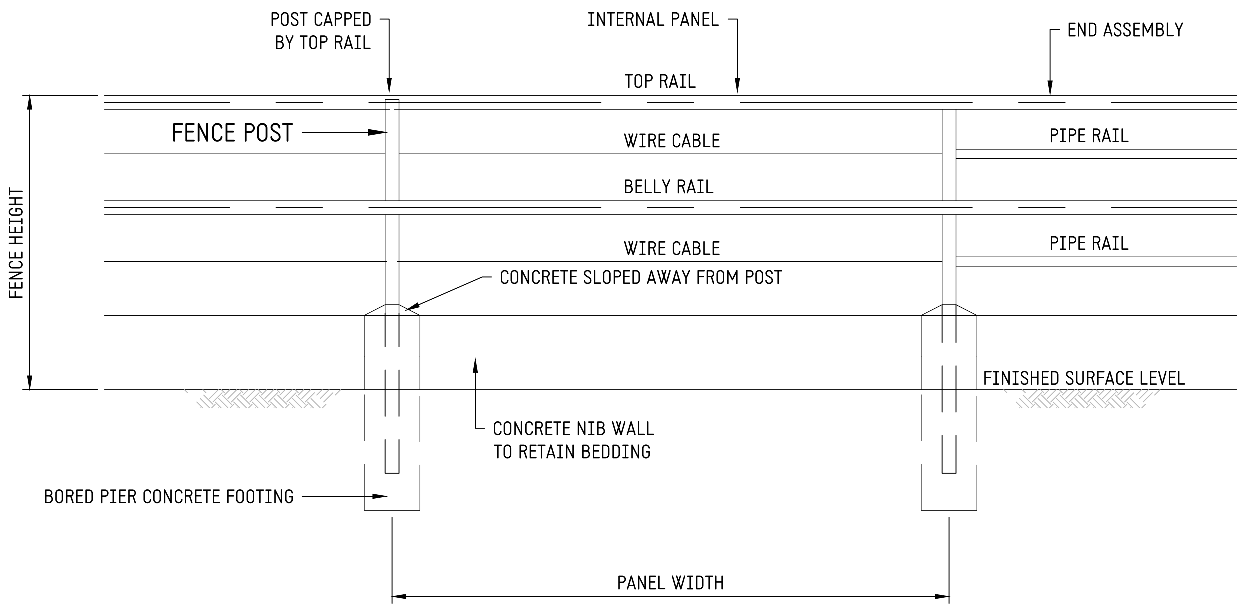
Top rails and belly rails strengthen and stabilise the fence. They also help to prevent cattle from escaping from pens where the cables have stretched or become loose. These rails can be made from either wood or steel. Wooden rails should be at least 150mm wide. Steel used for top rails and belly rails needs to be strong, ideally round pipe or heavy walled RHS/cattle rail at least 100mm wide.

Photograph 37: Cattle rail and curly cables effectively contain cattle



Photograph 38: Rail fencing provides great strength

Figure 16: Typical fence configuration for a covered housing system with bedding



7.10.2 Gates

The size and location of gates are important; they must provide effective, safe access to the pens for both the cattle and pen cleaning equipment. They must also be easy for pen riders to open from a horse. Most covered housing systems will have a gate at the rear of the pens that opens across the cattle lane for movement of stock and pen cleaning equipment, and another across the feed bunk apron to provide for ease of apron cleaning and movement of pen riders between pens.

A good lane system will promote efficient movement of cattle, pen cleaning equipment and pen riders throughout the covered housing system with a minimum number of gates and lanes crossing roadways and drains. Lanes should be 5–6m wide to provide good access but not be so wide that cattle can turn around easily and come back on themselves and pen riders.

A herringbone gate arrangement for cattle lane gates (see Figure 17 and Photograph 39), provides easier access for pen cleaning equipment and promotes effective stock flow. In most good layouts, cattle approach pens from one direction only and therefore only one gate is required, and a fixed panel can face the gate. If cattle will need to enter the pen from both directions, the fixed panel would be replaced with another herringbone gate so the cattle don't have to enter the pen at an acute angle. Gates for stock and machinery movement should be the same width as the stock lane or slightly longer (up to 6m).

Because of the cost of installing roofing in fully covered systems, lot feeders may prefer to install gates that are in line with the fence, rather than a herringbone arrangement to maximise the pen area under cover. If the gate is longer than the lane width, the angle for entry into the pen will promote better cattle flow. If the facility layout means cattle will enter the pens from both ends of the lane, gates on either side of the pen providing access from different directions will be needed.

Where feed bunks are installed on both sides of the pen, a break will need to be provided between bunks on one side for gate installation (see Photograph 40). Installing a wide gate will help prevent the bunks being hit by machinery and chipped and will provide for easier machinery access.

Photograph 39: Herringbone gate arrangement on cattle lane

Photograph 40: Pen gate installation when bunks are installed on both sides of pens

A gate across the feed bunk apron at the top of each dividing fence between pens will allow for efficient cleaning of the full length of the feed bunk apron and also provide pen rider access between pens. Feed bunk apron gates should be at least 1m wider than the apron (e.g. 4m wide) and be able to swing fully open to rest against the fence line to optimise access.

Gates must be strong to confine the cattle, but also lightweight so they are easy to open. A wide, ribbed steel panel at mid-height provides strength but also a visual barrier that may stop cattle from knocking the gate around. Gates must not have any sharp protrusions such as badly positioned hinges and latches that can bruise cattle as they move in and out of the pen. Latches on gates that provide for pen rider access between pens should be designed so that pen riders can safely open the gate without dismounting from their horses and should prevent curious cattle from working out how to open the gate.

7.11 Feeding

There are several options for the supply of feed to cattle confined within a covered housing system. The feeding system must be well designed to achieve good cattle performance, efficient facility operation and for maintaining high environmental standards.

7.11.1 Bunks

The open feed bunks in use at most uncovered feedlots can also be utilised in a covered housing system (see Photograph 41). All types of diets, including those that are moist or containing large amounts of coarsely chopped fibre, can be fed in feed bunks. Bunks are usually made from concrete. Bunks may be slipform or precast. Slipform bunks are constructed on the long fenceline/s of pens using formwork that is filled with concrete in a continuous process. Precast bunks are constructed by pouring concrete into a mould. The bunks are then transported to the site and placed.

Fibre reinforcing is not recommended for feed bunks as exposed fibres can cause tongue lesions in the cattle.

Feed bunks in covered housing systems are fundamentally the same as feed bunks in uncovered feedlots. Section 19 – Feeding systems in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) provides more detail and design considerations for feed bunks.

For new developments, feed bunks can be located along one or both long edges of a building depending on the bunk space required and functionality of the layout. Feed bunks are never within the pen but adjoining a long edge or edges so that they can be easily filled.

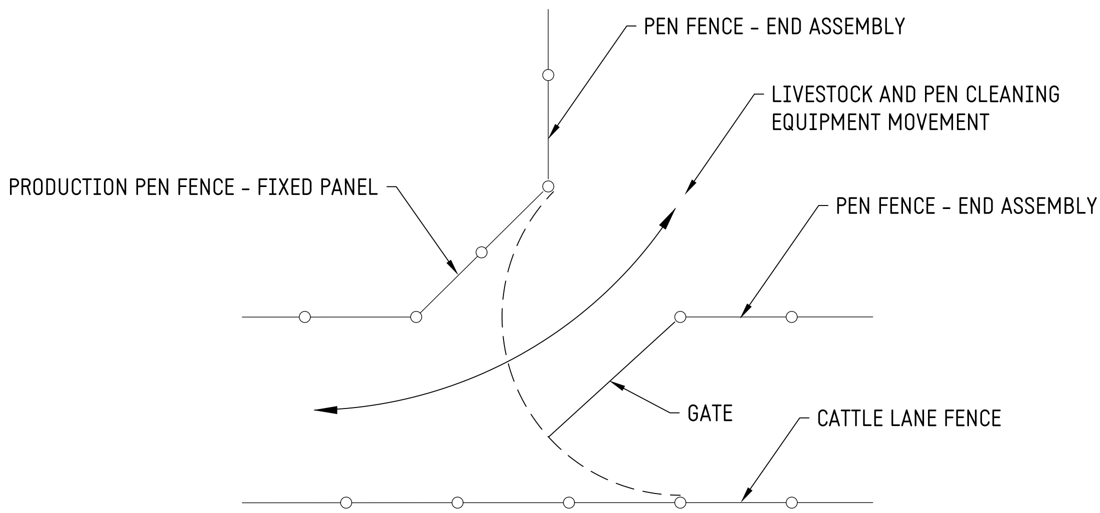
Bunks usually run the entire length of the building although designs with bunks on both sides will usually have breaks on one side of each pen to provide for cattle and machinery access. The bunk space recommendation of 250–300mm/SCU is no different to that for uncovered feedlots.

Unless the feed alley is fully covered, it should be graded down away from the feed bunk on the feed lane to drain any moisture away from the feed bunk.

Cattle must be prevented from entering the feed bunk and escaping the pen. Typically, this is achieved with a single bunk rail or bunk rail and cables strung out over the feed bunk. Posts for attaching the bunk rail (and restraint system) along the feed bunk may be cast into the bunk itself for slipform bunks, attached to the vertical wall of the bunk on the pen-side or concreted into the ground behind the vertical wall of the bunk on the pen-side. Posts built into slipform bunks are ideal as they allow the pen-side wall to remain flush without obstruction. However, they will require a larger wall thickness to provide sufficient coverage for the preferred post section and strength when cattle are pushing on the rail, which adds to cost.

Whilst posts concreted into the ground provide a sturdier construction over posts attached to the outside of the bunk wall or cast into the bunk wall itself, they are not recommended as the obstruction makes cleaning of the apron more difficult. Cleaning of the bunk apron may need to occur more frequently in a covered housing system (e.g. fortnightly/monthly) to avoid excessive wet manure build up. If manure accumulates to a point where the cattle are standing on a surface that is higher

Figure 17: Herringbone gate configuration on cattle lane



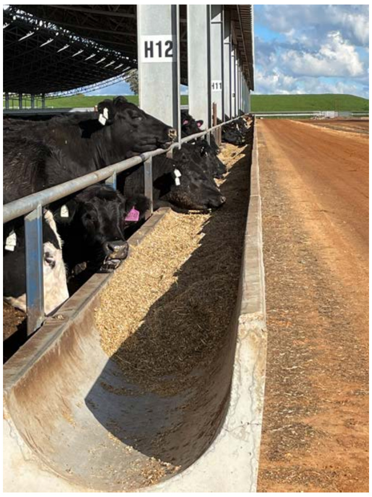
than the inside base of the bunk, the manure needs to be removed. Removing wet feed bunk apron manure may also reduce overall bedding usage.

Slipform bunks have the advantage over precast bunks in that almost any bunk geometry can be formed by designing and fabricating a mould for use. However, the bunk machine requires clearance on both sides of the bunk for the machine and mould to move so slipform bunks may be more problematic when columns are on the edge of the bunk line. It is recommended to engage with a slipform contractor early in the planning stage to identify whether a slipform bunk can be practically constructed.

The size of the bunk is important. The cross-sectional area of the bunk determines the amount of feed that can fit per unit length. If the cross-sectional area is too small, frequent filling will be necessary, particularly if silage or other bulky ingredients are fed. If the feed bunk is too wide, feed pushed to the back of the bunk is less accessible and cattle may be tempted to try to step into the bunk to try to reach it.

Precast and slipform feed bunks both require a solid and even foundation. For precast bunks this may be a concreted extension of the feed bunk apron or it can be compacted gravel. Feed bunks will maintain their position for longer (if not bumped) if a well compacted, even foundation of at least 300mm of well graded gravel thickness is provided. This also allows a feed bunk segment to be pushed back into line if bumped by a feed delivery vehicle or by cattle.

For slipform bunks, the surface should be levelled and free from humps, sags and other irregularities. An uneven surface uses more concrete and leads to uneven feed bunks.



Photograph 41: Precast concrete feed bunk

7.11.2 Self-feeders

Self-feeders often suit smaller facilities that do not manufacture feed onsite or have limitations in feed manufacturing capacity. A self-feeder consists of a hopper that can hold multiple days' feed requirement, with a trough or troughs at the bottom from which cattle feed. Slide gates at the bottom of the hopper allow for regulation of the amount of feed that moves into the trough. The self-feeders used in covered housing systems are usually rectangular units with feeding troughs on either side or one side, or round self-feeders located close to the feed alley fence for ease of feed transfer.

Section 19 – Feeding systems in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) details the pros and cons of self-feeders. Advantages include:

- low cost and can usually be readily purchased
- have their own storage hoppers and so need filling only once or twice a week
- are readily movable, so they can be quickly installed
- can be used elsewhere on the farm, for instance for drought feeding
- can be moved around pens if needed although they would usually be located on an apron.

Disadvantages include:

- Monitoring feed intake and access is more difficult than daily feed delivery to bunks. Depending on characteristics of diet, bridging can occur, preventing flow of feed into feed trough.
- Limitations on the types of ingredients. High moisture, high roughage and use of liquid ingredients (molasses, vegetable oils, liquid supplements, water) reduced suitability when not manufacturing and feeding daily. Moist diets have a limited shelf life and will spoil more rapidly.
- The possible need to use hay racks as well as self-feeders during the introductory feeding phase.
- Manure and spilt feed may accumulate under self-feeders, providing a source of odour and fly breeding sites, unless the feeder has an enclosed base.
- Self-feeders with troughs on both sides should be located so that cattle can access both troughs but this can make filling the hopper more difficult.

Photograph 42: Self-feeders need sufficient roof height for filling

Image: Central Steel

7.11.3 Feeding tables

A feeding table is a simple open feeding system where the feed is placed directly on a concrete slab. This design is widely used in dairy barn systems.

The feeding table extends along the entire length of one side of the covered housing with frontage to the drive alley. If a feeding table is used, it should be placed under the roof structure so that the feed is not washed out during a rainfall event. Typically, the feeding table will include a 3m wide reinforced concrete slab extending outside of the pens on which the feed truck or wagon directly places the feed. This slab must be designed to withstand the loading of feeding equipment.

A concrete nib wall (500mm) beneath the feed apron fence is required to prevent the feed from entering the pen. A nib wall rail will need to be in place above this and a cable may also be needed to prevent cattle stepping over the nib rail. The nib rail placement height and design will be similar to a rail for a feed bunk. A 3m wide concrete apron extends from this wall into the pen. As they eat, the cattle will push the feed forward away from the fence. A feed pusher, which is a blade set at an acute angle to the nib wall and fitted to the front of a skid steer or tractor, is used throughout the day to push the feed back in front of the cattle. Robotic feed pushers that can also remove waste feed are also available.

Photograph 15 shows dairy cows eating from a feeding table, including detail of the nib wall and nib wall rails.

7.11.4 Automated feeding

An automated feeding system streamlines feeding operations, increasing efficiency and reducing labour costs. The fundamentals of feeding do not change with automated systems. Automated feeding systems fall into two categories: fixed systems such as conveyors or mobile systems such as feeding robots.

Fixed systems used in the sheep and dairy industry deliver feed using flexible screw auger systems. These screw auger systems are better suited to pelletised feeds, and therefore, not typically used for lot feeding beef cattle. Belt conveyors for feed delivery have been used at Australian covered housing systems. These reduce feed-out labour. However, capital costs need to be considered. Break downs may cause significant problems with feeding delays. A back up system that can service all pens with conveyors in a timely manner needs to be in place.

Feeding robots are used in European housing systems for dairy and beef cattle. Feeding robots are self-contained battery-operated machines that can automatically dispense self-mixed feed. They use a precise map of the covered housing system to work out the ideal routes for distributing feed. The robot can constantly localise its position, using a stainless-steel strap which is attached to the concrete pathway, recognise obstacles and avoid collisions, safely navigating between buildings, on uneven floors and grades up to 10%. Whilst feeding robots can deliver only small quantities of feed (e.g. 2.2m^3) during a circuit compared to a tractor drawn or truck-mounted mixer wagon (9.0m^3), they can operate 24 hours a day.

As feeding robots need a smooth surface to operate on, concrete surfaces are required. Feeding robots also place the mixed feed directly on the ground so they are used with feeding tables. Feeding robots can also sweep the feed back towards the nib wall so it is always within reach of the cattle.

7.12 Water requirements and infrastructure

7.12.1 Water supply

Provision of clean drinking water is a primary requirement of all animal housing and it must be available at all times and with adequate supply to cope with peak demands. The water supply and reticulation system for a covered housing system is similar to that of an uncovered feedlot and therefore the same design criteria and performance standards apply.

The water reticulation system should:

- ensure the layout, pipe size and pump capacity of the system can efficiently supply the facility with water
- be sized to supply water throughout the covered housing system during peak demand periods
- incorporate a storage system to cater for fluctuations in supply and demand and to act as an emergency supply in the event of water supply failure
- allow easy maintenance of pipes, valves and pumps
- allow maintenance on some parts of the system while maintaining a continuous water supply to all areas of the covered housing system
- be protected from damage by cattle and machinery
- supply fresh, cool, clean, palatable and high-quality drinking water to the cattle.

When designing the mainline and submains, some redundancy should be factored in to allow for any future expansion of the development. Increasing the size of pipes and/or pumps is the best way this can be achieved as the marginal cost of increasing the capacity of these elements far outweighs the cost of the supply and installation in the future.

For most covered housing systems, pipelines to individual troughs will be 25mm or 32mm inside diameter. Main feeder line sizes will depend on the flow required and may range up to 110mm. Coiled polyethylene pipe is usually used for pipe sizes of up to 110mm diameter and rigid straight lengths of HDPE pipe is used for larger pipe diameters. Pipe with a diameter of 110mm is available in 50m, 100m or 150m coils. Minimising the number of joins in a line will reduce the number of potential leak points.

All polyethylene (PE) pipeline joints and fittings should be thermal butt-welded where possible, particularly for any underground joints or fittings. Compression fittings should only be used above ground where they can be accessed easily.

As a rule of thumb, lines to individual troughs should supply at least the daily peak consumption in a four-hour period (MLA, 2006). For example, in a pen of 100 head with a daily peak consumption of 60L/head/day, the supply line should be able to provide about 25 litres per minute.

A looped or ring line reticulation system is recommended to provide redundancy in supply. This also reduces friction losses when compared to a branched network with dead ends.

Within the building, water pipelines should be located in ground as far as practical and not beneath concrete aprons, as leaks are difficult to identify and repairs are more difficult.

The location of the water supply and reticulation pipework should be recorded, including a valve register (size and type) for easy reconciliation.

A pipe network analysis may be required to ensure sufficient flow rate and pressure at all locations or off-take points.

The water supply and reticulation system should be designed in consultation with a suitably qualified and experienced hydraulics engineer or a company specialising in hydraulic engineering services.

Refer to Section 3 – Water supply sources and onsite water storages and Section 14 – Water reticulation in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) for further information on water supply and water reticulation requirements.

7.12.2 Water troughs

Water trough placement, length and capacity are important in ensuring the supply of adequate water for the cattle.

Water is frequently spilt at and around water troughs. It is therefore sensible to locate water troughs in an area that drains freely, so as to not cause a build-up of moisture either in bedding or by creating an area of damp floor. They should also be positioned away from feed bunks to minimise contamination with grain that sours the water. The top of the trough should be at least 0.85m above floor level and the water level should be 5–10cm below the trough top to minimise splashing.

For fully covered pens with a feed bunk only on one side of the pen, the water trough should be located at the rear of the pen with its length parallel with the back fenceline or in the dividing fenceline between pens away from the bunk as shown in Photograph 43 and Photograph 44. Locating the trough on the fence between pens reduces the number of troughs and therefore capital costs but increases the risk of BRD transmission between cattle (Barnes et al., 2014). If water troughs are installed within the pen or perpendicular to the rear fenceline, they may impair the manoeuvrability of pen cleaning equipment. For this reason, parallel fenceline water troughs are more commonly used in covered systems. For partially covered pens, locating the water trough on the bottom fenceline should be avoided as this will restrict drainage out of the pen. For pens with bunks on both long sides, the water trough will need to be placed on the dividing fenceline.

As housed cattle are not exposed to significant changes in weather conditions, a minimum of 25mm/head of linear trough space available should be adequate (MLA, 2006). Available length is the trough length less the length unavailable due to float protection.

Water troughs should be provided with a concrete apron as outlined in Section 7.9.3 and sewered for cleaning purposes as outlined in Section 7.13.3. A tip over trough located on a gateway above a concrete crossover is an alternative design where the water can be tipped out of the pen and onto a concrete slab that drains to a catch drain. Photograph 51 shows an example of a tip over trough in a dairy composting barn.

Photograph 43: Water trough in edge fenceline

Photograph 44: Water trough in dividing fenceline

7.13 Drainage

In accordance with the *National guidelines for beef cattle feedlots* (MLA, 2012a) and *National beef cattle feedlot environmental code of practice* (MLA, 2012b), those areas of a covered housing system complex from which stormwater runoff would result in an adverse environmental impact shall be contained within a controlled drainage area. The controlled drainage area shall be designed to an acceptable hydrological standard that prevents unauthorised discharges of runoff from the feedlot complex (MLA, 2012b). Consequently, any parts of a covered housing system from which stormwater runoff has a high or potentially high organic matter load must be contained within a controlled drainage area.

In a covered housing system, stormwater runoff from building roofs or other 'clean' impermeable areas (such as in and around a building) is unlikely to have a high pollution potential and consideration should be given to excluding this runoff from the controlled drainage area for two reasons. Firstly, to minimise the required drainage system capacity and secondly to recognise the potential of this 'new' source of clean water for potable and non-potable within the development.

Stormwater runoff from building rooves may be collected in eaves gutters prior to diversion to the ground, or a tank, or it can be allowed to freefall off the roof for collection directly into a surface drainage system.

Manure storage/composting areas are generally outdoors. Consequently, these areas also need to be designed and constructed within a controlled drainage area. For some covered housing systems, this will be the only runoff that needs to be managed. If there will be significant manure in stormwater runoff, a sedimentation system is recommended. Runoff collection will need to comply with relevant state environmental regulations and the *National beef cattle feedlot environmental code of practice* (MLA, 2012b).

7.13.1 Catch drains

Catch drains or diversion banks are required to divert any 'clean' or uncontaminated upslope runoff (sometimes termed 'run-on') around the covered housing complex and away from the controlled drainage area to minimise the capacity of the conveyance and storage infrastructure.

Diversion banks or drains should be designed to carry flow rates resulting from a design storm event with an average recurrence interval of 20 years and duration equal to the time of concentration of the catchment. Diversion banks and drains should carry flow at a non-scouring velocity which, in practice, for a well grassed drain means less than 1.5m/s.

Catch drains are needed to capture rainfall runoff from the buildings or ancillary areas and all other surfaces within the controlled drainage area and convey that contaminated runoff to a collection and utilisation system. The drains must have sufficient capacity to handle the design storm event.

Where high velocities (i.e. generally >1.5m/s) are unavoidable, the catch drain should be lined with an appropriate, durable liner (e.g. compacted gravel or concrete – see Photograph 45). Drop structures or energy dissipaters may be installed to reduce the slope and flow velocities in a catch drain, without having to line the entire length.

Catch drains would usually have a trapezoidal cross-section. As the catch drain in this application is fundamentally the same as catch drains referred to in the *National guidelines for beef cattle feedlots* (MLA, 2012a) and Section 10 – Pen and drainage systems in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) the design principles are the same and will need to comply with the same design criteria or performance standards.

Photograph 45: Concrete catch drain

7.13.2 Stormwater harvesting

Stormwater runoff from the roof catchment can be collected and stored for later use. Potential uses could be as a water source for the development (cattle drinking water, road dust suppression, feed processing, potable use) or as irrigation water. If the water will be used for potable purposes, water treatment such as a UV system with pre-filtration may be required.

Whilst a little of the rain hitting the roof may evaporate at once from the roof surface, typically over 95% will run off. As a general rule of thumb, each square metre of roof space collects around one litre of water for every millimetre of rainfall.

The following table provides an indication of the theoretical volume of water able to be collected from a building with a catchment area of 6,000m^2 (e.g. 30m span width x 200m long with 95% yield). The yield that can be realised depends on how much storage is provided, the type of storage (e.g. covered or uncovered, tanks or dams), rainfall frequency and intensity and daily demand (which is very site-specific). As shown in Table 9, a substantial volume of water that can be considered clean runoff can be collected from a covered housing system. Where practical, this should be excluded from the effluent management system to minimise the required system capacity.

Table 9: Roof runoff harvested from a building with a catchment area of 6,000m^2

Average annual rainfall	Volume	
mm	L	ML
450	2,565,000	2.565
500	2,850,000	2.850
550	3,135,000	3.135
600	3,420,000	3.420
650	3,705,000	3.705
700	3,990,000	3.990
750	4,275,000	4.275

7.13.3 Water troughs

Water troughs in covered housing systems need to be cleaned frequently by emptying, then adding more during scrubbing, and emptying again before refilling. Suitable drainage systems must be in place to facilitate cleaning and to accommodate spills.

For covered housing systems, the water trough should ideally be sewered so that cleaning water can be directed straight to a drain or preferably to the holding pond. Alternatively, tip over troughs that empty directly onto a concrete pad which is graded to a concrete catch drain may be used.

Sewered troughs must be fitted with a large drainage outlet to enable flushing as shown in Photograph 46. An overflow pipe within the trough going to the sewer will also direct overflow water out of the pen if a float valve is broken or jammed.

The sewered system should be designed with at least a 100mm diameter rubber ring joint (RRJ) and socket weld joint (SWJ) pipe with swept bends aligned in the downhill direction to minimise blockages from straw, grain and hair. A flushing valve and inspection point for a drain cleaning worm should be installed on the upstream side of the building.

Drainage pipes should be installed in the same trench as water submains and with at least 600mm (900mm under roads) of cover over the pipes to protect them from damage by equipment.

Photograph 46: Water trough overflow pipe

7.13.4 Sediment removal system

If there will be significant manure in runoff, a sediment removal system will be an integral part of the controlled drainage system. This needs to be constructed to capture and detain rainfall runoff, allowing entrained sediment to 'settle out' before the runoff enters the holding pond.

For fully covered housing systems, there will be little sediment entrained in the stormwater runoff as manure is not washed off the pens during rainfall events. However, manure may still be washed from around the edges of the building, laneways, cattle handling yards and manure storage or composting areas. Settling or sedimentation of solids by gravity is the most effective method for removing solids from the effluent.

The concepts and hydraulic design principles contained within Section 11 – Sediment removal systems in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) can be similarly applied to the design and construction of sediment removal systems in a covered housing system.

7.13.5 Effluent pond

According to the *National guidelines for beef cattle feedlots* (MLA, 2012a) and *National beef cattle feedlot environmental code of practice* (MLA, 2012b), stormwater and rainfall runoff from a feedlot controlled drainage area shall not be allowed to flow uncontrolled, into the external environment.

A holding pond needs to be located at the lower end of any controlled drainage area, immediately below any sediment removal system. It is designed to capture and store the runoff from the controlled drainage area until it can be sustainably utilised or evaporated.

Greenfield sites can be designed to minimise the area from which 'dirty' rainfall runoff is collected, thereby minimising the capacity of the holding pond and the volume of effluent to manage.

The optimum size of the effluent pond should be determined from the inflows (rainfall, runoff etc.) and the outflows (evaporation and water use). The daily time step method outlined in Appendix A of the *National guidelines for beef cattle feedlots in Australia* (MLA, 2012a) should be used. The water use component may include a demand for the facility as well as irrigation to land.

The storage capacity of the effluent pond must be large enough to safely store the captured effluent, without spilling at an unacceptable frequency. The spill frequency should be no more often than once every 10 years on average in accordance with the *National guidelines for beef cattle feedlots in Australia* (MLA, 2012a) or licence/permit conditions.

For retrofit sites, the existing development will have a controlled drainage area and associated holding pond system in place that should have been designed in accordance with relevant guidelines at the time of approval. Manure influences the runoff rate from the surface of a conventional uncovered feedlot pen. The runoff coefficient for pens, manure stockpiles or composting pads is typically about 0.8 (MLA, 2012a). The runoff from an impermeable surface such as a roof may be over 95% or equivalent to a runoff coefficient of 0.95. Consequently, where a covered housing system is retrofitted to an existing conventional uncovered production pen area and roof runoff enters the existing drainage system, the capacity of the storage infrastructure may need to be increased to accommodate the additional runoff.

The concepts and hydraulic design principles contained within Section 12 – Holding pond design in *Beef cattle feedlots: Design and construction* (Watts et al., 2015) can be similarly applied to the design and construction of holding ponds in a covered housing system.

8 Bedding

For systems with solid floors, bedding provides a soft surface to improve animal comfort, helps with the management of manure moisture via absorption and evaporation, assists with maintaining good floor conditions, minimises odour, promotes ventilation characteristics and helps to keep the animals clean. However, it may also be possible to operate covered housing systems without bedding, at least in the drier months of the years. Systems with slatted flooring require no bedding.

Most covered housing systems will use loose bedding that may be replenished throughout the feeding period before being removed and replaced at regular intervals. The feed bunk and a 250mm high nib wall beneath fences will help to confine the bedding to the pen area (see Photograph 47).

Photograph 47: A nib wall along the fenceline will help to keep bedding inside the pen

Some dairy farms use compost bedded pack systems to house cows. In these systems, intensive bedding management is necessary for success. Section 8.3 provides details on bedding management in composted bedded packs.

8.1 Bedding types

The type of bedding used will usually depend on what is locally and economically available, however, material absorbency is also an important consideration. Fine bedding materials (e.g. sawdust) absorb more moisture while more coarse materials (e.g. straw) provide a protective layer across manure pad, reducing contact with cattle.

To date, winter cereal straw is the most commonly used bedding material for Australian covered housing systems since it is generally readily and economically available (see Photograph 48). However, its large particle size means that it tends to retain water and this may inhibit drying. Chopping straw, which is done in other livestock industries, may help overcome this issue and enable straw to be blown into pens, although it may also reduce the durability of straw as bedding. Research to demonstrate the effect of chopping straw is yet to be done for Australian beef covered housing systems. If straw is frequently added, the surface will be drier and the moist straw underneath will compact and decompose anaerobically.

Some covered housing systems may be geographically located to make use of pine or hardwood sawdust, wood shavings, or materials like rice hulls as viable alternatives if they are available.

Dry wood chips, fine wood shavings and sawdust provide very good bedding (see Photograph 49) and these are recommended, particularly for compost bedded packs. Sawdust is the most durable and lasts longer than woodchips or shavings. It has a high surface area to volume ratio and is therefore highly absorbent. Availability of these materials may vary throughout the year. Where woodchips, wood shavings or sawdust are in short supply, blending these with other bedding materials may extend bedding life.

Some dairy facilities use composted manure as a bedding material and this may be an option for covered housing systems for beef cattle. Blending the compost with sawdust may improve its bedding properties and longevity. Keeping compost dry ahead of its use as bedding may also be a challenge unless it can be stored in a shed. In particular, composted manure may be unsuitable for southern covered housing systems in winter when wet conditions and low evaporation may prevent it from drying effectively.

Table 10 provides a summary of the suitability of bedding types for Australian covered housing systems.

Photograph 48: Straw is the most common bedding material used in Australian covered housing systems

Photograph 49: Sawdust is an excellent bedding material

Table 10: Suitability of bedding materials for Australian covered housing systems

Type	Absorbency	Durability	Porosity	Recyclability	Key factors that influence the suitability and uptake of bedding materials
Woodchip	Very good 3kg/kg*	Good	Fair	Good for large chip, lower for post peel	More durable than straw and sawdust. Porosity within woodchip bedded area typically lasts longer than a straw or sawdust bedded area. Easier to handle, transport, distribute and remove from pens than straw. Sharp woodchip pieces assist in removing/wearing dags off cattle.
Sawdust	Good to very good 1.5kg/kg for hardwood, 2.5kg/kg for pine*	Very good	Poor	Poor	Good absorbency and may provide softer, more comfortable lying surface for cattle than woodchip. Can be dusty when first added to pen.
Straw	Good to very good 2.2kg/kg for wheat straw, 2.5% for oat straw	Fair	Good	Poor	Good absorbency and provides softer, more comfortable lying surface for cattle than woodchip. Longer straw creates a stronger, more durable bedded area that allows better drainage than chopped straw.
Composted manure	Fair	Fair	Fair	Medium to high	Readily available. While this material is likely to have good absorption, durability and porosity properties if tilled, this is unlikely to occur in practice. It may only be suitable for use in northern Australia and in southern Australia in summer as the manure may be unable to dry sufficiently in winter.
Rice hulls	Poor	Poor	Good	Poor	Rice hulls have good porosity and thermal insulation properties. However, their fluffy nature reduces transport efficiency and makes them difficult to handle. Almond hulls have average absorbency and porosity but tend to break down into very fine particles under the cattle. Availability and uptake limited to processing locations in north-western Victoria and the Riverina.
Almond hulls	Fair	Poor	Fair	Poor	

*From Doran (2018). The estimated absorption capacity of different bedding materials is at 10% moisture.

Operators of Australian covered housing systems have tried using sawdust, wood chips, wheat straw, barley straw and canola straw as bedding materials.

The significant cost of bedding is an issue that operators have raised. One Victorian covered housing system is experimenting with using straw for bedding in the winter, and no bedding in the summer to reduce operating costs.

8.2 Bedding rates

Sufficient dry bedding needs to be provided to ensure animal comfort and absorb manure moisture (see Photograph 50). As stocking density increases, the amount of moisture added by manure also increases, so more bedding may be needed in the wet season (summer in northern Australia, winter in southern Australia); although if there is insufficient moisture loss via evaporation, it will be difficult to add enough bedding to maintain suitable pen conditions. Estimating moisture additions and losses is complex, with evaporation rates varying with temperature, ventilation, manure moisture additions, bedding properties and other factors. Bedding moisture content is best assessed either by measurement or through visual and squeeze tests. The bedding should appear dry to damp but not soggy. If a handful of bedding is squeezed hard, it should not be possible to squeeze out more than a few drops of water.

In most Australian covered housing systems, bedding is spread evenly over the entire pen surface after each pen cleaning. Some lot feeders do not add any further bedding between pen cleanings, others top up bedding sometimes up to once or twice every week. If straw is used, bedding can be added without removing the cattle from the pen by using a bale processor to chop the straw and blow it into the pen. Alternatively, straw bales can be placed in the pens and left for the cattle to spread. Adding straw regularly may provide better pen conditions, reduce bedding usage and prolong the time between pen cleanings.

For covered systems with space allocations between 4.0–9.0m²/SCU, the amount of bedding required will vary with stocking density and seasonal conditions. For straw bedding it is likely that between 2–3kg/SCU/day will be needed (on average). Some Australian covered housing systems have successfully used rates of ~4kg/SCU/day (on average) for sawdust. Removing moist bedding from the feed apron area between pen cleanings (e.g. fortnightly to monthly) may reduce bedding usage.

If on-site storage for fresh bedding is needed, the storage area should be included on the covered housing facility layout plan. This may need to be considered as part of the planning/development and environment permissions application process.

Australian research is needed on bedding rates for compost bedded pack systems and also on the feasible of systems that do not use bedding or do not use bedding year-round.

> Operators of Australian covered housing systems are still experimenting with bedding application rates and patterns.
>
> Operators of two covered housing systems using sawdust manage this bedding in different ways. One applies a depth of ~7.5cm over the pen. All manure and bedding are cleaned from the pen and the bedding is replaced about once every 10–12 weeks. The other is spreading a thick depth of sawdust (~35cm) but removes only half the depth at cleaning (~3–4 months) after the application and the balance at the next cleaning (~6–8 months after the bedding was spread).
>
> Some operators have tried applying straw at the start of a lot only, although most have found it necessary to apply more on a weekly basis.

Photograph 50: Using sufficient bedding will keep cattle clean and comfortable and will absorb moisture from manure

8.3 Bedding management in compost bedded packs

Some dairy farmers use composted bedded packs to house their cows. To date, this type of housing has not been adopted in Australian feedlots, however there is significant interest in the possibility of using these systems. In composted bedded pack systems, the building is usually divided into a bedded area along the full length of the back of the pen area, a feeding area along the full length of the front of the pen area and a feed alley for feed delivery. Photograph 51 shows the interior of a compost bedded barn. The bedding is on the left-hand side of the photograph, confined by a concrete wall. In the right-hand side of the photo is the feeding area. The wall between the bedded area and the feeding area supports a tip over water trough.

Compost bedded pack systems require solid flooring, a significantly larger building (m²/SCU) and a commitment to intensive bedding management to be effective. They can only be considered by those prepared to commit to the daily bedding management needed to maintain a consistent composting process. Composting is an aerobic microbial process. The microorganisms in the pack breakdown organic matter into carbon dioxide, moisture and the heat that dries the manure pack. Aerobic composting requires optimal moisture and oxygen levels and a suitable carbon to nitrogen ratio. The temperature within the pack provides a good indicator of whether effective composting is occurring. Ideally the temperature at 15–30cm below the surface of the pack should be within the range of 43–60°C. Cooler temperatures mean the composting process is too slow, likely due to elevated moisture, insufficient oxygenation or excessive heat loss in winter. Hotter temperatures suggest composting is too rapid and the surface may become too warm for the cattle to want to lie on the pack. High temperatures tend to occur when the material is too dry. (Dairy Australia and Agriculture Victoria 2023).

The moisture content of the pack should ideally be maintained at 45–55%, although a moisture content of 40–60% may still be effective. If a handful of manure is squeezed hard, it should not be possible to squeeze any free water from it. If free water can be squeezed from the manure, more bedding needs to be added. If a handful of manure cannot be formed into a loose ball, the material is to dry. However, the surface of a compost bedded pack should look dry and fluffy, never wet and chunky (Dairy Australia and Agriculture Victoria 2023). To help manage moisture content, large amounts of bedding may be needed in cold or humid conditions (Leso et al., 2020). The alternative is to operate at a lower stocking density.

To provide sufficient oxygen levels within the pack, the bedding must be tilled at least two to three times a day to a depth of at least 30cm to incorporate air. Periodically using a chisel plough to deep till the pack adds oxygen at a depth which helps to increase pad temperatures and may reduce bedding usage (Dairy Australia and Agriculture Victoria 2023). Photograph 52 shows a newly tilled pack. Tilling the pack frequently is relatively simple for a dairy farm as the cows leave the barn 2–3 times per day for milking. Additionally, dairies typically keep all the cows in a single large pen either side of a central feed lane, providing a large area that is tilled more easily and efficiently than the smaller pens used in a feedlot. If the manure is not regularly and frequently tilled, it will retain more moisture and be less aerated, which will reduce its suitability and may result in excessive odour. If a manager cannot commit to tilling the pack at least twice every day, a compost bedded pack is not a suitable system for their feedlot.

The carbon to nitrogen ratio should be 25–30:1. Carbon is mostly added by bedding while nitrogen (and some carbon) is added by manure. If ammonia can be smelt within a compost bedded barn, the carbon to nitrogen ratio is likely too low and additional bedding should be added (Dairy Australia and Agriculture Victoria 2023).

Overstocking is the most common reason for failure of a compost bedded pack due to the amount of moisture added by manure. Wet manure also tends to compact under the animals' hooves, compromising aeration. During winter, it may be necessary to alter bedding management and apply thin layers of bedding more frequently. Bedding usage may be 2–3 times higher in summer than in winter. (Dairy Australia and Agriculture Victoria 2023).

Ideally, a new compost bedded pack should be started during warm weather to assist the establishment of the microbial populations responsible for the process. For established systems, retaining 150–300 mm of old pack material over the pad floor also helps to activate microbial activity within the pack. However, some 300–500mm of dry bedding should be placed over the floor of both new and established systems (Dairy Australia and Agriculture Victoria 2023).

Photograph 51: Dairy compost bedded pack barn

Photograph 52: Tilled bedding in a dairy compost bedded pack barn

9 Manure management

9.1 Pen cleaning

Regular pen cleaning is important to:

- optimise cattle performance and welfare
- minimise dag formation
- minimise odour
- minimise dust formation
- provide a safe work environment for staff (particularly pen riders)
- ensure good pen floor integrity
- minimise the costs of pen maintenance.

Australian covered housing systems generally spread bedding evenly over the entire floor of the pen. If sufficient bedding is used and this is maintained in a suitable condition, the recommended pen cleaning frequency is at least once every 13 weeks, although this will vary depending on stocking rate, bedding type, bedding usage and other factors. Cleaning every six weeks may be needed in some cases. The bedding depth and moisture content may also vary over the pen. If bedding around the aprons or at the edges of the building is wetter, it may need to be removed from the apron and replaced more frequently (e.g. fortnightly to monthly) (see Photograph 53). The inside base of a feed bunk should be no lower than the surface the cattle are standing on. If manure has accumulated to a point where the cattle are standing on a surface that is higher than the inside base of the bunk, the apron needs cleaning.

Photograph 53: Manure may accumulate more quickly on higher use areas

The pen cleaning frequency of Australian covered housing systems ranges from once every six weeks to once every five months, although typically pens are cleaned at least every three to four months.

A covered housing system in South Australia that uses sawdust as bedding puts in a deep layer and removes half at each pen cleaning before adding new bedding after every second pen clean.

Section 1 – Solid wastes, in *Beef cattle feedlots: Waste management and utilisation* (Tucker et al., 2015) provides information on pen cleaning for uncovered feedlots. Most of the guidance in this section is also applicable to pen cleaning in covered housing systems. In most cases, all of the bedding will be removed with manure at regular pen clean outs. However, if a generous amount of clean sawdust bedding was added at the start of the batch, it may be possible to skim the top layer off and retain the dry sawdust underneath, with full replacement at every second clean-out.

Most new covered housing systems will have relatively shallow pens, which may limit the type of equipment that can be used for pen cleaning. Larger pens may be found in retrofit covered housing systems or partly covered pens, although roof support posts within pens may be a barrier to using large equipment. Depending on the equipment used, manure may be loaded directly into a truck or formed into a pile within the shed (see Photograph 54) before being loaded into a truck.

Photograph 54: Manure mounded for removal during pen cleaning

The equipment used to clean pens may include:

- Tractor-drawn box scrapers – box scrapers are commonly used in large, uncovered pens in conjunction with wheel loaders but may be difficult to manoeuvre in small pens particularly if there are posts within the pens. If they can be used, they will be particularly suited when composted manure or no bedding are used. They provide good depth control which protects the pen surface, ensures a smooth pen finish and allows for efficient bedding removal.
- Wheel loaders – wheel loaders may be used to clean large pens but are also needed to load the manure into trucks. Wheel loaders are efficient for pen cleaning but need to be carefully used to prevent damage to the pen surface. Fitting small teeth to the buckets helps to minimise the damage.
- Excavators – while compact excavators can efficiently remove manure, they need to be carefully used to avoid damage to the pen surface. Excavators can efficiently transfer mounded manure into trucks.
- Skid-steer loaders or compact tracked loaders – are commonly used to clean smaller pens. They are also well suited for cleaning aprons and under fences using a slider bar attachment (see Photograph 55).

- Under-fence pushers – manure should not be allowed to accumulate under fence lines where it can become an odour generation and fly breeding site. Under-fence pushers mounted on tractors, front-end loaders, skid-steer or compact tracked loaders can be used to remove manure from under fences (where a nib wall is not fitted) but also from around roof support posts and water troughs and from along feed bunk aprons.
- Tip trucks – trucks are needed to transport the manure from the pen to the manure storage or composting area.

Photograph 55: A tracked skid-steer is ideal for cleaning smaller pens

Building roofs will need to be high enough to allow for the access and operation of pen cleaning equipment. It will usually be more efficient to drive the truck into the pen and load the manure directly into it. If this is done, the height of the building roof at the loading points will need to be high enough (at least 5m) to allow for the loader to safely transfer the manure into the truck.

> Equipment being used to clean pens in Australian covered housing systems include articulated tractors with buckets, front end loaders, skid-steer loaders, telehandlers and tip trucks.

9.2 Manure production

As most covered housing systems will use some bedding, it can be expected that more material will need to be cleaned from these than from uncovered feedlot pens. The rate of manure production (t/SCU place/yr) will vary with the type and rate of bedding use, the moisture content of the manure, the time between pen cleanings and possibly other factors (Photograph 56).

Australian research into manure production from covered housing systems is yet to be done. For uncovered feedlots, Section 1 – Solid wastes of *Beef cattle feedlots: Waste management and utilisation* (Tucker et al., 2015), estimates are that the harvested yield of manure from pens could be as low as 0.4–0.42t of TS/SCU/yr for uncovered feedlots that retain an interface layer. However, where this is not possible and uncovered feedlots are harvesting a lot of gravel, rock or soil, the feedlot could be removing up to 2t TS/SCU/yr of manure plus pad material. Covered housing systems should not have the same pad breakdown as uncovered feedlots exposed to prolonged wet conditions, and good pen cleaning practices will help to avoid the harvesting of significant pad material. If 3kg/SCU/day of bedding is added to pens, the annual addition is approximately 1t of TS/SCU/yr (at 90% dry matter). If 50% is lost through decomposition from the pad, then about 0.5t TS/SCU/yr will remain. Consequently, there could be 0.9–0.92t TS/SCU/yr to harvest. If this has a moisture content of 45% on removal, the wet mass of manure for removal is ~1.65t/SCU/yr. Since pens are typically cleaned quarterly, there would be some 0.4t/SCU per cleaning to harvest.

If the harvested material has a bulk density of 650kg/m^3, the volume removed is estimated to be 2.55m^3/SCU/yr or 0.64m^3/SCU per cleaning.

Kohl & Rieck-Hinz (2013) present nutrient loss rates for different housing systems.

Photograph 56: The mass of manure for harvest depends on a range of factors

9.3 Manure storage

9.3.1 Facility

Manure storage or composting areas for covered housing systems need to be located within a controlled drainage area. The storage area should slope towards a runoff collection pond with an even grade of ~2% to facilitate good drainage. For some covered housing systems, this will be the only runoff that needs to be managed. If runoff is being collected into a holding pond from other parts of the facility, the runoff from the manure storage or composting area can be directed to that pond. The base of the manure storage or composting area will need to have low permeability. If there is a serious risk that soil leachate movement might contaminate groundwater, the area will also need to be underlain by a liner able to satisfactorily mitigate that risk. Runoff collection and pad permeability will need to comply with relevant state environmental regulations and the *National beef cattle feedlot environmental code of practice* (MLA, 2012b).

The manure storage or composting area will need to be sized to manage the expected manure production. As the manure from a covered housing system will usually contain significant solids from bedding, it is likely that a greater storage area will be needed to manage this manure compared with that of an uncovered feedlot. However, this will depend on whether covering pens enable the harvesting of less pad material (e.g. gravel and rock). As a guide, the area required might be double that of an uncovered feedlot of the same capacity.

9.3.2 Manure handling

Manure removed from the pens that is managed on-site can either be aged or composted. Both processes are best undertaken using low windrows rather than large piles. Windrows are more manageable and less likely to self-ignite. Compost turners or front-end loaders can be used to form the manure into a long pile with a triangular cross-section, a base width of 3–4m and a height of 1.5–2m. A windrow that is 4m wide at the base and 2m high has a cross-section of $4m^2$, and a 75m long windrow will store approximately $300m^3$ of manure. The sloping sides of the windrow promote water-shedding, preventing the manure from becoming too wet and odorous. In most cases, windrows should be spaced at least 5m apart, with room at each end to allow for vehicle manoeuvring and windrow turning, although windrows can be much closer together if a self-propelled turner will be used. The long axis of the windrows should be perpendicular to the slope to promote drainage.

Aging involves leaving the manure in static windrows for a period of months. The resulting product will be more friable and easier to spread than fresh pen manure, although it may still be inconsistent and may contain pathogens and weed seeds brought into the pens in cattle feed or bedding. Composting is the microbiological breakdown of organic matter into compost or humus. It typically involves forming the manure into windrows that are allowed to heat to >55°C for at least three days before they are turned. This process is repeated at least four times. Once the manure no longer heats after turning, the material is allowed to cure. Although composting is a more labour and capital intensive process than simply aging manure, it produces a more consistent, low odour product with the nutrients stabilised into a slow-release form. Additionally, because the composting process involves multiple heating and turning cycles, most weed seeds and pathogens that might have been present in the manure will be destroyed.

The recommended process for manure composting is detailed in Section 2 – Solids waste storage and processing, of *Beef cattle feedlots: Waste management and utilisation* (Tucker et al., 2015). A number of uncovered feedlots have also differentiated their product by ensuring their process meets the requirements of AS 4454: 2012 Composts, soil conditioners and mulches (Standards Australia Limited 2012). This is necessary to market material as compost.

To save space, aged or composted manure that no longer heats after turning can be formed into a larger stockpile for storage.

9.3.3 Manure value

Research into the composition and value of manure and compost from Australian covered housing systems is yet to be done, although some north American data is available. Euken et al., (2012) provide an estimate of the amount of manure and nutrients for application. The percentage of each nutrient per ton of manure has also been calculated.

Euken et al., (2012) recorded 165% more manure from bedded confinement than solid manure from uncovered feedlots. The manure from these systems also contains about double the nutrients of uncovered feedlots. Deep pit systems contain the highest level of nutrients, possibly due to more complete manure collection.

Manure can be valued based on its nutrient content. More nutrients are retained in the manure from bedded confinement and there is a greater mass per animal place. Additionally, the nutrient concentration in the bedded system manure contains ~20% more nitrogen and ~40% more phosphorus and potassium.

Given increased nutrient concentration in manure removed from bedded facilities, it is likely the value of stockpiled and composted manure can be increased if pricing occurs on a nutrient cost/availability and accounting for field losses versus conventional fertilisers. Feedlots should also consider shrink and any nutrient losses during composting when pricing compost versus stockpiled/aged alternatives. A manure value pro forma is included in Appendix 4 of *Beef cattle feedlots: Waste management and utilisation* (Tucker et al., 2015).

According to Euken et al., (2012), for both liquid and solid manure, nutrient availability in the first year after spreading could be expected to be:

- 30–40% of nitrogen (although this does not account for nitrogen losses during and after land application, which may be greater if the manure is not injected or incorporated)
- 60–100% of phosphorus
- 90–100% of potassium.

In the year after application, nitrogen availability is likely to be 10%. The year after that, availability might be 5%.

9.3.4 GHG mitigation and energy capture opportunities

Reducing fossil energy consumption and/or transitioning to renewable forms of power generation are options for reducing overall GHG emissions. Short to medium term options include solar power installation and improving on-farm energy efficiency, however other options may emerge in the future.

Manure-related GHG emissions represent around 11–12% of the Scope 1 and Scope 2 emissions of uncovered beef cattle feedlots in Australia. These emissions are the result of the release of methane and nitrous oxide, with these emissions occurring from freshly excreted manure (faeces and urine), losses on the feedlot pad and during manure storage and handling (stockpiling or composting). A further 3.5–5% are from emissions associated with fossil energy use, primarily grid electricity and gas usage by the feedmill and for supplying water. Thus, waste-to-energy technology that can utilise the 'wasted' energy in feedlot manure can reduce both manure and fossil energy use and GHG emissions. Scope 1 GHG emissions are direct GHG emissions that occur from sources that are owned or controlled by a company and Scope 2 are GHG emissions from the generation of purchased electricity consumed by a company.

There is currently no known waste-to-energy system in use within Australian beef cattle feedlots, however, the introduction of covered housing systems may provide opportunities for this to occur. The two key components that could make waste-to-energy viable for covered housing systems compared to uncovered feedlots are:

1. The reduction in contamination of the manure with stone and soil
2. Shortening the time between manure excretion and harvest, which could retain more of the volatile solids (VS) and potential energy.

In most circumstances, covered housing systems with bedding will solve the first major problem of soil and rock contamination. This is due to the pen surface not being subject to climate variables (rainfall and prolonged dry/heat). The age of manure at harvest may still be an issue, with the manure still breaking down in the pen before removal and hence losing a large proportion of its energy potential.

There are also several other technical issues with bedding systems that use large amounts of straw or sawdust material. The bedding material component (straw/sawdust) of the harvested manure generally has a low digestibility in liquid waste to energy systems time (covered ponds and engineered digesters) with a relatively short hydraulic retention. This is due to the complex lignocellulosic structure, including cellulose, hemicellulose, and lignin, which reduce its digestion efficiency and also problems with floating layers of low-density material (Pecar et al., 2020; Fjortoft et al., 2019) that can clog the system. These traditional anaerobic digestion systems also require large amounts of liquid to adjust the incoming material (manure/bedding mix) to <5–6% solids to function effectively. This liquid (clean water or effluent) would need to be available and would also require capture and evaporation or disposal after the treatment process.

Alternative waste-to-energy systems that can handle much higher solids concentrations (30–40%) are solid phase leach bed systems that are best suited to drier substrates such as bedding/manure mixes. They work by recirculating leachate through a digester that can either operate as a batch system or continuous flow. These digesters may need to operate in combination with other systems, such as high-rate anaerobic digestion and ammonia removal to work effectively. The feasibility of this combined system would need to be tested for technical and economic feasibility before adoption.

A covered housing system that could enable the generation of considerable methane from traditional anaerobic digestion systems would be slatted floor pens, where manure falls through slats and is collected in a pit under the floor, before being flushed or scaped out and into an anaerobic digestion system. This would provide clean digestate (no soil and bedding) and if the manure was regularly and frequently moved from the buildings to the digester (daily to < weekly), the greatest energy potential from the manure could be realised. The disadvantage is that they would likely require more fresh cleaning water to function that the facility would need access to.

Table 11: Estimated manure nutrients for application from different feedlot housing systems – annual amount per head space

Facility type	Estimated annual amount of manure per head for application	Nitrogen	Phosphorus	Potassium
Solid manure from open lots	2.72t	20.4kg	10.9kg	15.0kg
Liquid run off from open lots	10,221L	2.3kg 225mg/L	0.9kg 88mg/L	5.0kg 489mg/L
Manure from bedded confinement	4.5t	40.8 kg	25.0kg	31.8kg
Deep pit manure	9,464L	51.3kg 5,420mg/L	27.2kg 2,874mg/L	40.8kg 4,311mg/L

For a 10,000 head facility producing 6,000t/yr of VS or organic matter in manure from a slatted and flushed covered housing system, a maximum biochemical methane potential (BMP) of 0.17m^3 CH_4/kg VS, a methane conversion factor (MCF) of 0.75 and a digester efficiency of 75%, the methane yield from a digester could be around 570,000m^3 per annum. The amount of heat energy that could be generated annually from a boiler with an energy efficiency of 90% would be ~18,500 GJ. Typically, a feedmill uses 49–160 MJ/hd on feed/month. Hence, for a 10,000 head covered housing system, energy requirements are between 5,900 and 19,200 GJ/yr, with the average energy required for a steam flaking operation being ~14,400 GJ/yr. This brief assessment shows that the energy generated by the capture and use of methane from a slatted floor covered housing system would exceed the energy requirements of a typical 10,000 head operation. Alternatively, if all the methane produced was used to generate electrical energy via a generator, the methane generated in a digester from a slatted floor covered housing system could produce around 1,800 MWh annually.

Other potential waste-to-energy recovery processes that have been investigated for manure biomasses, such as manure/bedding from covered housing systems, include combustion, gasification and pyrolysis. Further details on these processes can be found in Section 6 – Energy sources and supply in *Beef cattle feedlots: Design and construction* (Watts et al., 2015).

10 Welfare standards

Welfare expectations for feedlot cattle are described by the industry quality assurance system, the National Feedlot Accreditation Scheme (NFAS). The NFAS specifies animal welfare performance indicators for uncovered feedlots that are based on the Australian Animal Welfare Standards and Guidelines for Cattle. There are no separate standards for covered housing systems. An open feedlot is defined as a constructed facility with designated water points where cattle are confined with a stocking density of 25m^2 per Standard Cattle Unit (SCU) or less and are only fed a prepared ration for the purposes of production (NFAS, 2022). The standards and guidelines allow for verification of good animal welfare outcomes, specify the duty of care required by those responsible for the animals and enable transfer of the standards into legislation. All states and territories of Australia also have an animal welfare and prevention of cruelty to animals Act/s.

The current welfare standards place greater emphasis on duty of care and responsibility of persons caring for cattle. Those responsible must have the necessary knowledge, experience and skills in animal husbandry to perform procedures and meet the requirements defined by the standards.

When considering an investment in covered housing, early contact with the applicable state Department of Agriculture or Primary Industries to discuss design requirements for good animal welfare outcomes is recommended.

> The animal welfare regulations in some states currently mandate a minimum space allowance of 9m^2/SCU for feedlots irrespective of whether these are uncovered facilities or covered housing systems. It is important that lot feeders check the legislation and regulations that apply in their state.

11 Animal health considerations

A well-designed and managed covered housing system improves production efficiency by reducing the maintenance energy requirement of the cattle. This is the energy required to maintain functions critical for life. This is important as 30–40% of the feed consumed daily by cattle is directed to maintenance (Caton et al., 2000). Environmental interactions that create adverse pen conditions (heat, cold, mud) increase maintenance energy requirements due to greater physical exertion (mud) and/or challenges with body temperature control (thermoregulation) (NRC, 1981). These adverse environmental interactions can increase the maintenance energy requirement by 10–15%.

Covered housing systems enable modification of the pen surface through the use of bedding. When protected from rainfall, bedding enhances pen floor comfort (cushioned surface), enhancing freedom of movement, lying time (see Photograph 52) and reducing incidence of lameness and other hoof disorders. Bedding also controls moisture, avoiding the creation of dust or mud. Sufficient moisture can result in manure adherence (dags) and ammonia production. Eliminating dags reduces energy required to maintain body temperature as discussed in Section 7.1.1. Preventing dags also avoids the need to wash cattle prior to slaughter, reducing risk of stress related impacts on carcase shrink and meat quality.

Moisture control in combination with ventilation, avoids welfare issues caused by ammonia generation as discussed in Section 7.1.3. With poor ventilation, ammonia can accumulate around cattle, displacing oxygen and irritating the respiratory tract, observed through increased nasal discharge and coughing incidence (Phillips et al., 2010). Ammonia concentrations greater than 35mg/m^3 depress feed intake, daily gain and feed conversion (Atia, 2006). Ammonia concentrations in well-ventilated facilities remain under 15mg/m^3 (Atia, 2006). (Spiehs et al., 2011). As discussed in Section 7.1.3, a maximum ammonia concentration of 25ppm is recommended to limit any effects on animal health.

Photograph 57: Dry bedding may encourage cattle to spend more time lying down

Covered housing systems also allow for the use of higher stocking densities (typically providing space of 6–8m^2/SCU, but as low as 4m^2/SCU with good bedding management) compared to uncovered feedlots (9–25m^2/SCU) mainly due to better control over pen surface conditions. However, cattle feeding activity remains unchanged, so it is important to provide sufficient bunk space to avoid depressing feed intake. Cattle may have reduced water requirements during the summer feeding period as the quantity of water required for body temperature regulation is reduced. A challenge of operating at a higher stocking density is the greater social interactions among the pen group. Promoting positive interactions such as lying, social licking and rubbing/scratching through the use of enrichment devices (see Photograph 58) will reduce social stress and the development of adverse interactions such as head butting, displacement behaviour, chasing and riding. The use and value of enrichment devices for cattle under different management conditions requires further investigation.

Photograph 58: Yard broom heads attached to a post provide for cattle scratching

Supplementation of vitamin D_3 is not needed by cattle kept in Australian uncovered feedlots as the stock are exposed to sufficient intensity and duration of sunlight (ultraviolet B). Sunlight enables the conversion of 7-dehydrocholestrol present in the skin to vitamin D_3, before further metabolism occurs in the liver and finally the kidney to create the active form of the vitamin, 1,25-dihydroxyvitamin D_3. In fully covered housing systems, vitamin D_3 supplementation is required as exposure to direct sunlight is limited or prevented completely. The vitamin D_3 requirement of cattle is 275 IU/kg DM (NRC, 1996).

12 Costs

12.1 Capital cost

The scope of works for a feedlot project (uncovered feedlot or covered housing system) can be divided into several categories, including approvals, design, construction, infrastructure and equipment.

The evaluation of a feedlot project usually requires the preparation of a budget capital cost estimate at an early stage. A budget set very early in the life of a project tends to set expectations. The first estimate of construction cost is usually the most remembered but is also the least accurate.

The cost estimate is a budget estimate and should be considered a guide only. The budget estimate is not accurate enough to provide a firm commitment for construction. The actual cost of development can only be obtained once the site-specific layout is agreed to and a detailed design of the facility has been undertaken. No capital cost is shown for the development site as it was assumed that the site was already owned.

For this manual, a budget construction cost estimate for an uncovered feedlot and a covered housing system of the same scale has been prepared to provide an indicative comparison of the cost of establishing the two different types of feedlots.

A beef cattle feedlot typically comprises the following components:

- production and sick pens with associated earthworks and drainage, fencing, feed and water systems, water supply, on-site storage and reticulation, manure storage/composting and drainage infrastructure (sedimentation basins, holding ponds etc.) areas
- energy supply, generation, reticulation
- site access, access control, site security, internal roads
- horse stables, day yards, spelling paddocks
- cattle receival, induction and drafting facilities
- grain storage and processing facilities (silos, feedmill)
- commodity storage and feed delivery
- shade infrastructure
- workshop, machinery sheds, weighbridge, chemical storage, office and staff amenities.

Several of these components are required and the same design could be used irrespective of whether the system is a conventional uncovered feedlot or a covered housing system. These include:

- water supply and on-site storage and reticulation
- energy supply, generation, reticulation
- manure storage/composting
- site access, access control, site security, internal roads
- horse stables, day yards, spelling paddocks
- cattle receival, induction and drafting facilities
- grain storage and processing facilities (silos, feedmill)
- commodity storage and feed delivery
- workshop, machinery sheds, weighbridge, chemical storage, office and staff amenities.

These elements are excluded from this budget cost estimate as they are common elements. Further, their style, design and fitting is heavily dependent on site and personal preference and requirements of the business.

Therefore, the main differences between a conventional uncovered feedlot and a covered housing system can be separated into the following categories:

- earthworks and drainage associated with production and sick pens
- pen fencing
- covered housing system
- feed bunks and water reticulation systems
- area required for stockpiling and composting of solid wastes
- Drainage infrastructure (sedimentation basins, holding ponds etc.).

12.1.1 Example uncovered feedlot

An example layout for a 5,000 head uncovered feedlot was developed to provide a standard base for comparison with the covered housing system construction cost estimate shown in Figure 18. The model site was gently sloping at 0.5% and climatic factors for southern Queensland were used to allow the design of the drainage infrastructure.

Sub-sections were developed for each category and a list of required items and materials was derived for each of these.

12.1.1.1 Production pen layout

The pen layout is a bunk-to-bunk design as shown in Figure 18. Each pen has a feed bunk width of 48m and a depth of 54.5m. Allowance for herringbone gates gives an area of about 2,380m^2 for each pen. This equates to 160 SCU at 15m^2/SCU with a bunk space of 275mm per SCU. The layout includes 6m wide pen gates, a 5m wide bunk apron gate and 6m wide cattle lanes.

The pen slope is 3% with a drain slope of 0.5%.

Site preparation is required for the construction of the pens, including site preparation, topsoil stripping, bulk earthworks, and treatments. It was assumed the pen surface would be gravelled with 200mm gravel using material sourced from on-site.

12.1.1.1 Water troughs

It was assumed that a 5.1m long concrete water trough with a reinforced concrete apron with a thickness of 125mm located perpendicular to the rear fenceline would be used.

12.1.1.1 Fencing

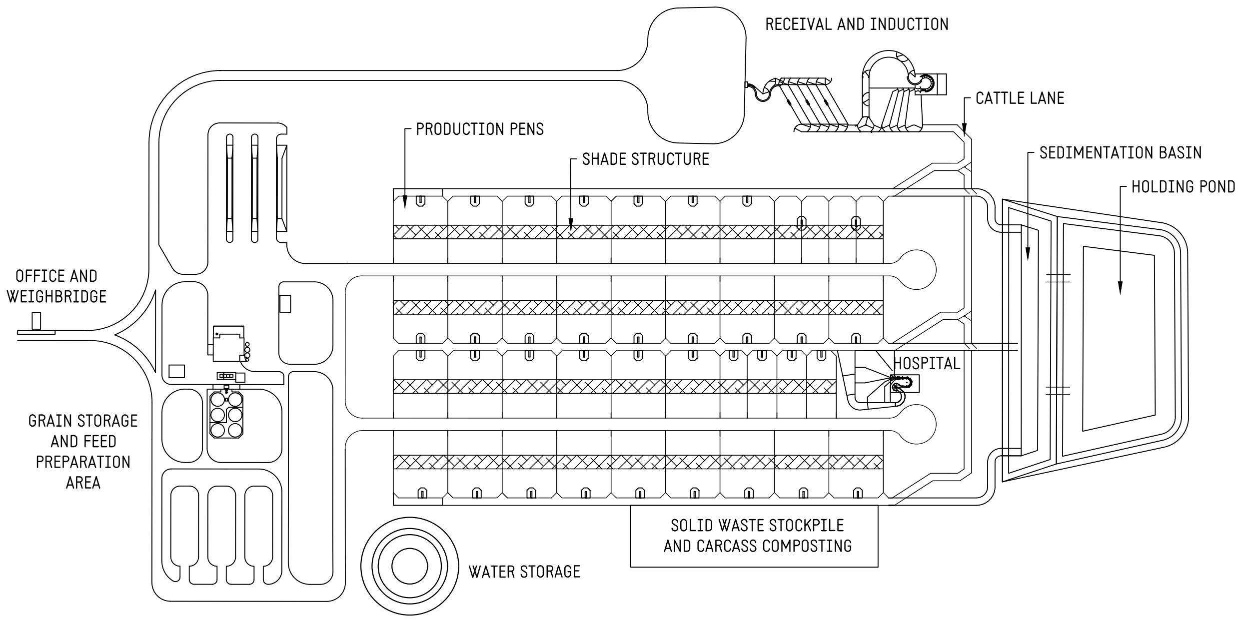
The fence design includes a circular hollow section post with top rail and belly rail and three ‘staytight’ wire cables. Strainer assemblies at each corner and a 6m wide five rail gate.

12.1.1.1 Feed bunk and aprons

The layout design includes a slip-formed 1.1m wide concrete feed bunk.

A slip-formed 3.0m wide unreinforced concrete apron on the pen side of the feed bunk with a thickness of 125mm has been allowed along the width of each pen.

Figure 18: Layout 5,000 SCU uncovered feedlot



12.1.1.1 Shade

The layout design includes the installation of shade structures over the production pens to reduce the impact of heat wave conditions on cattle.

The shade system design uses tensioned wire-rope cables running in opposite directions to create an overhead grid pattern. The shade strip is a continuous cloth that casts a shadow to the west. The proposed shade design provides about ~3.25m^2 of shaded pen floor space per animal. The structural elements include wooden posts and steel wire rope cables. The shade design is a commonly used design within beef cattle feedlots.

12.1.1.1 Solid waste storage

An area of 10,000m^2 has been allowed for storage and screening of solid waste and composting of carcases.

12.1.1.1 Drainage

The controlled drainage area upstream of the sedimentation basin is in the order of 16.25ha. The drainage infrastructure includes a sedimentation basin with a capacity of 4.5ML and holding pond of 40ML.

12.1.2 Example covered housing system

An example layout of a 5,000 head covered housing system was developed (see Figure 19) to allow comparison with the uncovered feedlot layout construction described above. The model site was gently sloping at 0.5% and climatic factors for southern Queensland were used to allow the design of the drainage infrastructure.

The layout of the office/weighbridge, grain storage and feed preparation area, cattle handling and hospital were kept the same as the uncovered feedlot design.

12.1.2.1 Covered housing system layout

The covered housing system layout is shown in Figure 19. There are six (6) sheds with dimensions 22m in width and 220m in length. There is one (1) shed with dimensions 22m wide and 110m in length for production and hospital pens. A feed bunk is located on one side. Each shed has been divided into pens with a bunk length of 27.5m per 100 SCU or 55m per 200 SCU. Allowance for gates gives an area of about 605m^2 for each pen. This equates to 100 SCU at 6m^2/head with a bunk space of 275mm per head. The layout includes 6m wide pen gates, a 4.5m wide bunk apron gate and 6m wide cattle lanes.

The pen slope is assumed to be 0% with a drain slope of 0.5%.

Minimal site preparation is required for the construction of the building including site preparation, topsoil stripping and bulk earthworks. It was assumed the pen surface would be gravelled with 200mm gravel using material sourced from on-site similar to uncovered pens.

12.1.2.1 Water troughs

A 3.0m long concrete water trough with a reinforced concrete apron with a thickness of 125mm located in and parallel with the rear fenceline has been allowed in 100 SCU pens and a 5.1m long trough in the 200 SCU pens.

12.1.2.1 Fencing

A fence design identical to the uncovered feedlot example was used.

12.1.2.1 Feed bunk and aprons

Precast concrete feed bunks are typically available in 6m lengths. The layout design includes a 6m long precast concrete feed bunk.

A 3.0m wide unreinforced concrete apron on the pen side of the feed bunk with a thickness of 125mm has been allowed along the width of each pen. The design includes a 1m wide concrete slab under the precast feed bunk with a thickness of 125mm.

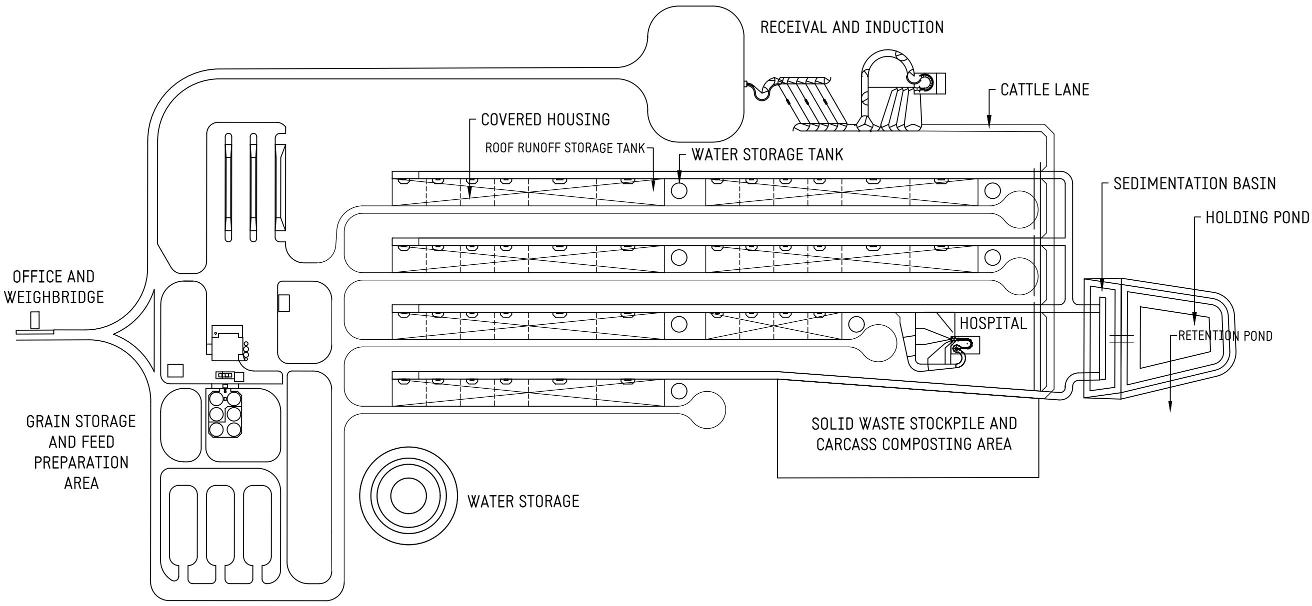
12.1.2.1 Solid waste storage

An area of 15,000m^2 has been allowed for storage of bedding material (e.g. sawdust, woodchip), storage of solid waste and composting of carcases.

12.1.2.1 Drainage

The controlled drainage area upstream of the sedimentation basin is in the order of 14.00ha. Which is about 85% of the controlled drainage area of the uncovered feedlot as separation between buildings is required for adequate ventilation.

Figure 19: Layout 5,000 SCU covered housing system



The drainage infrastructure includes a sedimentation basin with a capacity of 1.0ML and holding pond of 8.5ML, about one fifth of the capacity required of the uncovered feedlot as the majority of the controlled drainage area is soft catchment or grass.

12.1.3 Capital cost comparison

The cost of construction of the example uncovered feedlot and covered housing system is provided in Table 12. Whilst the two examples have been developed to represent the design and layout of a real life feedlot, each scenario is an example only and therefore the costs are not intended to reflect actual costs which are subject to change over time. The relative difference between the two costings and not the absolute value of each is key when making a comparison. The absolute value of construction of any project is very site and design-specific and material and labour costs vary considerably between regions and over time. Table 12 shows that in the example provided, the cost of civil works, feed bunks and fencing in an uncovered feedlot does not offset the cost of the buildings in a covered housing system.

The cost per SCU equates to ~$1,230/SCU for an uncovered feedlot and ~$2,060/SCU for a covered housing system.

12.2 Repairs and maintenance

Repair and maintenance costs of feedlot infrastructure are a considerable and necessary component of the operating cost. The main items requiring repairs and maintenance within a feedlot are pen surfaces, pen fencing, internal roads and drainage infrastructure. Repairs and maintenance is also carried out on other infrastructure, plant and equipment such as in the feedmill (rollers, bearings, motors), mobile plant (trucks, tractors, loaders), stationary motors etc.

The largest component of the repairs and maintenance expenditure in an uncovered feedlot is the repairs to the pen surface. This includes surface treatment repairs such as gravel capping and may also include repairs to the clay subgrade. The cost of pen repairs is very site specific and depends on climatic conditions, type of materials used, material source, quality of repairs etc.

With a covered housing system, repairs to the pen surface are expected to be reduced as rainfall is excluded from the pen surface. However, with lower space allowances, pen surfaces may stay wetter and therefore require similar levels of repairs and maintenance on a square metre basis, particularly where no bedding is used. As there are few covered housing systems which have been in operation for a significant time, pen maintenance costs are not well defined.

The cost of repairs and maintenance on fixed and mobile plant and equipment is expected to be similar between both types of facilities if similar levels of ration are processed and delivered on a tonne/km basis.

The design life of infrastructure within uncovered and covered housing systems such as concrete elements and steel is about 20 years. There are continuous slip form concrete bunks in uncovered feedlots which are approaching 20 years of service life and are showing no signs of dilapidation.

Table 12: Uncovered feedlot and covered housing system costings

Item	Description		Uncovered	Covered
			Amount (Ex GST)	Amount (Ex GST)
1.1	Approvals and design schedule		$514,000	$501,500
1.2	Civil works schedule		$1,708,750	$491,325
1.3	Feed bunks and aprons schedule		$923,127	$462,286
1.4	Water troughs and aprons schedule		$348,228	$374,721
1.5	Fencing and gates schedule		$2,069,932	$1,957,300
1.6	Utilities schedule		$183,925	$160,700
1.7	Infrastructure schedule		$400,000	$6,320,000
		TOTAL	$6,147,961	$10,267,833

Table 13: Repairs and maintenance comparison

Aspect	Uncovered feedlot	Covered housing system
Pen repair	✓ Gravel/Clay	✓ A reduction in overall cost due to reduced pen area.
Fence repairs	✓	✓ Similar on a per metre basis but overall reduction due to less fencing required.
Feeding plant	✓ Mobile equipment repairs	✓ Similar if ration delivery is similar on a tonne per km basis.
Drain cleaning and maintenance	✓	⬇ Greatly reduced. Little manure in drains.
Drainage infrastructure – Sedimentation system	✓	⬇ Greatly reduced. Little manure captured in sedimentation system.

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MEAT & LIVESTOCK AUSTRALIA

PO Box 1961
North Sydney NSW 2059
P: 02 9463 9333 E: info@mla.com.au

mla.com.au